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DEVELOPMENT OF PRODUCTION MACHINES WITH RESPECT TO THE HUMAN FACTORS

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Review article

Abstract: The inappropriate adaptation of the machinery to human properties and abilities may result both in physiological effects on the operator (e.g. muscle skeletal damage) resulting, for example, from inappropriate body posture, excessive or repeated exertion, and also in psycho-physiological effects such as mental overload or insufficient workload or stress, which may occur due to the operation, inspection or maintenance of the machine within the limits of its intended use. Psycho-physiological effects can lead to an increase in operator's errors, lower safety or quality, thus directly affecting the quality of the production process. For these reasons, the ergonomics needs to be of high importance. The submitted paper describes the use of advanced virtual reality technologies and risk management in machine development.

Keywords: Human factors; risk analysis; production machines.

Introduction

A motivation to modify the traditional development process of machine tools is to achieve higher utility properties of newly developed machines in the efficient use of expended costs, i.e. to increase the competitiveness of the developed machines at the global market. It should be borne in mind that the mere higher utility properties of the newly developed machines do not always mean greater competitiveness. (Holota, 2016) The development of competitive machines is usually linked to a balanced compromise, depending on the objective assessment of customer requirements, legislative requirements, requirements on standards, behaviour of competing companies, and the expected development and the actual market condition at the time of the market launch of newly developed machine. Therefore, higher utility properties of machines are a necessary, but not sufficient, condition to ensure greater competitiveness.

The works of other authors that have been published in this field are focused on partial objectives in the machine tool development and other manufacturing technologies; for example the following publications (Lu, 1999; Bernard and Hasan, 2002; Zwolinski, 2007; Kayis, 2007; Daaboul, 2011; Tůma, 2013) show the progress of scientific and research work in this field, not only within the framework of the International Academy for Production Engineering (CIRP), where the experience is exchanged along with a cooperation between the academic and industrial representatives from around the world. These constructional approaches are described in detail in the publication (Altintas, 2005), which justifies deployment of virtual prototyping technology to verify the virtual model. (Kovar, 2017)

Also the human factor is one of the most important elements influencing the safety of process, but it is also a component that is often neglected under the prevailing emphasis on technical reliability. Therefore, it is important to identify the postural deviations and possible ergonomic errors at workingplace and reduce the likelihood of occupational injury and disability. The cheap way how to deal with this problem is through an automated ergonomics analysis, which become the new ergonomics approach. We try to fully implement the automated ergonomics analysis into the virtual reality for the design phase of workingplace; the objective of the present article

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is to design an automated evaluation process using the virtual reality of HTC VIVE and the Kinect system.

There are many simulation programs available for modeling - Siemens Process Simulate, Siemens Classic Jack, Plant Simulation, IC: IDO dealing with the ergonomic aspects of manual work in the early stages of design and planning of product manufacture. Jack and Process Simulate Human will allow for improvement of safety, performance and comfort of working environment with the use of digital human models.

Key options for the virtual reality analysis from the view of operator are:

- Consideration of flexible human body builds;
- Supporting ergonomic analysis of total work-force using country-specific databases of workers and advanced anthropometric parameters;
- Analyse how the body responds to the force exerted in a particular direction;
- Managing a wide range of workplace options that include work at different heights, stairs and ramps;
- Views and analysis of field of view;
- Envelope curves radius for fast workplace configuration;
- Wide support for virtual motion capture technology;
- Possibilities of utilization in virtual reality.

Materials and methods

The proposed methodology for machine tool development with regard to ergonomics and reliability of the human factor has been designed to enable the manufacturer both to consider machine safety requirements and also to independently identify potential deficiencies, thereby minimizing the costs associated with the development and prototype production of the machine (Fig. 1).

Identification of machine requirements

In this development phase, it is necessary to identify the real requirements of the machine being developed. It is necessary to acquire the information on the activities of the manufacturer's service department. Based on the analysis of the requirements and their evaluation, the organ structure of the machine (design concept) can be proposed.

System analysis of the proposed organ structure

The proposed structure of the machine under development is analysed by a team of specialists at the appropriate resolution level (creating a block diagram with plotted significant interactions between its individual elements). (Huzlík, 2014) Following the interaction between these elements, energy, information and power flows, potential adverse events and the associated relevant hazards

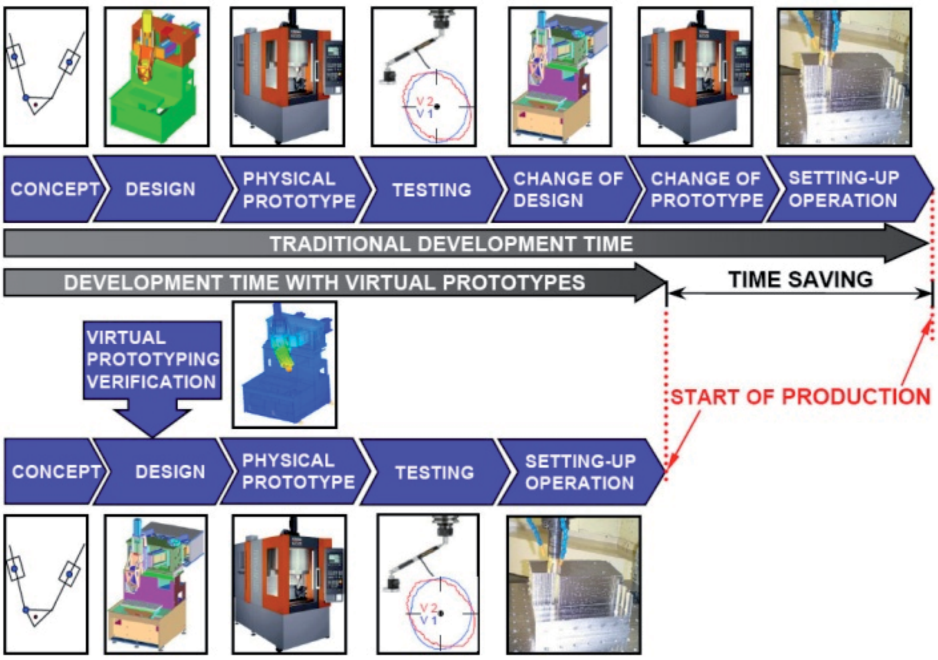

Fig. 1. Comparison of machine tool development process using virtual prototyping

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are identified for each phase of the machine's life cycle. (Augste, 2013) This information is then used in two parallel development processes focused on the safety and reliability of the new machine.

Analysis and assessment of risk

This development phase of the machine is aimed at ensuring its competence in the area of requirements for its safety, ergonomics and limitation of operator errors. (Blecha, 2011) The implementation of this phase of the solution lies mainly in the consistent application of technical risks management. Guidance on carrying out risk assessment can be found in many places. EN ISO 12100 is the main standard for risk assessment for machinery as it sets down the principles for the process.

Analysis and assessment of reliability

Based on the results of the risk assessment, it is possible to design the safety parts of the control and management systems to ensure the so-called functional safety of the production machine, which plays a significant role in the cases where the safety of the production machine cannot be ensured by a suitable construction (e.g. technological reasons). (Hnilica, 2013)

Functional safety is the part of the safety that depends on the trouble-free operation of the machine; therefore, it depends on the proper operation of its control and management system. The basic rule in preventing failure of human factor errors is to avoid an undesirable machine behaviour also in the case of individual human errors.

Preparing the instructions for the machine operation

This development phase is focused on preparing the instructions for the machine operation, considering the relevant preventative measures in the field of ergonomics and operator error prevention proposed in the previous two steps. Here, particular attention must be paid to the unambiguity and clarity of the texts used and their competence to anticipate human factor actions (including a reasonably foreseeable misconduct of the machinery operator). Therefore, due attention must be paid to both the unintentional and also the intentional errors of the machine operator; the intentional errors do not yet mean that the operator would intentionally proceed against the given rules (Fig. 2).

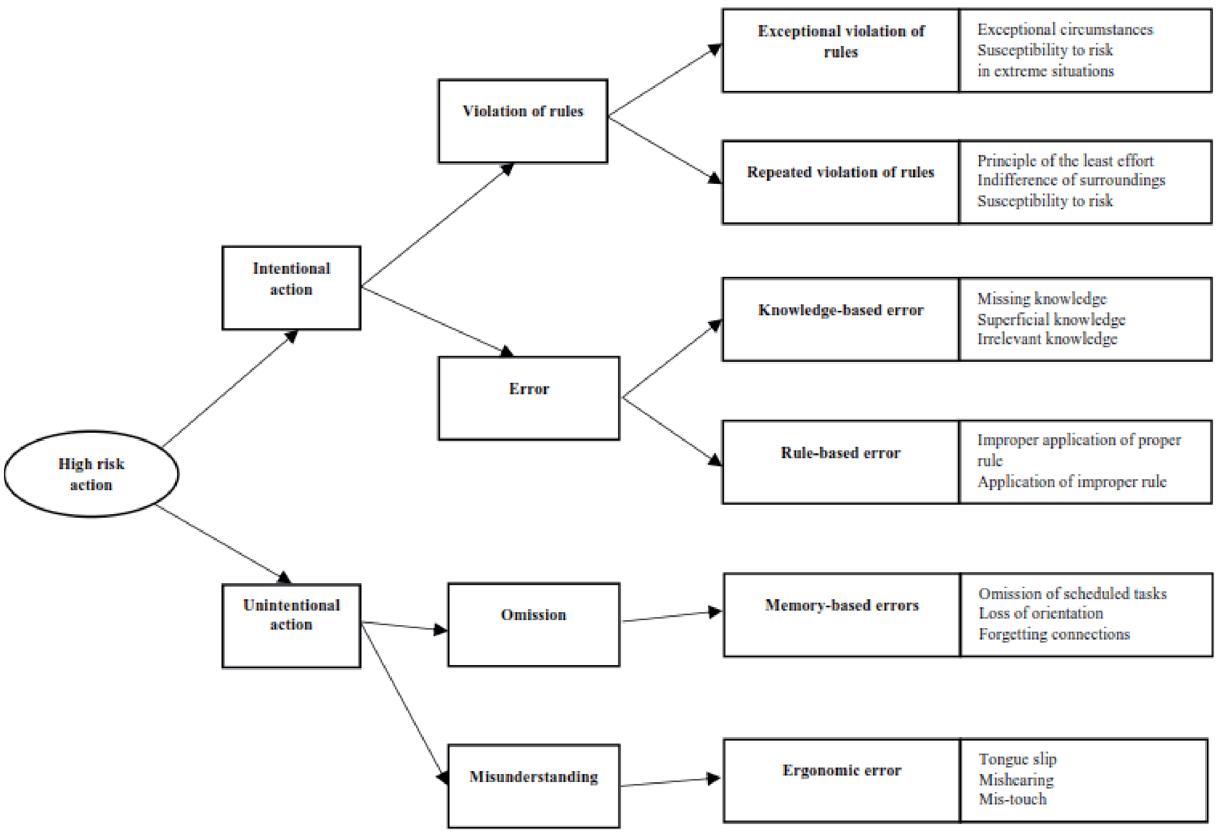

Fig. 2. Types of human behaviour leading to high-risk actions

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Results

Mastering the technical risk management process is a prerequisite for ensuring the machine's competence to be marketed or put into operation. Following the entry into force of the new Machinery Directive 2006/42/EC, there have also been significant changes in the field of harmonized standards (more than 300 standards are being issued). This period of significant changes is notably reflected in the time requirements affecting the competence of the machine being developed.

The pressure on ever-increasing production changes and the trend of increasing the number of variants and complexity of products while decreasing the time for development require the implementation of a high transparency element at all stages of development process both at the manufacturer and later at the customer. It is a virtual reality technology that, compared with other technologies, offers the best basis for interdisciplinary synergy and ensures a transparent product verification already in the early stages of its development (Fig. 3). For this purpose, it is most appropriate to use a three-wall, three-dimensional stereoscopic projection equipped with optical tracking, complemented by a computational cluster and the necessary service software. This allows for effective decision-making by executives who can test the designed machine along with the interdisciplinary team. It is in this area that the projections in real dimensions and the intuitive work with the model are particularly noticeable. The realistic display of digital models in conjunction with the three-dimensional user interface allows for a fast analysis of 3D data evaluation in a 1:1 scale as it is not possible with common desktop systems. This activity allows for detection of potential development errors before manufacturing the first real prototype. Not only does this have a positive economic impact, but it also allows for even shorter development times. In this way, it is possible to include all the up-to-date technological processes of the use of digital three-dimensional data for planning and verification processes in the field of manufacturing technology.

The technology of so-called immersive virtual reality (VR) allows for manufactured digital products to be viewed not only stereoscopically (similar to a 3D cinema), but also to interact with them in real time - e.g. rotate, manipulate or modify various design variants, and then evaluate (Fig. 4). Within the virtual reality, ergonomic parameters of the production equipment can also be tested very efficiently and verified for potential operator errors (Kotek, 2015).

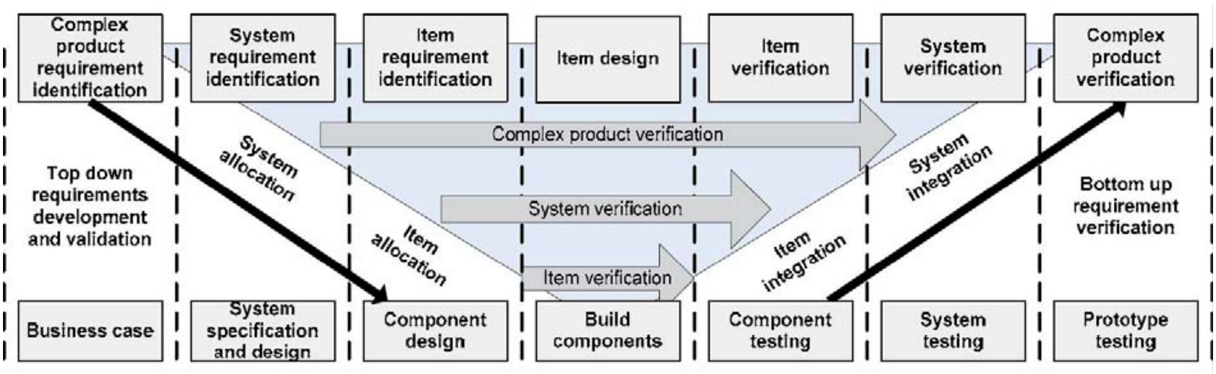

Fig. 3. V model for the verification of complex engineering products (Maropoulos, 2010)

Fig. 4. Ergonomic analysis of positioning of production machine controls

A very important area of application of VR technology is the assessment of ergonomic aspects while designing the safe machinery. It is because the virtual systems allow for direct control of

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ergonomic parameters of prototypes using an anthropometric three-dimensional human model with accurately pre-defined attributes (see Fig. 5). Thus, it is possible to plan appropriate positioning of the control panels, to verify the working radius and working space of the operator and to examine his/her field of view, or viewing dispositions.

The identification of customer requirements and their fulfilment is the task of the sales department but the engineering department is also involved to a great extent. As indicated, in many cases, it is necessary to identify customer requirements that are often not too clear. Apart from this, there is a group of customers whose requirements are quite clear and on which they are uncompromisingly insistent. There are cases of total inconsistency of requirements that are incompatible with technical possibilities, physical reality etc., which is very difficult for manufacturers. It is important to distinguish between the phases in which the development or innovation are implemented. A different situation is especially in the case of customisation to the needs and requirements of the customer in the phase of:

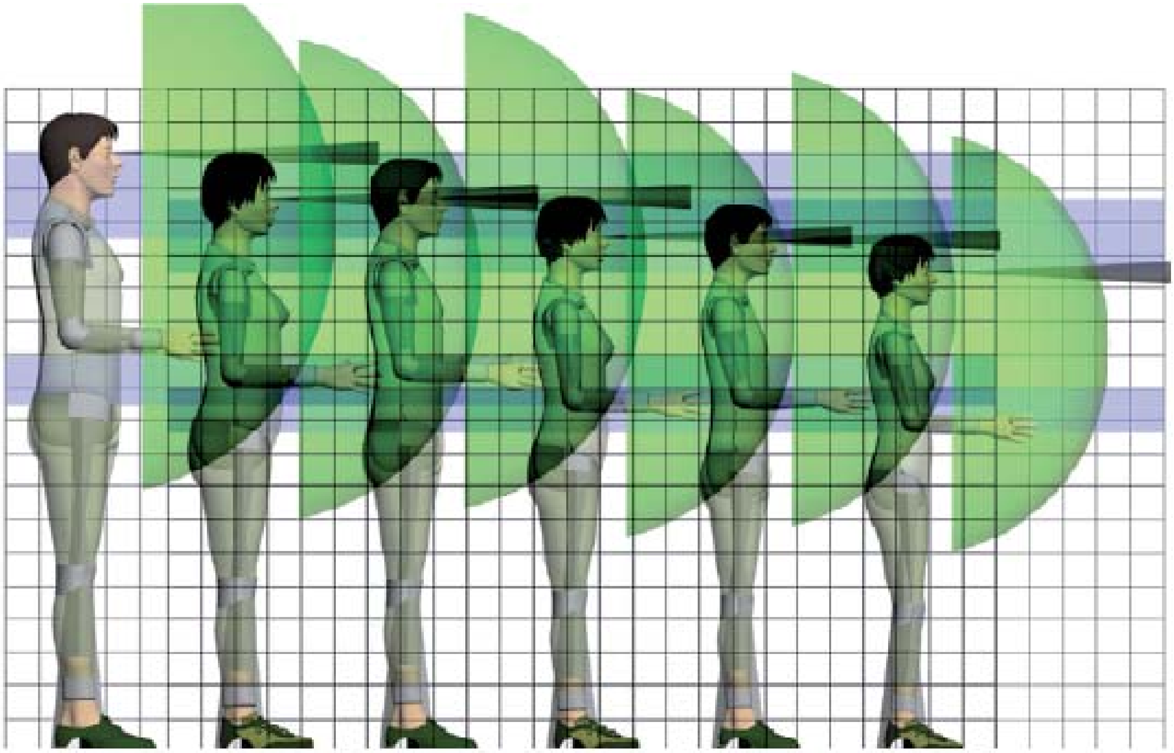

Fig. 5. Examples of human anthropometric three-dimensional model with accurately pre-defined attributes

a) the finished machine (it may already be an operating machine, or in the phase of dispatch or just prior to dispatch, at the acceptance phase);
b) in the tangible phase of production;
c) in the intangible phase of production;
d) projection;
e) the tendering procedure;
f) the development of new equipment without a specific customer.

In some cases, deviations from standard procedures can be observed, both due to time and local aspects affecting the production equipment being developed. However, they are not only reflected in this point, but their impacts can also be traced in other areas of the structure. These impacts are largely verifiable by internal processes, in particular by change management, and the quality flow of information (in the vertical and horizontal business structure, and in particular it must be bi-directional) is of fundamental influence in minimizing the consequences.

These findings do not in any way violate the designed structure, but incorporating them into such a complex structure would lead to a deterioration in its clarity. Furthermore, it can be stated that the incorporation of one of the (non-standard) states described below would lead to a violation of the universality of the proposed methodology.

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Conclusion

The above considerations require a radical change in the approach to determination of the competence of the machines to be developed, whether in terms of safety, ergonomics or avoidance of operator errors. This change should be based in particular on abandoning the existing practices and on switching to very efficient quality assurance tools and technologies (e.g. FMEA or immersive virtual reality technology) and safety. Particularly, in the area of safety of machines being developed, it is imperative to apply a risk management system that is already mandatory in the existing EU directives on product safety, consumer and environmental protection, and is a prerequisite for launching the product at the market.

Early detection of constructional errors of machine tools in ergonomics and limitation of human factor errors through the technology of immersive virtual reality helps to reduce financial costs and shorten the development time for a new machine.

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