COMMUNICATIONS

Dear readers,

the 7th International scientific conference TRANSCOM 2007, organised with the support of the European Commission within the framework of FP6 European Project SurfTran (CETRA project, Centre for Transportation Research, University of Zilina, Slovak Republic), was held in the University of Zilina, Slovak Republic, in June 2007.

The main purpose of the conferences TRANSCOM organised regularly every other year since 1994 is a presentation of scientific works (from the fields of transportation, telecommunications, mechanical, electrical, civil, security, forensic engineering and social sciences) of young research workers incl. PhD students up to the age of 35 from universities, scientific institutions and industry.

More than 447 contributions were published in 10 proceedings of the conference TRANSCOM 2007 (205 contributions were from abroad, Austria, Bulgaria, Czech Republic, Denmark, Finland, Germany, Greece, Great Britain, Hungary, Ireland, Italy, Lithuania, Poland, Romania, Russia, Switzerland, Ukraine 35 were from the universities of the Slovak Republic and 207 contributions were from the University of Zilina).

I should express my gratitude to all participants for contributing to the TRANSCOM 2007 and to the TRANSCOM 2007 scientific committee incl. organizing committee members for cooperative spirit, motivation and enthusiasm.

This volume of the Communications is devoted to the selected contributions (recommended by the scientific committee) of the 7th International scientific conference TRANSCOM 2007, Zilina, Slovak Republic.

Otakar Bokuvka

Konstantinos Birkos – Theofilos Chrysikos – Stavros Kotsopoulos *

QoS ISSUES IN COMPLEX-BASED HIGH ALTITUDE PLATFORM COMMUNICATION SYSTEMS

The use of High Altitude Platforms is a promising solution towards the integration of different wireless networks. Complex-based High Altitude Platform communication systems can offer high quality wireless services combined with enhanced bandwidth efficiency. Inter-system handover and power control are major factors affecting the provided quality of service. The impact of these factors under strong fading environments is studied in the present work.

1. Introduction

High Altitude Platforms (HAPs) are unmanned airships that carry communicational equipment and provide a great variety of wireless services in a certain area on the ground. Local Multipoint Distribution Services (LMDS) including Broadband Fixed Wireless Access (BFWA), navigation, localization, 3G and beyond, environmental surveillance are some of the potentials this technology can provide [2]. The advantages of the use of HAPs are more evident in cases of areas suffering from deficient telecommunication ground infrastructures or in cases of emerging need for wireless coverage, exceeding the capacity of fixed networks. Systems of multiple HAPs are of great interest, as they enhance network performance, offering flexible architectures. They can be deployed as part of extended heterogeneous networks and they can contribute to the integration of different wireless networks. Two main issues are addressed in the present work: the effects of inter-HAPs handover and fairness in downlink broadcasting quality for different groups of subscribers.

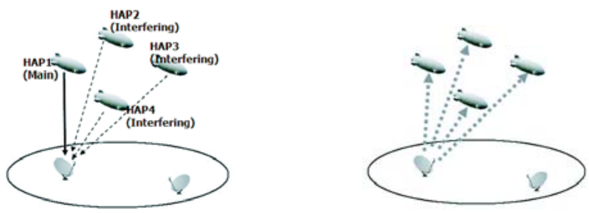
2. System Description

In the proposed work, a constellation of four HAPs in the stratosphere serves an area on the ground. The platforms share the same bandwidth and they illuminate the area using omni-directional antennas. Users on the ground may be either fixed or mobile. In order for the system to be feasible, users have to carry directional antennas. The directionality makes possible the usage of common resources by the HAPs transmitting systems, as analyzed in [1]. There, by means of interference analysis, it is proved that sufficient levels of Carrier to Interference plus Noise Ratio (CINR) are achieved. Each user is served by a single platform. This is called the *main HAP*. The other platforms of the constellation produce interference (*interfering HAPs*). As a result

$$CINR = \frac{P^{main}_{C\_received}}{N_F + \sum_{k \in I} P_{I\_received,\,k}} \quad (1)$$

where the nominator is the received signal power from the main HAP, N_F is the noise floor and $P_{I-received,\,k}$ is the received power from the k-th interfering HAP. The interfering signal is received via the side lobes of the user antenna. Figure 1 (a) shows the system's topology.

Although users can be served by any HAP with satisfactory levels of quality of service, only one HAP at a time can achieve optimal performance. Consequently, enhanced performance could be achieved if it was possible for the users to choose the HAPs that offer optimal coverage conditions. This could be realized by means of constant monitoring. The received power of the pilot channels of the HAPs could be the monitored parameters. One major factor that enables this operation is that because of the nature of the architecture, the users can be easily redirected from one HAP to another. It is important that there is a mechanism to control inter-HAP handover properly. The system must be protected from unnecessary handovers. For example, there must be a minimum



(a) *(b)*

Fig.1 (a)Multiple HAPs coexistence (interference scenario), (b)Inter-HAP handover

* **Konstantinos Birkos, Theofilos Chrysikos, Stavros Kotsopoulos**
Wireless Telecommunication Laboratory, Department of Electrical & Computer Engineering, University of Patras, Greece,
E-mail: kmpirkos@ece.upatras.gr

number of samples in which a HAP is detected as the optimal one before it is selected as the main HAP, in order to avoid ping-pong effects.

In case of voice and video-oriented networks, the downlink broadcast performance is another matter of interest. In particular, for systems of multiple HAPs, a power control mechanism would guarantee fairness in terms of certain performance evaluation criteria for groups of users served by different platforms. Inter-HAP handover may guarantee enhanced uniformity of coverage and outage probability for the area of coverage but it cannot always offer optimal performance without proper power control. This is evident in packet-transmission-based systems in which delays, throughput and consumed energy depend on the number of receiving nodes. These issues are addressed in the present work.

A send-and-wait Automatic-Repeat-ReQuest (ARQ) scheme is considered in the downlink for the broadcasting feature. It means that each transmitting platform repeatedly retransmits each packet until all nodes served by it receive it correctly. The average number of retransmissions per packet is a function of the probability of successful reception and the number of receiving nodes. With the inter-HAP handover enabled, different platforms serve different numbers of subscribers according to optimal coverage requirements. Therefore, when uniform power allocation among HAPs is implied, differences in average end-to-end delays and energy-per-successful-packet-reception will be observed. As shown next, a scheme able to re-allocate power among HAPs transmitters could yield in the equalization of delays for users served by different platforms.

Two factors affect the probability of successful packet reception: the ratio of bit energy to power spectral density Eb/No and the packet length. In the examined system, Eb/No is a function of the user's position, the modulation, the bit rate, the transmitting power of each platform and which platform the user is served by. The probability of successful reception ps is given by

$$p_s = (1 - BEP)^L \tag{2}$$

where *BEP* is the bit error probability and *L* is the packet length in bits. The packet reception is a Bernoulli procedure as each packet is correctly received with probability p_s or incorrectly received with packet error probability $PEP=1-ps$. As a result, the geometric distribution describes the number of trials in order to achieve a successful reception. Following the analysis presented in [15], the average number of transmissions per packet is expressed as

$$N_{tr\_ave} = \sum_{n=1}^{N_C} \binom{N_C}{n} \cdot \frac{(-1)^{n+1}}{1 - PEP^n} \tag{3}$$

where N_C is the number of receiving nodes. The average number of transmissions affects the average service time according to the following formula

$$t_{serv\_ave} = N_{tr\_ave} \cdot (t^{trans} + RTT) \tag{4}$$

where t_{trans} is the transmission delay and *RTT* is the round trip time.

3. Channel modelling

The received signal is given by $y(t) = h(t)s(t - \tau) + n(t)$, where $h(t)$ is the complex channel function that inserts the multiplicative attenuation effects on the transmitted signal $s(t - \tau)$, which suffers from an average propagation delay τ, and $n(t)$ is the additive noise effect. The propagation delays in each path (therefore for each component of the signal) are considered relatively small compared to the symbol period of the modulation method. Therefore the fading is considered *flat* or *frequency non-selective*.

A worst-case channel scenario is considered, assuming heavy obstruction and mostly in-building user movement, so that a strong LOS component is missing. In this case, Rayleigh fading is most appropriate for the description of the fading effects due to multipath propagation (small-scale fading). The received signal consists of a sum of reflected components (NLOS case) and the instantaneous amplitude of the received signal follows a Rayleigh distribution, whereas the instantaneous received power follows an exponential distribution. For the shadowing effects (large-scale fading) the lognormal distribution is considered as most appropriate and is more commonly used [3]. A mixed Rayleigh-lognormal distribution is therefore used to represent both shadowing and fast fading effects [4, 5]. The Rayleigh-lognormal model, also known as Suzuki model, has been evaluated by HAPs surveys as one of the most appropriate for the study of HAPs systems, especially in 'bad channel performance' scenarios [6]. It has also been proposed as a model for the description of the satellite channel [7].

The joint pdf of the Rayleigh-lognormal fading is an integrated product of the conditional joint Rayleigh-lognormal pdf and the lognormal pdf. The following equations are expressed in terms of instantaneous received power [8]:

$$p(s) = \int_0^{\infty} f_{R|\Omega}(s) f_{\Omega}(\Omega) d\Omega \tag{5}$$

Where $f_{R|\Omega}$ is the conditional joint Rayleigh-lognormal pdf. The exponential distribution originating from the Rayleigh 'component' of the 'composite' Rayleigh-Lognormal (RL) fading model expresses the instantaneous received power s as it varies around a mean value Ω which is calculated by path loss models. In a case of multipath-only fading ('pure' Rayleigh fading), this would be the average received power. In this study, however, the shadow fading is also taken into consideration, therefore Ω represents the *local* mean value, which in long term also varies in the accordance of the lognormal distribution:

$$f_{R|\Omega}(s) = \frac{1}{\Omega} e^{\left(-\frac{s}{\Omega}\right)} \tag{6}$$

$$f_{\Omega}(\Omega) = \frac{1}{\sqrt{2\pi}\,\sigma_{sh}\,\Omega} e^{\left\{-\frac{1}{2}\left(\frac{\ln(\Omega) - \mu_{sh}}{\sigma_{sh}}\right)^2\right\}} \tag{7}$$

$f_{\Omega}(\Omega)$: lognormal distribution which expresses the long-term variation of the (local) mean value Ω. In order to express the standard shadow deviation in dB, the following adjustment needs to be made: $\sigma_{dB} = \frac{10}{\ln(10)} \sigma_{sh}$, therefore: $\sigma_{sh} = \frac{\ln(10)}{10} \sigma_{dB}$. For the mean value, which stands for the area mean power, it is suggested in [9] that it is dependent on the distance between the transmitter and the receiver: $\mu_{sh} = \mu(r) - \beta \ln \frac{r}{R}$, β being the path loss exponent, r the distance between transmitter and receiver, R the cell radius and μ_R the mean value (area mean power) at the edge of the cell, where $r = R$. It has been estimated that in a dynamic range cell for Rayleigh small-scale fading, the area mean power at the edge of the cell is around 60–80 dBm, it is safe therefore to presume a value of 70 dBm for μ_R. The pdf of the composite Rayleigh-lognormal fading can be expressed – in terms of instantaneous received power – as:

$$p(s) = \int_0^\infty \frac{1}{\Omega} e^{\left(-\frac{s}{\Omega}\right)} \frac{1}{\sqrt{2\pi}\,\varphi\sigma_{dB}\,\Omega} e^{\left\{-\frac{1}{2}\left(\frac{\ln(\Omega) - \mu(r)}{\varphi\sigma_{dB}}\right)^2\right\}} d\Omega \quad (8)$$

where $\varphi = \frac{\ln(10)}{10}$.

Since the instantaneous received power follows a certain pdf, it can be assumed that the intantaneous received SNR follows the same pdf, based on the fact that it is a 'scaled' depiction of the received power [10]:

$$\mathrm{p}(\gamma) = \int_0^\infty \frac{1}{\Gamma} e^{\left(-\frac{\gamma}{\Gamma}\right)} \frac{1}{\sqrt{2\pi}\,\varphi\sigma_{dB}\,\Gamma} e^{\left\{-\frac{1}{2}\left(\frac{\ln(\Gamma) - \mu(r)}{\varphi\sigma_{dB}}\right)^2\right\}} d\Gamma \quad (9)$$

where γ expresses the instantaneous SNR and Γ the average SNR.

The Outage Probability is the probability that the received SNR falls below a certain threshold γ_{th}. It is derived out of the CDF (Rayleigh):

$$F(\gamma) = 1 - e^{\left(-\frac{\gamma}{\Gamma}\right)} \quad (10)$$

$$P_{out}(r\,|\,\Gamma) = \Pr\{\gamma < \gamma_{th}\} = F(\gamma_{th}) = 1 - e^{\left(-\frac{\gamma_{th}}{\Gamma}\right)} \quad (11)$$

This is the conditional outage probability since we have only taken into consideration the Rayleigh component of the composite fading model. It has been calculated for a given Γ and it is also dependent on the distance between transmitter-receiver [9]. Taking into account the lognormal variation of Γ, the Outage Probability is dependent only on the distance r and is expressed as:

$$P_{out}(r) = \int_0^\infty 1 - e^{\left(-\frac{\gamma_{th}}{\Gamma}\right)} \frac{1}{\sqrt{2\pi}\,\varphi\sigma_{dB}\,\Gamma} e^{\left\{-\frac{1}{2}\left(\frac{\ln(\Gamma) - \mu(r)}{\varphi\sigma_{dB}}\right)^2\right\}} d\Gamma \quad (12)$$

By averaging the Outage Probability over all the coverage area and assuming a circular approximation of this coverage area (for all possible transmitter-receiver distances), the dependence on the distance is gone:

$$P_{out} = \frac{1}{\pi R^2} \int_0^R P_{out}(r) 2\pi r dr \quad (13)$$

This formula can be approximated through the complimentary error function but still cannot be expressed in closed-form. It is one of the reasons of the RL composite model being non-practical, even though it is an important model for many different applications, especially in satellite communications.

The average BER Probability (BEP) in the mixed Rayleigh-lognormal fading scenario is given by:

$$P_e = \int_0^\infty P_{e|AWGN}(\gamma)\, p(\gamma)\, d\gamma \quad (14)$$

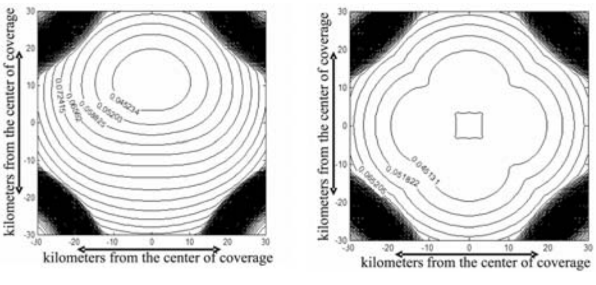
$P_{e|AWGN}$ is the BEP in AWGN channel, which depends on the type of modulation and the instantaneous SNR γ. In our case study, BPSK modulation technique is used, for which $P_{e|AWGN}(\gamma) = Q(\sqrt{2\gamma})$. The formula above is a very complex one. To simplify the mathematical equation, the pdf $p(\gamma)$ can be replaced by the MGF through Laplace transformation. The expression of the MGF is dependent on the diversity technique and the fading model used [11]. Our choice of diversity technique for this case study is the MRC technique, because the amount of fading is lower in MRC systems than in other techniques, i.e. SC systems [12]. Therefore the MGF function for the Rayleigh-lognormal model can be expressed as [13]:

$$M_{R^2}(\xi) = \frac{1}{\sqrt{2\pi}\sigma_{sh}} \int_0^\infty \frac{1}{\Omega(1 + \xi\Omega)} e^{\left\{-\frac{1}{2}\left(\frac{\ln(\Omega) - \mu_{sh}}{\sigma_{sh}}\right)^2\right\}} d\Omega \quad (15)$$

Even in the case of MGF use, instead of the composite pdf, the Rayleigh-lognormal model proves to be quite complicated in the mathematical formulas involved and cannot be simplified any further (Gauss-Hermite method).

In the following, a performance comparison between two systems is presented. The difference between them is the inter-HAP handover feature.

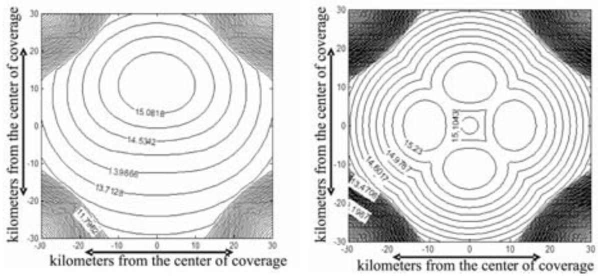
4. Simulation results



(a) (b)

Fig. 2 Outage probability using MRC Diversity Technique over a Rayleigh-Lognormal fading channel in an area of 3600 km2 (a)inter-HAP handover disabled, (b) inter-HAP handover enabled

The elements characterizing the system's performance are the CINR, the Bit Error Probability (BEP) and the Outage Probability. The obtained results confirm that the inter-HAP handover-based system achieves a higher degree of uniformity of coverage on the ground. Figure 2 (a) shows that the outage probability is low only in a part of the covered area in the absence of handover. On the contrary, mobile users take advantage of low levels of outage probability almost everywhere (b). As mentioned in the previous section, the reason is that the CINR is more uniformly distributed. (Figure 3) In figure 4 it is clearly shown that inter-HAP handover yields in increased percentage of covered area that meets the threshold requirements for several BEP requirements. It is observed that it is more suitable for demanding digital applications.



(a) (b)

Fig. 3. CINR in the covered area (a)inter-HAP handover disabled, (b) inter-HAP handover enabled

In figure 5, the effect of inter-HAPs handover in the average service time is depicted. The handover capability outperforms the single-HAP coverage especially for lower values of transmitted power.

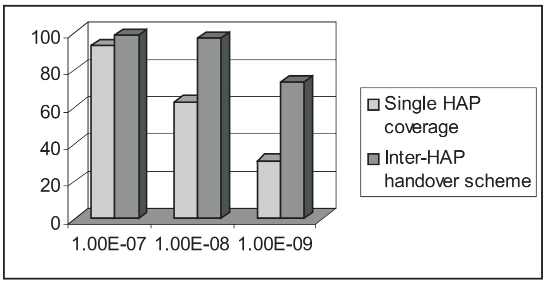


Fig. 4. Percentage of covered area with BEP< 10^{-7}, 10^{-8}, 10^{-9} respectively

Figure 6 shows the effects of the transmitted power and the number of receiving nodes in the average number of transmissions per packet. It is obvious that an increase in the number of nodes reduces the probability of successful packet reception whereas an increase in power has the opposite result. In particular, the following scenario was evaluated. At first, all HAPs serve the same number of subscribers on the ground-10 subscribers each. Power is uniformly distributed among all HAPs. This basic configuration

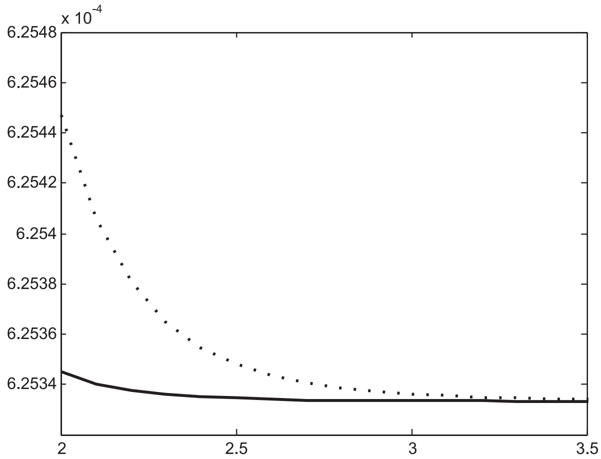


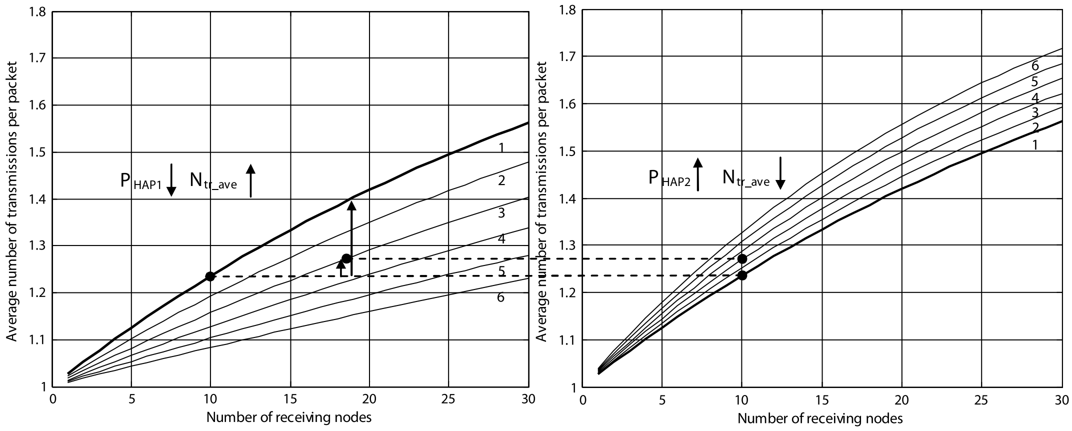
Fig. 5. Average service time (straight line: handover enabled, dashed line: handover disabled)

is depicted by the bold line. An increase of users served by HAP1 (Fig. 6a) would normally yield in an increase in the number of transmissions to about 1.4 in case the power configuration remained uniform. The number of transmissions for users served by HAP2 would not be affected.

When power control is invoked, a certain amount of power is re-allocated from the other HAPs to HAP1 in order to compensate for the augmentation in users. Because of the co-channel interference, changes in power affect not only the users served by the corresponding HAP, but also all the other users via the side lobes of their antennas. It is shown that when configuration 3 is chosen, the average number of transmissions is increased from 1.24 to 1.28 for all HAPs. What is achieved is the fairness in the performance of downlink broadcasting.

5. Conclusions and future work

In this paper a multiple HAPs coexistence scenario was presented. In particular, the effect of inter-HAP handover on the overall performance was examined. A worst case scenario was chosen, assuming a NLOS case study. A combined Rayleigh-lognormal model was therefore most appropriate in order to describe both multipath fading and shadowing effects. It was proved that under those conditions, inter-HAP handover increases uniformity of coverage. In addition, a performance evaluation in terms of downlink broadcasting was used to quantify the effects of optimal power control in fairness among different groups of users. In the future, there is the perspective of producing a detailed algorithm allocating subscribers to the platforms according to quality and fairness criteria presented in the present work. Moreover, a series of studies have shown that instead of the lognormal distribution, the gamma distribution can be applied to describe the shadowing (large-scale fading) effects. The Rayleigh-Gamma composite model is also known as the K distribution. The gamma distribution plot is almost identical with that of the lognormal distribution for the majority of μ and σ values met in real-life scenarios [13]. Further



(a) *(b)*

Fig. 6. Average number of transmissions per packet as a function of the number of receiving nodes for different power configurations for two HAPs of the constellation and a graphical method of power control. (a)HAP1, (b)HAP2

more, unlike the Rayleigh-Lognormal model, the K distribution provides closed-form BEP expressions for certain modulation schemes (including the BPSK technique used in our case study), with the usage of mathematical special functions available in modern simulation software [14]. All the above suggests that the K distribution (Rayleigh-gamma) can provide, in certain cases, a more convenient alternative to the complicated Rayleigh-lognormal model. The application of this practical approximation to High Altitude Platform Systems and the examination of the resulting performance criteria, especially in comparison with the results acquired in this paper, is part of immediate future work.

References

[1] GRACE, D., THORNTON, J., GUANHUA CH., WHITE, G. P.; TOZER, T. C.: *Improving the system capacity of broadband services using multiple high-altitude platforms,* IEEE Transactions on Wireless Communications, vol. 4, Issue 2, 2005, pp. 700–709.

[2] KARAPANTZIS, S., PAVLIDOU, F.: *The role of High Altitude Platforms in beyond 4G networks,* IEEE Wireless Communications, vol. 12, 6/2005, pp. 33–41.

[3] CAVERS, J. K.: *Mobile Channel Characteristics,* Kluwer Academic Publishers, 2000.

[4] SUZUKI, H: *A statistical model for urban radio propagation,* IEEE Trans. Commun., vol. 7, No. 25, pp. 673–680, 1977.

[5] HSIN-PIAO L. MING-CHIEN T. DING-BING L.: *Performance Analysis of M-ary PSK Adaptive Modulation System over Rayleigh-lognormal fading channel,* 61st IEEE Vehicular Technology Conference, Spring 2005, vol. 1, pp. 576–580, 2005.

[6] KARAPANTAZIS, S., PAVLIDOU, F.N.: *Broadband Communications via High Altitude Platforms (HAPs) – A survey,* Dept. of Electrical & Computer Engineering, Telecommunications Division, Faculty of Engineering, Aristotle University of Thessaloniki.

[7] MOULSLEY, T. J., VILAR, E.: *Experimental and theoretical statistics of microwave amplitude scintillations on satellite down-links,* IEEE Transactions on Antennas Propagation, vol. 30, pp. 1099–1106, 1982.

[8] HANSEN, F., MENO, F. I.: *Mobile fading-Rayleigh and lognormal superimposed',* IEEE Transactions on Vehicular Technology, vol. 26, pp. 332–335, 1977.

[9] EMAMIAN, V., KAVEH, M., ALOUINI, M. S.: *Outage Probability with Transmit and Receive Diversity in a Shadowing Environment,* IEEE, 2002.

[10] AGUIAR, A., GROSS, J.: *Wireless Channel Models,* Telecommunication Networks Group, Technical University Berlin, 2003, Berlin.

[11] ANNAMALAI, A., TELLAMBURA, C., BHARGAVA, V. K.: *A unified approach to performance evaluation of diversity systems on fading channels,* chapter 17 of Wireless Multimedia Network Technologies, Kluwer, 2002.

[12] SHANKAR, P. M.: *Performance Analysis of Diversity Combining Algorithms in Shadowed Fading Channels'*, Wireless Personal Communications (2006) 37: 61–72, DOI: 10.1007/s11277-006-1080-9.

[13] ABDI, A., BARGER, H. A., KAVEH, M.: *A Simple Alternative to the Lognormal Model of Shadow Fading in Terrestrial and Satellite Channels,* IEEE Vehicular technology conference, 2001, vol.4, pp. 2058–2062, 2001.

[14] ABDI, A., KAVEH, M.: *K distribution: an appropriate substitute for Rayleigh-lognormal distribution in fading-shadowing wireless channels,* Electronic Letters, vol. 34, pp. 851–852, 1998.

[15] SRIDHAR, A., EPHREMIDES, A.: *Comparison of satellite and cellular architectures for downlink broadcast data transmission'*, International Journal of Satellite Communications and Networking, Wiley InterScience, 2006, DOI: 10.1002/sat.844

Adam Szeląg – Marcin Steczek*

ANALYSIS OF INPUT IMPEDANCE OF THE TRACTION VEHICLE WITH DC CHOPPER AS A FUNCTION OF OPERATION MODE

A problem of analysis of the input impedance of a converter traction vehicle is presented in the paper. The value of input impedance of a traction vehicle has significant influence of compatibility between track circuits and traction vehicles. The model of chopper controlled DC series motor vehicle was implemented as a simulation model including all significant parameters of the whole system: substation-catenary-input filter-chopper. Exemplary results of analysis of the specific locomotive EM10 are included. The results both of analytical and simulation approach for low frequency input impedance computations were compared.

1. Introduction

Dynamic development of semiconductor technology in the seventies was the main cause of high-power converters prevalence in traction vehicles. Initially DC-DC converters were most popular and effective in reducing energy losses during DC series motors starting (so called: second generation traction drive). At the beginning thyristor technology was applied while expansion of transistor devices provided possibility of common use of the AC motors fed with inverters (third generation of traction drives) both with DC and AC power supply systems. Asynchronous motors have significant advantages comparing with DC motor in the aspect of construction and maintenance. However, the main part of traction vehicles used in Poland, applied „conventional" vehicles with DC series motors and rheostatic control (first generation of traction drive). So the possible solutions to modernize rolling stock fleet in Poland are: re-engineering old vehicles or exchanging them to completely new ones. The decision which option is to be chosen, must be based on results of both technical and financial-economic analysis.

The easiest way of reengineering old traction vehicles when DC motors will be kept is to equip them with chopper systems which will reduce energy consumption during starting and allow regeneration of energy during braking. However chopper-controlled vehicles generate harmonics in current taken from catenary, so compatibility aspects of traction system with signaling and command-control systems are to be taken into account when re-engineered vehicles are to be put into service on lines when previously only vehicles with first-generation of drive were used. So in most of the countries, limits of certain harmonics in a vehicle's current were imposed in order to protect track circuits against disturbances. An example of limits being in law at the Polish State Railways [9] are presented in Fig. 1.

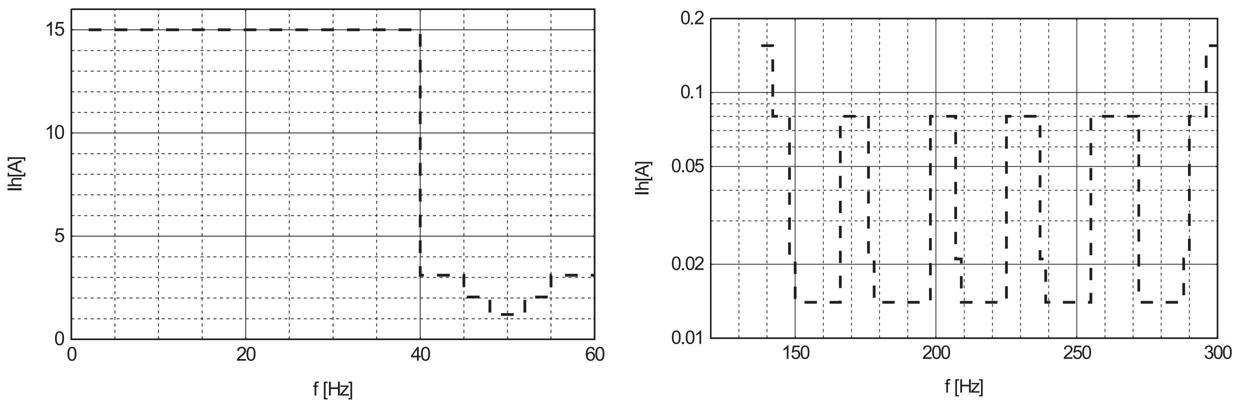


Fig. 1 Limits of harmonics in input vehicle's current

* **Adam Szeląg[1], Marcin Steczek[2]**
[1]Electric Traction Division, Faculty of Electrical Eng., Warsaw Univ. of Technology, Warsaw, Poland, E-mail: aszelag@nov.iem.pw.edu.pl
[2]Faculty of Electrical, Electronic, Computer and Control Engineering, Technical University of Lodz, E-mail: msteczek@p.lodz.pl,

One of the parameters, which determinate a degree of possible disturbance propagation from the power supply system to track circuits is the traction vehicle's input impedance Zin. Predictable is the fact that in case of a vehicle with converter this impedance may vary and be dependent on parameters of the input filter of the vehicle, frequency and chopper mark-period ratio. This problem was discussed in literature [1], while the following paper presents a simulation method of calculation of low frequency, converter traction vehicle input impedance for a specific vehicle. The object of simulations was a modernized traction vehicle equipped with a power step-down chopper with DC series motors drive.

The influence of the supply line, substation filters, parameters and failure states of the converter were also considered.

2. Methods of analysis

For the purposes of verification of the results of computer simulations were compared with analytical calculations. The analytical formula for input impedance was derived with the assumptions discussed in [1]

When one assumes that the input and output powers of the converter are equal (efficiency=1), one- phase chopper (Fig. 2a) load impedance is given by:

$$Z_c = \frac{Z_1}{k^2}\,. \tag{1}$$

where: Z_c – chopper load impedance, Z_1 – static load impedance, k – chopper mark-period ratio (simple control- as ratio: on time to period).

With this assumption, one-phase chopper input impedance Z_{in1} is given by:

$$Z_{in1}(j\omega) = R_f + j\omega L_f + \frac{R_l + j\omega L_l}{k^2 - \omega^2 L_l C_f + j\omega C_f R_l} \tag{2}$$

The similar approach is applied for a two-phase chopper (Fig. 2b). In this case the chopper load impedance is given by: $Z_c = Z_{c1}/2 = Z_l/2k^2$ where Z_{c1} is the impedance of a single converter load. Finally two-phase chopper input impedance Z_{in2} is given by:

$$Z_{in2}(j\omega) = R_f + j\omega L_f + \frac{R_l + j\omega L_l}{2k^2 - \omega^2 L_l C_f + j\omega C_f R_l} \tag{3}$$

A verification of this analytical approach based on the above equations (1)–(2) was carried out with the results of the simulation method, where the input impedance Z_{in} of a chopper equipment was calculated using a theoretical circuit model (Fig. 2).

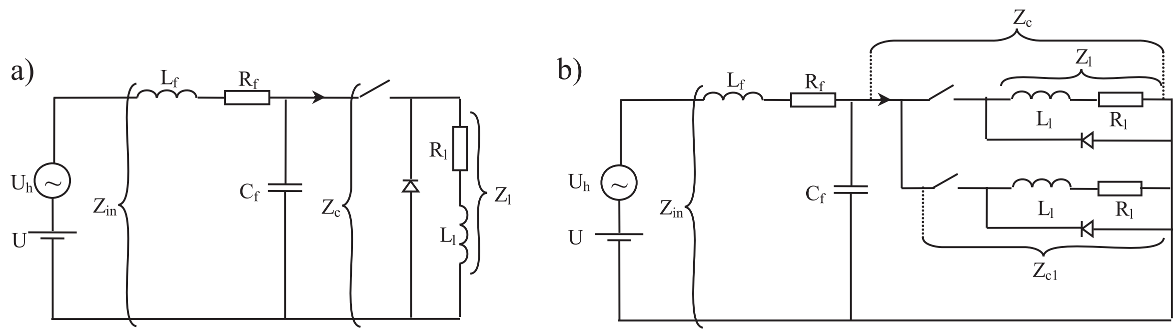


Fig. 2 A scheme of a circuit for a chopper input impedance Z_{in} calculation a) one-phase chopper b) two-phase chopper.

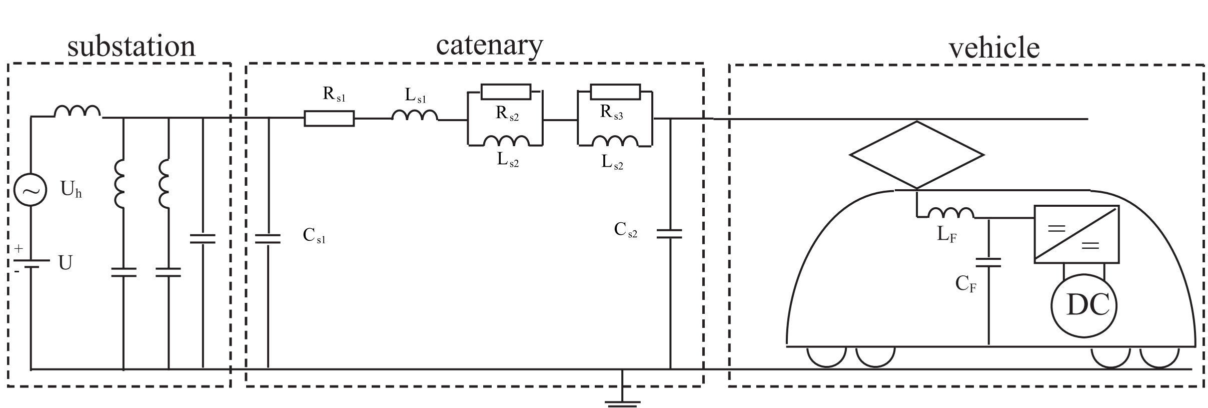


Fig. 3 Simulation model of the whole system for a input impedance calculation

3. Simulation model

The model of EM10 traction vehicle main circuit was implemented as a simulation model. The model of a chopper – controlled DC series motor proposed in [3] was used with adequate assumptions. Moreover excitation winding inductance was implemented as dynamic inductance given by $L(I) = Z\dfrac{d\Phi(I)}{dI}$

where: Z is the number of excitation winding coils and Φ is a main flux of the machine. The eddy current circuit decreases flux pulsations, such an effect was observed in chopper-controlled motors. The switching strategy was specified assuming the maximum start-up current of 320 A for a single motor group, with the constant operating frequency. The model of a catenary proposed in [2] was considered in the calculations.

Additionally an eddy currents circuit and smoothing inductance were modeled. The eddy currents phenomena is caused by current pulsations during chopper drive control and causes stray load losses in solid parts of the motor magnetic circuit. This results in reduction of motor efficiency. Transistor choppers are operating at 400 Hz, the analysed scheme of the vehicle is presented in Fig. 4.

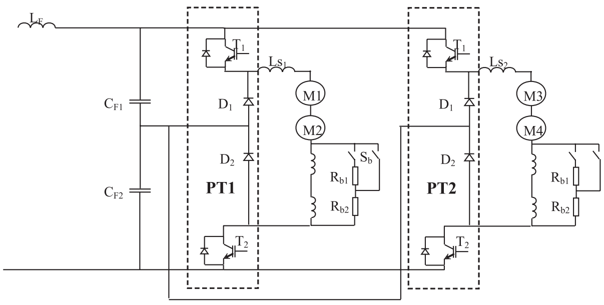


Fig. 4 A scheme of the analysed vehicle

4. Simulation results

The input impedance was computed using a simulation tool in time domain with FFT option. In input impedance calculations following aspects were taken into consideration: influence of catenary, substation filters (for 6- and 12-pulse rectifier), failure states of the converter (variant phase shifts between converters or different individual chopper operating frequencies), operation of two vehicles on the line. The most interesting results were observed at frequencies close to the input filter resonant frequency (~22 Hz). The parameters of the input filter (L = 18 mH, C = 2.8 mF) compared with DC motor parameters [4] were significant for the results. The most important for low-frequency track circuit disturbances is 50Hz frequency. The results of simulations did not find disturbing currents in this range. In many available in literature articles on chopper-controlled DC motor simulations authors omitted influence of eddy currents. However, the damping influence of eddy currents on the input impedance was observed from the results of simulations (Fig. 5). Fig. 6 shows a variation of the input impedance

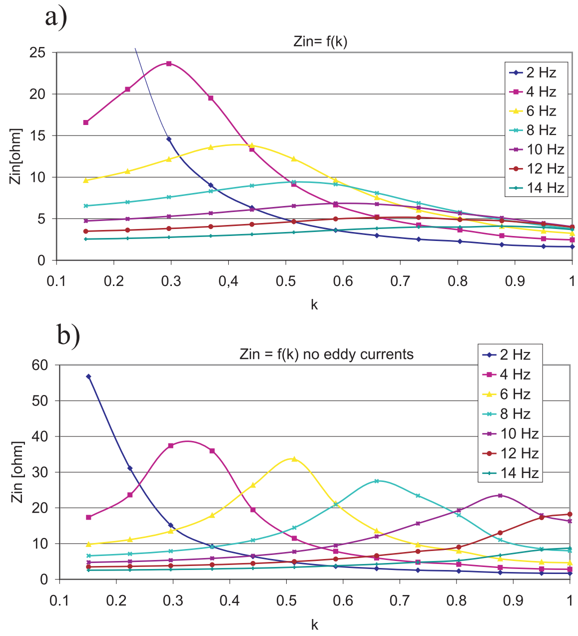


Fig. 5 Variation of low frequency input impedance with chopper mark-period ratio
a) including eddy currents influence
b) eddy current influence omitted

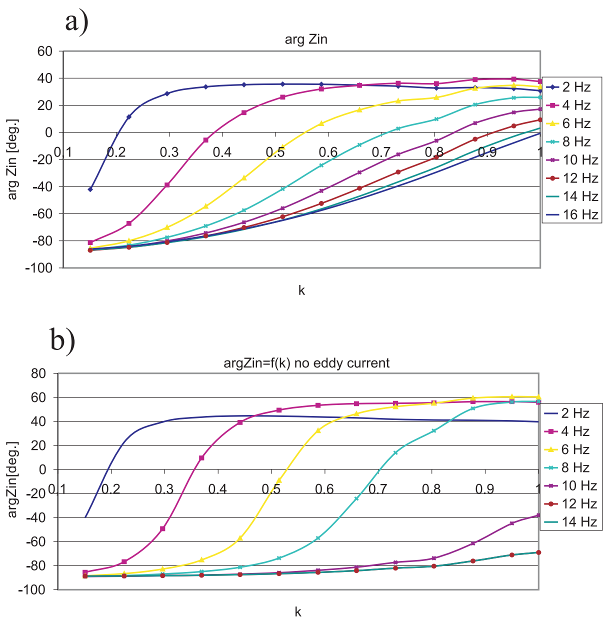


Fig. 6 Variation of low frequency input impedance phase with chopper mark-period ratio
a) including eddy currents influence
b) eddy current influence omitted

ance phase with k for low frequencies. It is shown that the vehicle can change its load character with a mark period from inductive to capacitive. Eddy currents have also significant influence on such changes.

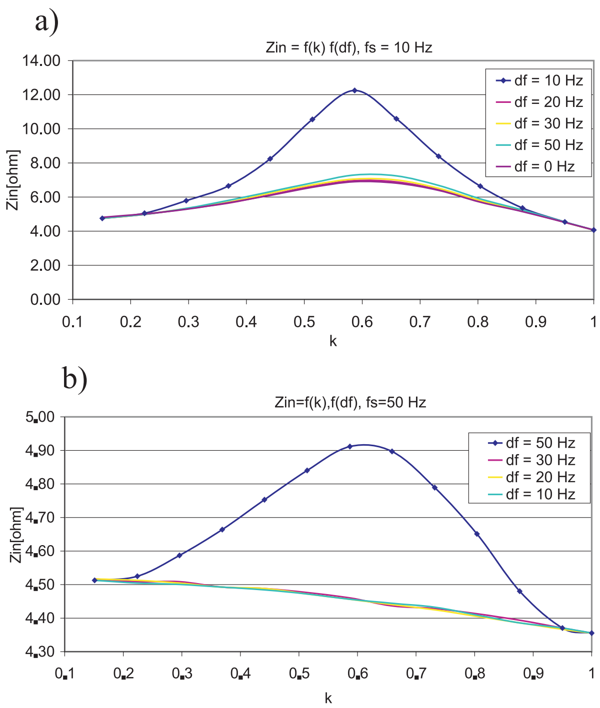


Fig. 7 Variation of low frequency input impedance with chopper mark-period ratio for different frequency of converters; difference equal df a) Zin impedance for 10 Hz b) Zin impedance for 50 Hz

The influence of operating frequency difference between individual choppers on the input impedance was carried out. Fig. 7 shows variation of the input impedance with a chopper mark period and with difference between operating frequencies (df). The influence is significant for frequencies equal to df .

5. Conclusions

The input impedance analysis with usage of the derived model for the specific vehicle with chopper-controlled motors and the influence of substation filters, length of supply line and parameters of vehicle filter were analyzed brought the following conclusions:

- the most significant input impedance variations can be observed for frequencies near the input filter resonant frequency (in this case it is 22 Hz),
- 50 Hz input impedance of the analysed vehicle is practically constant with a chopper mark-period ratio,
- as 50 Hz current limit is 1,25 A [Fig. 1] it means (for the calculated input impedance) that if 50 Hz voltage at the vehicle's pantograph is below 5,6 V this current limit will not be exceeded; typically 50Hz voltage component at DC side voltage of 3kV DC traction substation with bridge 6-pulse or 12-pulse rectifiers is much lower,
- a supply current pulsation reaches its maximum for $k = 0.25$ and 0.75 for a two – phase chopper with 180 degree phase-shift,
- the operation of two vehicles supplied from one substation had no disturbing influence on track circuits,
- the offset value (nominal 180 degree) does not affect the input impedance variations,
- eddy currents phenomena significant for the value of input impedance of a chopper- controlled DC series motor, however the analytical method based on eq. (1)–(2) does not take it into account,
- analytical and simulation methods of analysis of the input impedance of a chopper-controlled R L static load give similar results, but the analytical method may be used only for low frequency,
- for high frequencies (above the operation frequency of a chopper) in order to calculate input impedance of a vehicle simulation methods are to be used.

Reference

[1] MELLITT, B., TAUFIQ, J. A., XIAOPING, J.: *Input impedance of chopper equipment and its significance in low-frequency track circuits,* IEEE PROCEEDINGS, vol. 136, Pt. B, No. 1/1989,

[2] SZELĄG, A.: *Problems of analysis and design of DC electric traction system with application of modelling and simulation technique (in Polish)*, Warsaw University of Technology Press, Warsaw, 2002,

[3] *Power electronics in electric traction. Selected problems of electrotechnics (in Polish),* Symposium - Institute of Electrotechnics, Warsaw, 1973,

[4] GIZINSKI, P.: *Transistor IGBT control system of EM10 locomotive (3000 – 1 MW) – (in Polish)*, Technika Transportu Szynowego, pp. 30 - 35, 6/2004,

[5] JABLONSKI, M.: *D.C. machines,* Script for Technical University of Lodz, Lodz, 1973,

[6] GOGOLEWSKI, Z., GABRYŚ, W.: *D.C. machines, constructions, construction, special issues,* PWT Warsaw, 1960,

[7] *Power electronics in electric D.C. traction – pulse control,* The Polish Academy of Science, Polish Scientific Publishers, Warsaw 1976,

[8] SZELAG, A., ZAJAC, W: H*armonic distortion caused by suburban and underground rolling stock with D.C. motors,* CIEP 96, Cuernavaca, Mexico, 1996,

[9] BIALON, A: *Accepted parameters of disturbances for signalling and control systems and traction vehicles (in Polish)*, 6^{th} International Conference MET 2003 Warsaw, September 25-27, 2003.

Vladimir Vavrus – Jan Vittek – Michal Malek *

VELOCITY VECTOR CONTROL OF A LINEAR PERMANENT MAGNET SYNCHRONOUS MOTOR

The paper presents a design of vector control algorithm for electric drive employing a linear permanent magnet synchronous motor (LPMSM). For simulation and further experimental verification it was necessary to formulate a mathematical model of the LPMSM. This model was derived from a standard mathematical model of a rotary PMSM and then exploited to verify vector control of the machine. The presented simulation results are used to control the LPMSM drive system with maximum efficiency.

1. Introduction

The construction principles of linear motors are known as long as principles of rotational motors. The principle of the induction linear motor was described by Charles Wheatson in 1841, [1]. But these motors have been exploited in industrial applications for last ten years mainly. This expansion was enabled by the development of new materials for permanent magnets, new controlled elements and topologies of power converters and new control techniques, which are suitable for applications with linear motors.

2. Basic Principles of Linear Motors

There are two basic definitions of linear motors. One of them introduces linear motors as a classical synchronous or induction rotational motor, where the transformation from rotary to linear system is shown in Fig. 1. The second definition describes generally a linear motor as a corresponding rotational motor with the infinite stator and rotor radius.

The stator of linear motors is usually called primary part and the rotor is called secondary part. The primary part consists of ferromagnetic plates and three phase winding, which is stored in slots. Opposite of the primary part is secondary part, sometimes called mover, which contains permanent magnets, usually made from Neodymium – Iron – Boron (Ne-Fe-B). Magnets are stacked on the iron base. In induction linear motors, the secondary part is composed as a squirrel cage stored in slots, or stacked on the iron base or sometimes as a simple aluminium sheet. For many applications it is a primary part which is moved on the path as a mover. The path is usually composed of many sections of permanent magnets, which create a secondary part. Such concept requires flexible supply cables, flexible position sensor cable and for high power linear motors also flexible tubes for water cooling.

In general, linear drives consist of a linear motor, power converter and position or velocity sensors. For industrial applications the linear drives also need special equipment such as a guiding system, extra cooler and safety parts. Due to the fact that many linear drives are position controlled servo drives, these applications need for control a special circuitry which usually utilises the information from a position or velocity sensor.

3. Principles of Vector Control of LPMSM

Vector control is used the most often for control of electric drives for which a high precision and fast response to the demanded values of speed or position are required. This is impor-

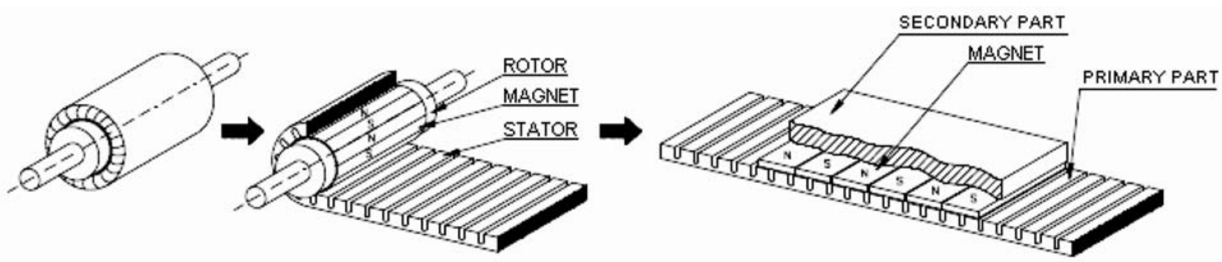


Fig. 1 Analogy between rotary motor and linear motor

* **Vladimir Vavrus, Jan Vittek, Michal Malek**
Department of Power Electrical Systems, Faculty of Electrical Engineering, University of Zilina, Slovakia, E-mail: Vladimir.Vavrus@kves.uniza.sk,

tant for steady-states as well as for transient states of the drive. The basic idea is to achieve control properties of the drive with a separately-excited dc motor. For dc motors positions of magnetic flux vector (*created by stator winding*) and armature current are mutually orthogonal (*given by commutator brushes position*) to create always maximum torque of the machine. Due to the fact that exciting winding and armature winding are not only separately mounted inside of the motor but also separately supplied, these two control variables can be controlled independently. Exploiting this analogy, the basic principle of vector control of the LPMSM is independent control of two state variables, currents of primary part and magnetic flux [2]. The most widely used block diagram for velocity control of the LPMSM has a cascade structure, which is shown in Fig. 2.

$$F = \frac{3}{2} \cdot K_x \cdot \Psi_{PM} \cdot i_q \quad F = \frac{3}{2} \cdot K_x \cdot \Psi_{PM} \cdot |I_s| \cdot \sin \alpha_m \quad (2a,b)$$

where: α_m is the angle between vectors of primary part I_s current and permanent magnet flux Ψ_{PM}.

During such conditions the flux of permanent magnet Ψ_{PM} is maintained constant and maximal force is achieved for angle $\alpha_m = 90°$. This condition is satisfied for $d-q$ coordinate system, which has *d*-axes identical with the direction of the permanent magnet flux and a primary part current vector in this frame is orthogonal to *d*-axes and therefore i_d current will be 0.

The structure of velocity vector control of the LPMSM is shown in Fig. 2. It has a nested structure which consists of two loops.

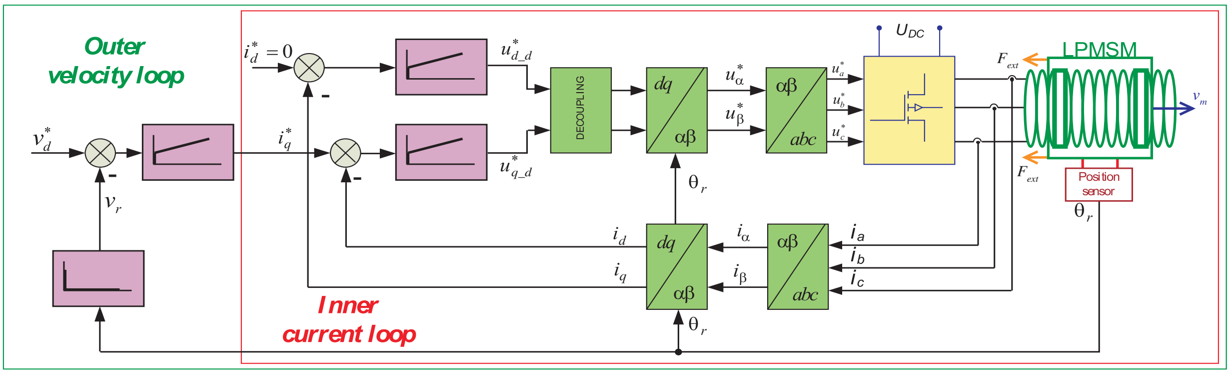


Fig.2 Typical cascade structure for velocity vector control of LPMSM

3.1 Vector control applied to LPMSM

The basic principle of vector control strategy for the LPMSM is decomposition of a primary part phase current vector into two orthogonal components. The first component is i_d current component (*which produces a magnetizing flux*). This component is in the phase with permanent magnet flux. The second component is i_q current (*which produces an electromagnetic force*), which is orthogonal to the first one (see Fig. 3). For rotor flux-oriented vector control of the LPMSM, the direct-axis stator current and the quadrature-axis stator current must be controlled independently. The force produced by the motor is in a $d-q$ coordinate frame equal (details in sect. 4.1):

$$F = \frac{3}{2} \cdot K_x \cdot [\Psi_{PM} \cdot i_q + (L_d - L_q) \cdot i_d \cdot i_q] \quad (1)$$

Equation (1) describes two parts of the motor force. First one '*magnetic*' is independent of the primary part current i_d, and it is proportional to i_q current. The second part '*reluctance*' is proportional to both currents i_d, i_q of the primary part multiplied by the difference between primary part inductances in $d-q$ axes $(L_d - L_q)$.

When the direct a quadrature inductances are the same, eq. (1) can be simplified as (2a), from which the most efficient control by controlling i_q current only, can be determined as (2b):

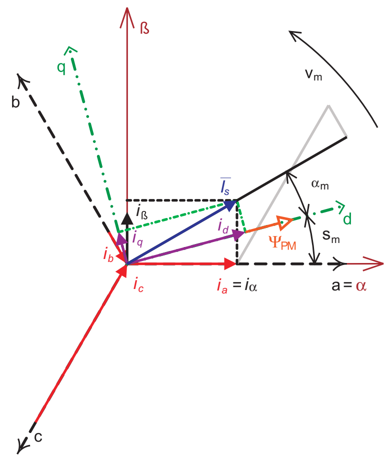


Fig. 3 Phase diagram of stator current

The outer loop is a velocity control loop and the inner loop is a current control loop. The value of the demanded current i_q (*force producing component*) is determined by the velocity PI regulator having the difference between demanded velocity, v_d and real motor velocity, v_m as an input. Controlling i_d current at 0 value, the motor will produce maximal electromagnetic force up to the nominal

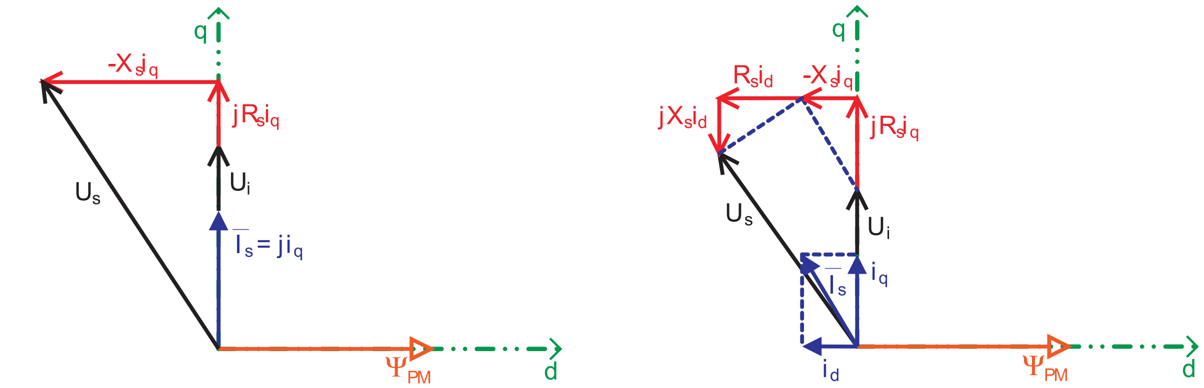


Fig. 4 Phase diagram of LPMSM vector control
a) up to nominal velocity, b) over a nominal velocity

velocity. The phase diagram shown in Fig. 4a describes normal vector control up to the nominal velocity. If a higher velocity than nominal is demanded then the field weakening must be applied by controlling the i_d current, which is shown as the phase diagram in Fig. 4b.

4. Simulation of LPMSM Vector Control

Verification of the designed LPMSM vector control was made in Matlab-Simulink environment. The block diagram of the proposed control is shown in Fig. 5. Simulations run with different sampling frequencies for the both control loops and the model of the motor. Sampling frequency of the outer velocity control loop is 1 kHz and inner current control loop has the sampling frequency of 10 kHz. The LPMSM model in orthogonal $d-q$ transformations has a sampling frequency of 1 MHz.

However, the equations for primary part voltage components are coupled. The demanded voltages are increased for the part which contains also decoupling components as follows:

$$u_d = u_{d\_d} - L_q \cdot i_q \cdot v_m \quad \text{and}$$

$$u_q = u_{q\_d} + L_d \cdot i_d \cdot v_m + K_e \cdot v_m, \qquad (3a,b)$$

where: u_{d_d}, u_{q_d}, are the demanded voltages from current PI regulators.

The parameters of the primary part of the real LPMSM which was built in DPES are listed in Tab. 1 and used for simulations. The real LPMSM has four sections of the primary part which are connected in series.

Parameters of one primary part of LPMSM Table 1

R_s [Ω]	2.35	L_q [mH]	0.12	τ_p [mm]	82.5	K_e [Vsm^{-1}]	52.9
L_d [mH]	0.12	p [–]	4	K_f [NA^{-1}]	45.8	M [kg]	40

4.1 LPMSM mathematical model

The LPMSM mathematical model can be derived through analogy to a rotary permanent magnet synchronous motor (PMSM). After transformation from the tree-phase a-b-c frame to the equiv-

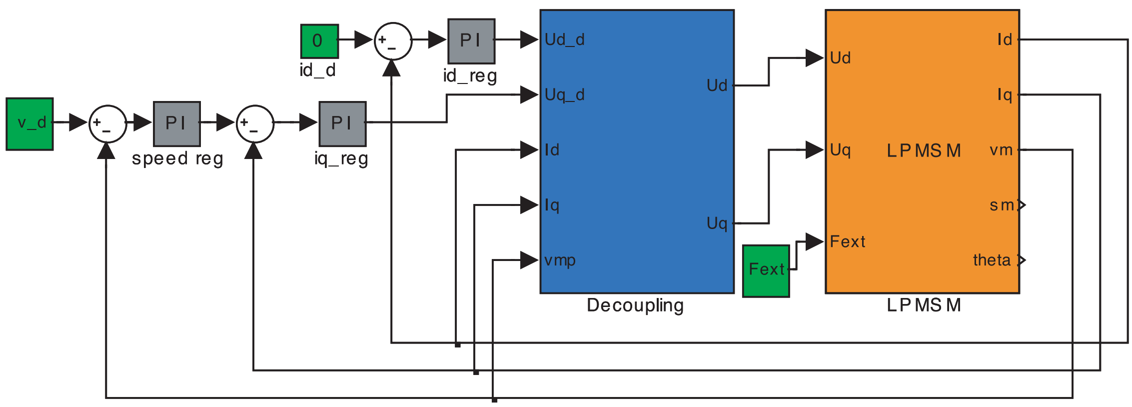


Fig. 5 Simulation model of vector control of PMLSM

alent orthogonal synchronous d-q frame, the relations between the d-q components are given as [1], [3] and [4]:

$$u_d = R_s \cdot i_d + \frac{d\psi_d}{dt} - \omega_e \cdot \psi_q, \tag{4}$$

$$u_q = R_s \cdot i_q + \frac{d\psi_q}{dt} - \omega_e \cdot \psi_d, \tag{5}$$

$$\psi_d = L_d \cdot i_d + \Psi_{PM}, \tag{6}$$

$$\psi_q = L_q \cdot i_q \tag{7}$$

$$J\frac{d\omega_e}{dt} = \frac{3}{2} \cdot p \cdot (\psi_d \cdot i_q - \psi_q \cdot i_d) - \Gamma_{ext}, \tag{8}$$

$$\omega_e = p \cdot \omega_r, \tag{9}$$

where:
R_s is the phase winding resistance,
ω_r is the mechanical angular speed,
p is the number of pole-pairs,
J is the lumped moment of inertia,
Γ_{ext} is the external load torque,
u_d, u_q are the d and q axis voltages,
i_d, i_q are the d and q axis currents,
ψ_d, ψ_q are the d and q axis fluxes,
Ψ_{PM} is the permanent magnet flux linkage,
ω_e is the electrical angular speed.

Equations (4) – (7) represent voltages respective fluxes equations of the rotary PMSM in the d-q coordinate system, where L_d, L_q are the d and q axis inductances. Eq. (8) is an electro-mechanical equation of the PMSM and eq. (9) defines the relation between electrical and mechanical angular speed.

Linear motors, unlike rotary motors, produce a translation movement, therefore, it is necessary to define the rate constant between the stationary reference frame and the rotating reference frame. This definition is valid only when the synchronous angular speed is the same as the electrical angular speed $\omega_s = \omega_e$.

$$K_x = \frac{\omega_e}{v_m} = \frac{2 \cdot \pi \cdot f_s}{v_m} \quad \text{and} \quad v_m = 2 \cdot \tau_p \cdot f_s \tag{10a,b}$$

where:
v_m is the electric linear velocity,
τ_p is the pole pitch
f_s is the frequency of the power supply voltage
K_x is the rate constant between the stationary reference frame and the linear reference frame

Using eq. (4) – (8) together with eq. (10a,b) a new form of stator voltage equations can be derived:

$$u_d = R_s \cdot i_d + L_d\frac{di_d}{dt} - K_x \cdot L_q \cdot i_q \cdot v_m, \tag{11}$$

$$u_q = R_s \cdot i_q + L_q\frac{di_q}{dt} + K_x \cdot L_d \cdot i_d \cdot v_m + K_x \cdot \Psi_{PM} \cdot v_m, \tag{12}$$

If the mechanical power of the rotary and linear motor are same, then it is possible to derive:

$$M_m \cdot \omega_r = F_m \cdot v_m \Rightarrow M_m = F_m \cdot \frac{v_m}{\omega_r} = F_m \cdot \frac{\tau_p}{\pi} \cdot p, \tag{13}$$

where:
M_m is the mechanical torque of the rotational PMSM
F_m is the mechanical trust of the linear PMSM

When the principles of vector control are respected then electromagnetic torque of the rotational PMSM is done as:

$$M_m = \frac{3}{2} \cdot p \cdot \Psi_{PM} \cdot i_q. \tag{14}$$

Comparing (13) and (14) the electromechanical force of the LPMSM can be expressed as:

$$F_m = \frac{3}{2} \cdot \frac{\pi}{\tau_p} \cdot \Psi_{PM} \cdot i_q = \frac{3}{2} \cdot K_x \cdot \Psi_{PM} \cdot i_q = K_f \cdot i_q, \tag{15}$$

where: K_f is the force constant of the LPMSM.

The definition of the voltage constant K_e is as follows:

$$K_e = \frac{\pi}{\tau_p} \cdot \Psi_{PM} = K_x \cdot \Psi_{PM}. \tag{16}$$

Applying the constant (16) into the equations (11) and (12) the new stator voltage equations are defined as:

$$u_d = R_s \cdot i_d + L_d\frac{di_d}{dt} - K_x \cdot L_q \cdot i_q \cdot v_m, \tag{17}$$

$$u_q = R_s \cdot i_q + L_q\frac{di_q}{dt} - K_x \cdot L_d \cdot i_d \cdot v_m + K_e \cdot v_m. \tag{18}$$

Using the force constant and a vector control strategy (*the demanded current in d axis up to nominal velocity is zero*, $i_{d\_d} = 0$) a mechanical equation for the LPMSM has the form:

$$\frac{dv_m}{dt} = \frac{1}{M}(F_m - F_{ext}) = \frac{1}{M}(K_f \cdot i_q - F_{ext}) \text{ and}$$

$$\frac{ds_m}{dt} = K_x \cdot v_m, \tag{19}$$

where: M is the total mass of the moving element system,
F_{ext} is the external disturbance term (external load force),
s_m is the position of moving element.

The mathematical model of the LPMSM in Matlab-Simulink environment is shown in Fig. 6.

4.2 Simulation Results

The simulation results of the LPMSM vector control are summarised in Fig. 7. Fig. 7a shows demanded velocity, real motor velocity and applied external load force as a function of time and Fig. 7b presents the motor currents in a synchronously moving reference frame in d-q axes as a function of time.

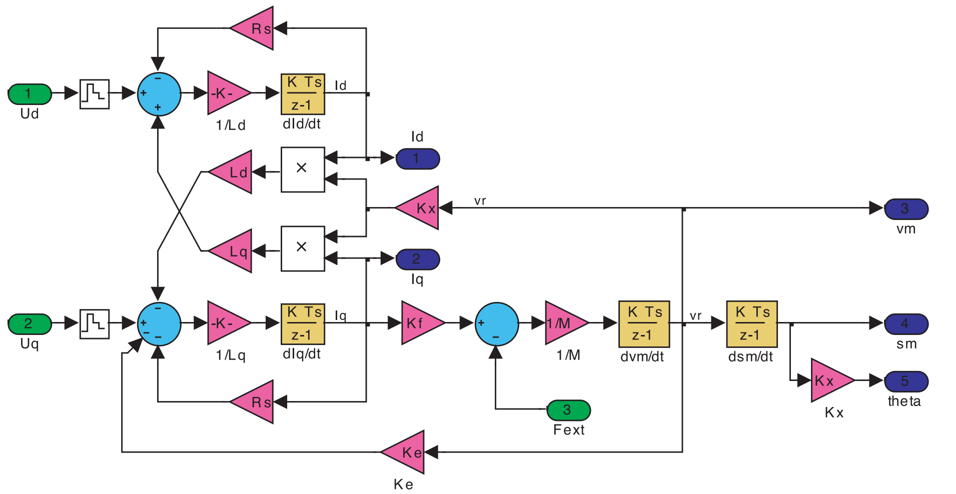


Fig. 6 Matlab-Simulink model of PMLSM.

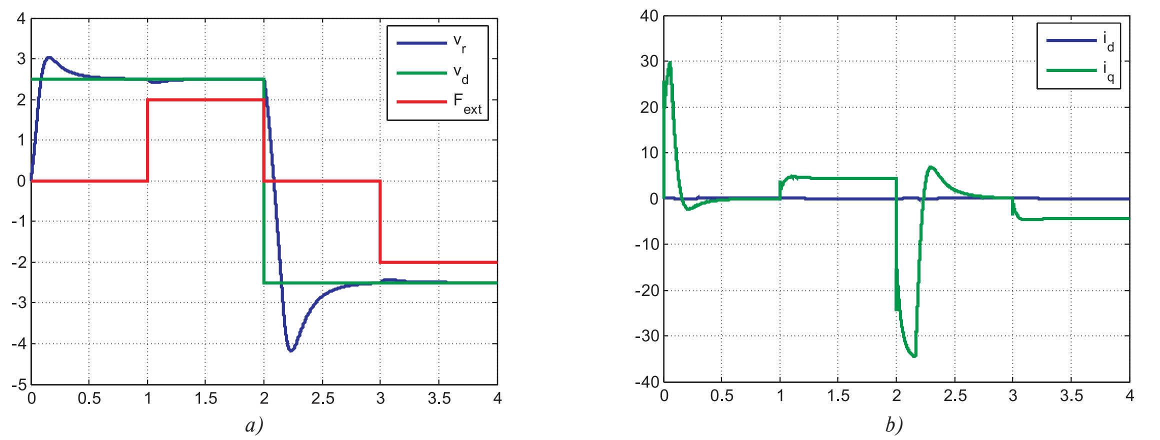


Fig. 7 Simulation results, a) motor velocity and applied external load force vs. time; b) motor current components vs. time in d-q reference frame

The simulation results of the proposed vector control for electric drives employing the LPMSM show a good agreement with theoretical predictions. As can be seen from Fig. 7a the LPMSM reach the demanded velocity in both directions of turning with a small overshoot. Fig. 7b demonstrates the proper operation of both regulators. The flux regulator keeps i_d current component at the zero value as it is demanded up to the nominal velocity of the motor and the force regulator produces i_q current component to reach the demanded velocity for both directions and also to cover the external force disturbance.

5. Conclusion

Based on the analogy between a permanent magnet synchronous motor and the LPMSM this paper developed a mathematical model of the machine. The model is then exploited to derive vector control of the drive with the LPMSM. Vector control of the rotational and linear motor is based on the same principles, but it is important to precisely define the differences between them. Analogy of both motors enabled that all the fundamental equations of the LPMSM where derived in an orthogonal synchronous *d-q* frame, and from them the LPMSM model Matlab-Simulink environment was built and tested for a designed vector control strategy. The presented simulation results predicted possibility to control this motor exploiting vector control technique and also confirmed the possibility to achieve good drive performance.

Preliminary experimental investigation of the proposed control technique of the LPMSM already started and experimental results on the proposed drive system with the LPMSM would be a natural next step. Extension of the vector control algorithm to the forced dynamics control would be of interest.

Acknowledgements

The authors wish to thank Slovak Grant Agency VEGA for funding the project No.4087/07 'Servosystems with Rotational and Linear Motors without Position Sensor'.

References

[1] ZALMAN, M., JOVANKOVIC, J.: *New trends in control of linear motors (in Slovak)*, AT&P journal 2/2006, pp. 67–70.

[2] BOLDEA, I., NASAR, S. A.: *Vector Control of AC Drives*, CRC Press, Boca Raton, 1992

[3] VITTEK, J., VAVRUS, V., MALEK, M., BUCHNER, P., MICHALIK, W.: *Prescribed Closed-loop Speed Dynamics Control of the Actuator employing Linear Permanent Magnet Synchronous Motor,* ICIT 05, Hong-Kong.

[4] ZENG, J., BARRE, P., DEGOBERT, P.: *Modeling and Trust Control of PMLSM Using Principle of Local Energy,* ICEMS 2003, Vol. 1, 2003, pp. 26–30.

[5] HONG, G., KAIPEI, L.: *Model of the permanent magnet linear synchronous motor on the bias of the field orientation*, Electrical Machines and Systems, ICEMS 2005, Vol. 1, pp. 442–445.

Marcus Einbock – Gudrun Stranner *

INTEGRATING ECOLOGICAL COMPONENTS IN KILOMETRE-BASED ROAD TOLL SYSTEMS

Some member states of the European Union (e.g. Germany, the Czech Republic) have already included ecological components in their pricing systems of kilometre-based road tolls for road freight transport on the motorway-net. This means that vehicles with very modern emission standards have to pay less per kilometre in contrast to older trucks with a higher volume of exhaust-emissions. Austria implemented a kilometre-based road toll system in 2004, but without an ecological component. The goal of the paper is to evaluate the effects of considering EURO emission standards in the price systems of road tolls in Austria with the help of the scenario technique. Consequences as the shift in total travelled vehicle kilometres on the Austrian motorway net are discussed as well as hypothetical changes in the behaviour of the road freight forwarding industry to purchase and/or rent modern clean-exhaust vehicles.

1. Introduction

In general road user charges help to finance the road infrastructure and serve as an instrument in the fields of transport policy. This seems to be of utmost significance with regard to its potential for allocating social cost according to the polluter pays principle and reducing negative effects of road traffic on the environment.

The model for calculating toll rates and emissions which is presented in the course of this paper acts on the basic assumption that raised toll rates for heavy-duty vehicles with higher emission factors lead to a shift in the number of total travelled vehicle kilometres. This is because of an alteration in the investment structure of the road freight transport industry towards cleaner trucks and busses resulting in an increased number of modern fleets with the latest emission standards. However, the dimension of a reduction of or an increase in vehicle kilometres is dependent on the specific amount of the toll rates charged for clean exhaust and heavily emitting trucks and buses. Here the price is seen as the general indicator for creating incentives to use or invest in cleaner vehicles.

The modification of the current road toll system to a more ecological one is more and more discussed. Especially the amendment of the directive 1999/62/EC by the European Parliament and the Council in May 2006 emphasises the need for ecologically differentiated toll systems.

2. Theoretical background

2.1 Price differentiation and the internalisation of negative externalities of road traffic in connection with road user charges

In the context of using road infrastructure there exist many different concepts for differentiating prices, but not all of them lead to an optimal allocation of resources. The most important advantage of toll rates being differentiable is found in their ability to take the individual circumstances of road users and the road infrastructure itself into account. In the technical literature though there is no coherent definition of the term "*price differentiation*" [1]. A useful typology of approaches for varying prices was created by Pigou (1920) who distinguishes between three levels of price differentiation [2]. The technical literature offers various forms of differentiating prices [3]: (a) individual-oriented, (b) regional, (c) temporal, (d) utilisation-oriented or (e) vehicle-oriented. Following the recognition of ecological aspects as possible price differentiation criteria could be classified as vehicle-oriented.

On the one hand the above listed approaches rarely pursue the aim of an optimal allocation of resources, but try to maximise revenues or to achieve politically desired benefits for special groups of individuals. On the other hand an optimal pricing of road infrastructure does not automatically lead to an efficient pricing with regard to the financing of the actor operating the road infrastructure.

External costs are a result of individuals' negative influence on the production or consumption function of third parties without getting paid compensation and lead to a situation, where the marginal private cost of an activity diverges from the accruing marginal social cost [4]. In the case of marginal social cost being less than marginal private cost we speak about positive external effects, where third parties benefit from activities of other individuals [5]. Negative external effects, however, accrue from marginal private cost being less than marginal social cost with the differing amount representing the external costs [6]. Without an internalisation of these adverse effects the activity causing the negative externality will be over-performed, because the party acting in his or her own interest only confronts his or her marginal private utility with the correlative marginal private cost, but not with the marginal social

* **Marcus Einbock, Gudrun Stranner**
Institute of Transport Economics and Logistics, Vienna University of Economics and Business Administration, Nordbergstraße 15, 1090 Vienna, E-mail: Marcus.Einbock@wu-wien.ac.at, Gudrun.Stranner@wu-wien.ac.at

cost. Thus, the additional social cost is passed along to third parties whose welfare deteriorates as there are no compensating payment flows [7]. The party causing the negative effect, however, has no reason to consider the extra social cost in his or her individual decision (Fritsch/Wein/Ewers 2005).

The emergence of external costs can be integrated in the standard model of road pricing which dates back to studies by Pigou (1920), Knight (1924), Walter (1961) or Johnson (1964). The model basically explains the occurrence of social marginal cost caused by the addition of marginal congestion cost to the sum of private marginal cost of the road user. The road users are characterised by a varied level of willingness to pay. Consequently, the introduction of a road toll which aims at the internalisation of the accrued social marginal cost will lead to a situation where road users who are not willing to pay the increased price will abandon the journey. The aim is to raise the price for using the road infrastructure as long as it is necessary to achieve an optimal deployment level of the road infrastructure.

In addition to the internalisation of marginal congestion cost road tolls can also integrate external costs accruing from transport activities or traffic in general. Road traffic leads to serious negative consequences for humans, the natural environment, materials and surfaces. These costs partly accrue from the existence of road infrastructure itself, but mainly from operating means of transport on it like costs of air and noise pollution, of accidental implications or congestion [8].

2.2 Analysing the EU legislation with regard to an ecological differentiation of road toll systems

The legal framework for the introduction of the kilometre-based truck road in Austria in 2004 is set by the European Parliament and the Council and is valid for all member states within the European Union. Therefore, in the next section the EU legislation with regard to an ecological differentiation of road toll systems will be analysed first to continue with the actual situation in Austria.

In the directive 1999/62/EC, "directive on the charging of heavy goods vehicles for the use of certain infrastructures", the European Parliament and the Council created a framework for introducing road toll systems. This regulation was amended though in May 2006 by the directive 2006/38/EC. The comparison of the two directives has shown that the variation of toll rates by ecological, vehicle-oriented components as well as the internalisation of external environmental cost becomes more and more important.

According to Article 7, passage (10), point (a) of the amended directive each member state of the European Union is generally allowed to vary toll rates for the purpose of preventing environmental damage, congestion or infrastructural damage, for optimising the use of infrastructure or for road safety. Moreover, the variation of toll rates must be proportionate, transparent, non-discriminatory and should not be intended to generate additional toll revenues. When it comes to a variation of toll rates by EURO emission classes the amended directive sets new limits for the variation of toll rates. The old regulation states that the highest toll rate is not allowed to exceed 50 % of the rate for an equivalent vehicle meeting the strictest emission standards. However, according to the amended directive, Article 7, passage (10), point (b) varied toll rates may exceed the rate for an equivalent vehicle meeting the strictest emission standards by 100 %. Thus, the new regulation concerning the variation of toll rates by EURO emission classes sets an upper limit for raising toll rates, which is also considered in the model for calculating toll rates and emissions.

3. Model for estimating effects of an ecologically differentiated road toll system

A deliberate control of the price system for the use of the Austrian motorway net shall create incentives for an intensified deployment of clean-exhaust trucks and buses and simultaneously for a reduction of the number of vehicles heavily exhausting air pollutants. In such a scenario vehicles with a maximum loaded weight over 3.5 tons that fulfil the newest emission standards (EURO IV and V) are charged reduced toll rates in contrast to those which are emitting high volumes of pollutants (EURO 0 and I). In connection with pricing systems for the use of road infrastructure the only question is at what level prices must be set so that controlling effects are evolved.

Therefore, a model for calculating toll rates, volumes of exhaust-emissions and external costs was established which serves as a tool for creating the above pictured scenario theoretically. On the basis of an intensive data collection and various assumptions scenarios with varied toll rates were elaborated in order to measure the effects of varied toll rate amounts on:

- the total toll revenues collected by the ASFINAG;
- the volume of airborne exhaust-emissions of heavy-duty vehicles;
- the level of external cost caused by airborne exhaust-emissions of heavy-duty vehicles.

Another goal of the model is to generate realistically enforceable toll rates which lead to a maximal possible impact in the sense of reduced volumes of exhaust-emissions. Moreover, it is about testing whether a system which only subsidises clean-exhaust vehicles is sufficient for achieving a maximal reduction of exhaust-emissions or whether a combined system is needed. In the latter case vehicles with low or no emission standards are additionally penalised with increased toll rates. Each scenario of the model is elaborated in a way that it always shows these two different possibilities, a bonus-system and a bonus-malus-system.

3.1 Methodology

The scenario technique is applied in the model for projecting scenarios where a maximal reduction of exhaust-emissions in the future becomes possible and following a decline of external costs caused by road traffic with heavy-duty vehicles on the Austrian motorway net. The general advantage of the scenario technique lies in its ability to project future development paths and to derive adequate action from the gained results. Therefore, scenarios must be generated which can be understood as reasonably formulated, hypothetic future images of a delimited problem. They help to consider different variants and possibilities for developing and serve as a tool for preparing decisions.

In the model three model scenarios were designed. The decision for the different toll rate levels included a complex task of finding amounts which are "realistically enforceable", "overpriced" or "understated" with regard to the Austrian situation. It was necessary to set up assumptions which represent the impact of changed/varied toll rates on the total travelled vehicle kilometres on the Austrian motorway net and on the investment structure of the road freight transport industry in clean-exhaust vehicles in the most realistic way.

The model produces a multitude of results for each price system in each scenario which then needs to be evaluated for an effective decision-making. To sum up, the methodology of the whole model is summarised in *Fig. 1:*

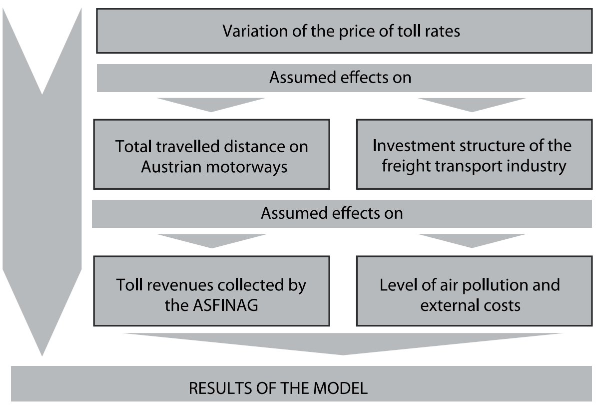


Fig. 1 Methodology and parameters used in the model (Individual design)

3.2 Calculation methods

3.2.1 Characteristics of the total travelled vehicle kilometres

In a first step it is necessary to collect data concerning the total travelled heavy-duty vehicle kilometres on the Austrian motorway and to distinguish them first by nationality of the vehicles, second by axle category and third by EURO emission class. For finding out the nationality of the travelled vehicle kilometres for the year 2005 the ASFINAG is consulted as they are continuously assessing various characteristics of the trucks and buses which are using the Austrian motorway net. The nationality of the vehicles is of great importance, because in a next step the statistics of all registered trucks and buses of each country can be consulted to evaluate axle categories and EURO emission classes which are needed to calculate the total toll revenues and second the reduction potential for exhaust-emissions and external costs.

As a matter of reducing complexity only for the first six countries in the ranking which hold the greatest proportions of the total travelled vehicle kilometres further inquiries concerning axle categories and EURO emission classes are undertaken. These countries are Austria, Germany, Hungary, Italy, the Czech Republic and Slovenia and represent 81.42 % of the total travelled vehicle kilometres (starting with the country holding the greatest proportion of travelled vehicle kilometres). For the remaining 59 countries an average is calculated for indicating vehicle category and EURO emission class.

After the total travelled vehicle kilometres are differentiated by nationality, axle category and EURO emissions class the shift of travelled vehicle kilometres can be calculated for the three scenarios with the help of the above explained assumption concerning the reduction of the total travelled vehicles kilometres. Therefore, the assumed percentages must be weighed for each country depending on their proportion of travelled vehicle kilometres in the three axle categories. This calculation method guarantees a more precise result concerning the shift of total travelled vehicle kilometres.

With the newly generated vehicle kilometres per axle category it is possible to calculate the toll rate revenues for each scenario.

3.2.2 Calculating the reduction potential of the volume of road traffic air pollutants

The model also evaluates the effects of a road toll with ecological components on the total volume of emitted air pollutants. An ecologically differentiated toll rate could lead to a reduction of road traffic exhaust-emissions because of a decreased number of heavily emitting vehicles on the Austrian motorway net. Calculations are carried out for a number of air pollutants: Carbon dioxide (CO2), Nitrogen dioxide (NOx), Hydrocarbon compounds (HC), Particle emissions, Sulphur dioxide (SO2) and Carbon monoxide (CO). The aim of the calculations was to indicate the reduction potential in tons of each pollutant. Therefore, data was obtained from the Austrian Federal Environmental Agency indicating the volume of exhaust-emissions for a reference vehicle with the following characteristics:

Characteristics of the reference vehicle for calculating the reduction potential of the volume of exhaust-emissions (Individual design) — Table 1

	Number of axles	Max. loaded vehicle weight	Deadweight	Vehicle load capacity
Tractor trailer	2	18 tons		
Road semi-trailer	3	32 tons		
Articulated lorry	5	40 tons	14 tons	26 tons

The exhaust-emission data was derived for an articulate diesel lorry with a maximal loaded vehicle weight of 40 tons, an average loading of 15 tons with a constant driving style and an average speed of 75 km/h. With regard to the quality of the road, the degree of the road inclination and meteorological conditions ideal road conditions were assumed as well as a steady flow of traffic. Thus, the Austrian Federal Environmental Agency calculates emission volumes for a selected number of air pollutants in g/km. In a last step these numbers were first multiplied with the actual vehicle kilometres in each EURO emission class of the axle category ≥ 4 travelled in 2005, then with the number vehicle kilometres calculated in the scenarios. The generated tons of particular air pollutants in the year 2005 and in the model scenarios can then compared with each other to find out the most effective scenario in terms of reducing exhaust-emissions.

3.2.3 Projecting the external costs of road traffic air pollutants

All data needed for undertaking the calculations in the model refer to the calendar year 2005. In the case of collecting data concerning external costs caused by exhaust-emissions of road traffic in Austria though the study being most up to date dates back to the year 2000. Hence, the numbers given for the year 2000 are projected for the year 2005 via the increase of the real GDP in Austria in percentages. The individually designed formula is given below:

$$ExCost_{\,air\ pollutent\ '05} = ExCost_{\,air\ pollutent\ '00} \times \Delta GDP_{real}$$

where:

$ExCost_{\,air\ pollutent\ 2005}$ External costs of a specific air pollutant in the year 2005

GDP_{real} Alteration of the Austrian real GDP in %

$$= \frac{GDP_{real'05} - GDP_{real'00}}{GDP_{real'00}}$$

Thus, the particular external costs for a selected number of different air pollutants in Austria can be calculated for the year 2005. They are listed in following table:

Particular external costs of selected air pollutants in Euro per ton per pollutant in 2005 (Source: [9]) Table 2

	CO_2	NO_x	HC	Particles	SO_2	CO
[€/t]	88.08	10,228.44	21,575.60	4,628.24	4,813.38	46.31

3.3 Results

In the model which is set up for the calendar year 2005 three different scenarios with varied premiums and surcharges are created. Depending on the scenario the model starts either with realistic, minimal or maximal amounts of toll rates as it is described below:

In scenario I clean-exhaust vehicles are granted a premium amounting 16 % of the basic toll rate of 13 Cent per kilometre. The surcharge for heavily emitting trucks and buses accounts for an additional 20 % of this basic toll rate. The percentages for the premium and the surcharge are chosen in a way so that the new generated rates represent amounts with realistic chances of being enforced.

In scenario II the price reduction for clean-exhaust vehicles as well as the surcharge for heavily emitting ones is calculated in a way so that the new toll rates will probably evolve a minimal possible effect. Following, vehicles with modern emission standards only get a price reduction of 10 %, whereas heavily emitting ones are charged plus 12 % of the basic toll rate. With regard to the achievement of the aim of maximal controlling effects through differentiated toll rates lower amounts than these minimal toll rates are not recommendable.

In scenario III it is important to bear in mind the upward limit set in the amended directive 2006/38/EC which is not allowed to exceed 100 % of the toll rate charged for an equivalent vehicle fulfilling the strictest emission standard. Thus, the price reduction for clean-exhaust vehicles amounts to 24 % in the model, whereas strongly polluting trucks and busses have to pay an extra fee of 32 %.

The model has shown that the bonus-malus-system with maximal toll rates as hypothesised in scenario III represents the most powerful effects. The results are summarised below:

- *Shift in total vehicle kilometres*

The result of the calculations is that a differentiation of the existing toll rates by EURO emission classes leads to a reduction of the total travelled vehicle kilometres which amounts to 2,756,337,788 km on the Austrian motorway net. The reduction potentials range from −1.13 % in scenario II (bonus-system) to − 3.54 % in scenario III (bonus-malus-system).

- *Shift in total revenues collected by the ASFINAG*

Four out of six scenarios lead to a loss of revenues for the ASFINAG. The minus ranks between −3.14 % (scenario III bonus-system) and −0.27 % (scenario II bonus-malus-system). In the case of a bonus-malus-system with maximal price reductions and surcharges a slight surplus in total toll revenues amounting to 0.53 % is possible. The worst impact for the financial situation of the ASFINAG, a decrease of −3.1 %, is calculated for the same scenario only with a bonus-system.

- *Shift in the volume of air pollutants emitted by trucks and busses*

Here a combined bonus-malus-system and toll rates being as high or low as hypothesised in scenario III represent the best opportunity as the volume of each air pollutant declines. The air pollutants which show the most substantial reduction potential are particle and NO_x emissions (−11.13 % and −10.67 %). In such a scenario CO_2 emissions for example can be reduced by −10.38 % which equals 152,791 tons.

- *Reduction of external cost caused by road traffic exhaust-emissions*

Also with regard to the external cost of air pollution caused by road traffic a combined bonus-malus-system with toll rates as being set in scenario 3 would be recommendable, because it leads to the highest decrease of cost compared with the other scenarios.

4. Conclusion

A lot of European countries have introduced kilometre-based road toll systems for road freight transport on the motorway-net or intend to implement it in the next years. The goal of the paper is to find out the effects of considering the different quantities of pollutants in Austria in the price systems of road tolls. Different approaches like a bonus-system, a malus-system or a combined bonus-malus-system are subject to this paper. Using the scenario methodology premises are discussed concerning changes on the overall driving kilometres on motorways and on changes concerning the behaviour to purchase respectively rent new environment-friendly vehicles.

References

[1] FASSNACHT, M., HOMBURG, C.: *Preisdifferenzierung und Yield Management bei Dienstleistungs-Anbietern, Meyer, A. (Ed.), Handbuch Dienstleistungsmarketing,* Vol 1, Stuttgart, 866–879, 1998
[2] PIGOU, A.: *The economics of welfare*, Macmillan, London, 1920
[3] PARRY, I.: *Comparing the efficiency of alternative policies for reducing traffic congestion,* Journal of Public Economics, Vol 85, 3/2002, 333–362.
[3] JONES, P.: *UK Public Attitudes to Urban Traffic Problems and Possible Countermeasures: a Poll of Polls,* Environment and Planning C: Government and Policy, Vol. 9, 2003, 245–256.
[4] VERHOEF, E.: *The Economics of Regulating Road Transport,* Elgar: Cheltenham, 1996
[5] FRITSCH, M., Wein, T., Ewers, H.-J.: *Marktversagen und Wirtschaftspolitik,* 6^{th} edition. München, 2005
[6] BUCHANAN, J., STUBBLEBINE, W.: *Externality"*, Economica, Vol. 29, 116/1962, 371–398, 2005
[6] BORGER, B., PROOST, S.: *Transport problems: the economic diagnosis,* Borger, B. D. and Proost, Reforming Transport Pricing in the EU. Cheltenham, 9–36, 2001
[7] BUTTON, K.: *Transport, the Environment and Economic Policy,* Elgar: Aldershot, Hants, 1993
[8] EISENKOPF, A.: *Effiziente Straßenbenutzungsabgaben,* Gießener Studien zur Transportwirtschaft und Kommunikation, 17/2002, 303–321.
[9] BMVIT *Osterreichische Wegekostenrechnung fur die Strasse, 2000,* Wien.

Marian Josko *

MODELLING THE ULTRASONIC DIAGNOSIS OF ADHESIVE BONDS

In the paper, the conception of modelling the diagnosis of adhesive bonds by ultrasonic method is presented. Two complementary models of bonds diagnosis are presented and discussed. The models proposed reduce an evaluation of coating adherence to assessment of condition of bond between coating and substrate. The models are connected with period of production of adhesive bonds (so called control diagnostic) and with the operational or maintenance period of its existence (operational diagnostic).

1. Introduction

As a results of own investigation of adhesive bonds between coatings and substrate a number of relationships between mechanical and ultrasonic parameters of strength of those bonds [1–3] were received. Some courses of gain of ultrasonic wave amplitude were also obtained with monitoring of the bonds by ultrasonic wave during their loading by bending moment on the special test stand [4]. These results give us a basis to the proposal of complementary diagnostic models of adhesive bonds between the coating and the substrate.

Those models formalize the coating adherence evaluation, reducing it to the assessment of the bond condition at various stages of its existence. Both the verification of the models and the analysis of their precision [4], confirmed significantly better accuracy and diagnostic possibilities of the ultrasonic rather than the tearing method of evaluation of adhesive bonds.

2. Presentation of the problem

A practical evaluation of the bond condition between the coating and the substrate can be performed with the use of the developed ultrasonic set (Fig. 1), and depends on the diagnostic susceptibility of the whole evaluation system.

As it can be seen in Fig. 1, the evaluation of adhesive bonds can be realized with the use of different kinds of ultrasonic waves under condition of an immediate access to an examined part of machine or by immersion method. However, some examples of industrial evaluation of condition of various adhesive bonds placed in the machine parts already exist, but till now there have not been any models of the ultrasonic diagnosis of adhesive bonds. The necessity of certain formalism of an ultrasonic evaluation in this area appears. Therefore, the purpose of this work is to present some proposals of models of ultrasonic diagnosis of adhesive

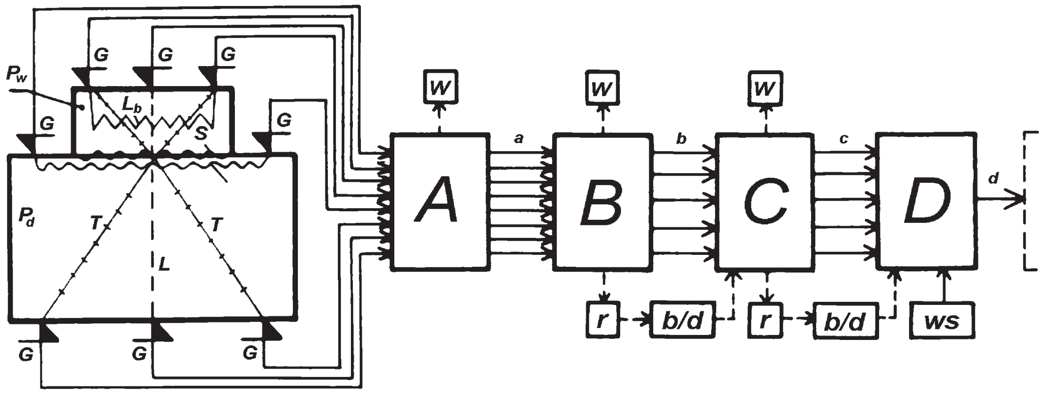


Fig. 1 The measurement set for diagnostics of adhesive bond between two elements: A, B, C, D – respectively: ultrasonic, processing, diagnostic and decision modules, G – ultrasonic probes, S, T, L – respectively: surface, transverse and longitudinal waves

* **Marian Josko**
Poznan University of Technology, Institute of Working Machines and Motor Vehicles, Piotrowo 3, 60-965 Poznan, Poland, tel. +48 061 6652247, fax. +48 061 6652736, E-mail: Marian.Josko@put.poznan.pl

bonds as a contribution to modelling the diagnosis of these bonds using the ultrasonic method.

3. The proposal of a control diagnostic model

This proposal can be generated and presented with aid of some collections of input and output quantities as shown in Fig. 2.

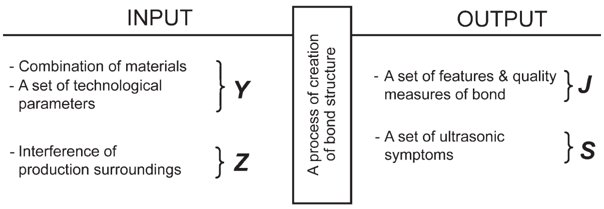


Fig. 2 Two collections of input and output quantities connected with forming and evaluation of quality of adhesive bonds during their production

These collections of quantities give us a possibility of the proposal for the diagnostic control model, related to quality control during production of adhesive bonds (Fig. 3). The models presented bellow in this paper can be numbered to a category of so-called black box models.

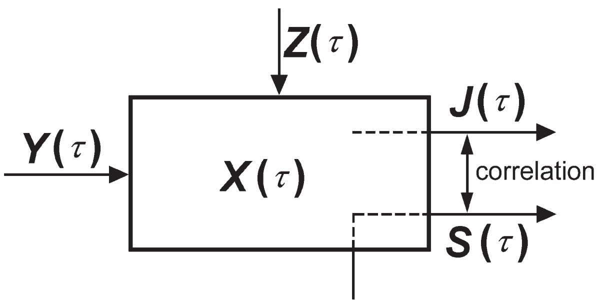


Fig. 3 Graphical presentation of the quality diagnostic model by technical control during production of adhesive bonds (X – a set of structure parameters of adhesive bonds, the other quantities shown here are explained in Fig. 2 and formulas 1,2)

Using an overall form of symptom diagnosis equation [5], the mathematical model of the control diagnostic can be presented as the following dependencies:

$$J(\tau) = \Phi\,[X(\tau), Y(\tau)] + Z(\tau), \quad (1)$$

$$S(\tau) = \Phi\,[X(\tau), Y(\tau)] + Z(\tau), \quad (2)$$

where: $J(\tau)$ – features of bond quality, Φ – operator of signal transformation (functional of transition), $X(\tau)$ – a set of structural parameters, $Y(\tau)$ – an input set of materials and technological parameters, $Z(\tau)$ – interferences of technological surrounding, $S(\tau)$ – ultrasonic parameters (symptoms), τ – time of production during which dispersion of quality can occur (dynamics of technological dispersion).

The input set of materials and technological parameters $Y(\tau)$ of the model (Fig. 3) is a collection of parameters of a coat spreading and can be presented in the following form:

$$Y(\tau)=\{T_1(\tau), T_2(\tau), ..., T_l(\tau)\}. \quad (3)$$

Parameters $T_1(\tau), ..., T_l(\tau)$, involve a combination of parameters of coating and substrate as a set of technological parameters of coat spreading, ex. parameters and sort of substrate preparation, temperature, distance, angle of tool inclination, etc.

The set of structure parameters $X(\tau)$ consists of all the elements connected with the boundary of adhesive joint, both quality (continuity, defectiveness) and quantity values (forces of adhesion and cohesion, stress and hardness gradient, size and orientation of filler grains). It can be expressed by the following parameters:

$$X(\tau)=\{X_1(\tau), X_2(\tau), ... X_m(\tau)\}. \quad (4)$$

An evaluation of bonds condition between the coating and substrate by hitherto methods is rather impossible without destruction of examined bonds.

Interferences of technological surroundings $Z(\tau)$ determine a set of such external features as:

$$Z(\tau)=\{Z_1(\tau), Z_2(\tau), ... X_k(\tau)\}. \quad (5)$$

This set includes such environmental impulses as atmospheric (temperature, humanity), pollutions (dust powders, greasiness), mechanical, physical and chemical effect (aggression), and results of technical and organizational mistakes and all random events.

A collection $J(\tau)$ as a set of quality of adhesive bond contains such elements as follows:

$$J(\tau) = \{J_1(\tau), J_2(\tau), ... J_n(\tau)\}. \quad (6)$$

This collection comprises such measured features of adhesive bond as the peel, shear and fatigue strengthens, durability, thickness, porosity and permeability of coating. Here are also non-measured characteristics of coatings as its homogeneity, smoothness and an overall appearance. A determination of measured features of quality of the adhesive bonds between coatings and substrate is connected – as rule – with destruction of the bonds and as well as with insight into area of the adhesive bond. The role of generalized measure of quality of adhesive bonds plays mechanical adhesion strength determined in different ways, predominantly by peel strength.

The set of ultrasonic parameters $S(\tau)$ can be described as follows:

$$S(\tau) = \{S_1(\tau), S_2(\tau), \dots S_p(\tau)\}. \quad (7)$$

The set S((), described by dependency (7), comprises certain parameters of ultrasonic stimulators, inserted in boarding structures of adhesive bonds in the form of some ultrasonic waves. These waves excite the examined structure and propagate across or along the adhesive boundary. They are received by an ultrasonic probe and can carry information about the condition of such structure as the adhesive bond.

For the purpose of solving the problem of evaluation of the adhesive bond condition, i.e. to determine values of the features of condition of adhesive bond $X(\tau)$ and the characteristics of quality $J(\tau)$ on the basis of values of ultrasonic diagnostic signals $S(\tau)$, the following conditions [5, 6] must be satisfied:

$$m \leq n, \quad (8)$$

$$n \leq p, \quad (9)$$

where: m – a number of independent parameters of bond condition, n – a number of parameters of bond quality, p – a number of ultrasonic symptoms.

During the succeeding control diagnosis, all the components of collection of technological parameters should be maintained on the constant level. Also, the influence of surrounding disturbances is maintained on the constant level or is reduced, or even is minimised. Therefore, assuming – according to [7] – the constancy of two sets of the below-mentioned quantities, namely:

$$Y(\tau) \cap Z(\tau) = const, \quad (10)$$

we can obtain a simplified mathematical model of control diagnosis, reducing dependencies (1, 2) to the following equations:

$$J(\tau) = f\,[X(\tau)], \quad (11)$$

$$S(\tau) = f\,[X(\tau)]. \quad (12)$$

It means that the output sets parameters $J(\tau)$ and $S(\tau)$ (Figs. 2 and 3) depend on the parameters of structure of adhesive bonds $X(\tau)$ and adequate regression equations can be determined by experimental investigations. These investigations enable to obtain the expected relationships between some structural and ultrasonic parameters.

If we assume that the mechanical strength of adhesive bond p is a representative parameter for the quality of adhesive bond, and modulus of the reflection coefficient of ultrasonic wave $|r|$ provides satisfactory information for the evaluation of a condition of adhesive bond, we can present equations (11 and 12) in a more detailed way:

$$p(\tau) = f[X(\tau)], \quad (13)$$

$$|r|(\tau) = f[X(\tau)]. \quad (14)$$

Then, we are searching relationships between $p(\tau)$ and $|r|(\tau)$.

4. The proposal of an operational diagnostic model

This proposal can be generated and presented with aid of some collections of input and output quantities as shown in Fig. 4.

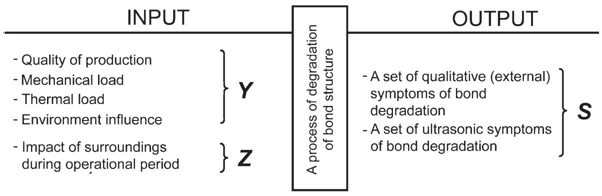


Fig. 4 Two collections of input and output quantities connected with degradation and condition evaluation of adhesive bonds during operational period of their existence

These collections of quantities give us a possibility of the proposal for the operational diagnostic model, related to diagnostic procedure during maintenance of the bonds (Fig. 5).

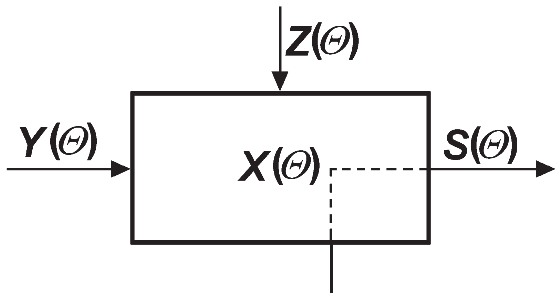


Fig. 5 Graphical presentation of the operational diagnostic model by condition evaluation during maintenance of adhesive bonds (X – a set of condition parameters of adhesive bonds, the other quantities shown here are explained in Fig. 4 and formula 15)

The model of the operational diagnostic connected with a process of degradation of the adhesive bonds can be presented graphically in Fig 5 and described mathematically with the aid of the following equation [3]:

$$S(\Theta) = \Phi[X(\Theta), Y(\Theta)] + Z(\Theta), \quad (15)$$

where: $S(\Theta)$ – ultrasonic symptoms, Φ – operator of signal transformation (functional of transition), $X(\Theta)$ – a set of features of bond condition, $Y(\Theta)$ – a set of input parameters (quality of production, mechanical, thermal and environmental impact during operational time – Fig. 4), $Z(\Theta)$ – interferences during operational period, Θ – operational time (period of maintenance of adhesive bond).

The input collection $Y(\Theta)$ of the operational diagnostic (Fig. 5) determines a set of parameters of forces during an operational period, which can be described as follows:

$$Y(\Theta) = \{W_1(\Theta), W_2(\Theta) \dots W_l(\Theta)\}. \quad (16)$$

Parameters $W_1(\Theta) \dots W_l(\Theta)$ are, first of all, dynamics parameters as mechanical forces and moments loaded. Here, thermal loading, environmental influence and deformations caused by mistakes of assembling can be numbered.

The set of features of bond condition $X(\Theta)$ can be expressed by the following formula:

$$X(\Theta) = \{X_1(\Theta), X_2(\Theta) \dots X_m(\Theta)\}. \quad (17)$$

The set $X(\Theta)$ comprises the whole quality and quantity relations between both connected materials, namely the coating and the substrate. These relations are determined by mechanical, adhesive, cohesive and chemical connections on the boundary and in the adjoined areas of the bonds. The main measure of these connections is the strength of bond for the particular kind of destructive load.

All interferences during the operational period $Z(\Theta)$ include the following collection of features:

$$Z(\Theta) = \{Z_1(\Theta), Z_2(\Theta) \dots Z_k(\Theta)\}. \quad (18)$$

These interferences, which belong to $Z(\Theta)$, are dynamics, thermal and environmental impulses from so called near-by (direct) surroundings of machine parts including adhesive bonds. They have a form of random vibrations, aggressive influence of surroundings, overloads or failure ex. seizing.

The collection of ultrasonic symptoms of bond condition $S(\Theta)$ can be described in the following way:

$$S(\Theta) = \{S_1(\Theta), S_2(\Theta) \dots S_n(\Theta)\}. \quad (19)$$

As in the previous example, i.e. the control diagnostic model, this collection consists of a set of parameters of ultrasonic stimulators in the different form of ultrasonic waves. Selected ultrasonic parameters can be symptoms of bond condition, because they are sensitive to the degraded changes of the adhesive bonds during the operational period considered.

With the aim of solving the diagnostic problem of condition evaluation of the adhesive bonds by ultrasonic method during the operational period, i.e. determination of values of some condition features $X(\Theta)$ on the basis of values of ultrasonic parameters $S(\Theta)$, the following condition must be satisfied [5, 6]:

$$m \le n, \quad (20)$$

where: m – a number of independent parameters of bonds condition, n – a number of ultrasonic parameters (symptoms).

In order to simplify the operational diagnostic model (Fig. 5) and its mathematical notation (15) during the normal operational process, we can assume minimization or even stabilization of all disturbances from the surroundings. Such approach is motivated in references [5, 7]. It can be also assumed that for the succeeding times Θ, when the operational diagnosis will be carried out, the elements of the set $Y(\Theta)$ should be constant in respect of the number and value. Constant values of the input set for succeeding evaluations of bonds state is an essential condition of repeatability of ultrasonic diagnosis of the adhesive bonds analysed. Therefore, permitting a possibility of stability of two sets of input quantities, namely:

$$Y(\Theta) \cap Z(\Theta) = const, \quad (21)$$

a simplified mathematical recording of the graphical operational model shown in Fig. 5 and written by (15), can be presented finally as the following equation:

$$S(\Theta) = f[X(\Theta)]. \quad (22)$$

It means that output parameters, i.e. visual and ultrasonic symptoms $S(\Theta)$ are dependent only on parameters of condition of the adhesive bonds $X(\Theta)$. It is necessary to receive some dependencies between parameters of condition of the adhesive bonds and parameters of ultrasonic waves using both visual and ultrasonic techniques for monitoring of the bonds.

For this purpose should be planed a kind of active diagnostic experiments aimed at receiving some collections of the run of ultrasonic parameters during an operational time, dependent on condition of the adhesive bonds.

5. The proposals of procedures of ultrasonic diagnoses of adhesive bonds

The first proposal, in the case of using longitudinal ultrasonic wave for evaluation of bonds condition during control diagnosis, the procedure of qualification of the adhesive bonds to appropriate state is presented by schematic diagram in Fig. 6.

The second proposition is grounded on realization of some ultrasonic measurements of adhesive bonds during their operational (maintenance) period by ultrasonic surface wave, according to the procedure shown in Fig. 7.

Both proposed procedures allow us to qualify the examined adhesive bonds using commercial ultrasonic probes for longitudinal or surface waves and main ultrasonic parameters, namely a modulus of reflection coefficient $|r|$ and a gain of ultrasonic impulse W. The selection of diagnostic model and the procedure of ultrasonic diagnosis of adhesive bonds depend on the period of life-time of machine parts comprising the bonds analysed.

6. Conclusions

The diagnostic approach to adhesive bonds evaluation allows us to formalize the problem of evaluation of coating adherence,

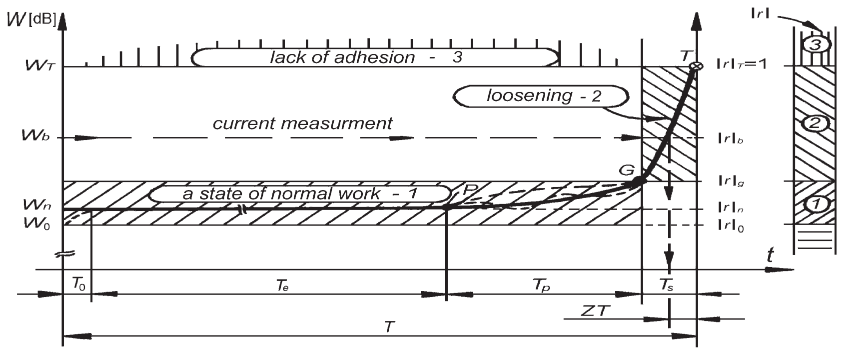


Fig. 6 The schematic diagram of the procedure of realization of bonds condition by ultrasonic longitudinal wave during control diagnosis of adhesive bonds by ultrasonic measurements: numerals 1, 2, 3 mean respectively: good, weak and bad adhesive bonds; W – ultrasonic parameter, t – time of a bond existence, T – durability of a bond, |r| – modulus of reflection coefficient

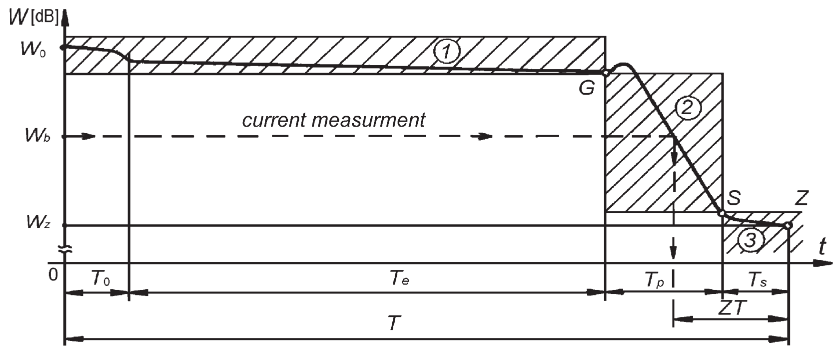


Fig. 7 The scheme of the proposed procedure of operational diagnosis of adhesive bonds by ultrasonic measurements: numerals 1, 2, 3 mean respectively: good, weak and bad adhesive bonds; W – ultrasonic parameter, t – time of existence of a bond, T – durability of a bond

reducing that problem to the assessment of the condition of adhesive bonds between coatings and substrate at the various stages of their existence.

Two complementary models proposed, both in graphical and mathematical forms, reflect two periods of existence of the adhesive bonds, namely period of their production and period of their operational (maintenance) time.

Some equations obtained in this work motivate experimental investigations with the aim to obtaining relationships between parameters of the structure of adhesive bonds and selected ultrasonic parameters which can be understood as symptoms of condition of the adhesive bonds.

References

[1] JOSKO M.: *An Ultrasonic Assessment of Adhesive Bonds between Coating and Substrate,* Proceedings of the Conference Transcom 97, University of Zilina, 1997, Vol. 3, pp. 261–264.

[2] JOSKO M.: *Correlation between an Ultrasonic Signal and Adhesive Strength (in Polish),* Proceedings of 28th Polish Conference of Nondestructive Testing, Warsaw, 1999, pp. 103–106.

[3] JOSKO M.: *Methodological Aspects of Evaluation of Regenerative Coatings Adherence Using an Ultrasonic Method (in Polish)*, PP Poznan, 2002.

[4] JOSKO M.: *Investigation of the Degradation of Joints by Ultrasonic Method,* Proceedings of the Conference Transcom-99, University of Zilina, 1999, Section 6, pp. 47–50.

[5] ZOLTOWSKI B.: *A Basis of Technical Diagnostics (in Polish)*, ATR, Bydgoszcz, 1996.

[6] CEMPEL C.: *Data Reduction in Machine Diagnosis (in Polish),* Zagadnienia Eksploatacji Maszyn (Polish Journal), 1980 Vol. 15, No. 4, pp. 571–585.

[7] TOMASZEWSKI F.: *Determination of Technical Condition of Complex Technical Object (in Polish),* PP, Poznan, 1998.

Juraj Jagelcak *

EQUATION OF THE STANDARD EN 12195-1 STIPULATES UNREASONABLE DEMANDS FOR CARGO SECURING

Cargo securing is a factor influencing safety and quality of transport considerably. In this paper the problem of calculation of over top lashing to prevent tipping is mentioned. "European standard EN 12195-1 Load Restraint Assemblies. Safety. Part 1: Calculation of lashing forces" stipulates unreasonable demand for number of over top lashings to prevent tipping of load. The calculation of number of lashings gives infinite results for certain lashing angles. The reason can be found in equation (8) of the standard.

1. Introduction

How many lashing do we need, is often a big issue when it comes to cargo securing. There are various demands for cargo securing in European countries. The demand for the number of lashings is really confusing for international road haulers. The lorry driver travelling through different countries of Europe is often afraid of how many lashing straps or other equipment the controlling authorities and consignors at loading sites will want to see and if the straps are proper to use and fulfil the demands of standards or guidelines. Over top lashing, as the most frequent lashing method, is used everywhere when it comes to cargo securing by lashing. But what the effectiveness of over top lashing is each driver must take into consideration. The driver knows what the friction and acceleration are and he also knows that the force on the opposite side without a tensioner is lower when compared to the tensioner side. These points are the main points influencing over top lashing and these points create controversy between the EN 12195-1 standard for calculation of lashing forces and IMO/ILO/UN ECE Guidelines for packing cargo transport units (CTU's). The discussion was opened during the work on *European Best practice guidelines on cargo securing for road transport* of the European commission, and led after some years to the revision of European standard EN 12195-1 which is in a revision process now. The standard is, as national standards, implemented in the EU but not obligatory in all the member states. In several states the standard is only on a voluntary base. The discussions of experts showed that the standard stipulates very high and costly demand on cargo securing when it comes to over top lashing. Therefore it has been called for the revision.

The main points of discussions were about friction, acceleration sideways and k-factor. K-factor was always the biggest problem during the discussions. The standard defines it as the "*coefficient which allows for the loss of tension force due to friction between lashing and load*".

Because of the friction on the corners the force on the opposite side is usually lower than the force on the tensioner side. This is presented in the calculation by k-factor with value 1.5 for over top lashing with a tensioner on one side of the lashing only. The value 1.5 means that on the side without a tensioner there is only half of the force of the tensioner side. Of course, this value is very conservative and measurements [9], [10] showed that also the values more than 2 are possible to measure. The value of k-factor mainly depends on the corner friction. The issue is clear. The use of k-factor lower than 2 influences the number of lashings and which is important to highlight is that no hauler wants to increase the number of lashings because it costs money.

2. Over top lashing securing load against tipping

The results of equation (8) of standard EN 12195-1 for over top lashing to prevent tipping are shown below. The illustration from the standard is given in the following figure. By solving practical examples it was found out that equation (8) of the standard, as defined, creates unreasonable results which are practically unusable.

According to equation (8) holds:

$$F_{x,y} \cdot \frac{h}{2} + n \cdot F_T \cdot h \cdot \cos\alpha = F_z \cdot \frac{w}{2} + n(k-1) \cdot$$
$$\cdot F_T \cdot w \cdot \sin\alpha + n(k-1) \cdot F_T \cdot h \cdot \cos\alpha \qquad (1)$$

Modification of equation (8) gives the following equations for a number of lashings:

- for load with the centre of gravity (CoG) in the geometrical centre:

$$n \geq \frac{1}{2} \cdot \frac{m \cdot g \cdot (c_{x,y} \cdot h - c_z \cdot w)}{F_T \cdot [(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha]}$$

$\Rightarrow$ equation (11) of the standard (2)

* **Juraj Jagelcak**
Department of Road and Urban Transport, Faculty of Operation and Economic of Transport and Communications, University of Zilina, Slovakia,
E-mail: juraj.jagelcak@fpedas.uniza.sk

– for load with CoG off the geometrical centre:

$$n \geq \frac{m \cdot g \cdot (c_{x,y} \cdot d - c_z \cdot b)}{F_T \cdot [(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha]} \quad (3)$$

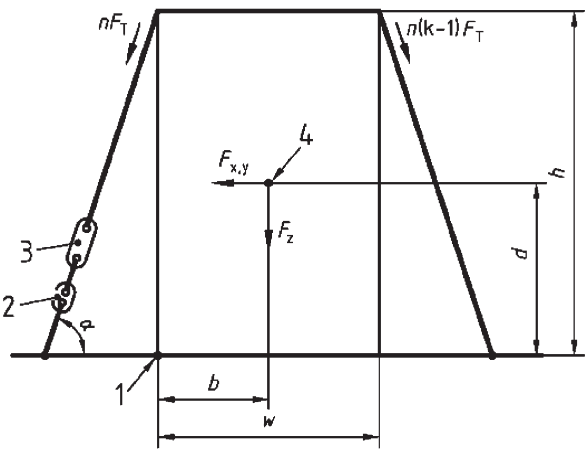


Fig.1 Fig. 4 from EN 12195-1

When unstable loads are to be secured against tipping the situation is quite different. The EN 12195-1 standard calculates this equation by using the tensioners on one side only. The equation (8) should hold for load secured by one over top lashing only. For load where more lashings are necessary the results of equations are wrong.

The following example explains the situation. The load with weight $m = 2000$ kg, height $h = 2$ m and width $w = 0.9$ m are to be secured sideways by over top lashing** with the lashing angle of 66° and friction factor 0.3. The load is unstable sideways. For this load we need, according to the formulas in the standard, 3 lashings to prevent sliding but 300 lashings to prevent tipping.

The number of lashings to prevent sliding: according to equation 5 of the standard:

$$n \geq \frac{m \cdot g \cdot (c_{x,y} - \mu_D \cdot c_z)}{k \cdot F_T \cdot \sin\alpha \cdot \mu_D} =$$

$$= \frac{2000 \cdot 9.81 \cdot (0.5 - 1 \cdot 0.3)}{1.5 \cdot 3750 \cdot \sin 66° \cdot 33} = 2.55 \Rightarrow 3 lashings \quad (4)$$

The number of lashings to prevent tipping according to equation 11 of the standard:

$$n \geq \frac{1}{2} \cdot \frac{m \cdot g \cdot (c_{x,y} \cdot h - c_z \cdot w)}{F_T \cdot [(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha]} = \frac{1}{2} \cdot$$

$$\cdot \frac{2000 \cdot 9.81 \cdot (0.7 \cdot 2 - 1 \cdot 0.9)}{3750 \cdot [(1.5-1) \cdot 0.9 \cdot \sin 66° - (2-1.5) \cdot 2 \cdot \cos 66°]} =$$

$$= 300.08 \Rightarrow 300 lashings \quad (5)$$

This happens because the calculation supposes the tensioners on one side only.

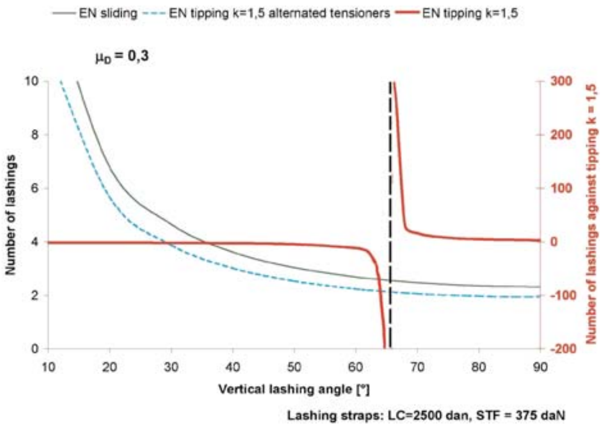


Fig. 2 Influence of transmission factor "k" for number of lashings to prevent tipping by using over top lashing according to EN 12195-1

The comparison of different calculation methods is shown in the figure above. The worst situation is for tipping with k factors different from 2. For certain lashing angle the value is infinity and for lower angles the values are negative. That means, from practical point of view, that infinite number of lashings can't be used. As it can be seen from the figure above this doesn't correspond to the expected hyperbolical trend. What is the cause? The cause is *k* factor, strictly speaking, the difference between forces on the tensioner side and opposite side. If we lash the load according to the method in Fig. 1 then, from theoretical point of view, the lashing itself creates instability of the load and can cause tipping of the load with a sufficient number of lashings. This means, from practical point of view, the tensioners can't be placed on one side of the load only but must be placed alternately. This is also the general demand for securing of load.

The lashing angle for infinite number of lashing can be found out from a denominator of eq. (11) of the standard:

$$(k-1) \cdot w \cdot \sin\alpha - (2-k) \cdot h \cdot \cos\alpha = 0 \quad (6)$$

$$\alpha = \mathrm{arctg}\left(\frac{2-k}{k-1} \cdot \frac{h}{w}\right) \quad (7)$$

And for our example a is as follows:

$$\alpha = \mathrm{arctg}\left(\frac{2-k}{k-1} \cdot \frac{h}{w}\right) = \mathrm{arctg}\left(\frac{2-1.5}{1.5-1} \cdot \frac{2}{0.9}\right) =$$

$$= 65.77225468... \quad (8)$$

So we get real lashing angles for infinite number of lashings. Of course, this lashing angle is not possible to use but the angles around this value still stipulate very high and also negative results.

** lashing straps $LC = 2500$ daN, $STF = 375$ daN

In case of alternating tensioners the situation is as follows:

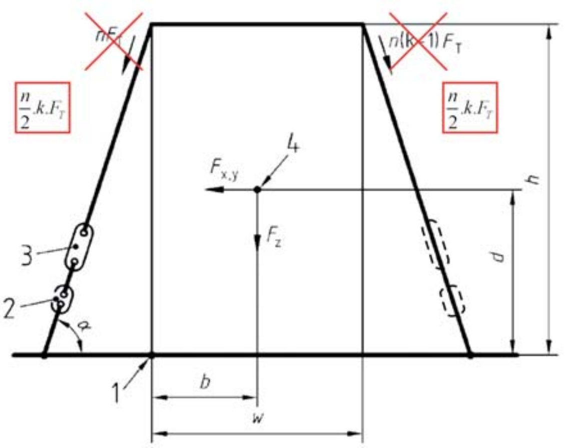


Fig. 3 Modified Fig. 4 of the standard EN 12195-1 for tensioners placed alternately

Modified eq. (8) of the standard is as follows:

$$F_{x,y} = \frac{h}{2} - F_z \cdot \frac{w}{2} - \frac{n}{2} \cdot k \cdot F_T \cdot sin\alpha \cdot w = 0, \qquad (9)$$

- for the load with CoG of the geometrical centre (GC):

$$F_{x,y} \cdot d - F_z \cdot b - \frac{n}{2} \cdot k \cdot F_T \cdot \sin\alpha \cdot w = 0 \qquad (10)$$

Then equations for the number of lashings should be as follows:

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{k \cdot F_T \cdot \sin\alpha}, \text{ CoG in GC} \qquad (11)$$

$$n \geq \frac{2 \cdot m \cdot g \cdot (c_{x,y} \cdot d - c_z \cdot b)}{k \cdot F_T \cdot w \cdot \sin\alpha}, \text{ CoG off the GC} \qquad (12)$$

where, for our example, holds:

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{k \cdot F_T \cdot \sin\alpha} =$$

$$= \frac{2000 \cdot 9.81 \left(0.7 \cdot \frac{2}{0.9} - 1\right)}{1.5 \cdot 3750 \cdot \sin 66°} = 2.121 \Rightarrow 3 \textit{lashings} \qquad (13)$$

if $k = 2$ and $c_y = 0.5$ which present the requirements given in IMO the result is as follows

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{k \cdot F_T \cdot \sin\alpha} =$$

$$= \frac{2000 \cdot 9.81 \left(0.5 \cdot \frac{2}{0.9} - 1\right)}{2 \cdot 3750 \cdot \sin 66°} = 0.318 \Rightarrow 1 \textit{lashing}. \qquad (14)$$

According to the latest agreement from revision works the experts decided to delete k factor in all equations of the standard to avoid confusion in the future. As the calculations in the standard are based on theoretical principles, operational factors (when applying top-over lashing) can positively or negatively impact the required number of lashings, e.g.
- retention not feasible,
- self-tensioning effect,
- influence of the corner frictions.

To compensate these uncertainties the safety factor of 1.1 is to be included. The *k* factor shall be deleted in all the equations [11]. According to the other agreement unstable goods in combination with over top lashing shall be calculated as follows

$$n \geq \frac{m \cdot g \cdot \left(c_{x,y} \cdot \frac{h}{w} - c_z\right)}{F_T \cdot \sin\alpha} \cdot 1.1 \qquad (15)$$

which, for our example, gives

$$n \geq \frac{2000 \cdot 9.81 \left(0.5 \cdot \frac{2}{0.9} - 1\right)}{7500 \cdot \sin 66°} \cdot 1.1 = 0.350 \Rightarrow 1 \textit{lashing}.$$

3. Conclusion

This paper presents that the calculation of over top lashing to prevent tipping according to standard EN 12195-1 is practically unacceptable. For certain lashing angles an unreasonable number of over top lashings is calculated. Therefore, the work of experts, participating on revision works to achieve reasonable level of cargo securing in road transport and to obtain the European standard practically applicable all over the Europe, is very important.

References:

[1] JAGELCAK, J.: *Top-over lashing securing the load against tipping, equation (8) of the standard EN 12195-1 stipulates infinite number of lashings for specific lashing angles.* University of Zilina, Department of Road and Urban Transport. Document CEN/TC 168/WG6 N 180, CEN 13.12.2006

[2] JAGELCAK, J.: *Tension forces in top-over lashing & k-factor theoretical explanation and practical results.* University of Zilina, Department of Road and Urban Transport. Document CEN/TC 168/WG 6 N 191, 2. 1. 2007

[3] JAGELCAK, J., ANDERSSON, P.: *Calculation of required number of top-over lashings for sliding and tilting sideways with different input data,* MariTerm AB, document CEN/TC 168/WG 6 N 209, 22. 5. 2007
[4] STN EN 12195-1 *Load restraint assemblies.* Safety, Part 1: Calculation of lashing forces
[5] VDI 2700 *Ladungssicherung auf Straßenfahrzeugen,* November 2004
[6] IMO/ILO/UN ECE Guidelines for Packing of Cargo Transport Units (CTUs), International Maritime Organization, London, 1997, ISBN 92-801-1443-3
[7] Safe Packing of Cargo Transport Units (CTUs) - COURSE, Model course 3.18, International Maritime Organization, London, 2001, ISBN 92-801-5116-9
[8] Safe Packing of Cargo Transport Units (CTUs) - WORKING BOOK with quick lashing guides for transport on road and in sea areas A, B, & C, Model course 3.18, International Maritime Organization, London, 2001, ISBN 92-801-5127-4
[9] PETERSEN, S. S.: *Practical tests of pretension ability,* MariTerm AB. Document CEN/TC 168/WG 6 N 174, 06.12.2006
[10] DANEKAS, R: *Expert's report prepared on the issue: When lashing down, is the pretension force, which is applied on the ratchet side, being reduced by friction in the area of the respective deflection leading to a lower pretension force of the side (loose end) that is opposing the ratchet,* Von der Industrie und Handelskammer zu Aachen Offentlich Bestellter und Vereidigter Sachverstandiger fur Ladungssicherung und Anschlagtechnik im Landverkehr, Document CEN/TC 168/WG 6 N 219, 12. 06. 2007
[11] Report of the 15th meeting of CEN/TC 168/WG 6 on 19/20 June 2007 in Stockholm, Document CEN/TC 168/WG 6 N 221, 03.07.2007.

Martina Siposova *

THE EFFECTS OF REFERENTIAL QUESTIONS IN THE EFL CLASSROOM

The article deals with complexity and importance of asking questions in the foreign language classroom. Since questions are one of the most essential teaching tools, teachers use them quite frequently during their lessons. The importance of referential questions, which are often referred to as "genuine or real" questions, lies in the fact that they have highly positive influence on the learning process. The qualitative study reported here shows that the impact of referential questions on university students can be characterised as constructive (i.e. effective and creative), leading to constructive conversation in the language seminars.

1. Introduction

Questions, and of course, answers create an inevitable part of the usual human use of any language – native, as well as foreign. There are different questions asked for different reasons. Following the Webster's College Dictionary definition of a question we find out that it is a sentence in an interrogative form addressed to someone in order to get information in reply. Thus, it seems that the most natural reason for asking questions is to find some unknown information. In non-educational settings, people rarely ask questions to which they already have answers. It would be at least unnatural if someone asks you: "What's the time?" You answer, e.g.: "It's twelve o'clock." Then the questioner says: "Fine, well done, thank you." This is an example of a typical question-answer interaction in which the teacher checks whether the subject matter, time, has been understood by a learner. Thus, it is evident that asking questions in educational settings, especially in foreign language teaching is completely different from the real-life situations.

2. Questions in the EFL Classroom

In any language classroom, questions and answers are a very important part of the technique of teaching, as well as a way to improve learners' use of language. According to Brown ([1], 2001) appropriate questioning can fulfill a number of different functions: teacher questions give students the impetus and opportunity to produce language comfortably without having to risk initiating language themselves; teacher questions can serve to initiate a chain reaction of student interaction among themselves; teacher questions give the instructor immediate feedback about student comprehension; teacher questions provide students with opportunities to find out what they think by hearing what they say. Obviously, teachers have to ask a lot of questions in their lessons and learners get used to answering. Each question that is asked in the lesson can be seen as a mini-learning task as well as a necessary stepping stone to foreign language communication. For this reason, the type of question teachers ask heavily impacts the learning process.

Teachers' questions can be categorized in many ways, therefore different taxonomies have been developed. Long and Sato ([2], 1983) in their study of classroom discourse modified one of the first taxonomies proposed by Kearsley and grouped the teachers' questions into "**ECHOIC**" (consisting of **comprehension checks, clarification requests, and confirmation checks**) and "**EPISTEMIC**" (referential, display, expressive, and rhetorical questions). Out of the seven sub-categories of Long and Sato's taxonomy, **display** (e.g. What's the opposite of "up" in English?) and **referential questions** (e.g. Why didn't you do your homework?) as opposing ones in their nature, have been the most frequently investigated and discussed by researchers. However, Pica ([3], 1999) points out that both referential and display questions can be further divided into the open and closed type. Therefore, within the referential/display distinction there are four types of questions:

1. Open referential questions (e.g. Can you tell me how to make chocolate chip muffins?)
2. Closed referential questions (e.g. What's your name?)
3. Open display questions (e.g. Can you summarize five ways to get to the airport?)
4. Closed display questions (e.g. What's the opposite of "up" in English?)

3. Referential Questions

Referential questions are questions to which the response is not known by the teacher. They are often referred to as "genuine or real" questions. Thus, these questions meet the natural reason for asking which is to find out some unknown information in reply. Since the questioner does not know the answer to the question, there is a genuine exchange of information. The focus should be on what is said, not on how it is said. Typical examples of class-

* **Martina Siposova**
Department of English Language and Literature, Faculty of Science, University of Zilina, Slovakia, E-mail: martina.siposova@fpv.uniza.sk

room referential questions: "Have you got a brother or sister? What is your mother's/ father's job? Have you been on holiday abroad? Why do/ don't you like...? What's your favourite ...? What did you do over the weekend? What do you think about...?" The answers to these questions are usually difficult to predict as they refer to personal details, experiences, attitudes, opinions and so on. They demand more than the respondent's knowledge of learned facts, and they give the opportunity for a more extended answer by requiring a wider range of linguistic resources. However, it should be noted that referential questions can also be closed and often answered with one word only (e.g. "Have you been on holiday abroad?").

The importance of the use of referential questions has been analyzed and discussed by many researchers. Brock's research revealed ([4], 1986) that the use of referential questions increased the amount of learners' output. Learners' responses to referential questions were on average more than twice as long and more than twice as syntactically complex as their responses to display questions. Moreover, the learners used a far greater number of connective (e.g. *and, because, yet, so*) to make explicit the links between the propositions they expressed. They also took a significantly greater number of speaking turns. Obviously, referential questions foster the growth of speaking students do in the classroom and they enable students to use the target language meaningfully. Lynch ([5], 1996) introduces three reasons for asking referential questions in classrooms. The first reason for including these "real" questions is quantitative, which corresponds with Brock's research, i.e. learners tend to give longer and more complex and authentic responses. Another is qualitative, i.e. learners in classrooms cannot only be passive responders to teacher's questions; they should also practice taking the initiative in speaking. Thirdly, there is a risk that if teachers mostly use questions to test students' knowledge, it can discourage students from wanting to answer, especially when the teacher insists on answers in full sentences and penalizes for mistakes. Undoubtedly, teachers need to realize and view the whole complexity and potentiality of referential questions before asking them in the EFL classroom.

4. Design of the study

The qualitative study reported here shows the impact of teacher's referential questions on the first year university students, aged 19-20, in English language seminar classrooms in November – December 2006. The study was divided into two parts: observation and personal interviews. During the observation of four English language seminars, four students were selected on the basis of their participation in the classroom. Two students (one male and one female), were considered as the most active and enthusiastic about responding to teacher's referential questions, and two students (one male and one female), were considered to be non-active, passive and not willing to respond to questions or take part in the conversation. Having explained the subject matter of referential questions to the students, the personal interviews were carried out with the students. The 25-minute long interviews were taped-recorded to be transcribed and coded on the basis of application of the grounded theory methodology.

5. Method of the study

With regard to the methodology of the grounded theory, which is viewed (Pandit, [6]) as the inductive discovery of theory grounded in systematically analysed data, data from the interviews are analysed using the potentials of open, axial and selective coding. Initially, open coding fractures the data into concepts and categories, axial coding then puts the data back together in new ways by making connections between a category and its sub-categories, and finally, through selective coding the categories are integrated to form the initial theoretical framework. A story line is either generated or made explicit. A story is simply a descriptive narrative about the central phenomenon of study and the story line is the conceptualisation of this story (abstracting). When analysed, the story line becomes the core category and subsidiary categories are related to the core category according to the paradigm model, the basic purpose of which is to enable the researcher to think systematically about the data and relate them in complex ways.

The paradigm model: Causal Conditions → Phenomenon → Context → Intervening Conditions → Action/Interaction Strategies → Consequences

Explanation of the model: Causal Conditions are the events that lead to the development of the phenomenon. The phenomenon is defined as the core category (i.e., the central idea, event or happening). Context refers to the particular set of conditions and intervening conditions, the broader set of conditions, in which the phenomenon is couched. Action/Interaction Strategies refer to the actions and responses that occur as the result of the phenomenon. And finally, the outcomes of these actions and responses are referred to as Consequences.

6. Findings

The main story is about the impact of English teacher's referential questions on university students. This impact is defined as constructive, leading to constructive conversation in the language seminars. Conceptual meaning of the word "constructive" can be viewed as effective and creative. The basic potential of intervening conditions of such conversation lies in the fact that students come to realise changes in the atmosphere of the classroom. Four respondents in the research characterise the atmosphere as relaxed, friendly, connected with pleasure and good feelings. "*...the person gets rid of the strictly formal feeling that s/he is at school; it seems to me more relaxed and friendly...*". Having been influenced by referential questions, the respondents emphasize their subjective preferences of work in the classroom. Two students, being the most active and enthusiastic, appreciate these questions and their effectiveness in conversation. On the other hand, two non-active, passive students express their dislike of referential questions – one of them prefers written assignments, in which he is not required to give an immediate response, and the other one simply claims that group work and doing grammatical exercises is on the top of her preferences. Overall, the referential questions are viewed individually. Thus, general referential questions promise smooth procedure in conversation. When the referential question is a kind of specific personal (intimate) question, individual students feel tension and fear to a certain degree. *... sometimes the kind of intimate question can be unpleasing for the questioned student, e.g. when the student's parents have been divorced and s/he should describe the relationships in the family ...*".

In direct teacher-student interaction the students normally respond to teacher's questions. Research shows that the striking feature of the student's response is in the transfer into English. The most demanding part of this transfer seems to be the correct form of the response on phonetic, morphological, lexical and syntactic levels."*...it is difficult to think quickly, first to think about the content of the response and at the same time to seek the proper grammatical form and words, to create sentence(s) in order to say right what I want to say ...*". The topic of the conversation, linguistic competence and personality of a student (especially the student's temperament, mood, physical and mental conditions) determine whether the response is distinguished by its length or shortness. The two eloquent students in the research performed long and meaningful utterances to such extent that the teacher was forced to set limits so that other students could take part in the conversation. "*... you know, I tend to speak so much that the teacher has to stop me ...*". In cases when the student is not interested and involved in the topic, lacks linguistic competence and is considered to be shy as well as introverted, then the teacher is compelled to call such student by name, otherwise the student does not show any willingness to take part in the conversation. However, the response of such student is usually expressed in two or three sentences maximum.

Constructive conversation takes place in context of the class, which is characterised by the educational setting (classroom) and people. The class induces functional influence on the consequences of the conversation. Research shows that the functional influence of people is much more important than the setting. Good feelings of students are evoked in the familiar, smaller-sized classroom, highlighted in the kind of informal, non-educational setting (e.g. café, restaurant). Contrary to this, bad feelings are associated with large lecture rooms. The people (teacher, classmates vs. other students) who are present in the class play a crucial part in developing conversation. The teacher-student relationship has a very positive influence on student performance, especially when the teacher is young, connotatively closer in opinions to the student, has a good sense of humour, is liberal and tolerant, and is interested in the student's response. "*... our teacher is very nice, she is young; but if we had another teacher, without any sense of humour and tolerance, I wouldn't feel so good and I would certainly be afraid of speaking ...*". On the contrary, when the teacher is older, and at the same time aloof and reserved, the student becomes wary and tensed up, and his/her responses are shorter and more concise. The most significant feature of the classmates category is the length of acquaintanceship with them, their tolerance towards the length, correctness and accuracy of the response, and the number of classmates in the group, which also makes a difference between the positive influence of classmates and the negative attitude of other students (e.g. unfamiliar students from different study groups). "*... when we had the first seminar I didn't want to speak at all; those students around me seemed to me strange, I didn't know them ... or, e.g., if we were somewhere in the lecture hall, let's say all 120 first-year students together and I would know only those 12 who were in my study group, I would decide not to show off and hide in the crowd...*".

Through constructive conversation in the language seminar, the student gets good opportunities to express his/her subjective opinion and view on the topic, which subsequently leads to the exchange of views and more creative thinking. The fear of not being consistent with views of the rest of the group is a different matter as it can lead to a negative image of the student before the others. "*... the problem arises when my opinions don't correspond with the opinions of my colleagues, then I worry about creating a negative image before others ...*" In constructive conversation the student realises his/her individual performance in the English language, applies subjective creativity in speech and at the same time demonstrates individual qualities hence developing and improving his/her own communicative competence. "*... basically, I practice and improve my speaking skills, I can be imaginative and inventive, I can create my own response...*". "*... as I know that my English is very good, I love speaking English and showing others my ego...*". Last but not least in the research is the category of creating interpersonal relationships in the class. Since the students listen to each other, give and receive a lot of information about each other as well as the teacher, who also takes part in conversation, students grow closer to each other. "*...we manage to know each other better, it can be, in a way, coming closer to each other; we speak about ourselves, express our views and opinions, of course, if we are open and sincere, and the teacher too, s/he can also tell us about herself/himself; it's reciprocal ...*".

7. Conclusion

Many well-known researchers (M. Long & Ch. Sato, T. Lynch, T. Pica, J. White & P. Lightbown, C. Brock, etc.) have investigated and discussed the issue of referential questions in the language classroom. Their predominantly quantitative and quantitative-qualitative studies showed that the distribution of asking the two basic types of questions – display vs. referential was approximately 4:1, i.e. display questions outnumbered by far referential ones. Moreover, the researchers highlighted that asking referential questions in the classroom is important because they can trigger longer and syntactically complex answers from students and produce more classroom interaction.

The purpose of the qualitative research carried out in the language seminar classroom was to point out the importance and usefulness of asking referential questions from the point of view of the first – year university students. Having applied the methodology of the grounded theory, it can be claimed that the impact of

English teacher's referential questions on students is viewed as constructive, leading to constructive conversation in the language seminar. This conversation takes place in a class, which is characterised by educational setting (classroom) and people (a teacher, students).The action/interaction part of this constructive conversation lies in a student's answer/response which is given to a particular referential question. The striking feature of the student's response is in the transfer into English. Both causal (topic of the conversation, linguistic competence and personality of a student) and intervening conditions (subjective preferences of a student, student's individual perception of referential questions and atmosphere) set influence on the procedure of the constructive conversation in the language seminar. To conclude, the most significant consequences of such conversation are: expressing the student's subjective opinion; demonstrating his/her individual performance in the English language; developing and improving his/her communicative competence; and creating interpersonal relationships in the classroom. Further research is necessary for verification and deeper analysis of all the factors which influence this conversation.

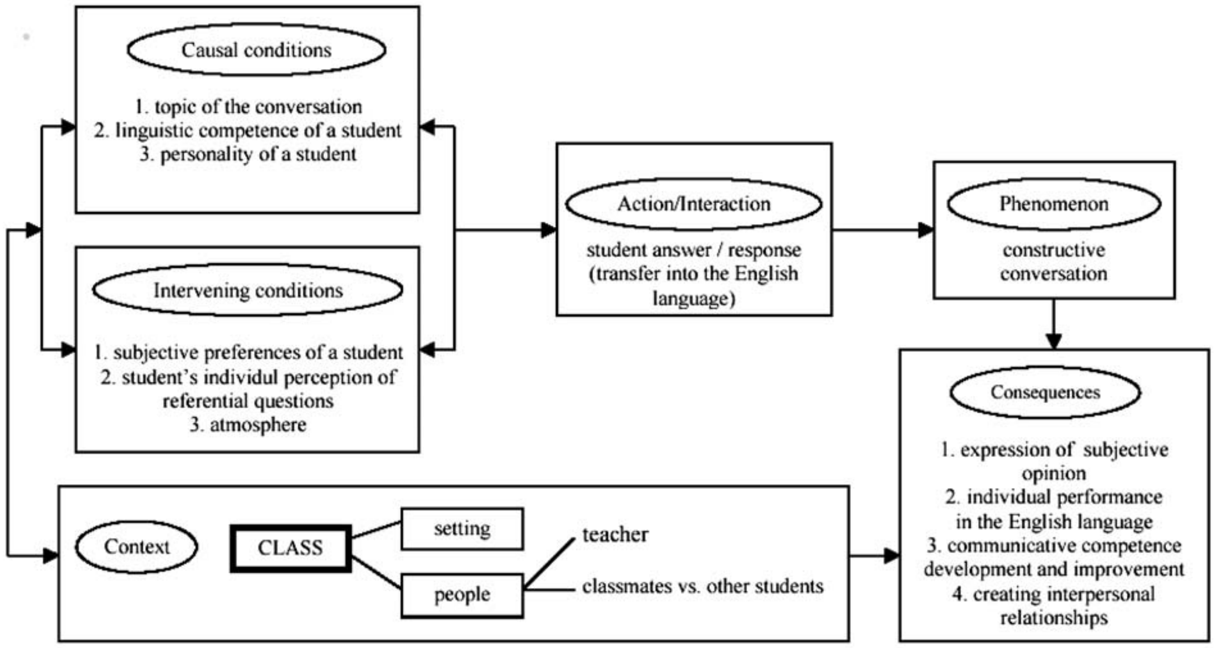


Fig. 1 Diagram of the development of constructive conversation

References

[1] BROWN, H. D.: *Teaching by principles. An Interactive Approach to Language Pedagogy.* New York: Pearson Education, 2001

[2] LONG, M., SATO, C.: *Classroom Foreigner Talk Discourse: Forms and Functions of Teachers' Questions.* In Herert Seliger & Michael Long (Eds.), Classroom oriented research in second language acquisition, Rowley: Newbury House Publishers, 1983, pp. 268–286

[3] PICA, T.: *Lecture on November 1, 1999.* In Cheryl Wey-yu Chen. Teachers' Questions in Language Classrooms. [online], [cited 2007-07-30] http://english.nccu.edu.tw/academic/ doc/Paper/

[4] BROCK, C.: *The Effects of Referential Questions on ESL Classroom Discourse.* TESOL Quarterly, Vol. 20, No. 1, March 1986, pp. 47–59

[5] LYNCH, T.: *Communication in the language classroom.* Oxford: Oxford University Press, 1996

[6] PANDIT, N. *The Creation of Theory: A Recent Application of the Grounded Theory Method.* [online], [cited 2007-07-31], http://www.nova.edu/ssss/QR/QR2-4/pandit.html

Marta Kadorova – Zuzana Ondrackova *

NAMES OF HISTORICAL GEOGRAPHICAL PLACES AND ARTICLES USED WITH THEM

The paper analyses the use of articles with the names of historical geographical places and related issues (focused on prehistoric and ancient times) in the English language. The paper is divided into three parts. The first one summarizes general rules for the use of articles with geographical names in prescriptive English grammar books. The second part contains a table which aims to present the list of the historical geographical names with corresponding articles. The final one concentrates on the analysis of the actual use of articles with the historical geographical names as found in the following books on history: The Concise History Encyclopaedia and The Western Experience.

1. Introduction

Generally, the functioning of articles in the English language is far from being clear. As for geographical names, the rules for the use of articles with these lexemes have been summarized and are easy to be found in any book on English grammar. Nevertheless, the use of articles with historical geographical place names is the area which has not been covered yet. Due to the large amount of the gathered material, we were bound to concentrate only on two historical periods – prehistoric and ancient times.

2. Various approaches to the use of articles with geographical names

Studying the essential prescriptive grammars of the English language we have found the following information:

The Heinemann ELT English Grammar (1998, p. 172) suggests the zero article for the following geographical names: continents (*Africa*); countries, states, departments (*England, California, Hampshire*); cities, towns, villages (*Sydney, Bilbao*); individual islands (*Crete*); lakes (*Lake Geneva*); individual mountains (*Mount Fuji*) and streets (*Oxford Street*). However, the definite article is introduced for: countries and states when they include a countable noun (*the Federal Republic of Germany*); plural place names (*the West Indies*) and for names such as *the Arctic, the Antarctic, the Far East, the Costa Brava*.

The definite article is to be used with the names of oceans, seas (*the Pacific*); rivers (*the Mississippi*); canals (*the Panama Canal*); deserts (*the Sahara*); island groups (*the Canaries*); hotels, cinemas (*the Plaza Hotel, the Cannon Cinema*); museums, clubs (*the Prado Museum, the Black Cat Club*) and restaurants, pubs (*the Hard Rock Café*).

Names of hotels, restaurants named after the people who started them + the possessive's (*Marcy's Hotel*) and churches named after saints + the possessive's (*St Peter's Church*) represent the exceptions to the above mentioned rule.

According to Murphy (1989, p. 148), the definite article is obligatory also in these instances: mountain ranges (*the Rocky Mountains, the Rockies*); galleries (*the National Gallery*); bridges (*the Golden Gate Bridge*) and cardinal points (*the north of Mexico*).

Moreover, articles are not applied in the following geographical names: roads, squares, parks (*North Road, Time Square, Central Park*) and names of important buildings and institutions when the first word is the name of a person or a place (*Lincoln Centre*).

Eastwood (1994, p. 210) introduces the definite article in these cases: *the Gambia, the Ukraine, the Matterhorn, the Eiger, the Hague, the Bronx, the Mall, the Strand* and also for the names of by-passes, motorways (*the York by-pass, the M6*). The definite article is not placed before the names of most bridges (*Westminster Bridge*). If the name is premodified by an adjective, the definite article is to be used (*the Royal Opera House*).

Swan (2005, p. 65) recommends the zero article when a title of the principal public building and organization of a town begins with the town name (*Salisbury Cathedral*). However, the usage varies with the names of less important institutions (*(the) Newbury School of English*).

Longman English Grammar (1998, p. 70) contributes with these extra exceptions: *the Jungfrau* (mountain); *Death Valley* (the name of a valley without the definite article); *the Argentine, Argentina, (the) Sudan, (the) Yemen* (countries).

At the same time, this is the only book where the use of articles with some historical references is mentioned: *Ancient Greece,*

* **Marta Kadorova, Zuzana Ondrackova**
Department of English Language and Literature, Faculty of Science, University of Zilina, Slovakia, E-mail: marta.kadorova@fpv.uniza.sk, zuzana.ondrackova@fpv.uniza.sk

Medieval Europe, Pre-war/Post-war Germany, Roman Britain (all of them used with the zero article); t*he Dark Ages, the Renaissance, the Stone Age* (all of them used with the definite article).

According to A Comprehensive Grammar of the English Language (1985, p. 293), the definite article is suggested for these exceptions: *the Great Salt Lake, the Bodleian (Library); the City, The West / East End (of London)*;

The usage of the definite and indefinite article alternates in the following instances: *(the) Argentine, (the) Ukraine, (the) Sinai, (the) Bosphorus*.

The definite article is the only acceptable option with the names of other geographical names of coastline (*the Gulf of Mexico, the Cape of Good Hope, the Bay of Biscay, the Strait of Magellan, the Sound of Bute, the Isle of Man, the Isle of Wight*) and with the names of regions (*the Crimea, the Saar, the Punjab, the Ruhrthe (Deep) South, the Midwest*).

3. The use of articles with the analysed geographical names and related issues

The table below aims to present the list of geographical names and related issues covering two historical periods - prehistoric and ancient times as found in the following books: *The Concise History Encyclopaedia* and *The Western Experience*. Articles with individual geographical names and related issues, as they occurred in the analysed texts, have been included, as well. The geographical names are classified according to their reference in the given books.

Empires

the Persian Empire	the Egyptian Empire	an Athenian empire	the western Roman empire
the Persian empire	the Roman Empire	the Athenian Empire	the Eastern Empire
a Persian empire	the Empire	the Athenian empire	the Mauryan Empire
Sumer	the Holy Roman Empire	Mediterranean empire	early Rome
	the late Roman Empire	the Byzantine Empire	the Great Babylonian Empire
	the Assyrian Empire	the Western Empire	the Gubta empire

Kingdoms

the Akkadian kingdom	kingdom of the Hittites	the Seleucid kingdom
Ebla as an independent kingdom	the Egyptian kingdom	Macedonian monarchy
the Babylonian Kingdom	the Hittite kingdom	the kingdom of Pergamum
the kingdom of Babylon	the Hittite Kingdom	the kingdom of Pontus
Babylon	the great kingdom of the ancient Near East	the Parthian kingdom
the kingdom of Egypt		the kingdom of Kush
Early Egypt	the Israelite kingdom of antiquity	Nubian kingdom of Kush
Upper Egypt	the Kingdom of the Medes	the strong kingdom of Mari
Lower Egypt	the Chaldean Kingdom	Maghada
the Old Kingdom	Oriental kingdoms	The kingdom of Axum
the New Kingdom	the Eastern kingdom	Middle Kingdom (China)
the Middle Kingdom	the kingdom of Macedonia	Germanic kingdoms
	Saxon England	

Empires

States	Media	the Athenian state	the state of Zhou
Turkey	Lydia	the Roman Republic	united imperial China
Iraq	Greece	the Republic	Han China
Syria	classical Greece	the Roman state	Gubta India
Palestine	the Dorian states	Roman Italy	Roman Britain
Ethiopia	the Greek states	Jordan	classical Japan
the modern state of Israel	Sparta	the ancient China	the Assyrian state
Phoenicia	Macedonia	Bavaria	the Chaldean state
Persia		Iberia	

Cities, towns & villages

Jericho, the city of Jericho	Niniveh	Pompeii	the city of Tiahuanaco
Jerusalem	Persepolis	Damascus	Chalcis
Jarmo	Knossos	the town of Sinope	Miletos
Uruk	Mycenae	Constantinople	Smyrna
Aleppo	Troy	Harappa	Eretria
the city of Ebla	Olympia	Mohenjo-daro	Cyrenaica
Babylon	Byzantium	Anyang	Marathon
Athens, the city of Athens	the city of Byzantium	Ur	Niani
Memphis	Corinth	Elam	Yelwa
Giza	Miletus	Anyang	Maghada
the city of Cairo	the city of Miletus	Isin	Ajanta
Cairo	the village of Plataea	Elam	Pataliputra
Thebes	the town of Potidaea	Napata	Nalanda
Akhetaton	Syracuse	Meroë	Heian
Karnak	the polis of Thebes	Jenne-jeno	Nara
Kadesh	the city of Alexandria	Laventa	Izumo
Hattuska	the city of Pergamum	the city of Babylon	Tikal
Carthage	the village of Cumae	Tarquinia	Palenque
Canaan	the city of Messana	Judah	Yaxchilán
the town of Sheckem	the village of Pidna	Tyre	Copán
the city of Ashur	the town of Pharsalus	Ecbatana	Calakmul
Sparta	Ephesus	the city of Teotihuacán	El Mirador
Delphi Sardis	Antioch		

Valleys

the Indus Valley the Nile Valley	the valley of the upper Tigris River the Valley of the Kings	the rich Po valley the Tigris-Euphrates Valley	the Danube valley

Mountain ranges

the Taurus Mountains	the Apennine range	the Hindu Kush mountains

Mountains & hills

Tell Mardikh	Mount Sinai	Mount Olympus	the Pnyx	Mount Ilopango

Rivers

the Tigris the Tigris River the upper Tigris River the Euphrates the Euphrates River	the Nile the Nile River the White Nile the Blue Nile	the Indus the Indus River the Jordan River the Halys River	the Po River the Tiber River the Tiber the Rubicon River	the upper Yellow River the Rhine River the Danube River

Seas

the Mediterranean the Mediterranean Sea	the Red Sea the Aegean Sea	the Aegean the Black Sea	the Dead Sea	the Adriatic Sea

Deltas

the Mekong delta

Regions

Asia Minor western Asia Minor the entire Near East the ancient Near East Anatolia central Anatolia the region of Akkad, Akkad the region of Syria Ebla's territory the Near East Mesopotamia the Fertile Crescent the European mainland	the Delta Punt, a territory the Balkan areas Ionia, the region of Ionia the territory of Messenia Etruria Illyria Achaea Nearer Spain Farther Spain Cilicia the Assyrian lands	Bithynia Thessaly the Roman province of Britain Gaul Judea the Middle East Siberia Brittany Alaska the Levant Alaca	the Hittite territories northern Arabia the Israelite territories Nubia Arabia the Tasili area the Bantu Nok Axum Bactria southern Mesopotamia northern Mesopotamia

Buildings & monuments

the Acropolis the Athenian Acropolis the Aswam Dam the Tower of Babel Bel, the Tower of Babel the Great Pyramid the Step Pyramid of Zoser the pyramid of Khefre the Temple in Jerusalem	the Wailing Wall the Hanging Gardens the Hall of a Hundred Columns the Palace of Minos the mighty Gate of the Lionesses/ the Lion Gate the Parthenon the Colosseum the Valley Temple	the Great Bath the walls of Jericho the temple of Marduk the Great Wall the Western Wall the ancient fortress of Masada the Shinto Kasuga Shrine

Nationalities & tribes

the Aztecs the Mayas the Sumerians the Semits the Eblaites the Mesopotamians the Babylonians the Egyptians the Macedonians	the Asiatics the Israelites the Hittites the early Indo-Europeans modern Jews the Canaamites the Phoenicians the Philistines the Assyrians the Romans	the Jews the Greeks the Chaldeans the Iranians the Medes the Melians the Persians the Minoans the Trojans the Dorians	the Etruscans the Athenians the Messenians the Spartans the Corintians the Romans the Apennines Celtic peoples known as Gauls the Gauls

Continents

east Africa East Africa	central Africa western Asia	central Asia Central America	southeast Europe negro west Africa

Islands & peninsulas

the Sinai Peninsula the island of Crete the Peloponnese the Peloponnesus	the island of Corcyra the island of Euboea the island of Salamis the island of Delos	the island of Samos the island of Melos the Italian peninsula	the island of Sicily the southern peninsula of Greece the island of Corsica and Sardinia

Others

the Dardanelles the coast of Attica the Persian Gulf	the Bering Strait the Atlantis seaboard	the Judaean desert the Sinai desert	the Silk Road the Indian subcontinent the Asia-North America land bridge

The rule that the definite article is used with countries when they include a countable noun applies according to our analysis to the names of empires and kingdoms, as well (*the Assyrian Empire, the Akkadian kingdom*). When the name of an empire or kingdom does not contain a common noun, the zero article is suggested (*Sumer, Upper Egypt*). The indefinite article is used only in constructions like *to become an Athenian empire, a Persian empire.* The use of articles with the names of historical states is based on the above mentioned general principles (*the Chaldean state, Han China*).

As for the names of cities, towns, and villages, all the analysed lexemes are combined with the zero article, except for the names with of-construction (*Uruk, the city of Ebla, the town of Sheckem, the polis of Thebes, the village of Plataea*).

The articles preceding the names of valleys (*the Indus Valley*), mountain ranges (*the Taurus Mountains*), mountains and hills (*Sinai*), rivers (*the Euphrates*), seas (*the Aegean*) and continents (*central Africa*) correspond with the generally prescribed rules; the only exception is *the Pnyx* (mountain).

Concerning the names of deltas, only one instance was found, namely *the Mekong delta* with the definite article.

Several instances of important buildings and monuments occurred, all with the definite article (*the Acropolis, the Wailing Wall, the Great Pyramid, the Tower of Babel*).

The names denoting regions are determined in two ways, either with the definite article (*the Near East, the Delta, the Levant*), or with the zero article (*Asia Minor, Nubia, Anatolia*). The use of the definite article with the of- construction is obvious (*the region of Ionia, the territory of Messenia*). It may be assumed that certain geographical names of regions (similarly to the names of mountains) penetrate into English in their original form i.e. with the article or not, e.g. Asia Minor taken from Latin.

Based on the general rule the definite article is applied with the names of nationalities and tribes if they refer to nations (or tribes) as a whole (*the Semites, the Mesopotamians, the Aztecs*). Only two instances with the zero article (not referring to the whole nation) occurred (modern Jews, Celtic peoples known as Gauls).

Concerning the names of peninsulas they are used with the definite article in all the found instances (*the Sinai Peninsula, the Peloponnnese*). When being a part of the of-construction the names of islands are combined entirely with the definite article (*the island of Salamis, the island of Sicily*).

The use of articles with other found geographical names of coastline and deserts is based on the general rule, i.e. the definite article is applied (*the Atlantis seaboard, the Dardanelles, the coast of Attica, the Judaean desert*). The following three non-classified geographical names are accompanied with the definite article (*the Asia-North America land bridge, the Indian subcontinent, the Silk Road*).

4. Conclusions

The analysis of the gathered material shows that general rules for the use of articles with geographical place names are applicable to the names of historical (some of them not existing any more) geographical places, as well. Our aim is to continue in this field of research focusing on further periods of human history, namely the Middle Ages and the New Age in order to cover the use of articles with remaining historical place names.

References:

[1] ALEXANDER, L. G.: *Longman English Grammar*, Longman, 1998.

[2] BEAUMONT, D. - GRANGER, C.: *The Heinemann ELT English Grammar,* Macmillan, 1998.
[3] CHAMBERS, M. - GREW, R. - HERLIHY, D. - RABB, T. K. - WOLOCH, I.: *The Western Experience*, New York: McGraw - Hill, Inc., 1991.
[4] EASTWOOD, J.: *Oxford Guide to English Grammar,* OUP, 1994.
[5] EASTWOOD, J.: *Oxford Learner's Grammar,* Grammar Finder, OUP, 2005.
[6] FOLEY, M., HALL, D.: *Advanced Learnersę Grammar*, Longman, 2003.
[7] HEWINGS, M.: *Advanced Grammar in Use*, Cambridge, 2000.
[8] MURPHY, R., SMALZER, W. R.: *Grammar in Use Intermediate*, CUP, 1989.
[9] QUIRK, R., GREENBAUM, S., LEECH, G., SVARTVIK, J.: *A Comprehensive Grammar of the English Language*, Longman, 1985.
[10] QUIRK, R., GREENBAUM, S., LEECH, G., SVARTVIK, J.: *A Grammar of Contemporary English*, Longman, 1984.
[11] QUIRK, R., GREENBAUM, S.: *A University Grammar of English*, Longman, 1975.

Juraj Gerlici – Tomas Lack – Zuzana Ondrova *

EVALUATION OF COMFORT FOR PASSENGERS OF RAILWAY VEHICLES

The passenger's complex sensation felt during the application of oscillations and/or inertia forces, via the whole-body transmission is defined and evaluated with the help of comfort indexes such as a mean comfort; mean permanent sensation evaluated according to the measurement procedures for the indexes, and comfort on curve transition, discomfort due to a perceived curve entry or reverse transmission, or comfort on discrete events - discomfort, due to a perceived transient oscillation on a straight track, curves and curve transitions. In the text the authors deal with mean comfort evaluation and its qualification with the help of the Comfort Indexes.

1. Introduction

The comfort of passengers in a vehicle is influenced by a number of different factors, for example temperature, noise, vibration etc. The paper considers only that part of the comfort influenced by dynamic behaviour of the vehicle. This part of the comfort is described as Ride Comfort or as Comfort. The European standard summarises the relevant works taking into account the effects on ride comfort for passengers from the vibration exposure measured on the car body floor (the simplified method for Mean Comfort evaluation), taking into account the vibration exposure measured on the interfaces (the complete method for evaluation) and taking into account the effects on Ride Comfort for passengers of discrete events (Comfort Discrete Events) and running on curve transitions (Comfort on Curve Transitions).

2. Ride comfort

The ride comfort for passengers, or ride comfort is the complex sensation produced on the passenger by car-frame movements of the vehicle transmitted to the whole body through the interfaces.

The sensation is classified as:

- *average sensation:* based on the vibration applied on a long-time basis (at least some minutes),
- *instantaneous sensation:* a sudden modification of the average sensation, due to a short basis event (change of the mean lateral acceleration value, roll movement at significant speed, lateral jerk with possible oscillation).

Both the first and the second type of sensation are taken into account in the Mean Comfort evaluation. The second type of sensation is taken into account in the Comfort on Curve Transitions and in Comfort of Discrete Events.

The quantification of Ride Comfort for passengers is performed through simulation computations [2, 4, 6, 7] or trough indirect measurements, i.e. measuring and post-processing the relevant parameters (accelerations and angular velocity, they were measured in the car-body).

3. Input parameters

The quantification of Ride Comfort for passengers is performed through indirect measurements, i.e. measuring and post-processing the relevant parameters (accelerations and angular velocity, they were measured in the carbody). Other types of tests and evaluation, such as a direct test based on the direct assessment of the perceptions of tested passengers, and combined tests including both direct and indirect tests are possible as well, but they are not quantified in [1]. The indirect measurements are classified as simplified or complete if the measurements are taken respectively on relevant points of the carbody floor, or also on the interfaces.

When travelling, the passengers' bodies are influenced by vibration due to dynamical movement of a vehicle.

Passengers are people travelling in a vehicle, without specific activities related to the transport.

4. Ride comfort for passenger evaluation

Comfort is the complex sensation produced on the passenger during the application of oscillations and/or inertia forces, via the whole-body transmission caused by vehicle – frame movements. It is defined and measured through comfort indexes as:

- *Mean comfort:* a mean feeling, continuously adjusted, as evaluated through a measurement following the procedures for comfort index N_{MV} and indexes N_{VA} and N_{VD}.

* **Juraj Gerlici, Tomas Lack, Zuzana Ondrova**
Faculty of Mechanical Engineering. University of Zilina, Slovakia, E-mail: juraj.gerlici@fstroj.uniza.sk, tomas.lack@fstroj.uniza.sk, zuzana.ondrova@fstroj.uniza.sk.

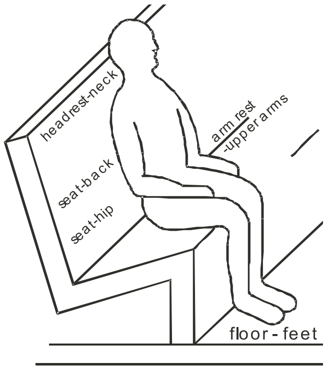


Fig. 1 Interfaces

- *Comfort on Curve Transition:* discomfort, due to a perceived curve entry or reverse transition, quantified by the recommended procedure indicated as comfort index P_{CT}.
- *Comfort on Discrete Events:* discomfort, due to a perceived transient oscillation on a straight track, curves and curve transitions, qualified by the recommended procedure indicated as comfort index P_{DE}.

The contact area is compounded from the contact parts between the carbody and the passenger with the function of sustaining and guiding the passenger and of transmitting the weight of the same passenger to the carbody itself; *In the standing position* (floor- feet), *in the seated position* (headrest – neck, arm rest – upper arm, seat – hip, seat – back, floor – feet), *Whole-body transmission:* this is an action transmitted to the whole body through the interfaces.

Indirect measurements/tests features:

This is a measurement or test or part of tests based on measurement and post-processing of the relevant parameters (acceleration and roll speed measured in the carbody).

Complete measurements are composed of measurements at the positions in accordance to [1, 5, 8]:
- measurements on interfaces,
- measurements on carbody floor, near to the seat.

Simplified measurements: composed of measurements on the carbody floor at the pre-defined positions.

Two methods are available for the assessment of the passenger perception of Mean Comfort:
- A simplified method based on measurement of acceleration on the floor (N_{MV}).
- A complete method based on measurement of acceleration at the interface between the passengers and the vehicle (N_{VA} and N_{VD}).

The complete method is more highly correlated with the passenger's perception of comfort than the simplified method. For a general assessment of the ride comfort of a railway vehicle, the simplified method shall be used. For a full assessment of the ride comfort of vehicles (with a view to the passenger's perception of comfort), it is recommended that the complete method is used where needed.

The simplified method of the Mean Comfort assessment can be performed through the following procedures:
- oscillation measurement,
- results of measured data evaluation,
- list of requested track characteristics for vehicles,
- test protocol form.

To find out effective values of weighted accelerations the registered signals must be elaborated with the help of the following methods: analogous, hybrid (analogous in connection with digital) or digital. In order to take into account the different degrees of sensitivity displayed by different individuals as a function of frequency, weighting curves have been established for vertical and horizontal acceleration signals. These curves are defined in tables [1, 5]. The curves were determined for sinusoidal vibrations; they are considered valid for broad-band stationary vibrations. Although each individual has his own weighting curves, the curves selected are optimum curves for assessing mean vibration comfort.

Statistical analysis technique is based on the following principle:

- In order to take into account the fluctuating aspect of the vibrations, vibration comfort as perceived by the passenger depends on the extreme values of the weighted rms values.
- The rms-level of vibration is therefore determined over a period of 5 s in each direction and at each interface.
- This 5 s interval is the best compromise if the lowest frequencies are to be taken into account and the rms values are to be varied over the range required.
- Different types of histogram of the rms weighted values calculated every 5 s may be constructed and the 95th quantiles may be determined; these values are needed for the calculation of the comfort index N_{MV}.
- The 95th quantile is obtained by cumulating values of the histogram expressed in percent beginning from lower acceleration classes up to the class where that sum becomes equal to 95% or just higher.

Weighting curves are defined by mathematical analytical formulae. Their purpose is to modify the final values of numerical elaboration of measured data as to emphasize crucial information which we want to achieve from the measured signal and at the same time to suppress non-essential information for the final value. Coefficients (see Tab. 1) that modify sensitivity of the final evaluation on input measurements according to the type (direction) of acquired accelerations have an important influence on their course.

The coefficients in Tab.1 are utilized in the equations from 1 to 4. The values are stated on the base of the norm [1].

Parameters coefficients for weighting curves evaluation Table 1

	Weighting frequency range			Weighting curve parameters							
	f_1 [Hz]	f_2 [Hz]	Q_1	f_3 [Hz]	f_4 [Hz]	f_5 [Hz]	f_6 [Hz]	Q_2	Q_3	Q_4	K
W_a	0.4	100	0.71	–	–	–	–	–	–	–	–
W_b				16	16	2.5	4	0.63	0.8	0.8	0.4
W_c				8	8	–	–	0.63	–	–	1.0
W_d				2	2	–	–	0.63	–	–	1.0

$$H_A(s) = \frac{s^2 \cdot 4 \cdot \pi^2 \cdot f^2}{\left(s^2 + \frac{2 \cdot \pi \cdot f_1}{Q_1} \cdot s + 4\pi^2 \cdot f_1^2\right) \cdot \left(s^2 + \frac{2 \cdot \pi \cdot f_2}{Q_1} \cdot s + 4\pi^2 \cdot f_2^2\right)} \tag{1}$$

$H_A(s)$ – *weighting curve W_a specification, where* $s = i(2 \cdot \pi \cdot f)$, $f =$ frequency in *Hz*.

$H_B(s)$ – *transition function of weighting filter W_b for vertical direction course*

$$H_B(s) = \frac{(s + 2\pi f_3) \cdot \left(s^2 + \frac{2 \cdot \pi \cdot f_5}{Q_3} \cdot s + 4 \cdot \pi^2 \cdot f_5^2\right)}{\left(s^2 + \frac{2 \cdot \pi \cdot f_4}{Q_2} \cdot s + 4 \cdot \pi^2 \cdot f_4^2\right) \cdot \left(s^2 + \frac{2 \cdot \pi \cdot f_6}{Q_4} \cdot s + 4 \cdot \pi^2 \cdot f_6^2\right)} \cdot \frac{2 \cdot \pi \cdot K \cdot f_4^2 \cdot f_6^2}{f_3 \cdot f_5^2} \tag{2}$$

$H_B(s)$ – *transition function of weighting filter W_d for horizontal direction course*

$$H_D(s) = \frac{(s + 2\pi f_3)}{\left(s^2 + \frac{2 \cdot \pi \cdot f_4}{Q_2} \cdot s + 4 \cdot \pi^2 \cdot f_4^2\right)} \cdot \frac{2 \cdot \pi \cdot K \cdot f_4^2}{f_3} \tag{3}$$

The course expression $H_C(s)$ – transition function of weighting filter W_c for the back – rest.

$$H_C(s) = \frac{(s + 2\pi f_3)}{\left(s^2 + \frac{2 \cdot \pi \cdot f_4}{Q_2} \cdot s + 4 \cdot \pi^2 \cdot f_4^2\right)} \cdot \frac{2 \cdot \pi \cdot K \cdot f_4^2}{f_3} \tag{4}$$

It has the same analytical expression as $H_D(s)$ – transition function of weighting filter W_d for horizontal direction. At computation they differ in the coefficient value f_3 and f_4.

5. Ride comfort computation

There are measured accelerations in the directions of separate coordinate axe a_x, a_y, a_z [3, 5, 9]. There is given a measured frequency of f_n. On the base of the frequency we state a number of samples which we scan within the time interval of 5 seconds. At the scan frequency of 200 Hz we acquire 1000 samples in five seconds. On the base of occurrence samples condition in 5 – second – time interval we divide the complete time of scanning (acquisition of samples) into 5 – second – time intervals following each other. Each interval has in time strictly determined its begin T_1 and the end T_2.

In this way we stated a number of data blocks. On the base of sampling frequency and time of 5 seconds we determine a number of scans which should be present in the given interval. For a further numerical elaboration it is necessary that this value be a multiple of two. In the case that it is not the above mentioned multiple we substitute it by the nearest higher value which is the multiple of two.

We do the Fast Fourier Transformation (FFT) for a file of data in each time interval defined by T_1 and T_2.

We do the computation *CAW* for the frequency range from 0.4 Hz to 80 Hz.

We apply the weighting filter *w* in dependence on the type of evaluation (floor, standing, seated).

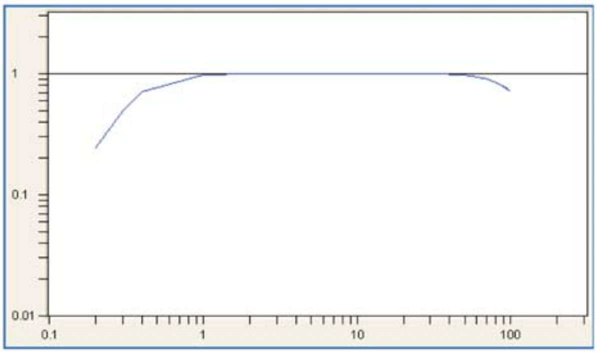


Fig. 2 Graph of $H_A(s)$ - weighting curve course

Floor: N_{MV}

$$N_{MV} = 6 \cdot \sqrt{aWx_{95}^2 + aWy_{95}^2 + aWz_{95}^2} =$$

$$= 6 \cdot \sqrt{(a_{XP95}^{W_{ab}})^2 + (a_{YP95}^{W_{ad}})^2 + (a_{ZP95}^{W_{ab}})^2} \qquad (6)$$

a standing position: N_{VD}

$$N_{VD} = 3 \cdot \sqrt{16 \cdot aWx_{50}^2 + 4 \cdot aWy_{50}^2 + aWz_{50}^2} + 5 \cdot aWy_{95}^2 =$$

$$= 3 \cdot \sqrt{16 \cdot (a_{XP50}^{W_{ab}})^2 + 4 \cdot (a_{YP50}^{W_{ad}})^2 + (a_{ZP50}^{W_{ab}})^2} + 5 \cdot (a_{YP95}^{W_{ad}}) \qquad (7)$$

Similar expressions can be written for a sitting person comfort index evaluation.

$$CAW = \sqrt{\frac{\sum_{f=0.4Hz}^{80Hz} |C \cdot C^*|}{2}} = \sqrt{\frac{\sum_{f=0.4Hz}^{80Hz} |w \cdot [\mathrm{Re}, \mathrm{Im}] \times [\mathrm{Re}, (-\mathrm{Im})]|}{2}} \qquad (5)$$

where

$C = w \cdot (\mathrm{Re}, \mathrm{Im}) \quad C^* = w \cdot (\mathrm{Re}, -\mathrm{Im})$

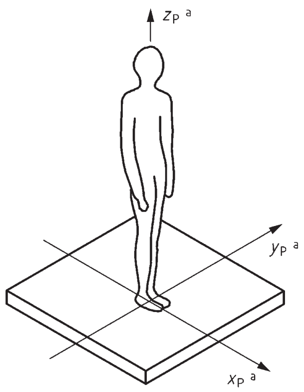


Fig. 3 Standing position

In a statistical way we evaluate acceleration values modified by the weighting function in corresponding directions and we determine summating functions in histograms.

From the histograms for the values of 95% and 50% of the summating function we find out the acceleration values aWx_{95}, aWy_{50}, aWy_{95}, aWz_{50}, aWz_{95}.

$$Wx = W_d \cdot W_a = W_{ad}, \quad Wy = W_d \cdot W_a = W_{ad},$$
$$Wz = W_b \cdot W_a = W_{ab}, \quad Wd = W_c \cdot W_a = W_{ac}$$

aWx_{50} = acceleration value in the direction x multiplied by the weighting function Wx at 50% quantile of the summating function.

We state the final values of ride comfort indexes for passengers from the following formulae.

For a sitting position: N_{VA}

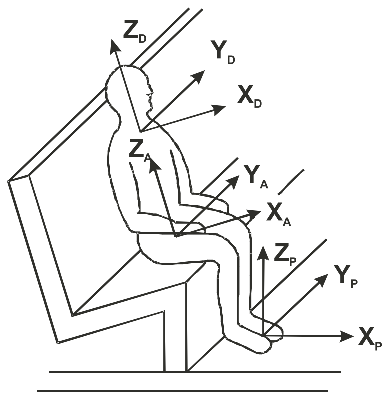


Fig. 4 A sitting person

$$N_{VA} = 4 \cdot aWz_{95} + \sqrt{2 \cdot aWx_{95}^2 + aWy_{95}^2} + 4 \cdot Wd_{95}^2 \qquad (8)$$

The other expression

$$N_{VA} = 4 \cdot (a_{ZP95}^{W_{ab}}) + 2 \cdot \sqrt{(a_{YA95}^{W_{ad}})^2 + (a_{ZA95}^{W_{ab}})^2} +$$

$$+ 4 \cdot (a_{XD95}^{W_{ac}}) \,. \qquad (9)$$

6. Conclusion

The evaluation of ride comfort for passengers is an extremely current issue. A subjective feeling of comfort when travelling is often the decisive criterion which influences the traveller - passenger when choosing a means of transport. Except for economic influences which arise from preferring or refusing some of transport means in the frame of transport system of a country or region, the level of transport system development has a direct

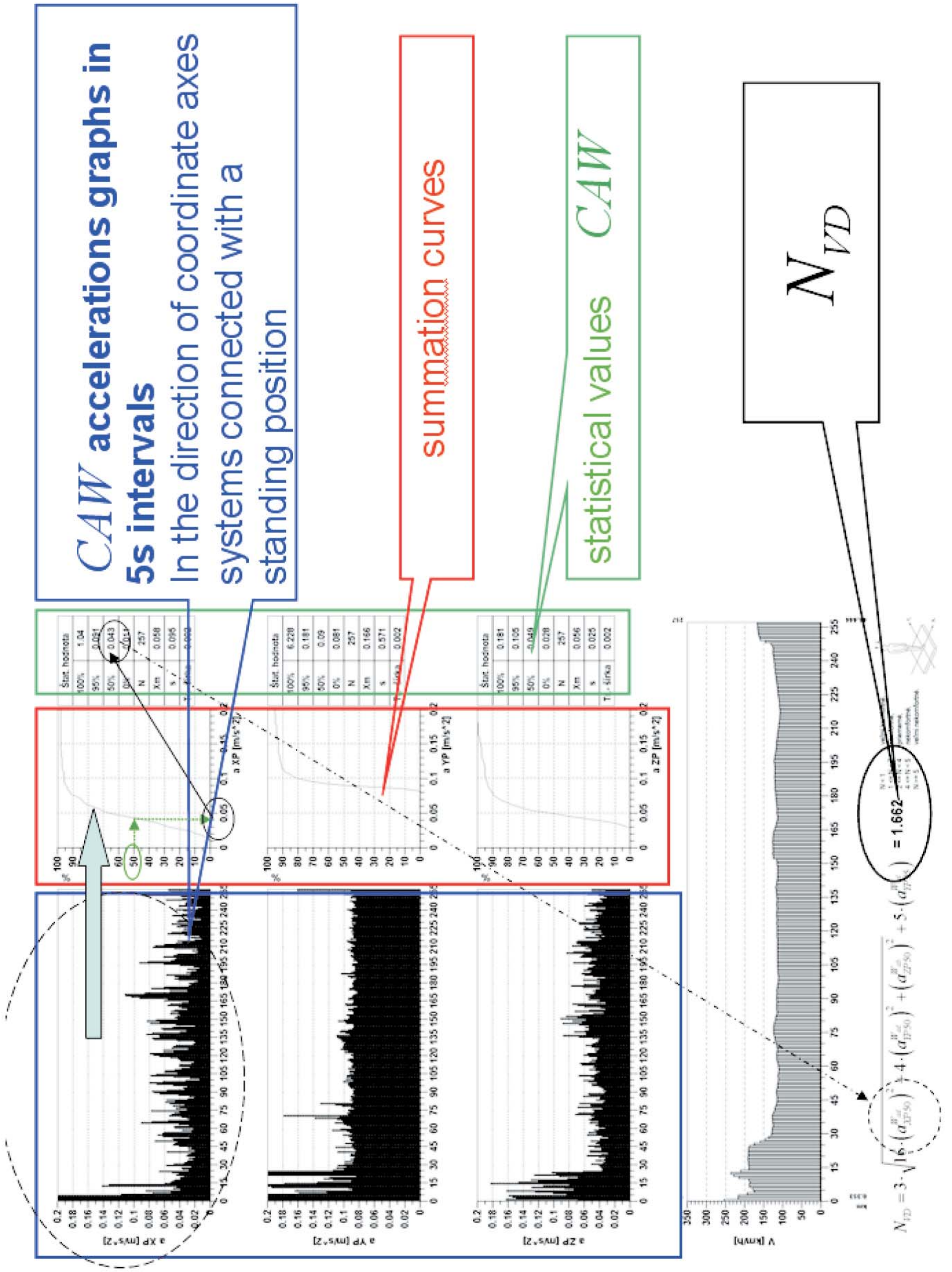


Fig. 5 The acceleration spectrum in the coordinates axe directions is depicted

binding to regional development, social, economic and environmental relations [10, 11, 12].

The aim of comfort evaluation procedures by the indirect method (acceleration measurements) and by statistical evaluation is to achieve a concrete number, a comfort index which, when doing the analysis, takes into consideration the quality of the couple vehicle/track and it is not influenced by subjective feelings of individual passengers.

Vehicle properties from the point of view of comfort have an essential influence on the reliability of vehicle parts which are placed on the vehicle -frame.

The coordinate systems are connected (Fig. 5) with a standing person. The right graphs column are histograms with acceleration summating functions, the tables on the right side of the figure contain statistical values of measurements and assessments.

There is a new comfort index evaluation scale in validity Tab. 2

$N < 1.5$	Very comfortable	$3.5 \le N < 4.5$	Uncomfortable
$1.5 \le N < 2.5$	Comfortable	$N \ge 4.5$	Very uncomfortable
$2.5 \le N < 3.5$	Medium		

The intervals of the comfort indexes values state the comfort classification. They are stated on the base of leaflets. The values specifying the intervals are renewed wen comparing them to he signal values 1999. The renewed values have been valid since the year of 2006.

7. Acknowledgement

The work was supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences in the project No. 1/3169/06 "Properties Research of Rail Vehicles in Movement with Emphasis on the Solution of a Wheel and Rail Contact at the Wheelset Rolling in the Rail via Computer Simulation", in the project No. 1/2116/05: "Interdisciplinary Solution of Modern Rail Transport Means by Usage of Virtual Models and Experimental Methods" and in the project No. 1/4119/07: "Investigation of a dynamical properties of a vehicle".

7. References

[1] ENV 12299: 1999E *Railway Applications – Ride Comfort for Passengers – Measurement and Evaluation,* European Prestandard, February 1999.

[2] GERLICI, J., LACK, T.: *Methods for Vehicle Vibration Analysis in Time Domain.* In: Prace naukowe Politechniki Warszawskiej. Z. 63, Transport, 2007. Pp. 71–81. Publishing House of the Warsaw University of Technology. ISSN 1230-9265, Warszawa 2007.

[3] GERLICI, J., LACK, T.: *Survey of Ride Comfort for Passengers (in Slovak)* In: Acta Mechanica Slovaca, Košice 4-B/2006, pp. 155–162, Optimization of Mechanical Systems, Vol. 10, ISSN 1335 - 2393, Kosice 2006.

[4] GERLICI, J., LACK, T.: *An Analysis of Bumpers and Springs Parameters Influence on the Ride Comfort, (in Slovak).* In: Dynamics of Rigid and Deformable Bodies. Proceedings of V. international conference. ISBN 978-80-7044-914-1. Pp. 39–48. Univerzita J. E. Purkyne v Usti nad Labem. Usti nad Labem, 2007.

[5] LACK, T.: *The Dynamic Properties Analysis of Vehicles from the Point of View of Ride Comfort, (in Slovak).* Habilitation Work, pp. 176, Faculty of Mechanical Engineering University of Zilina, 2007.

[6] LACK, T., GERLICI, J.: *Vehicles Dynamical Properties Analysis from the Point of View of Comfort for Passengers.* Archives of Transport. Vol. 19, issue 1-2, pp. 91–110. ISSN 8066-9546. Warszawa 2007.

[7] LACK, T., GERLICI, J.: *The Programme System DELTA Exploitation for Numerical Analysis Performances, (in Slovak).* In: 18-th. International Conference "Current Problems in Rail Vehicles - PRORAIL 2007" Proceedings of lectures, Part II. pp. 11–22, EDIS, ISBN 978-80-89276-07-3, Zilina 2007.

[8] LACK, T., GERLICI, J., HLAVNA, V.: *Evaluation of Ride Comfort for Passengers,* pp. 9–13, Horizonty dopravy, ISSN 1210-0978, 5/2006, Special Edition, Transport Research Institute, Zilina 2006.

[9] LACK, T., GERLICI, J., HLAVNA, V.: *The Vehicle Comfort, Case study,* Maintenance and Reliability 2006, ISSN 1507-2711, Nr 4(32)/2006, pp. 89–91, Polskie Naukowo-Techniczne Towarysztwo Eksploatacyjne Warszawa, 2006.

[10] ONDROVA, Z., GERLICI, J., LACK, T.: *Comfort for Passengers of Railway Vehicle Analysis.* In: Proc. of international conference "TRANSCOM 2007", ISBN 978-80-8070-696-8, Section 7, pp. 205–210, EDIS - Publishing house of University of Zilina 2007.

[11] ONDROVA, Z., GERLICI, J., LACK, T.: *Comfort for Passengers of Railway Vehicles, (in Slovak).* In: Dynamics of Rigid and Deformable Bodies. Proceedings of V. international conference. ISBN 978-80-7044-914-1. pp. 155–164. Univerzita J. E. Purkyne v Usti nad Labem. Usti nad Labem 2007.

[12] ONDROVA, Z., LACK, T., GERLICI, J.: *The Ride Comfort for Passengers of a Rail Vehicle, (in Slovak).* In: 18-th. International Conference "Current Problems in Rail Vehicles - PRORAIL 2007" Proceedings of lectures, Part II. pp. 127–131, EDIS, ISBN 978-80-89276-07-3, Zilina 2007.

Peter Brida – Martin Matula – Jan Duha *

USING PROXIMITY TECHNOLOGY FOR LOCALIZATION IN WIRELESS SENSOR NETWORKS

The localization in wireless sensor networks is very important for function of the network (routing...). The objective of the localization process is to determine the position of device (sensor, node) from the information acquired from the reference devices. These devices of course know their location. The aim of the paper is to give a survey of two proximity based location techniques performance. The results of basic proximity based localization techniques are compared with modified (enhanced) proximity technique. It does not belong to the most accurate techniques, but on the other hand, it is a low cost alternative to more expensive techniques.

1. Introduction

The physical world will consist of large networks of wireless sensor nodes. Particularly, applications like environmental monitoring of water and soil require that these nodes be very small, light and unobtrusive. A wireless sensor network consists of a possibly large number of wireless devices able to take environmental measurements. Typical examples are temperature, light, sound, and humidity. These sensor readings are transmitted over a wireless channel to a running application that makes decisions based on these sensor readings. Many applications have been proposed for wireless sensor networks, and many of these applications have specific quality of service (QoS) requirements that offer additional challenges to the application designer. Several applications have been envisioned for wireless sensor networks [1]. These range in scope from military applications to environment monitoring to biomedical applications. This paper deals with localization by using proximity technology.

In this paper, we review localization techniques and evaluate the effectiveness of a very simple proximity (connectivity-metric) method for localization in all environments that make use of the inherent radio-frequency (RF) communications capabilities of these devices.

2. Localization in Wireless Networks

The concept of location is not limited to the geographic representation of physical location with sets of coordinates (latitude, longitude, and altitude). It is also applicable to symbolic location in a nongeographic sense such as location in time or in a virtual information space such as a data structure or the graph of a network.

Common to all notions of location is the concept that the individual locations are all relative to each other, meaning that they depend on a predefined frame of reference. This leads to a differentiation of the relative and absolute positioning cases [2].

When talking about physical location in the traditional way, points are usually viewed as three-dimensional coordinates [x, y, z] in a Cartesian reference coordinate system. Many other transformations to other coordinate systems like polar coordinates are equivalent.

Usually, [x, y, z] coordinates by themselves are not meaningful for context-aware system services and other information needs to be associated with these position fixes. In these cases, it is important to introduce the fourth dimension – time, to be able to specify where and when a certain event took place resulting in sets of [x, y, z, t] for each position fix. This four-dimensional fix can then be used to put subsequent events into a context frame.

When position information is used in reference to a geographic map or a global time reference, context information can be extended. The position of node can be defined as absolute or relative position. An absolute position is given in respect to an inertial system and a reference point in this inertial system (see Fig. 1 a). On the other hand, a relative position can only be given in respect to other points resolving the distances and the geometric configuration, e.g., the topology (see Fig. 1 b). It means that absolute positioning data are used with respect to the absolute position of other nodes or to a reference position or a map. Relative positioning can discriminate topology information only in a node's local reference system.

Localization techniques that use positioning generally consist of three components [2]:

- Identification and data exchange.
- Measurement and data acquisition.
- Computation to derive location.

* **Peter Brida, Martin Matula, Jan Duha**
Department of Telecommunications, Faculty of Electrical Engineering, University of Žilina, Slovakia E-mail: peter.brida@fel.uniza.sk,

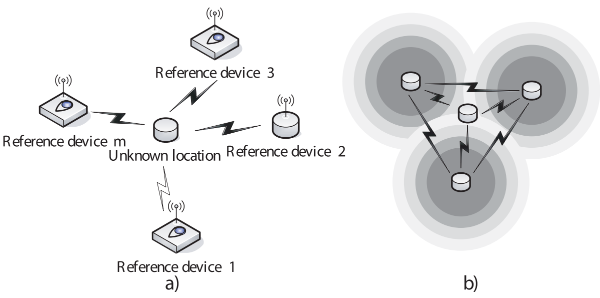


Fig. 1 a) Absolute positioning b) Relative positioning

The various approaches divide these tasks differently across their system components.

The mechanisms used for estimating location are possible to divide into two categories: range-based and range-free [3]. The range-based mechanisms are based on the indirect measurements of distance or angle between sensors. Examples of the mechanism are the following methods: received signal strength indicator (RSSI), time of arrival (ToA), time difference of arrival (TDoA), carrier phase and code measurements, ultra wide-band (UWB), ultrasound, and even visible light pulses or the angle of arrival (AoA) of a radio signal. The important thing to note is that these mentioned measurements always have errors and individual measurements are not independent of each other and are strongly influenced by the surrounding environment and the used transmission system.

The devices in some systems (e.g., wireless sensor networks) have the hardware limitations. To overcome the limitations of the range-based positioning methods, many range free solutions have been proposed. These solutions estimate the location of mobile devices (sensors, nodes or mobile stations) either by exploiting the radio connectivity information among neighboring mobile devices, or by exploiting the sensing capabilities of the mobile devices. Therefore the range-free positioning solutions are cost-effective alternative to more expensive range based approaches.

Due to the distinct characteristics of these two approaches, we categorize the range-free positioning methods into: reference device based methods and reference device free methods. For the first method, the presence of devices, that have knowledge about their location, is assumed in the network. And the second method requires no special sensor nodes for positioning.

2.1 Location in Wireless Sensor Networks

Wireless Sensor Networks (WSNs) are the special part of wireless ad hoc networks. The localization in WSNs is a little bit different in comparison with localization in traditional wireless networks (e.g. cellular networks).

WSN is usually characterized by subjects such as vast number of devices, high overall node mobility, considerable power and resource consumption at the nodes, and moderate network sizes, WSN have brought about quite a change in the traditional, connection-oriented, infrastructure-dominated telecommunications world [2]. Unpredictable dynamics due to failures and changes in nodes and the environment, as well as deployment in uncontrolled areas with high dynamics and possibly hostile to radio signal propagation, require adaptable networking mechanisms. Other characteristics of typical WSN nodes are the limited resources available on these low power embedded systems, especially the limited transmission range and low duty cycle operation of the radio transceivers. Nodes can be reactive and are able to wake up on demand [2]. Targeted for a very long lifespan, integrated into all kinds of everyday objects and building materials, deployed once, and in many cases never collected again or decommissioned, the vast majority of nodes will form a quasistatic, multihop network topology (see Fig. 2).

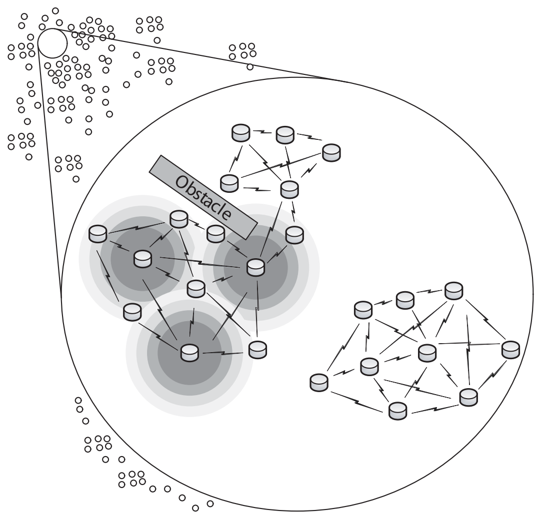


Fig. 2 Topology of wireless sensor network

The problem of localization, i.e., determination where a given node is physically located in a network is a challenging one, and yet extremely crucial for many of these applications. Practical considerations such as the small size, form factor, cost and power constraints of nodes preclude the reliance on Global Positioning System (GPS) on all nodes in these networks.

GPS may solve the problem of localization in outdoor environments for nodes. However, for large networks of very small, inexpensive, and low-power devices, practical considerations such as size, form factor, cost, and power constraints of the nodes preclude the use of GPS on all nodes. The GPS-less system [1] addresses the problem of localization for such devices, with the following design goals:

- RF based: they focus on small nodes that have some kind of short-range RF transceiver. The primary goal is to leverage this radio for localization, thereby eliminating the cost, power, and size requirements of a GPS receiver.
- Receiver based: in order to scale well to a large distributed network, the responsibility for localization must lie with the

receiver node that needs to be localized, and not with the reference points.
- Ad hoc: in order to ease deployment, a solution that does not require preplanning or extensive infrastructure is desired.
- Responsiveness: we need to be able to localize within a fairly low response time.
- Low Energy: small, untethered nodes have modest processing capabilities, and limited energy resources. If a device uses all of its energy localizing itself, it will have none left to perform its task. Therefore, we want to minimize computation.
- Adaptive Fidelity: in addition, we want the accuracy of our localization algorithms to be adaptive to the granularity of available reference points.

2.1.1 Proximity Based Localization

Localization using proximity measurements is popular, when low cost takes precedence in priority over accuracy. Since, messages necessarily pass between neighbors, there is no additional bandwidth required to proximity. Proximity measurements simply report whether or not two devices are 'connected' or 'in-range'. However, the term 'in-range' may mislead readers to believe that proximity is purely a function of geometry – whether or not two devices are separated by less than a particular distance. In fact, proximity is determined by whether or not a receiver can demodulate and decode a packet sent by a transmitter. Given the received signal and noise powers, the successful reception of a packet is a random variable. Yet, proximity carries considerable information regarding sensor location in a binary variable. The proximity has been used by numerous researchers for localization in ad hoc networks and wireless sensor networks [4, 5, 6, 7].

A fixed number of reference points in the network with overlapping regions of coverage transmit periodic beacon signals. Nodes use a simple connectivity metric that is more robust to environmental vagaries, to infer proximity to a given subset of these reference points. Devices localize themselves to the centroid of their proximate reference points. The accuracy of localization is then dependent on the separation distance between two adjacent reference points and the transmission range of these reference points.

3. System and Measurement Models

WSNs are made up of peer-to-peer links between devices (nodes). Pair-wise measurements can be made from any of these links, but only a small fraction of devices have coordinate knowledge. Thus, the measurements are made primarily between pairs of devices of which neither has known coordinates. The device with known coordinates is called a reference device. Otherwise, it is referred to as blindfolded device, since it cannot see their location. Specifically, consider a network of m reference and n blindfolded devices. The relative location problem corresponds to the estimation of blindfolded device coordinates. For simplicity we consider the location in 2D plane. Let $[X_i, Y_i]^T$ $i = 1, 2, ..., m$ are coordinates of reference devices and $[X_j, Y_j]^T$ $j = 1, 2, ..., n$ are coordinates of blindfolded devices. Pair-wise measurements $\{RSS_{i,j}\}$, where $RSS_{i,j}$ is a measurement between devices i and j. $RSS_{i,j}$ is received signal strength in device j from the device i.

3.1 Channel Model

We consider a fading channel in all measurements in this paper. The propagation path between two devices is shown in fig. 3, where RSS is received signal strength, T_x is transmitted signal strength. The influence signal attenuation is defined by: L_{LS} is signal degradation caused by large-scale propagation, L_{MS} is signal degradation caused by medium-scale propagation and finally L_{SS} is signal degradation caused by small-scale propagation. All these parameters are in [dBm]. Parameters L_{MS} and L_{SS} have the normal distribution, but their impact on the proximity based localization is negligible, because most of devices are static and these parameters are primarily changed during motion of device. Therefore, we take into consideration idealized radio model only L_{LS}. We chose this model because it is mathematically simple and easy. In this section, this model is presented. We make two assumptions in the model: the perfect spherical radio propagation and identical transmission range (power) for all devices.

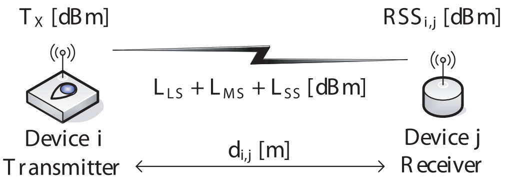


Fig. 3 Channel model

$RSS_{i,j}$ is the measured received signal strength at device j transmitted by device i (in dBm) is Gaussian

$$RSS_{i,j}\,(dBm) = P_0(dBm) - 10 \cdot n_p \cdot \log(d_{i,j}/d_0)\,, \qquad (1)$$

where $RSS_{i,j}$ is the mean power in dBm, P_0 is the received signal strength at the reference distance d_0. Typically $d_0 = 1$ meter, and P_0 is calculated by the free space path loss formula [2]. The path loss exponent n_p is a function of the environment.

3.2 Proximity Measurements

The proximity measurement S is determined based on the measured signal. $S_{i,j}$ is obtained from $RSS_{i,j}$ and it is equal to 1 if devices i and j are in range, and it is 0 if not. It is necessary to clearly define transition from status "in range" to "out of range". Therefore, we define a threshold. If the received signal strength ($RSS_{i,j}$) at j device transmitted by i device is higher as defined threshold then i devices is assumed to be in range of the j device. Thus,

$$S_{i,j} = \begin{cases} 1, & RSS_{i,j} \geq RSS_T \\ 0, & RSS_{i,j} < RSS_T \end{cases}. \qquad (2)$$

4. Simulation Environment

The presented numerical simulations compare the performance of various solutions of proximity localization. Simulations are done for one propagation environment. The all devices are situated in square 10 m × 10 m. The reference devices are situated randomly (according to Gaussian distribution $N(0,1)$) in mentioned area. Five hundred trials are performed. In each trial, the positions of reference devices and blindfolded device are generated at first. In the next step, *RSS* are calculated between each reference devices and blindfolded device based on the equation (1). Here, we use the parameters $n_p = 2$ (free space). Then, the devices are rejected which do not fulfill the threshold condition. The location coordinates of blindfolded device are calculated based on the remaining reference devices. The location coordinates can be calculated based on the following techniques (our working titles):

- Common proximity – the estimated location is determined on the basis of the closest device location, i.e. the blindfolded device has same location coordinates as the closest device.

$$[x_{est}; y_{est}] = [x_{closest-device}; y_{closest-device}] \quad (3)$$

- Centroid proximity – the position of blindfolded device is calculated as mean value of coordinates N of the closest reference devices. It is defined by the centroid of these reference devices (see equation (4)).

$$[x_{est}; y_{est}] = [\frac{1}{N}\sum_{i=1}^{N} x_i; \frac{1}{N}\sum_{i=1}^{N} y_i] \quad (4)$$

The accuracy of device positioning is compared by means of *RMSE* (Root Mean Square Error)

$$RMSE = \sqrt{(x_r - x_{est})^2 + (y_r - y_{est})^2} \ \text{[m]}, \quad (5)$$

where $[x_r; y_r]$ are coordinates of the real (precise) position and $[x_{est}; y_{est}]$ are coordinates of estimated position on the basis of the selected technique.

5. Simulation Results

In this section, we discuss obtained results by means of techniques described in the previous part. The results are simulated to evaluate the performance of the proximity localization in WSNs. The simulations are realized for two cases:

- Optimization of the number reference devices used for location estimation in centroid proximity.
- Influence of the number of all reference devices used in simulation of both proximity techniques.

In the first case was surveyed an influence of N number of reference devices used for the location estimation in centroid proximity. In the following figures are shown the results for two different numbers of reference devices used in simulation. The overall number of reference devices was 10 and 100. The experiments were realized for more values of m with similar results.

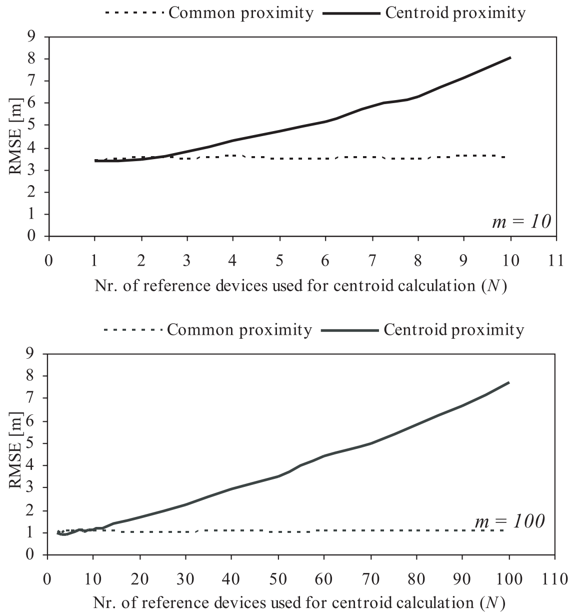


Fig. 4 RMSE [m] versus number of reference devices used for centroid proximity calculation

Fig. 4 depicts RMSE localization error properties in the cases for two different numbers of all devices used in simulation and the dependency of localization error on N (the number of reference devices used for calculation of centroid proximity location estimation). Naturally, the change of N doesn't impact on accuracy of common proximity (dash line). The number of reference devices used for estimation calculation plays an important role in localization accuracy. The minimal error is interesting. The results confirm the fact that centroid proximity achieves the smallest localization error in comparison of common proximity based technique. The difference of the minimal localization error is the most important factor of an objective comparison for the observed techniques. In both observed cases of m ($m = 10$ and 100), the minimal RMSE was obtained for case $N = 2$. Therefore in next simulation will be used only two reference devices for calculation of device coordinates in centroid proximity. In general, we can say that the accuracy

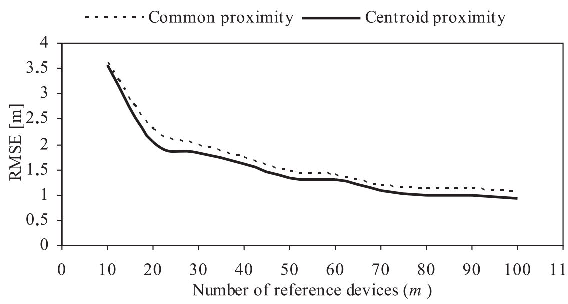


Fig. 5 RMSE [m] versus number of reference devices for both proximity techniques

decreases as the number of reference devices used for centroid proximity calculation (except $N = 2$) increases. Therefore, centroid proximity technique is suitable to use for estimation of location.

The following figure shows the performance comparison of common and centroid proximity for the same number of reference devices used for location estimation.

Fig. 5 shows the dependence of the *RMSE* on the number of reference devices *m*. For calculation of centroid proximity were used the two closest reference devices. On a basis of the obtained results we conclude that the centroid proximity technique achieves more accurate results comparing to centroid and common proximity. The *RMSE* is an exponential function of the number of reference devices *m*. Ascending value of the reference devices number means increasing of the *RMSE*.

The results (statistical characteristics) are compared and numerically expressed in Table 1. The *RMSE* is an average value of all 500 trials for one scenario and the *STD* is a standard deviation also for the same scenario.

RMSE and STD [m] versus number of reference devices for both proximity techniques — Table 1

Nr. of reference devices	Proximity			
	Common		Centroid	
	RMSE [m]	STD [m]	RMSE [m]	STD [m]
10	3.6372	1.9538	3.5644	2.0515
20	2.3049	1.2067	2.0434	1.3152
30	1.9693	1.0003	1.8265	1.1258
40	1.7319	0.951	1.618	0.9931
50	1.4721	0.8022	1.3357	0.7734
60	1.3863	0.7407	1.2943	0.7565
70	1.1892	0.6859	1.0708	0.7134
80	1.1061	0.5982	0.9853	0.6007
90	1.1182	0.6332	1.0008	0.6507
100	1.0644	0.5552	0.9246	0.5572

6. Conclusions

We discussed two techniques for the location determination based on the proximity technology for wireless sensor networks. We compare the common proximity with centroid proximity technique. According to the results, the performance of the centroid proximity technique is better in comparison to the common proximity when two reference nodes are used for calculation of position coordinates. Hence, it is possible to recommend using the centroid proximity with application of two reference devices for positioning. The common proximity achieved the worst results, but this variant does not need any calculation capacity for the localization procedure. The method is not accurate in comparison with the sophisticated localization methods, but it is sufficient for the less demanding applications in huge WSNs.

Acknowledgments:

This paper is based on the work supported by the grant VEGA 1/4065/07 of Scientific Grant Agency of the Slovak Republic.

References:

[1] STOJMENOVIC, I.: *Handbook of Sensor Networks: Algorithms and Architectures,* A John Wiley & Sons, 552 pages, ISBN: 978-0-471-68472-5, 2005.

[2] ILYAS, M., MAHGOUB, I.: *Handbook of Sensor Networks: Compact Wireless and Wired Sensing Systems,* CRC Press, 672 pages, ISBN 0-8493-1968-4, 2004.

[3] JAYASHREE, L.S., ARUMUGAM, S., ANUSHA, M., HARINY, A. B.: *On the Accuracy of Centroid based Multilateration Procedure for Location Discovery in Wireless Sensor Networks,* Proc. Wireless and Optical Communications Networks, 2006

[4] SUNDARAM, N., RAMANATHAN, P.: *Connectivity Based Location Estimation Scheme for Wireless ad hoc Networks,* IEEE Globecom 2002, volume 1, pages 143–147, 2002.

[5] DOHERTY, L., PISTER, K. S. J., GHAOUI, L. E.: *Convex Position Estimation in Wireless Sensor Networks,* IEEE Infocom, volume 3, pages 1655–1663, 2001.

[6] NAGPAL, R., SHROBE, H., BACHRACH, J.: *Organizing a Global Coordinate System from Local Information on an ad hoc Sensor Network,* 2nd Intl. Workshop on Inform. Proc. In Sensor Networks, 2003.

[7] NICULESCU, D., NATH, B.: *Ad hoc Positioning System,* IEEE Globecom 2001, volume 5, pages 2926–2931, 2001.

[8] MAUVE, M, WIDMER, J., HARTENSTEIN, H.: *A Survey on Position-Based Routing in Mobile Ad-Hoc Networks,* IEEE Network, volume 15, issue 6, pages 30–39, 2001.

[9] KAEMARUNGSI, K., KRISHNAMURTHY, P.: *Modeling of Indoor Positioning Systems Based on Location Fingerprinting,* IEEE INFOCOM 2004.

[10] PRASITHSANGAREE, P., KRISHNAMURTHY, P., CHRYSANTHIS, P. K.: *An Indoor Position Location with Wireless LANs,* Proc. IEEE International Symposium on Personal, Indoor, and Mobile Radio Communications (PIMRC02), Lisbon, Portugal, 2002.

Jana Steiningerova – Miroslav Neslusan – Stefan Nemeth *

ANALYSIS OF VIBRATION WHEN APPLICATION OF PROGRESSIVE GRINDING WHEELS

This investigation was undertaken to compare the performance of grinding wheels containing newly developed "seeded gel" aluminum oxide abrasive with the wheels containing conventional monocrystalline aluminum oxide. The experiments were carried out on the surface grinder BPH 20 over a wide range of removal rates with two grinding wheels on hardened bearing-steel specimens. It was found that the wheels containing "seeded gel" abrasive required less grinding power and gave higher grinding stability than monocrystalline abrasive wheels of the same grade with better surface waviness. The potential improvement in productivity using the "seeded gel" abrasive wheels was estimated. Optimal removal rates with the SG wheel are higher than the one for conventional monocrystalline aluminum oxide.

1. Introduction

Grinding is a widely used machining process in applications requiring high production rates and very good dimensional accuracy and surface finish. It is also one of the more complex metalworking processes and one of the less understood. Consequently, successful use of grinding in practice is highly dependent on the level of expertise of the machinist and engineer. Grinding is also viewed as an unpredictable process because of the large number of variables involved and inadequate understanding of the relationships between those variables and the grinding process performance. That is particularly true of vibration in grinding operations, commonly referred to as grinding chatter [1].

Grinding chatter poses many of the same problems that chatter in other machining operations presents. Chatter results in undulations or roughness on the grinding wheel or workpiece surfaces and is highly undesirable. One form of grinding chatter, referred to as self-excited chatter, is usually eliminated or reduced by lowering metal removal rates. Also, grinding wheel surface unevenness resulting from chatter necessitates frequent wheel redressing. Thus, chatter results in a worsening of surface quality and lowers machining productivity. Those limitations are particularly severe, since grinding operations are used in applications involving high production quantities and stringent dimensional accuracy and surface finish requirements [1, 2]. Improved productivity and workpiece surface finish would, therefore, result from better understanding of grinding chatter [1, 3].

Except application conventional monocrystalline aluminum oxide recent developments have lead to the use of chemical ceramic "sol gel" technology to produce a new class of alumina abrasives [4]. This process involves converting a colloidal dispersion or hydrosol containing goethite in a mixture with solutions or other sol precursors to a semi-solid gel to restrain the mobility of the components, drying to a glassy state, crushing to the required grain size, and firing at about 1300 °C. Subsequent developments resulted in a modification to the process whereby the gel is "seeded" with submicron alpha alumina particles before drying [3, 4]. The produced "seeded gel" (SG) abrasive grit consists of sub-micron size crystalline particles which can separate from the abrasive grit by wear during grinding. It was reasoned that this type of microcrystalline fracture wear would keep the abrasive sharper than conventional abrasives which become dull by the formation of wear flats on their tips, thereby reducing bulk wheel wear rates, improving grinding ratios, enhancing the ability of the wheel to hold form and finish, and providing higher removal rates with lower power [3, 4]. This investigation was undertaken to compare the performance of grinding wheels containing newly developed "seeded gel" aluminum oxide abrasive with wheels containing conventional monocrystalline aluminum oxide. This investigation is based on analyze of vibration and its influence on quality of ground surface.

2. Conditions of experiment

Grinding tests were performed under surface grinding conditions using the grinding machine BPH 20. The work pieces, used in the experiments were made of 100Cr6 bearing steel hardened to 62 HRC (100 × 10 × 60mm). The grinding performances of two types of wheels of the same hardness grade were compared: a monocrystalline alumina wheel (A99 01 250 × 20 × 76 38A 60 JVS) such as commonly used for grinding of bearing steels, a "seeded gel" wheel (5SG 01 250 × 20 × 76 60 JVX – containing 50% of SG grain in the wheel).

Cutting conditions:
cutting depth – a_p = 0.01 mm to 0.04 mm,

* **Jana Steiningerova, Miroslav Neslusan, Stefan Nemeth**
Department of Machining and Automation, Faculty of Mechanical Engineering, University of Zilina, Slovakia, E-mail: jana.steiningerova@fstroj.utc.sk

feed – $v_f = 8$ (m.min^{-1}),
cutting speed – $v_c = 28.39$ m.s^{-1},
cutting fluid – EMULZIN H (2% concentration).

Analysis of vibration was carried out through measurement of grinding forces (Fig. 1). Grinding forces were measured by piezoelectric dynamometer KISTLER type 9257A. A personal computer collects information from the dynamometer in the predetermined points of the grinding cycle. Analysis of the collected information were carried out in the software DasyLab 3.5. Surface topography was analyzed through its waviness (applied device MP125).

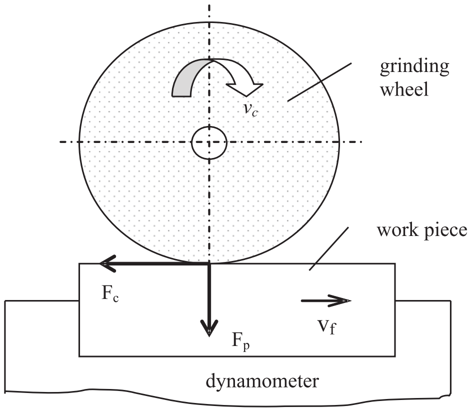


Fig. 1 Grinding forces F_c and F_p

3. Results of experiment

Grinding forces were analyzed in two frequency zones. The static components represent grinding force up to frequency 10Hz, the dynamic forces above the frequency 10Hz. Records of grinding forces are illustrated in Figs.2 and 3. These records represent the stage of a worn grinding wheel. There is a visible difference in the amplitude of vibration between the conventional and SG wheel. The negative values in Fig.2 are caused by persistence of grinding system.

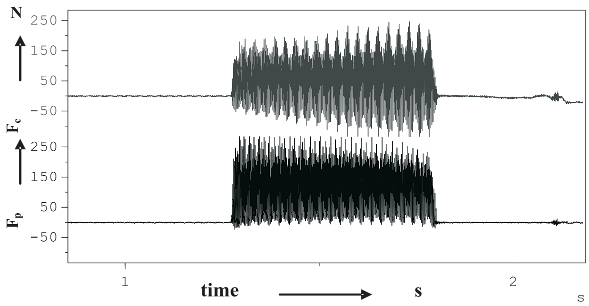


Fig. 2 Record of grinding forces F_c and F_p for $V_o = 1500$ mm^3, A99, $a_p = 0.03$ mm

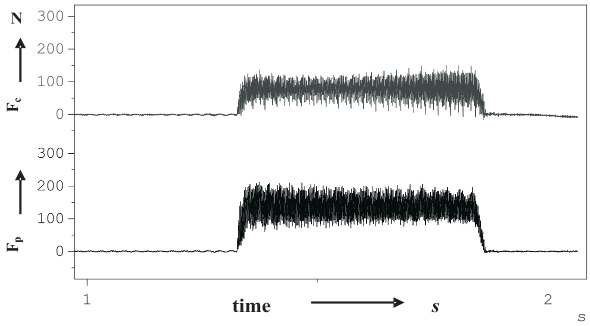


Fig. 3 Record of grinding forces F_c and F_p for $V_o = 1500$ mm^3, 5SG, $a_p = 0.03$ mm

The dynamic components of grinding forces were analyzed though the RMS values (the RMS value is the most relevant measure of amplitude because it both takes the time history of the wave into account and gives an amplitude value which is directly related to the energy content, and therefore the destructive abilities of the vibration). From the results in Fig.4 it can be seen that the RMS values progressively increase the same way with the continued grinding for both wheels. Next, there is visible only a slow rise of the RMS values after the dressing (approximately up to $V_o = 500$ mm^3). This interval represents the stable area of the grinding process. On the other hand, there is following intensive increase of RMS values. This stage represents the worn grinding grains. The grinding wheel should be redressed. Fig. 4 illustrates that there is no significant difference in the RMS values between the conventional and SG grinding wheels under the low cutting depth. On the other hand, there is a significant difference under the higher cutting depth. When compared with the conventional wheel (Fig. 5) there is no visible intensive increase of the RMS values for the 5SG wheel. This difference is related to self-sharpening effect of SG grain under the higher cutting forces generated by higher cutting depths (higher material removal rates). When working with lower cutting forces (lower cutting depths), it is necessary to produce the microchipage of the grains by implementing a dressing process.

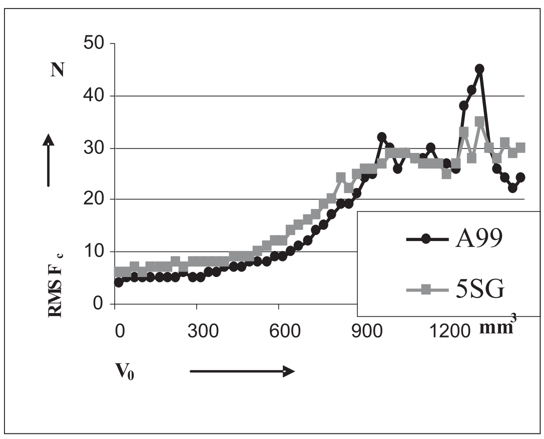


Fig.4 Influence of grinding grain wear on the RMS value of cutting force, $a_p = 0.01$ mm

Analysis of self-excited vibration is illustrated by frequency specters in Figs. 6 and 7. There is formation of waviness on the grinding wheel surface. This waviness can be identified through the frequency of approximately 400 Hz. This frequency is given by a number of revolutions of the grinding wheel per one second (40 times) and the number of waves on the grinding wheel surface (in this case 10 waves). Figs. 6 and 7 illustrate that this dominant frequency is higher for a conventional wheel than for a 5SG wheel. Then, the number of waves on the 5SG grinding wheel surface is higher because the dominant frequency is higher. This aspect is suitable considering the formation of waviness on the ground surface (the higher number of waves is obviously related to the lower amplitudes of waves). The lower amplitude and the higher frequency for the 5SG wheel lead to the lower surface waviness. This comparison is illustrated in Figs.8 and 9. Amplitudes of waves of the ground surface after grinding with the conventional wheel are significantly higher than the ones generated by the 5SG wheel.

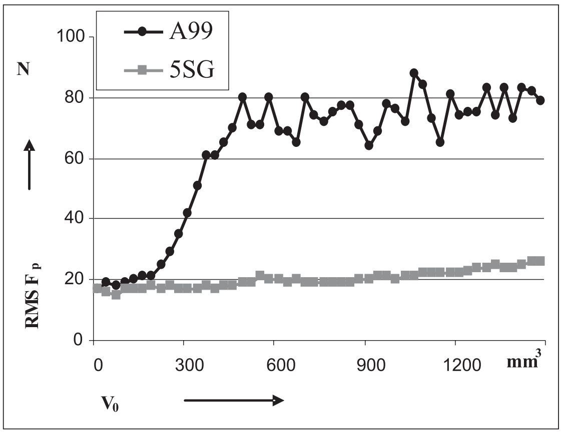


Fig.5 Influence of grinding grain wear on the RMS value of cutting force, $a_p = 0.03$ mm

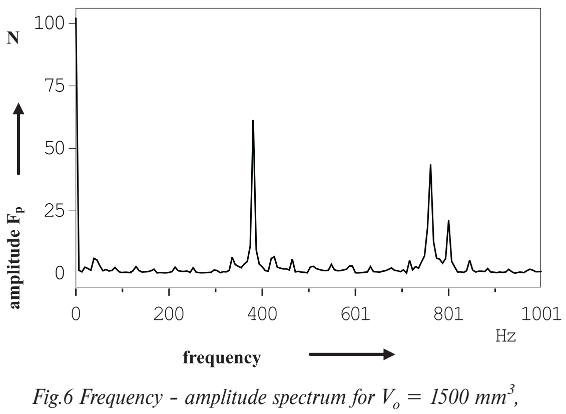


Fig.6 Frequency – amplitude spectrum for $V_o = 1500$ mm^3, $a_p = 0.03$mm A99 grinding wheel

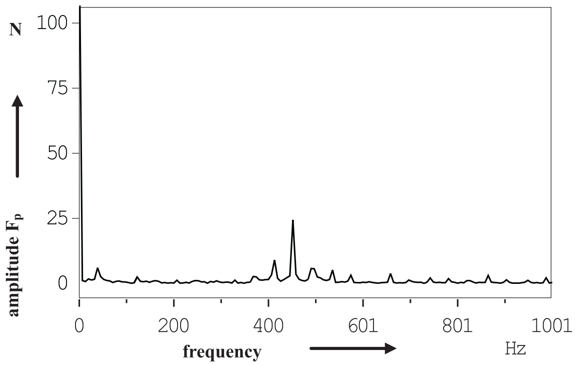


Fig. 7 Frequency – amplitude spectrum for $V_o = 1500$ mm^3, $a_p = 0.03$ mm 5SG grinding wheel

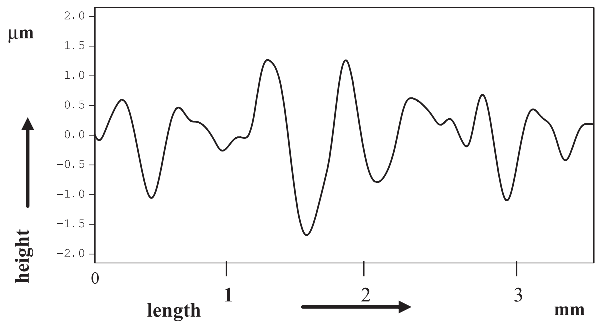


Fig. 8 Waviness of ground surface generated by conventional Al_2O_3 wheel, $a_p = 0.03$ mm, $V_o = 1170$ mm^3

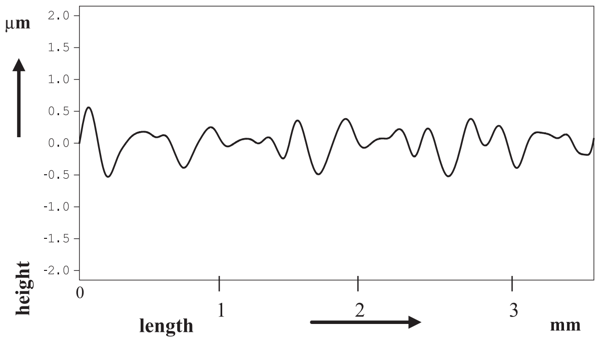


Fig. 9 Waviness of ground surface generated by 5SG wheel, $a_p = 0.03$ mm, $V_o = 1170$ mm^3

4. Conclusion

The objective of this investigation was to compare the performance of grinding wheels containing newly developed "seeded gel" abrasive with the wheels containing conventional monocrystalline alumina. It was found that 5SG abrasives lowered the intensity of vibration and surface waviness compared with the monocrystalline abrasive wheels of the same grade. The optimal removal rates for the "seeded gel" abrasive wheels were higher than for monocrystalline wheels. Similar results can be achieved by application of modified technology known as Targa gel wheel (TG wheels). Moreover, there are other aspects of SG and TG wheels application. First of all, it is higher G ratios for SG and TG wheels in comparison with the conventional wheel, the lower temperatures in the contact of grinding wheel and workpiece, more suitable state of residual stresses and longer interval between dressings.

Acknowledgement

The authors would like to acknowledge the financial support given by the VEGA for this project (project No 1/2080/05) included in the research programme of the University of Zilina.

References:

[1] TONSHOFF, H. K., FRIEMUTH, T., BECKER, J. C: *Process Monitoring in Grinding,* Annals of the CIRP, 51/2/2002, p. 551

[2] NESLU_AN, M., TUREK, S., MINICH, R.: *Study of vibration in grinding through the analysis of grinding force (in Slovak),* Strojárska technológia 2004, Súľov, pp. 177–184

[3] TUREK, S. – MINICH, R. – NESLUŠAN, M.: *Experimental Investigation of Chatter at SG Grinding Wheels Application,* 11th International scientific conference, Žilina, 2003

[4] UHLMAN, E., STARK, C.: *Potentiale von Schleifwerkzeugen mit mikrokristalliner Schleifen,* Honen und Polieren, Vulkan Verlag, Essen, 1997.

Katarina Holla *

DEALING WITH KEY TERMS IN RISK ANALYSIS AND PHENOMENON OF UNCERTAINTY IN THIS PROCESS

Unifying key terms in crisis management is one of the main vague field when performing risk analysis. Differences between terms and their definitions should eventuate into problems with communication in this area. I will mention a causal relationship between danger, treat and risk and I will try to integrate them into the surrounding of technological processes. In the next paragraph I will be dealing with risk analysis which should be characterized as a systematic use of available information to determine how often specified events may occur and the magnitude of their likely consequences. Therefore the wide range of uncertainty will occur when performing risk analysis. The main sources of uncertainty were described in projects made by Joint Research Centre as a part of whole assurance project, known as benchmark studies made for two chemical and one nuclear power plants.

Key words: technological process, danger, treat, risk, risk analysis, uncertainty, benchmark studies

1. Introduction

Any technological or technical system can not be considered as a perfect one. Oftentimes we should consider machine, technological process or another technical equipment as a reliable but there is no way to consider human being as a certain reliable. Companies which dispose of risk technologies should have sufficient knowledge in systematic and complex risk assessment. But it is not possible to do it right in the case of insufficient information or differences in key terms: hazard, danger, risk. In part 2.1 I present my point of view on causal relationship between these terms. But when all things are well done there is still one thing resonating. When performing a risk analysis a wide range of uncertainties will be inevitably introduced during the process especially in qualitative phase mentioned in part 2.2. In part 2.3 there are mentioned benchmark studies which were performed by Joint Research Centre at Ispra and Risk National Laboratory which pointed to an increased awareness of the potential uncertainties in Risk analysis and highlighted a number of important sources of such uncertainties. These are the main fields I would like to deal with in my PhD studies.

2. Uncertainty and Risk analysis

Risk analysis is often considered as an identification of appreciated system and detection of danger, treat and risk in considered system [8]. When talking about risk analysis we mostly mean Quantitative risk analysis (QRA). In many engineering situations, most variables used in analysis will be associated with uncertainty. And the next important thing after ending risk analysis is to identify how the uncertainty affects results. The impacts and sources of such uncertainty were presented in benchmark studies realized on chemical establishments and nuclear power plant.

2.1 Key terms resolution – danger, treat and risk

This first paragraph presents causal relationship between terms danger, treat and risk and highlights that using these terms request a correct understanding of their definitions. If we unify definitions of these terms we will avoid problems of misunderstanding in many fields of risk management especially in risk communication. I would like to introduce these terms from my point of view to show causality among them when trying to integrate them into technological processes environment. Each technological process needs inputs to be operated and to reach aims of the company – products and services. Fig.1 shows a technological process which disposes dangerous substances or machines and therefore it is running through the system danger – treat – risk. A product or service should be considered as an output if everything goes right. In case a floater impacts on the system because of interior or exterior causes the emergency situation should occur. It can result into stopping the technological process if there is no possibility to return the system to the starting point or, on the other hand, to revalue arrangements which were done for hazard reduction. Somebody should have restrictions against terminology of the key terms but it has to be said that in this area many differences of definitions of the key terms in crises management have been occurring (Fig. 1).

It is important to mention causal relationship between the three terms. Danger is taken as a source of treat, it is latent character of an object, machine, activity or technological process. And

* **Katarina Holla**
Department of Crisis management, Faculty of Special Engineering, University of Zilina, Slovakia Republic, E- mail : katarina.holla@fsi.uniza.sk

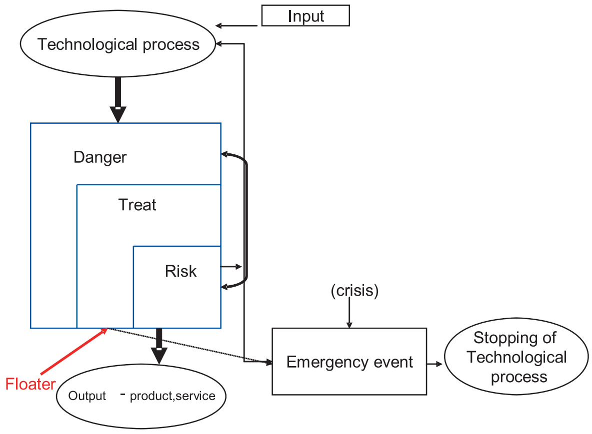


Fig. 1 Integration of danger, treat and risk into technological processes surrounding

treat is then a status where danger should be activated. Treat consequences has close relationship on probability that an undesirable event will happen and this relationship (correlation) is represented by "risk". Correct understanding of these words should eliminate uncertainty which results from misunderstanding and different point of view on their definitions.

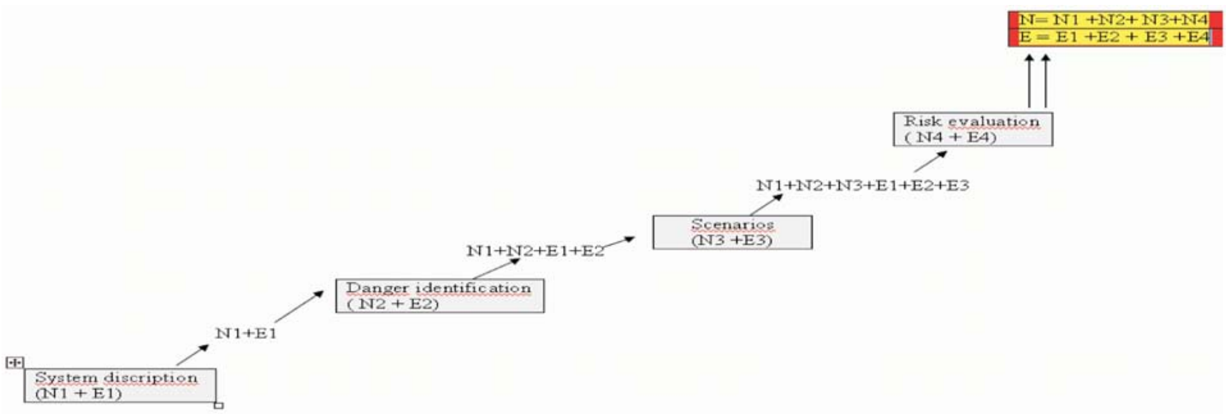
2.2 Uncertainty and Risk analysis

Risk analysis is in general considered as a identification of appreciated system and detection of danger, treat and risk in considered system [8]. That is why I explained their role in the paragraph 2.1. However there are many definitions of risk analysis in area of risk management. One defines it as a systematic use of available information to determine how often specified events may occur and magnitude of their consequences [5]. Phases of risk analysis are: system description, danger identification, scenarios and risk evaluation[6]. Results of any risk analysis are inevitably uncertain to some degree. Because of inevitable limitations of the risk analysis approach it must be acknowledged that the true risks could be higher or lower than estimated. In general, the word 'uncertainty' means that a number of different values can exist for a quantity [1]. The uncertainty should be divided into two categories: aleatory and epistemic. Aleatory stochastic uncertainty or due to randomness should result from bad knowledge of risk figures and their distribution, quantities such a failure rates, meteorological conditions at the time of release. Epistemic (reducible) is related to incomplete knowledge about phenomena of concern and inadequate matching available databases to the case under the assessment [1]. In addition, the application of different methods and methodologies will contribute to the total uncertainty of variability of risk analysis final outcome.

Fig. 2 shows gradualness of risk analysis where in each phase there are partial uncertainty and partial error increasing to the final N and final E. Each phase is characterized by its own uncertainty and errors and input uncertainty and errors from the previous phase. Finally we need to count not just with results of risk analysis but also estimate the uncertainty related to the final figure.

2.3 Benchmark studies

As it is shown on Fig. 2 uncertainty could increase into considerable amount what can affect final result of risk analysis. These impacts and sources of uncertainty were presented in benchmark studies (benchmark exercises) performed by Joint Research centre (JRC) directly or with cooperation for two chemical and one nuclear power plants. These benchmark studies could serve as a guide for dealing with uncertainty for specialist in area of risk analysis processes. Some important outcomes of benchmark exercises of chemical establishments for West Europe and the other one for Eastern Europe are presented in text undermentioned.



N- uncertainties, E- error

Fig. 2 Cumulation of uncertainties in phases of risk analysis.

2.3.1 Assessment of Uncertainties in Risk Analysis of Chemical Establishment in West European countries (Benchmark exercise)

Aniello Amendola and his team presented the assurance project called "Assessment of Uncertainties in Risk Analysis of Chemical Etablishments". Seven teams performed risk analysis for the same chemical facility, an ammonia storage. This project was made by the Joint Research Centre at Ispra and Risk National Laboratory. The research was accomplished through coordinated exercise and led to the comparison of results in order to reveal the causes for differences between the partners results. The results point out awareness of the potential uncertainties in risk analysis and highlight a number of important sources of such uncertainties. The research was divided into a documentation phase (description of a plant), qualitative analysis phase (hazard identification and qualitative risk ranking), quantitative analysis phase (quantitative risk analysis), and implication of uncertainties in risk assessment to risk informed decision. The hazard identification phase uncovered that the ranking of hazardous scenarios by probabilistic and deterministic approach imposed completely different conclusions. In spite of a big difference in frequency assessment of the same hazardous scenarios, there was good consensus on the ranking among the adhere of the probabilistic approach. There were found large differences in the frequency assessment as well as in the assessment of consequences. This assessment could serve as a guide to areas where caution must be taken when performing risk analysis [1].

2.3.2 Benchmark Exercise in Quantitative Area Risk Assessment in Central and Eastern European Countries (Benchmark exercise)

In order to better understand the risk analysis practices and methodologies adopted in the Accession and Candidate Countries, it was agreed to launch a third benchmark exercise focusing on the evaluation of the risk of a particular area in the proximity of a hazardous establishment. This was the next project made by the Joint Reseach Centre for Central and Eastern European Countries. The project was structured in three main phases: a documentation phase and two working phases. The countries involved in this research were: Bulgaria, Cyprus, Hungary, Latvia, Lithuania, Poland, Romania, Slovenia, and Slovakia. The report was launched in 2007. The main intention was to offer a general perspective on how independent reviews of the same risk analysis study conducted from the competent authority's standpoint might differ from each other and be reflected in a different evaluation of the risk of a certain Seveso type establishment. The outcome of such an analysis has the evident advantage of contributing towards better understanding the inspection criteria and current practices used by the different national authorities [4].

3. Conclusion

For all the reasons already mentioned I would like to point out the requirement of unifying the key words (danger, treat and risk) which is one of the main steps to avoid mistakes in the area of risk communication and to create appropriate field for risk analysis. As a part of it, risk analysis is inevitably uncertain to some degree what can bring in some problems in final results. And there is a question how issues of uncertainty are dealt with in existing safety regulations and in existing standards for risk analysis and management. I would like to highlight the fact that there is a big need to deal with uncertainty and to count with it in risk analysis and benchmark studies could serve as a guide to areas where caution must be taken when performing risk analysis. Slovak legislation does not consider impacts of such uncertainties in area of risk management and risk analysis. From my point of view it is necessary to incorporate this phenomenon into area of risk management.

References

[1] AMENDOLA, A., LAURIDSEN, K., KOZINE, I., MARKERT, F. , CHRISTOU, M., FIORI, M.: *Assessment of Uncertainties in Risk Analysis of Chemical Establishment,* The Assurance report, Final summary report, Denmark 2002, p. 49, ISBN 87- 550 - 3063 -7.

[2] PACAIOVA, H.: *Appraisal of risks - Comparison of Method Definitions and Advances (in Slovak),* Motivacia k panelovej diskusii, Forum BOZP 2003, Krpacovo, 2003.

[3] SIMAK, L.: *Crisis Management in Public Administration (in Slovak),* ZU Zilina 2004, ISBN 80-88829-13-5.

[4] FABBRI, L., JIRSA, P., CONTINI, S.: *Benchmark Exercise in Quantitative Area Risk Assessment in Central and Eastern European Countries (BEQUAR),* Final report. Institute for the Protection and Security of the Citizen, Italy, 2007.

[5] www.pce.govt.nz/reports/pce_reports_glossary.shtml, 9. 3. 2007.

[6] DANIHELKA, P.: *Modul 3 level 3 – Why Risk management,* Power point presentation, Ostrava, 2005.

[7] SINAY J.: *Risks of technical maintenances – Managing of risks (in Slovak),* OTA, a.s. Kosice. 1997. ISBN 80-967783-0-7.

[8] http://dict.die.net, 9. 3. 2007.

[9] http://www.mindtools.com/pages/article/newTMC_07.htm, 15. 10. 2007.

Dana Stredakova *

ANALYSIS AND EVALUATION OF THE KNOWLEDGE MANAGEMENT

There is a huge amount of knowledge in any organization. People at all levels have accumulated knowledge about what customers want, about how best to design products and processes, about what has worked in the past and what has not. A company that can collect all that knowledge and share it between employees will have a huge advantage over an organization that never discovers what its people know. Organizations must pay much more attention to the incentives that key workers have to share knowledge, and not focus only on developing the mechanisms that enable them to do so.

1. Introduction

Exponential growth of information in the knowledge economy focuses attention to the importance of managing knowledge in organizations. Specially the organizations, those that recognize the value of knowledge within their organizations, can grow and prosper through knowledge management.

It takes examples and lessons from some of the world's most successful businesses, corporations, including Shell Oil, British Aerospace, Dow Chemical, Hallmark, Pillsbury, Pfizer, Hewlet Packard, Nokia and the World Bank, and ideas from the smartest thinkers, including Peter Drucker, Michael Polanyi, and Ikujiro Nonaka.

Indeed, that is the academic world, which is the root of knowledge management.

Why has knowledge management suddenly become so prominent? And specially these days?

First, knowledge has become a competitive weapon. Manufacturing has fallen as a proportion of total economic activity in the economically advanced countries. Services, and particularly professional and consulting services, play a vastly more important role.

There is a second and related reason why knowledge management has acquired such prominence: many companies have painful experience of how easy it is to lose knowledge. The professional services, creative and consulting firms, are acutely aware of how vulnerable they are to their staff leaving. A key employee, or worse, a whole team that walks out of the door takes a huge amount of knowledge. They could also take some key customers.

A third reason why knowledge management has become so popular is that new technology makes it easier to share knowledge. At its simplest, conference calls mean that several people in different cities can talk together on the telephone. Video conferencing means they can see each other while they talk. Electronic databases make it possible to store vast amounts of knowledge, to which others can be given access. E-mail means people can communicate quickly, cheaply and over long distances. Company intranets mean staff can be given access to more information more quickly. But while new technology has made knowledge management easier, it has led many astray. Just because knowledge can be collected, this doe not mean it will be profitably used.

This is supported by new research on knowledge workers. Their work shows that organizations must pay much more attention to questions how to share knowledge and to culture, commitment, motivation and involvement.

Management consultancies, architectural practices, advertising agencies and law and accountancy firms are staffed by people with nothing to sell but what they know. What makes these organizations competitive and profitable is the collective expertise and ingenuity of the people who work for them. All companies contain knowledge that they need to exploit.

A company truly is a collection of people organized to produce something, whether it be goods, services, or some combination of the two. Their ability to produce depends on what they currently know and on the knowledge that has become embedded in the routines and machinery of production. The material assets of a firm are of limited worth unless people know what to do with them. Understanding the role of knowledge in organizations may help answer the question of why some firms are consistently successful

* **Dana Stredakova**
Faculty of Management Science and Informatics, University of Zilina, Slovakia, E-mail: dana.stredakova@fri.uniza.sk

There are many questions.

How to develop a preliminary understanding of what knowledge is within organizations? How does it look and sound in daily life and work? How is it different from data and information? Who has it? Where is it? Who uses it? What do we talk about when we talk about knowledge? On the other hand, what to do about knowledge? What key cultural and behavioural issues must we address to make use of it? What are the best ways to use technology in knowledge work? What are specific knowledge roles and skills? What does a successful knowledge project look like and how do you know if it has been successful? What measures and milestones can we use to evaluate it? Answers to these questions provide at least the beginning of a response to the essential question asked about knowledge in organizations: What do we do Monday morning to help make our organization's use of knowledge more effective, efficient, productive, and innovative?

Our aim, finally, is to provide a general perspective on how firms work that will give managers a means of decisively improving performance.

2. From History till Nowadays

"Knowledge" in today's world is the key source of competitive advantage. Some would say it cannot be 'managed', as it exists in people and they control it. However, that is an over simplification.

Tom Stewart in a 1994 Fortune magazine article warned companies to focus less on what they *own* and more on what they *know*: their intellectual capital.

Since then, Peter Drucker has identified knowledge as the new basis of competition in post capitalist society and Stanford economist Paul Romer has called knowledge the only unlimited resource, the one asset that grows with use.

In 1993 two Japanese academics, Ikujiro Nonaka and Hirotaka Takeuchi, published *The Knowledge-Creating Company*, a groundbreaking study of knowledge generation and use in Japanese firms.

That same year Dorothy Leonard-Barton wrote a finely detailed study of the role of knowledge to manufacturing firms, *Wellsprings of Knowledge*. Several other books exhorting managers to manage knowledge – without focusing much on how to do so – have appeared in the marketplace.

Firms such as Dow Chemical and Skandia and consultants such as McKinsey, Ernst & Young, and IBM Consulting have appointed "chief knowledge officers" and "directors of intellectual capital" to oversee the knowledge resources of their firms. They point to savings, improvements, and productivity increases that result from managing knowledge.

Knowledge is neither data nor information, though it is related to both, and the differences between these terms are often a matter of degree. It is important to emphasize that data, information, and knowledge are not interchangeable concepts.

Organizational success and failure can often depend on knowing which of them you need, which you have, and what you can and cannot do with each. Understanding what those three things are and how you get from one to another is essential to doing knowledge work successfully.

So it is best to begin with a brief comparison of the three terms and the factors involved in transforming data into information and information into knowledge.

Data – Data Management

Data is a set of discrete, objective facts about events. In an organizational context, data is most usefully described as structured records of transactions. Modern organizations usually store data in some sort of technology system.

Quantitatively, companies evaluate data management in terms of cost, speed, and capacity. How much does it cost to capture or retrieve a piece of data? How quickly can we get it into the system or call it up? How much will the system hold?

Qualitative measurements are timeliness, relevance, and clarity. Do we have Access to it when we need it? Is it what we need? Can we make sense out o fit?

Information – Information Management

Data becomes information when its creator adds meaning. We transform data into information by adding value in various ways.

Information has a sender and a receiver. It is meant to change the way the receiver perceives something, to have an impact on his judgment and behaviour. It must inform; it's data that makes a difference. The word "inform" originally meant "to give shape to" and information is meant to shape the person who gets it, to make some difference in his outlook or insight. The receiver decides whether the message he gets is really information, if it truly informs him.

Information moves around organizations through hard and soft networks. A hard network has a visible and definite infrastructure: wires, delivery vans, satellite dishes, post offices, addresses, electronic mailboxes. The messages these networks deliver include e-mail, delivery-service packages, and Internet transmissions. A soft network is less formal and visible too. Someone is handing you a note or a copy of an article marked "FYI" is an example of information transmission via soft network.

Quantitative measures of information management tend to include connectivity and transactions: How many e-mail accounts do we have? How many messages do we send in a given period?

Qualitative measures measure informativeness and usefulness: Did the message give me some new insight? Does it help me make sense of a situation and contribute to a decision or the solution to a problem?

Knowledge – Knowledge Management

Most people have an intuitive sense that knowledge is broader, deeper, and richer than data or information. People speak of a "knowledgeable individual" and mean someone with a thorough, informed, and reliable grasp of a subject, someone both educated and intelligent. They are unlikely to talk about a "knowledgeable or even "knowledge-full" memo, handbook, or database, even though these might be produced by knowledgeable, individuals or groups.

"Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organizations, it often becomes embedded not only in documents or repositories but also in organizational routines, processes practises, and norms."
(Thomas H.Davenport – Laurence Prusak)

"Knowledge has become the key economic resource and the dominate – and perhaps the only – source of competitive advantage." (Peter Drucker)

Knowledge is close and closer than data or information – to action. Knowledge can and should be evaluated by the decisions or actions to which it leads. Better knowledge can lead, for example, to measurable efficiencies in product development and production. We can use it to make wiser decisions about strategy, competitors, customers, distribution channels, and product and service life cycles.

Generally, three main categories of knowledge are distinguished:
- *Explicit,* that can be articulated in formal language, captured, exchanged and easily transmitted among individuals both synchronously and asynchronously. This includes information, experiences, and insights; that which we interact with every day through the written word and the Internet.
- *Tacit,* on the other hand, is personal knowledge embedded in individual experience, wisdom, involving such intangible factors as personal belief, perspective, instinct, and values and leads to decisions and advice, but which is difficult or impossible to articulate in any coded form.
- *Implicit,* certain knowledge can be harvested from its owner and codified in such a way as to make it more readily sharable. Implicit knowledge management employs tools, techniques and methodologies that capture these previously elusive processes and make them more generally available to the organization.

There are large numbers of complex and frequently incomprehensible definitions.

One company document described knowledge management as a way to 'give employees time to reflect, exchange thoughts and transfer knowledge by enriched connectivity'.

There is a far simpler definition. Knowledge management means using the ideas and experience of employees, customers and suppliers to improve the organization's performance.

A knowledge management website managed to be even more obscure, describes knowledge management as 'directly overlaying the information life cycle on to the business processes so as to reuse information as a resource across an organization'.

The central problem of knowledge management is how to create a climate in which everyone wants to share what they know. This has become more difficult, not easier, in recent years. The idea of a job for life has disappeared. Companies need to think of not only creating a knowledge database but to share knowledge much of it consists not of facts or figures but of 'the tacit and highly subjective insights, intuitions and hunches of individual employees'. These days, during times of economic uncertainty knowledge of employees is the key source of competitive advantage and power.

If companies want to get employees to share that knowledge, they will have to persuade knowledgeable staff to teach, mentor or talk to their colleagues. There is no simple situation. It requires the right corporate culture, the right people management, development policies, information technology, and time. It is a constant process. But the process needs items as pride, looking after the staff, and accepting that one does not know everything.

Teach one of your colleagues your special area of expertise and he or she might become an organizational star instead of you and win the performance-related bonus that could have been yours alone.

Defining knowledge management is not a simply issue. It requires a culture that promotes faith in collectively sharing and thinking. Knowledge management is the leveraging of collective wisdom to increase responsiveness and innovation.

Fundamental to the practical definition of knowledge management is the concept of the knowledge chain (K-chain). It is a series of interactions that constitute an organization's cycle of innovation. Knowledge management creates permeability between the four cells of the K-chain and accelerates the speed of innovation.

These four links are:
- internal awareness
- internal responsiveness
- external responsiveness
- external awareness

The four stages of the K-chain define the flow of knowledge through an enterprise. The ability to quickly traverse through the four cells of the K-chain is the essence of the benefit of knowledge management.

Why Evaluate Knowledge Management?

1. To build organizational stability and establish institutional memory,
2. to improve operational performance and introduce efficiencies, and
3. to improve impact and know what is being learned.

There is a growing need, of knowledge management, to find out which knowledge management strategies are delivering results within an organization and how those strategies are helping the organization to achieve its mission. Knowledge management is a function that supports evaluation by integrating the results of evaluation efforts into the everyday work of an organization. It helps to demonstrate the value of evaluation by making the learning it generates accessible and available for everyone in the organization.

Evaluation and knowledge management are two sides of the learning coin, and as such have a number of features in common:
- Both strategies have organizational learning at their core,
- Both are knowledge-intensive functions,
- Both have a systematic and intentional approach,
- Both are part science and part art,
- Both use knowledge-sharing to increase impact, and
- Both rely on each other to be effective.

3. Conclusion

The future studies of organizational knowledge will make an important contribution to understanding the sources of long-term success. Organizations with experiences in knowledge management have quickly found that success is entirely dependent on people – their commitment, disciplines, attitudes and capabilities. Knowledge management is not easy task but it is prosperous way.

References

[1] BARTOL, M. K., MARTIN, C. D.: *Management. Maryland,* McGRAW-HILL, INC., 1991, p. 658, ISBN 0-07-003926-7
[2] DAVENPORT, H. T., PRUSAK, L.: *Working Knowledge: how organizations manage what they know,* Boston, Massachusetts, Harvard Business School Press, 1998, p. 199, ISBN 0-87584-655-6
[3] FRAPPAOLO, C.: *Knowledge Management,* Chichester, Capstone Publishing Ltd, 2006, ISBN 1-84112-705-1
[4] *Investigating Knowledge Management, Chartered Institute of Personnel and Development,* 2000
[5] http://www.cipd.co.uk
[6] http://www.gurteen.com
[7] www.peoplemanagement.com

Jan Fabry *

A DYNAMIC MESSENGER PROBLEM

Messenger services provide customers to deliver their package from a specific origin to a specific destination. Real situations require the fast messenger's reaction to the on-line customer's request. While it is not possible to change the planned route in static distribution problems, a dynamic version enables a dispatcher the integration of a new request to existing route for optimization. The mathematical models proposed in the paper are based on the Miller-Tucker-Zemlin's formulation of Traveling Salesman Problem. Because of NP hardness of the problem it is impossible for most real problems to find the optimal solution in acceptable time. Heuristic algorithms represent the important alternative to solving real dynamic problems. Basic formulation of the messenger problem can be extended to problems with time windows. Limited capacity of the vehicle and multiple vehicles can be also considered.

1. Introduction

In a static messenger problem (Cordeau, 2006), requirements of all customers are known before a dispatcher starts to plan the route. Each customer specifies an origin where the driver has to pick up the package and a destination for the package delivery. Distances between all the points in the distribution network are given. A single vehicle is available for distribution of all the packages and a capacity of the vehicle is large enough to load all of them. First, no time windows are considered in the problem. The objective is to minimize the total length of the route for pick-up and delivery of all the packages.

Example 1. Figure 1 shows an example of a static messenger problem with four customers. Each arc in the network corresponds to the requirement of a customer for delivery. Customers are purposely situated in the even nodes, while destinations in the odd nodes. If i is a number of the customer, $i+1$ is a number of its package destination. A depot of the vehicle is located in node 1.

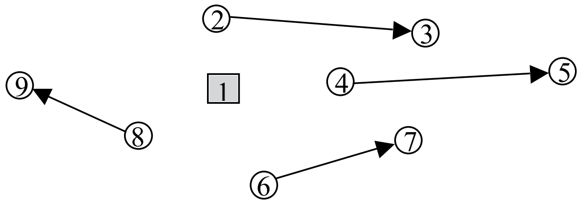


Fig. 1 Example of static messenger problem

2. Optimization model of a static messenger problem

Let us have n customers; each customer requires delivery of one package from his office to a specific destination. Considering one depot in the problem, there are $(2n + 1)$ locations in the distribution network. Let c_{ij} denote the shortest distance between locations i and j. The mathematical model of a static messenger problem is defined as follows (Fábry, 2006):

$$\text{Minimize } z = \sum_{i=1}^{2n+1} \sum_{j=1}^{2n+1} c_{ij} x_{ij} , \qquad (1)$$

subject to

$$\sum_{j=1}^{2n+1} x_{ij} = 1, \quad i = 1, 2, ..., 2n+1 \qquad (2)$$

$$\sum_{i=1}^{2n+1} x_{ij} = 1, \quad j = 1, 2, ..., 2n+1 \qquad (3)$$

$$u_i - u_j + (2n+1)x_{ij} \leq 2n, \qquad (4)$$

$$i = 1, 2, ..., 2n+1, \ j = 2, 3, ..., 2n+1, i \neq j$$

$$u_{2i} \leq u_{2i+1}, \quad i = 1, 2, ..., n \qquad (5)$$

$$u_1 = 0, \qquad (6)$$

$$x_{ij} \in \{0,1\}, \quad i,j = 1, 2, ..., 2n+1 \qquad (7)$$

A binary variable x_{ij} equals 1, if the vehicle goes from location i to location j, 0 otherwise. The objective (1) corresponds to the total length of the vehicle's route. The sets of equations (2) and (3) assure that each location is visited exactly once. Constraints (4) including variables u_i are Miller-Tucker-Zemlin's inequalities to avoid partial cycles in the solution. As each package has to be picked up before its delivery inequalities (5) must be respected.

Figure 2 illustrates the feasible route in the example given above. The package is delivered to location 9 immediately after its pick-up in location 8, while the package being picked up in location 6 is delivered to location 7 after several vists in other locations.

* **Jan Fabry**
Department of Econometrics, University of Economics Prague, Czech Republic, E-mail: fabry@vse.cz

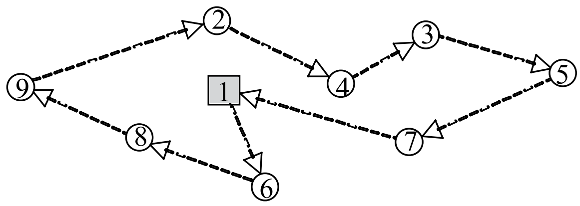


Fig. 2 Feasible route

3. Static messenger problem with time windows

In a real messenger problem each customer specifies time window for both pick-up and delivery of the package. For this purpose it is necessary to know travelling times t_{ij} between all pairs of locations. The optimization model follows (Fábry, 2006):

$$\text{Minimize } z = \sum_{i=1}^{2n+1} \sum_{j=1}^{2n+1} c_{ij} x_{ij}, \tag{8}$$

subject to

$$\sum_{j=1}^{2n+1} x_{ij} = 1, \quad i = 1, 2, ..., 2n+1, \tag{9}$$

$$\sum_{i=1}^{2n+1} x_{ij} = 1, \quad j = 1, 2, ..., 2n+1, \tag{10}$$

$$e_i \le \tau_i \le l_i, \quad i = 1, 2, ..., 2n+1, \tag{11}$$

$$\tau_i + t_{ij} - M(1 - x_{ij}) \le \tau_j, \tag{12}$$

$$i = 1, 2, ..., 2n+1, \; j = 2, 3, ..., 2n+1, \; i \ne j,$$

$$\tau_{2i} \le \tau_{2i+1}, \quad i = 1, 2, ..., n, \tag{13}$$

$$\tau_1 = 0, \tag{14}$$

$$x_{ij} \in \{0,1\}, \quad i,j = 1, 2, ..., 2n+1. \tag{15}$$

The value of a variable τ_i determines when the location i is visited by the vehicle. The objective (8) corresponds to the total length of the vehicle's route. The set of constraints (9) and (10) are taken from the previous model. Parameters e_i and l_i in the inequalities (11) are the earliest poss⊄ible and latest acceptable times of pick-up (in case of even nodes) and delivery (in case of odd nodes). Inequalities (12) avoiding partial cycles include large constant M. The constraints assure for each package that its delivery will follow its pick-up.

In real applications, time windows can be defined in a different way. The firm specifies the earliest possible pick-up time and latest acceptable delivery time that have to be respected:

$$e_{2i} \le \tau_{2i}, \quad i = 1, 2, ..., n, \tag{16}$$

$$\tau_{2i+1} \le l_{2i+1}, \quad i = 1, 2, ..., n. \tag{17}$$

In case the soft time windows are given in the problem it is possible to consider penalties for time windows violations (Fábry, 2006).

4. Dynamic messenger problem

After finding the optimal solution of the static messenger problem the vehicle starts to pick up and deliver packages of all advanced customers. A new requirement for pick-up and delivery can occur during the travel. These two actions will be integrated into the current route. In the paper two algorithms are described for this purpose: insertion method and re-optimization (Fábry, 2006).

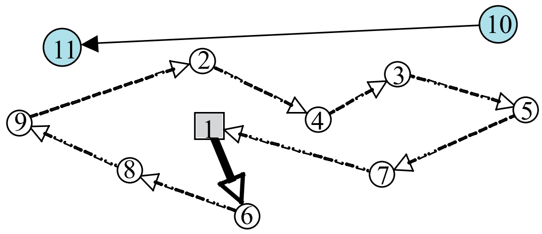


Fig. 3 A new on-line requirement

Example 2. Suppose the route in Figure 2 is the optimal solution of example 1. When the vehicle is travelling from the depot to location 6, a new customer calls for pick-up of a package in location 10 and its delivery to location 11 (see Figure 3).

Insertion algorithm.

Let $U_N = \{i_1, i_2, ..., i_m\}$ be a sequence of m locations ($i_m = 1$) that have to be visited by the vehicle according to the plan. Denote by r location where a new package is to be picked up and $r + 1$ destination to which it must be delivered. If location r is inserted between the locations i_k and i_{k+1}, the destination $r + 1$ has to be visited after the pick-up of the package. Two possibilities are considered:

(1) Destination $r + 1$ is inserted immediately behind the location r (see Figure 4).

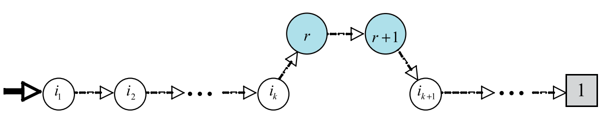


Fig. 4 Immediate delivery after pick-up of a new package

the extension of the current route is calculated as follows:

$$\Delta z_k = c_{i_k,r} + c_{r,r+1} + c_{r+1,i_{k+1}} - c_{i_k,i_{k+1}}, \tag{18}$$

$$k = 1, 2, ..., m-1$$

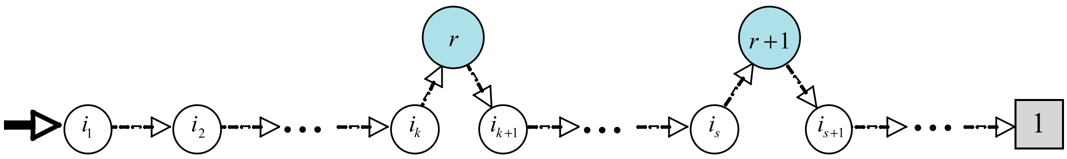


Fig. 5 Visiting other locations between pick-up and delivery of a new package

The objective is to determine the index t minimizing function (18):

$$\Delta z_t^1 = \min_{k=1,2,\ldots,m-1} \Delta z_k \,. \tag{19}$$

(2) While the location r is inserted between the locations i_k and i_{k+1}, the destination is inserted between the locations i_s and i_{s+1}. The destination has to be certainly inserted behind the location i_{k+1} (see Figure 5).

The extension of the route is

$$\Delta z_{ks} = c_{i_k,r} + c_{r,i_{k+1}} - c_{i_k,i_{k+1}} + c_{i_s,r+1} + c_{r+1,i_{s+1}} - c_{i_s,i_{s+1}}, \tag{20}$$

$k = 1, 2, ..., m-2,\ s = k+1, k+2, ..., m-1.$

The objective is to find the following indices t and p:

$$\Delta z_{tp} = \min_{\substack{k=1,2,\ldots,m-2 \\ s=k+1,\,k+2,\,\ldots,\,m-1}} \Delta z_{ks} \,. \tag{21}$$

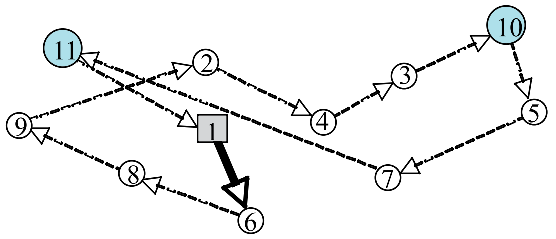


Fig. 6 Application of the insertion method

Comparing values (20) and (21), the lower of them determines the modification of the current route. The application of this strategy is illustrated in Figure 6.

Re-optimization.

Re-optimization algorithm consists in finding the optimal route of the vehicle after accepting a new request. The current route including all non-visited locations is re-optimized for the best incorporation of pick-up and delivery of the new package. For this purpose, it is possible to define the following mathematical model:

$$\text{Minimize } z = \sum_{i \in U_N} \sum_{j \in U_N} c_{ij} x_{ij} \,, \tag{22}$$

subject to

$$\sum_{j \in U_N} x_{ij} = 1, \quad i \in U_N \,, \tag{23}$$

$$\sum_{i \in U_N} x_{ij} = 1, \quad j \in U_N \,, \tag{24}$$

$$u_i - u_j + |U_N| \cdot x_{ij} \le |U_N| - 1, \tag{25}$$

$i \in U_N, j \in U_N - \{1\}, i \neq j \,,$

$$u_{i_{2k-1}} \le u_{i_{2k}}, \quad i_{2k-1}, i_{2k} \in \omega,\ k = 1, 2, \ldots, \frac{|\omega|}{2} - 1, \tag{26}$$

$$u_1 = 0, \tag{27}$$

$$x_{1 j_{next}} = 1, \tag{28}$$

$$x_{ij} \in \{0,1\}, \quad i,j \in U_N \,. \tag{29}$$

First, the original matrix of distances must be changed. Let j_{next} be an index of the location the vehicle is approaching when a new customer calls. Then, distance $c_{1j_{next}}$ between depot 1 and this location will be adjusted to the value corresponding to the length of the vehicle's route that will have been completed at the location j_{next}. Set U_N contains indices of locations that have not been visited yet, including depot 1 and two locations for pick-up and delivery of a new package. A number of all indices is denoted by $|U_N|$. The set includes two following subsets:

(1) the set of pick-up and delivery locations of packages that have not been picked up yet,

(2) delivery locations of the packages having been picked up before reaching the location j_{next}.

Let denote an increasing sequence of indices from the first of these sets. If j_{next} is the index of a pick-up location it will not be included (together with its delivery point) in the sequence ω. A number of all indices in the sequence denoted by $|\omega|$ is always an even value. The set of inequalities (26) is defined just for members of the sequence to assure each package will be picked up before its delivery. These constraints have the same relevancy as restrictions (5) in the static messenger problem.

In example 2 the set U_N contains all the indices, i.e. $U_N = \{1, 2, ..., 11\}$. As a new requirement occurs when the vehicle is approaching location 6, we set $j_{next} = 6$. The sequence of indices of pick-up and delivery locations which package will not be on the vehicle after visit location 6 is $\omega = \{2, 3, 4, 5, 8, 9, 10, 11\}$. Using the optimization model (22) – (29), we obtain the route shown in Figure 7.

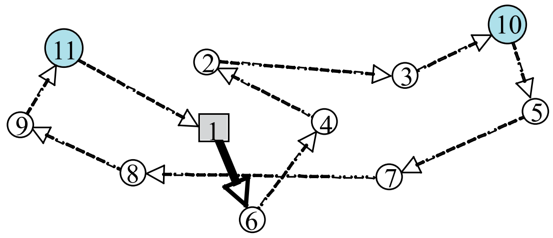


Fig. 7 Re-optimization of the route

5. Conclusion

In the paper, two approaches for a dynamic messenger problem are presented. While re-optimization algorithm can be used for problems with small numbers of locations that have to be visited, huge problems need heuristics. The insertion method is offered as a very simple and effective method. Considering time windows, the model is much closer to real messenger problems.

The analysis can be extended if a capacity of the vehicle is a significant attribute for tour designing (Cordeau, 2006). Several routes can be offered instead of the only one. In reality, the introduction of multiple vehicles is necessary for completing all requests in time. Vehicles can be located in one common depot or several separated depots. Besides the total distance travelled by vehicles, other criteria can be considered, e.g. total routing cost (Cordeau, 2006), time necessary for delivery of all packages, total profit, etc.

This publication was supported by the project 402/06/0123 funded by the Grant Agency of the Czech Republic.

References

[1] CORDEAU, J.-F.: *A Branch-and-Cut Algorithm for the Dial-a-Ride Problem,* Operations Research 54, 2006, pp. 573–586.
[2] FABRY, J.: *Dynamic Vehicle Routing Problems (in Czech),* Dissertation thesis, VSE-FIS, Praha 2006, p. 141.

COMMUNICATIONS – Scientific Letters of the University of Žilina
Writer's Guidelines

1. Submissions for publication must be unpublished and not be a multiple submission.
2. Manuscripts written **in English language** must include **abstract** also written in English. The submission should not exceed **10 pages** with figures and tables (format A4, Times Roman size 12). The **abstract** should not exceed 10 lines.
3. Submissions should be sent: **by e-mail** (as attachment in application MS WORD) to one of the following addresses: *holesa@nic.utc.sk* or *vrablova@nic.utc.sk* or *polednak@fsi.utc.sk* **with a hard copy** (to be assessed by the editorial board) **or on a CD** with a hard copy to the following address: Zilinska univerzita, OVaV, Univerzitná 1, SK-10 26 Zilina, Slovakia.
4. Abbreviations, which are not common, must be used in full when mentioned for the first time.
5. Figures, graphs and diagrams, if not processed by Microsoft WORD, must be sent in electronic form (as GIF, JPG, TIFF, BMP files) or drawn in contrast on white paper, one copy enclosed. Photographs for publication must be either contrastive or on a slide.
6. References are to be marked either in the text or as footnotes numbered respectively. Numbers must be in square brackets. The list of references should follow the paper (according to **ISO 690**).
7. The author's exact **mailing address of the organisation where the author works, full names, e-mail address or fax or telephone number,** must be enclosed.
8. The editorial board will assess the submission in its following session. In the case that the article is accepted for future volumes, the board submits the manuscript to the editors for review and language correction. After reviewing and incorporating the editor's remarks, the final draft (before printing) will be sent to authors for final review and adjustment.
9. The deadlines for submissions are as follows: September 30, December 31, March 31 and June 30.
10. Topic for issue 1/2008: Security engineering.

COMMUNICATIONS

SCIENTIFIC LETTERS OF THE UNIVERSITY OF ŽILINA
VOLUME 9

Address of the editorial office:
Zilinská univerzita
Office for Science and Research
(OVaV)
Univerzitna 1,
SK 010 26 Zilina
Slovakia
E-mail: komunikacie@nic.utc.sk, polednak@fsi.utc.sk,

Each paper was reviewed by two reviewers.

Journal is excerpted in Compendex

It is published by the University of Zilina in
EDIS - Publishing Institution of Zilina University
Registered No: 1989/98
ISSN 1335-4205

Published quarterly

Single issues of the journal can be found on:
http://www.utc.sk/komunikacie