ERGONOMIC RISK ASSESSMENT OF TAKING THE PRODUCT DIRECTLY FROM THE PRODUCTION LINE

DANIELA ONOFREJOVA[1], HANA PACAIOVA[1], ZUZANA KOTIANOVA[1], JURAJ GLATZ[1], JOZEF KULKA[1]

[1]Technical University of Kosice, Kosice, Slovakia

DOI: 10.17973/MMSJ.2022_12_2022084

e-mail: daniela.onofrejova@tuke.sk

Creating healthy workplaces considering ergonomic risks is becoming a necessary part of preventive approach in design of workplaces. Preventive approach has positive impact including economical, health and safety measures. Corrective approach can be used when e.g. health issues must be improved. Performance analysis is important for employers in competitive domestic or global market. If the analysis is made on the basis of faulty or incomplete information, such analysis may not be reliable and consequently the decision made might yield an unexpected result. Thus, proper usage of performance indicators is vital to avoid mistakes and minimise such risk. Our study is focused on workplace in automotive industry, where worker removes product from the line and place the product in crates located next to the line. Worker prepares crates continuously after he fills them with product for full capacity. Quantitative analysis of ergonomic risk was performed with wireless multisensory measurement system Captiv, based on complaints from workers related to upper limbs and neck pain. Improvements in workplace design were suggested, also process changes were analysed by working posture analysis based on results measured with Captiv system.

KEYWORDS

Ergonomic risk, healthy workplaces, multi-sensor measurement system, production performance

1 INTRODUCTION

Workers' health, safety and well-being are vital concerns to working people worldwide. It is of paramount importance to the productivity, competitiveness and sustainability of enterprises, communities, and to national and regional economies [Bevan 2015]. Most workers in many countries are employed in factories and companies where there are no records of work-related injuries or illnesses. Also any programmes to prevent injuries or illnesses are not processed. Challenge for employers and policy makers is elimination of disease, economic costs and long-term loss of human resources from unhealthy workplaces [WHO 2010].

In 2017, the European Commission adopted an important communication on safety and health at work, in which emphasized the importance of preventing psychosocial risks and musculoskeletal system damage. European employees identify these two issues as major cause of occupational diseases. They are the cause of many lost working days and their result is not just personal suffering, but also considerable financial loss for people affected by this problem, as well as for the companies in which they work [Nielsen 2021].

Companies should carefully consider which way to ensuring a good working environment is for them the best. There is no one-size-fits-all solution. At the same time, the involvement of both sides, owner / manager and the employees is important, in agreement on the cooperation and the changes needed to be done.

It is essential and scientifically proven to manage two relatively demanding problems associated with occupational health protection, which are common in the workplace: psychosocial risks, as factors that can lead to stress and negatively affect the mental and physical health of employees, and damage to the musculoskeletal system [WHO 2010, Stoewen 2016]. These problems have been shown to be interrelated. Psychosocial risks are considered one of the possible factors that may cause damage to the musculoskeletal system. The opposite is also true: musculoskeletal disorders can contribute to stress and psychological overload.

The innovation potential in digitalization to meet growing demand and increase productivity ranges from increasingly sophisticated robots replacing workers in customer-oriented roles to additive manufacturing technologies (3D printing) producing human organs [Constantino 2021, Panda 2019]. On the other hand, Industry 4.0 is moving towards the concept of smart factories [Onofrejova 2019]. The adoption of automation in industry has been growing over the last twenty years, intending to increase productivity while reducing the physical workload required for human workers [Pacaiova 2021]. By optimizing production processes, a company often finds a way to reduce certain costs or increase revenue. Optimization must respect limited resources, supplier and customer requirements, and various other limiting or limiting factors that may be caused by the market situation, human resources, production safety requirements, environmental protection, and many other factors [Kulka 2022]. Using computer simulation Monte Carlo in the field of quality management for determining the cost of poor quality can be analysed from retrospective scope of view, where the cost of poor quality and production process are calculated based on historical data. The second approach uses the probabilistic characteristics of the input variables by means of simulation and reflects as a perspective view of the costs of poor quality [Fabianova 2017]. Similar approach can be used for ergonomic risk assessment – preventive and retrospective analysis based on historical data on injury, accidents, and fatal accidents.

Wearable technology according to [Zampogna 2020, Bonato 2010, Khakurel 2017] has been proving convincing and useful results in evaluating motor impairments of subjects. [Strath 2005] used physiological and accelerometer data to improve physical activity assessment.

European directives, EU health and safety strategies, Member States' regulations, and best practice guidelines already recognize the importance of preventing musculoskeletal disorders. Risks of damage to the musculoskeletal system related to work fall within the scope of the framework directive on occupational safety and health [Directive 1989 and 2006, Act 2006] which aims to protect employees from work-related risks in general and to establish the employer's responsibility for ensuring safety and health at work. The directive requires a risk assessment in the work environment. Identifying risk factors highlight some of the problems faced by employees and the importance of understanding corporate practices to prevent damage to the musculoskeletal system, including the responsibilities of both employers and employees.

Manual handling risks can be found across all kinds of workplaces – on farms and building sites, in factories, offices, warehouses, hospitals and while making deliveries. Heavy manual labour, repetitive handling, awkward postures and previous or existing injuries or conditions are all risk factors for developing MSDs [Onofrejova 2022].

Work may also make worse an injury which was not caused at work, such as a sports injury. Report any signs and symptoms to you or their worker representative at an early stage, before they become more serious, so you can take steps to reduce the risk. The amount of detail required by manual handling risk assessments will depend on a number of factors, including the level of risk and complexity of the tasks being carried out. Working outside the limits is likely to increase the risk of injury, which can lead to ill health [HSE 2020]. Managing the risk of injury from handling operation can't overcome: a lack of mechanical aids, badly designed tasks, unsuitable loads, and an unsuitable working environment. Manual handling in the workplace involves any transporting or supporting of a load by one or more workers. This includes the lifting, lowering, pulling, pushing, carrying or moving of a load. There are several risk factors that make manual handling of loads hazardous and increase the risk of injuries, especially body limbs (upper and lower limbs) damages.

Two groups of injuries are often associated with manual handling:

1. The first includes cuts, fractures and others due to sudden or unexpected events such as accidents.

2. The second includes damage to the musculoskeletal system (MSDs) of the body. This is a result of gradual and cumulative wear and tear through repetitive manual handling.

Prevention is vital when it comes to work-related MSDs due to manual handling. These disorders may have serious consequences for the workers and could restrict their ability to undertake a wide range of work and leisure activities for the reminder of their lives. The risk of lifting or moving loads can be associated with all types of MSDs. The more workers are exposed (for longer periods or higher percentage of their work time) the more likely they are to report an MSD complaint [HSE 2020].

This contribution reveals the importance of the quantitative evaluation of physical workload to evaluate the ergonomic risk of using wearable systems. Also, the suggestion for the future verification and training of physiological human behaviour at the workplace using Virtual reality tool connected with Captiv system for active measurement of future improved physiology or workplace conditions.

The study was conducted according to the guidelines of the Declaration of Helsinki and approved by the Institutional Review Board (or Ethics Committee) of Technical University of Kosice (protocol code 8268/2021/R-OLP and date of approval 13.12.2021).

2 MEASUREMENT METHOD

A human exposed to a danger underlies to the effects of danger and at high exposure, the level of risk related to safety and health at work grows, see Fig. 1.

Especially industrial workers are exposed to various dangers having impact on their health, thus initiating a risk of the employee's health being damaged. Due to the long-term effects of the hazard, irreversible damage to health may occur, causing occupational diseases [Onofrejova 2022]. When assessing workplace risks associated with manual handling, it's important to take into account the various aspects of the load, the task, the environment and the individual [Onofrejova 2021]. The risk resides in repetitive handling, object twisting and stooping, holding loads away from the body, static monotonous work in standing position.

Production process "clutch release" consists of 4 tasks: 1) Select a clutch from the palette, 2) Check the DMC for the presence of the dot from OP 700, 3) Place the coupling on the pallet and mark with a green dot, 4) Press the button to close the barrier. Together the time allowance makes 16 s. Periodical tasks consist of activities: 1) Scan the folder with the connectors, 2) Print out the binder list and stick it on the pallet, 3) Move the pallet with connectors to the designated place. Together the time allowance for periodical tasks makes 90 s.

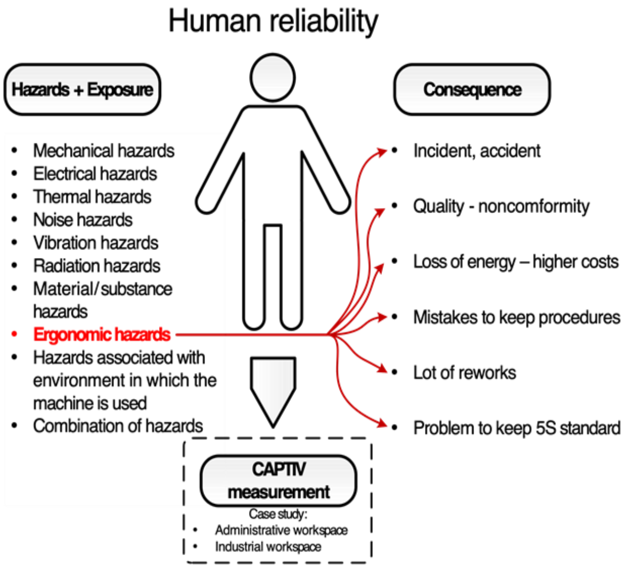


Figure 1. Ergonomic hazards and their effect on workplace losses. Human reliability in the centre of prevention of health and safety at environment

The weight of the load (part) is ± 6.1 kg. The manipulation height varies from 95 – 100 cm and at this height workers place the coupling on the pallet. Based on survey, operators claim back and inner forearm ache.

Worker with normal weight, in age group range 40 – 49 years participated in the measurements.

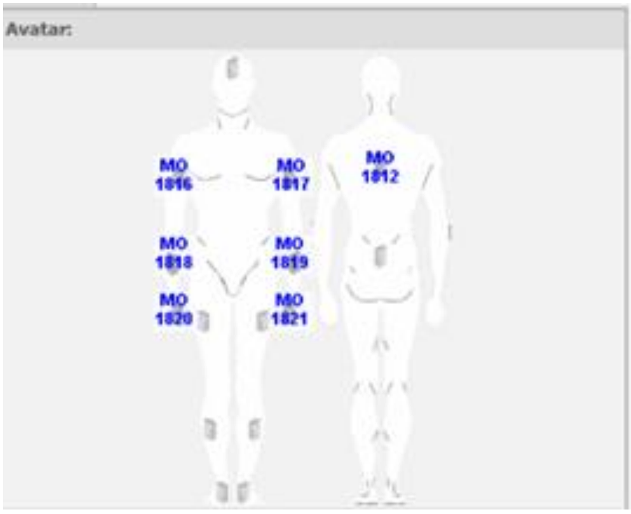


Figure 2. Setting and the implementation of the measurement in the industrial workspace: Placement of the Captiv wireless sensors on the body

The wireless sensory assessment of ergonomic risks is possible with the ergonomic software Tea Captiv. Captiv validates an adaptable and scalable solution for capturing workers in all their work environments thanks to a multifunctional analysis embodying body posture, carrying capacity, musculoskeletal limitations and repetitive movements and vibrations. [Steinebach 2020] compared the accuracy of motion capture for complex movements using Captiv system with Microsoft Kinect V2, and consider Captiv preferable for ergonomic analyses in terms of accuracy in the majority of cases, especially in industrial work environments with occlusions. The error may have been caused by the initialization (manual alignment of the sensors to minimize the impact of environmental influences) of the Captiv system. A moderate initialization quality may not be sufficient for the highest accuracy requirements and has to be taken into account when interpreting the results [Steinebach 2020]. Advantage of measurement with Captiv system was proven also by authors [Peeters 2018], who demonstrated the accuracy, reliability of IMU (inertial measurement units) for outdoor motion capturing in diverse activities (regular tasks as walking, and also fast, complicated tasks as rehabilitation, sports). The Captiv's representant – avatar represents the visualisation of measured data on the physical load, which exceed the threshold values in the monitored joints. Avatar also stands for initial settings for sensor placement, see Fig. 2. Sensors were placed on the body segments: Back (axis: pelvis—vertebral segment T2), Left shoulder, Right shoulder, Left elbow, Right elbow, Left wrist, Right wrist. For correct 3D visualization, the subject was equipped with a sensor on his back (for tracking the upper body).

After sensor have been placed and calibrated in order to avoid magnetic disturbances, measurement can be initiated. Measurement is combined with video capturing of human activity.

3 RESULTS

The result of the ergonomic evaluation is a comparison of the measured values with limit values given by the legislation or individually adjustable criteria, classification of works into categories, recommendations for the implementation of measures to reduce physical activity (organizational, ergonomic, technical, etc.). Ergonomic assessments are complementary in accordance with [Directive 1989 and 2006, Act 2006].

The results in Figs. 3 and 4 represent data for one evaluated worker proceeded by the Captiv system. It describes the ratio of time duration and how long the particular body segment spent in a certain position defined by threshold area for acceptable, conditionally acceptable and non-acceptable risk.

Pursuant to Decree of the Ministry of Health of the Slovak Republic no. 542/2007 Coll. on the details of health protection against physical stress at work, mental workload and sensory stress at work, the total working time in an eight-hour work shift in individual unacceptable work positions may not exceed 30 minutes.

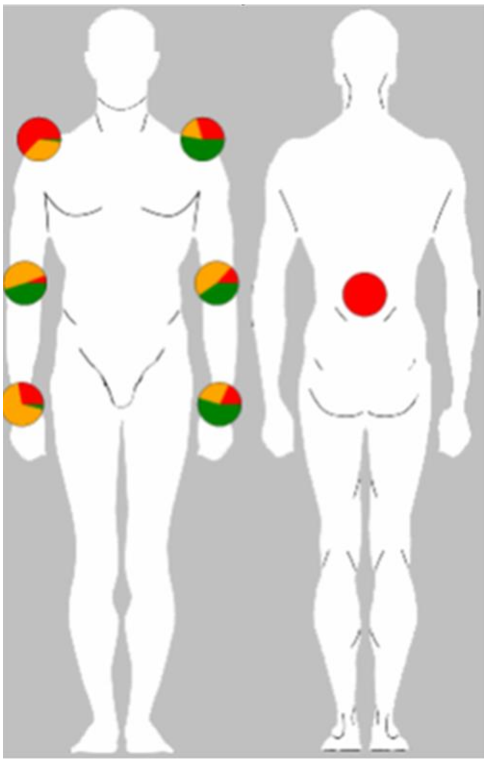
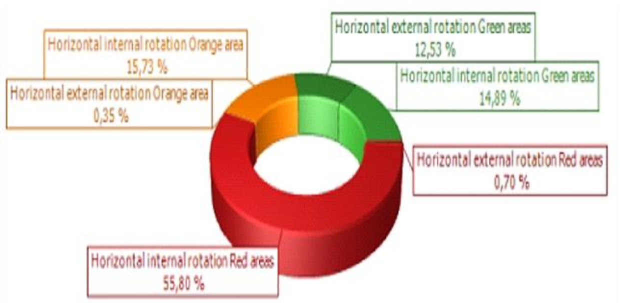
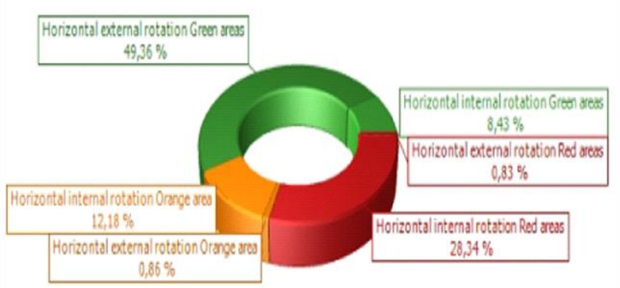


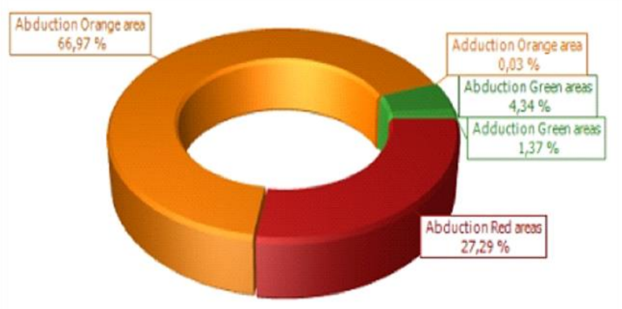
Figure 3. Posture's evaluation results for work activity "clutch release"



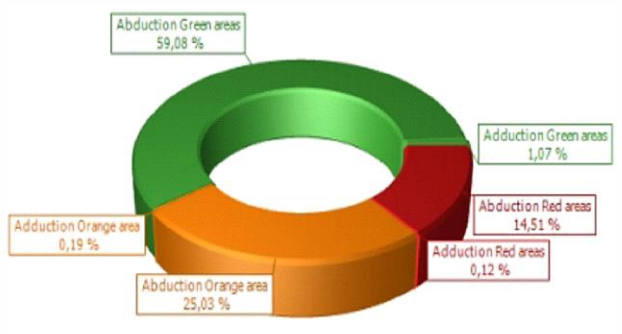
a) Right shoulder (horizontal rotation)



b) Left shoulder (horizontal rotation)



c) Right wrist (Abduction/Adduction)



d) Left wrist (Abduction/Adduction)

Figure 4. Ergonomic risk assessment of high-risk body segments

Unacceptable load in individual joints: right shoulder, left shoulder, left elbow, right wrist, left wrist (see Fig. 4) arose as a result of handling the coupling (removing parts from the line and then placing them on a pallet located next to the workplace). Based on the above, we recommend rotation for a given work activity after 2 hours at the latest. Detailed analysis of individual work tasks from the point of view of the physiology of movements is vital.

4 TRAINING USING VIRTUAL REALITY TOOL

Virtual reality is a three-dimensional, computer generated environment which can be explored and interacted with by a person. The person becomes part of this virtual world or is immersed within this environment and there, is able to manipulate objects or perform a series of actions. Wherever it is too dangerous, expensive or impractical to do something in reality, virtual reality can be used. Trainings applicable in virtual reality allows to take virtual risks in order to gain real world experience. The virtual reality becomes more mainstream and we can expect more serious uses, such as education or productivity applications. Virtual reality and even augmented reality could substantively change the way people interface with digital technologies.

Captiv-VR motion system was designed with the company TEA based on their ergonomic analysis software Captiv L-7000 (TEA-ergo, France) [Arbelaez 2020]. The proposed system architecture is presented in Fig. 5. The system uses two base stations that emits pulsed IR (Infrared) laser to track the position of the HMD (Head-mounted display) and the two wireless controllers. The positioning system allow the user to move in the 3D environment and interact with its elements. Steam VR running on a windows computer is used to communicate with the device trough a USB connection. The HMD allows the user to “see” the virtual scene proposed [Arbelaez 2020].

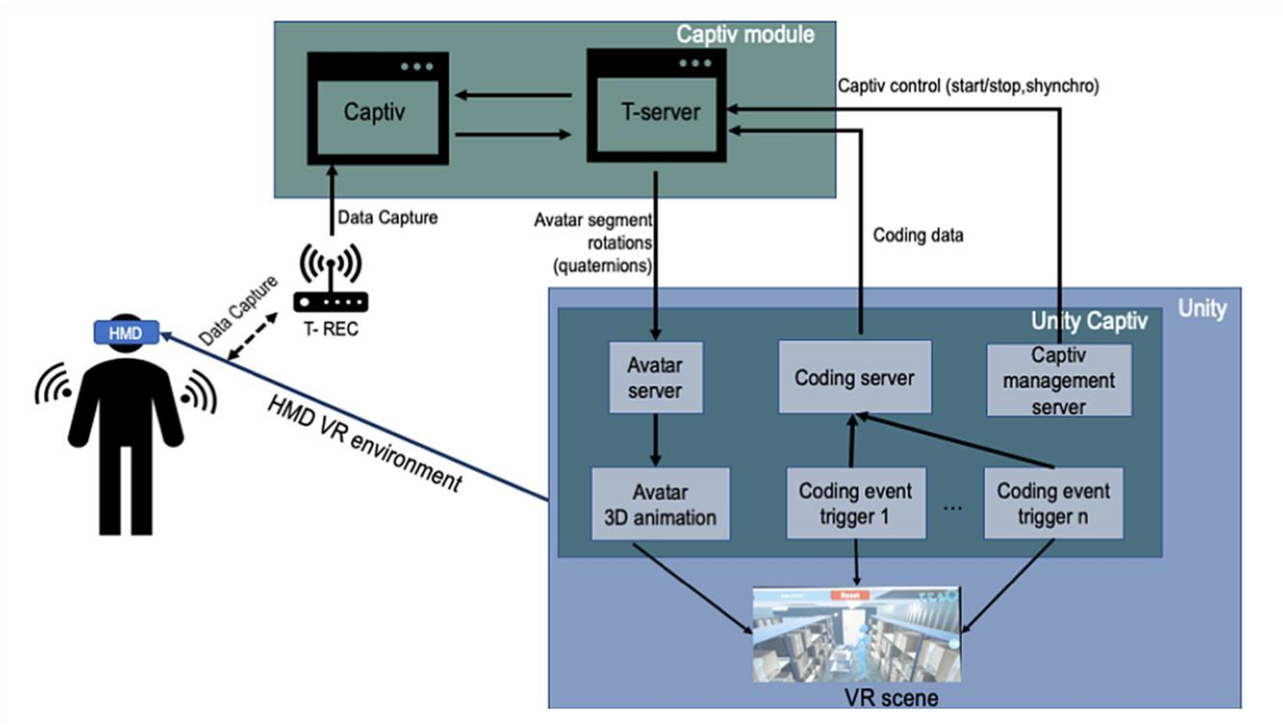


Figure 5. CAPTIV and VR system architecture [Arbelaez 2020]

VR together with CAPTIV system offer real assessment of the “future” performed task. Simulation of the production environment of the future setup configuration through a virtual reality scene can be used for training working tasks scenarios. This assessment facilitates and allows the improvement of the future scenarios by allowing to assess problematic situations during the design process before the job is performed on the real workplace. The use of IMU for motion capture and the use of the Captiv-VR platform allow to perform the same analysis once the workplace will be built.

5 CONCLUSIONS

The procedure of ergonomic risk assessment using multisensory wireless measurement system Captiv enables quantitative approach physical human behaviour data collection, as motion or additional biometric data. Such data can be used for real time ergonomic risk assessment. [Steinebach 2020] consider Captiv preferable for ergonomic analyses in terms of accuracy, especially in industrial work environments with occlusions. Nevertheless, findings and results can reveal hidden critical areas, which in time can cause development of musculoskeletal disorders. Workers in our case study were complaining about upper limbs pain. Results, measured by Captiv systems, have proven the risk body segments, which strained by high physical load: right and left shoulder, right and left wrist. Unacceptable load in individual joints arose as a result of handling the coupling - removing parts from the line and then placing them on a pallet located next to the workplace. Results show exceeding the treshold of unacceptable limbs position, in which workers spent, from 5 – 45 % working time (right shoulder: 45 %, left shoulder 18 %, right wrist 17 %, left wrist 4,5 %). Body posture, body parts position, movements, energy cost and workloads were assessed using an inertial motion capture (MC) system also by other authors [Kramarova 2016], [Winiarski 2021]. Corrective measures for elimination of the existing ergonomic risk can be verified by the means of virtual reality. Virtual reality application in the education and training of the future work scenarios actively contribute to cognitive interventions and effective learning process. The method and findings might help improve workstation ergonomics, increase workers' and organisational productivity, enrich H&S (Health&Safety) procedures, and improve automation on production lines. Concepts as job rotation and methods-time measurement (MTM) might be improved. The process management using results from Captiv system will also have impact on company risks, we assume decreased rate for incapacity for work, improved well-being, which can positively influence production planning and scheduling processes. Such behaviour means more efficient and effective production, as the workers would be available for the shifts due to decreased absences caused by incapacity for work. For company, it means decreased costs for workers' compensation, health care and administrative costs.

Future research with Captiv measurements will be focused on repetitive measurements in different work-shifts, taking into account the effect of fatigue on the worker and the assumed change in working positions in time. We plan to extend Captiv system with more motion sensors, having feedback from all body joints segments. For full body joint measurement, we need 15 motion sensors. For fatigue measurements, we will apply EMG electrodes on shoulders for capturing reactions from deltoid muscle and on lower back area for capturing reactions from erector spinae muscles.

Future research in VR platform will be aimed towards creating simulation models of the workplace for training working tasks scenarios before their final implementation at the workplace.

ACKNOWLEDGMENTS

The work has been supported by the Slovak Agency Supporting Research and Development APVV-19-0367 and APVV-19-0290 and the Slovak Grant Agency KEGA 013TUKE-4/2020.

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CONTACTS:

Daniela Onofrejova, Ing., Ph.D.
Technical University of Kosice
Faculty of Mechanical Engineering
Department of Safety and Production Quality
Letna 1/9, 042 00 Kosice, Slovakia
+421556022513, daniela.onofrejova@tuke.sk