Vibration effect on the anthropo-technical systems reliability

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Abstract. Man operates many different types of technical objects (one of which are motor vehicles). In most cases, these are anthropo-technical systems (A-T S) taking into account the essential components of the process of exploitation: man – the operator, the technical object – hardware and software, and the environment - external and internal. One of the important features of exploitation is reliability. It is specified method for assessing the reliability of the system A-T S. Many factors determine reliability. Selecting necessary to take into account factors was possible after analyzing literature and environmental monitoring and a set of representative factors make the man (behavior), the system (ready to use) and threats (vibration, sun, water, etc.). Given the above, indicators have been developed (probability) for the identification of system reliability. In the next planned to use these indicators in the research of the real environmental conditions. The authors engaged in this topic, because in the literature found no studies which take into account so many variables.

Keywords: vibration, vehicle, device, reliability, anthropo-technical system.

1. System

Nowadays, various types of technical objects are exploited being the result of technology development and civilization progress. Wide spectrum of properties characterizing technical objects of the system nature designed today can be divided into subsets of fundamental discriminates [1]:

– people being significant participants of each object exploitation process,
– role of an object as a system component and a participant of system-environment relations,
– complexity of the structure and variety and complexity of functions and tasks.

There are many indicators to split the system understood as a complex technical system/system. For the purposes of this publication, it is proposed to adopt a criterion in the form of: a man (operator), a technical object (hardware, software) and the environment (the impact of external and internal) operating system. Thus the system is divided into: classical and anthropo-technical (A-T S). Considerable financial losses, human health or even life, depending on a type and the amount of information lost, can be a consequence of failures [2]. Transmission of information between the terminal operator and the machine during is connected with the flow of data through interfaces in stationary and mobile, simple and complex architectures. This process is accompanied by anomalies related to the time-varying:

1) The state of technical and functional system.
2) Destructive: behavior of people, environmental factors (exposure).

Anomalies are different types of events that could disrupt the transport of data in the form of lost information. The article included an analysis of vibration effects, because they are special and important anomaly for mobile systems. The vibration exposure of the car depends on road roughness, speed, engine and powertrain parameters. To provide the best vibration isolation for the passengers the damping properties of the suspension have to be changeable to the drive condition. At the present the numerous automotive companies offer adaptive shock absorbers or active suspensions. It contains many of mechatronics systems and elements which are perfect to adjust the damping parameters of the suspension to the drive condition. The control system requires proper information on safety or comfort [3, 4].

The consequences of adverse events are reducing the number of services, financial loss or human health or life. Now, the growing importance of continuous - time identification of the state (technical and functional) of man and machine. Safety systems have a tendency to fail, which becomes the subject of a detailed analysis and examination procedure to eliminate such danger in the future. In most situations the direct cause of failure may be damage to the system, its exposure to unexpected load, or fault of the employee [5].

These important tasks from the perspective of situational awareness are the perception and understanding of events happening around in relation to time and space. Situation awareness is an essential determinant of operation in which data flow is significant and "bad" decisions can lead to serious consequences. For more information we recommend reading e.g. [6], where issues on proper maintenance strategy selection and its influence on dependability state of the system are reviewed or [7], where maintenance problems of complex technical systems are investigated in the context of different solution methodology use [8].

2. Anthropo-technical systems

The main predicate research complex technical objects are the concept of "system". Manifested by the existence of a synergistic interaction of its parts was present in publication [9]. The division of the system into elements – addicted to the study aimed to validate the functionality of the system services. The aim of unifying the nomenclature proposed to adopt a model system of human-machine. Then it analyzed the A-T S will contain three elements (Fig. 1) takes into account the Human Behavior Model (Operator), System Model (data, devices, vehicle, vibration) and the Environment Hazards Model (temperature, humidity, lightning, etc.).

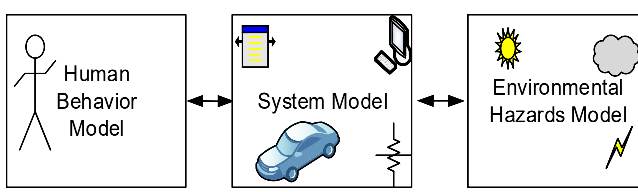

Fig. 1. Anthropo-technical system model

Accordance with the foregoing and publications in references, assumes that the measurable properties of a reliability system A-T S, respectively interpreted in a certain unit of time (t), are the probability of an ability condition of the system taking into account the properties of the inner. Given the multiplicity and complexity of the factors proposed to be grouped into meaningful sets of determinants in the form of intrinsic properties of the system, the properties of the operator and the harmful effects of the environment as a component of the formula for the probability of an ability condition:

$$P_{A-TS}(t) \cong f(P_{HBM}, P_{STM}, P_{EHM}), \tag{1}$$

where:

– P_{HBM} – probability of operator with regard to work condition ($P_{HBM_{WC}}$), stress (P_{HBM_S}) and vibration effects ($P_{HBM_{VE}}$) determined on the basis of the method of HCR (Human Cognitive Reliability) (Fig. 2):

$$P_{HBM}(t) = P_{HBM_{WC}}(t)\, P_{HBM_S}(t)\, P_{HBM_{VE}}(t), \tag{2}$$

where:

• Probability of work condition ($P_{HBM_{WC}}$) [10]:

$$P_{HBM_{WC}}(t) = 1 - \exp\left[-\left(\frac{t}{t_{0,5}} - C_{e,i}\right) C_{g,i}{}^{-1}\right]^{B_i}, \tag{3}$$

where: C_{ei}, C_{gi}, B_i – coefficients depend on the type of work being done (education, experience, reflexes, rules, etc.), t – time available to complete the task, $t_{0,5}$ – average time usually sufficient to complete the task (experience, the level of stress and ergonomic workplace, etc.).

• Probability of stress (P_{HBM_S}) [11]:

$$P_{HBM_S}(t) = P_{HBM_{So}} + P_{HBM_{Sp}} + P_{HBM_{Sn}}, \tag{4}$$

where: $P_{HBM_{So}}$ – probability of performance per operator, $P_{HBM_{Sp}}$ – probability of positive events per operator, $P_{HBM_{Sn}}$ – probability of negative events per operator.

• Probability of vibration effects (P_{HBM_S}) [12, 13]:

$$P_{HBM_{VE}}(t) = f(S_S, T_S, D_S, \ldots), \tag{5}$$

where: S_S – strength (power, concentration, intensity, speed of propagation i.e.), T_s – exposure time of vibration, D_S – depreciation vibration systems (mechanical and electrical modules absorb the vibrations).

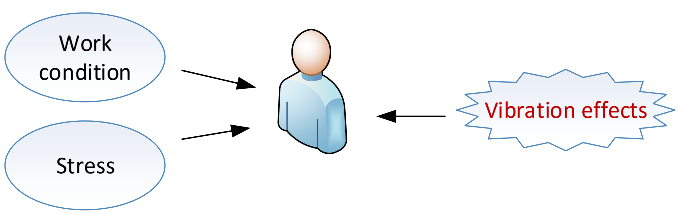

Fig. 2. Human (operator) model

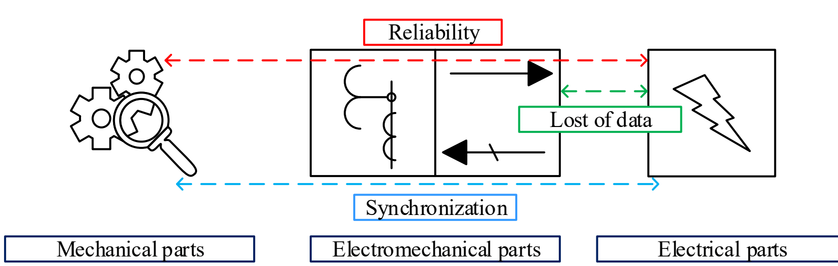

Fig. 3. System model

– P_{STM} – the probability of system with regard to unsteady readiness index (K_G), probability of blockages in the ith element (P_{Sr}) and probability of loss of data (P_{LoD}) (Fig. 3):

$$P_{STM}(t) \cong f(K_G, P_{Sn}), \tag{6}$$

where [14]:

• K_G – unsteady readiness index based on the intensity of damage λ_i and repair μ_i:

$$K_G(t) = \frac{\mu_i}{\lambda_i + \mu_i} + \frac{\lambda_i}{\lambda_i + \mu_i} e^{-(\lambda_i + \mu_i)t}. \tag{7}$$

• P_{Sr} – probability of blockages in the ith element taking into account the model of service requests,

• P_{Sn} – probability of loss of data in a stream of the ith element functioning as a result of incorrect synchronization (signalization). Probability value is determined on the basis of technical parameters of the signaling system.

– P_{EHM} – probability of system with regard to environmental hazards with regard to probability of damage systems (P_{dae_i}) (Fig. 4) [14, 15]:

$$P_{EHM}\left(t,U_k^{\times h}\right) = f\left(P_{re_i}\left(U_k^{\times h}\right)\right) = \prod_{k=1}^{h}\left[1 - P_{dse_i}^{U_k}(r_n^k)\right] = \left\{1 - \left\{1 - \exp\left[-\delta\left(\frac{r_n}{P_{dae_i}}\right)^2\right]\right\}\right\}, \tag{8}$$

where: $P_{re_i}\left(U_k^{xh}\right)$ – probability to remain in the state of element e_i after tripping on an object a series of factors U_k of multiplicity h (The line may include the harvest Ω, П factors, some of which may appear multiple times. It is understood that the impact area is divided into zones of different intensities of impact), $P_{dse_i}^{U_k}(r_n^k)$ – probability of destruction (electric, lower the state of airworthiness) e_i present in the nth (e.g. ring) the effect of factor U_k, δ – parameter of distribution, r_n^k – radius of influence of nth exposure of the πth set of types of exposures, P_{dae_i} – probability of damage element systems (e_i) of nth threat of the πth-set of types of threats (i.e. vibration, sun, rain, lightning, snow, etc.).

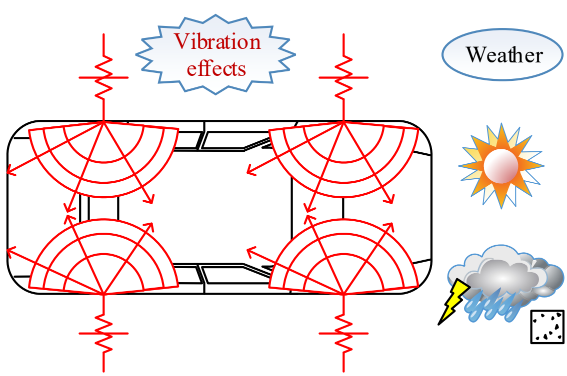

Fig. 4. Environmental hazards model

Forms of measure (indicator based on Eq. (1)) of the proper A-T S reliability are:

$$P_{A-T\,S}(t) \cong q_1 P_{HBM} q_2 P_{STM} q_3 P_{EHM}, \tag{9}$$

where: q_i – weight of component probability value depending on a number of components.

Inference on A-T S reliability was based on a statistical estimation fit potentiality based on the output patterns Eqs. (1)-(8) and the probability distributions.

3. Conclusions

The development of new techniques, technology and the progress of civilization meant that each of us can exploit modern technical facilities from the automotive, electronics, etc. Their correct functioning depends on the human environment operation and reliability of the technical object. The authors believe that reliability assessment should take into account all these factors and developed a comprehensive evaluation of reliability for anthropogenic – technical system. Due to the wide use of cars and European conditions selected for analysis, because car have many different mechanical, eletro-mechanical, electrical and electronic components.

The authors engaged in this topic, because in the literature found no studies which take into account so many variables. The division of the anthropo-technical system into elements addicted to the study aimed to validate the functionality of human-technical object-environment. It analyzed the A-T S will contain the Human Behavior Model, System Model and the Environment Hazards Model. Shown as a probability of an ability condition measure Eqs. (1), (2), (6), (8), (9) it is possible to calculate for each type of system. The component measures are variable and depend on a number of determinants. So it will take many inputs to achieve trustworthy and reproducible results. For selected test scenarios already carried out a pilot study to validate the mathematical formulas. The results are consistent with expectations. However, the authors are keen to get more numerous set of data to test representative systems and environmental conditions.

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