



Maciej KOWALSKI¹, Radosław PASZKIEWICZ², Przemysław ZAWADZKI³

VR TECHNIQUES IN WORK STAND DESIGN

ABSTRACT:

Use of Information Technologies in product design allows to improve it's efficiency. Application of different IT tools allows reducing the time of preparation of the product for production as well as to reduce the manufacturing costs and improve the quality of the product. When work stand is considered as product, the design process of that product is even more important. Besides of capabilities of work stand manufacturing cost limitations it also effects reduction of costs of products which are manufactured at this work stand.

Sometimes design process of the work stand can have some weakness which cause low level of the ergonomic quality and can be the source of farther economical loses like low production capacity of the work stand, high level of lack, rapid wear of machines and tools, accidents, employee's exhaustion and other professional diseases. All loses which have been described above are incurred through many years of work stand exploitation.

Author of this paper proposed the innovatory approach for work stand environment design by using virtual reality techniques. Elaborated IT tools for design with the use of VR techniques enable to work stand design at the different branches of industries. With the consideration of mass production the development of ergonomic, convenient work stands becomes more and more important. That is why author's research investigations concerned at testing of new tools at the work stand design process for automotive industry. The results of these investigations will be presented as well.

KEYWORDS:

virtual reality, ergonomics, work stand

INTRODUCTION

Product design phase affects the cost of its manufacturing. Between 80-90% of all costs of product lifecycle (PLC) depend on realisation of the design stage. All that comes to conclusion is that focusing on the design stage of PLC is important and can improve the overall effectiveness.

The common knowledge is that usage of IT during the design makes the whole process more efficient. By usage of different software and hardware solutions time spent on the design is reduced. Also the costs reduction and quality improvement is noticed with such approach [1]. If designed object is a work stand, the design process generates even more implications on the costs of elements manufactured using the stand. Improperly designed work stand with low level of ergonomic quality creates so-called economic lost such as: low productivity and capacity, high number of production faults, fast tools replacements requirement, increased hazards level, tiredness and work related diseases etc. It has to be mentioned that such costs are cumulated during years of the work stand usage.

If designer decided to use CAD systems he increases the potential to make better decision faster and in

earlier stage of whole process. Decision like that have impact on manufacturing costs, work conditions (ergonomic) and effectiveness. The costs of implementing improvements and amends in work stand design when it has been already constructed and used are incomparably higher than the costs of implementing changes in the design phase involving CAD systems.

There are systems which role is to simulate the work stand conditions basing on CAD solutions. Usually such systems are based on so-called CAD Digital Human representation. Usage of CAD Digital Human feature allows visualising the human factors in virtual environment. That leads to include most important element in design process of work stand environment - human influence [2, 3]. Digital dummy or digital human application provides solution of gathering data and design improvements by visualising work place ergonomics, visibility area FOV (field of view) and arm range. It also creates possibility of performing so-called RULA analysis (Rapid Upper Limb Assessment). Thanks to the RULA analysis it is possible to indicate points where the hazard appears. The RULA analysis shows the numerical values (fig. 1) based on data like weight, load and actions frequency. Those numbers are representing a risk of damage for specific parts of

human body. By using the digital human in CAD systems the designer can create safer and ergonomically approved work stands designs. Such approach is time consuming and bases on the following tasks which have to be completed:

- ❖ virtual scene creation,
- ❖ digital human creation,
- ❖ placing the digital human within the virtual scene,
- ❖ assigning the tasks to the digital human,
- ❖ tasks realisation analysis.

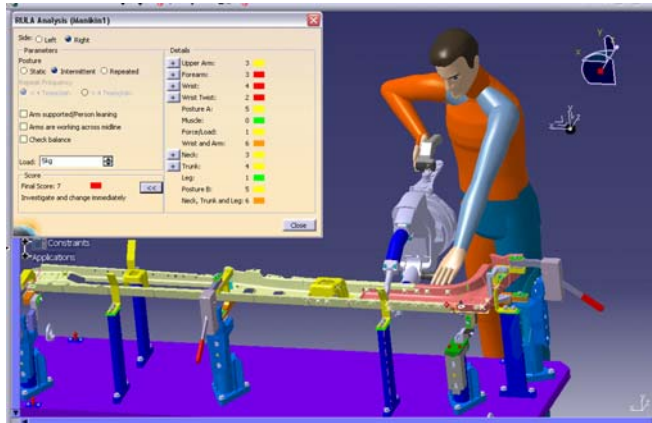


Figure 1 - RULA Analysis with usage of virtual dummy - digital human (CATIA Human module)

The fact that the setup of simulation requires time and specific knowledge is one of the main reasons of rare use of these tools by the designers. The second reason of not using such of tools is lack of knowledge to make adequate and relevant conclusions based on the achieved results and apply them in appropriate way within the designed elements. As a result, work stands designs rarely pass the validation procedures and examination.

The other method used for validation of the work stand design and setup the work standards is MTM (Methods-Time-Measurement). MTM is based on measurements of time of task realisation with regarding to choose method of work. It is using the basic movement analysis. These basic movements are called Trebling and can be combined into modules, for example: reaching, catching, and releasing = gathering.

The method allows estimating main time, time for completion of all activities and main time of preparation. MTM can be performed when the work stand already exists (then the process is called "manufactured analysis") or when it is still in design process (then the process is called "planning analysis"). The Manufactured Analysis is based on observations of existing work flow. The Planning Analysis instead is based on simulation of the work stand. For this second type of analysis the work stand sketches with tools and additional hardware are used to visualise the methods of work. Results of the analysis based solely on simulation are often inadequate in relation to real work results. One of the reasons of such situation is the difficulty of simulating the complex and compound production processes. This is especially

evident when process involves complex work stands with huge number of tools used.

VIRTUAL REALITY IN DESIGN

Simultaneously with development of the CAD systems also the virtual reality (VR) systems evolved becoming more popular and more applicable [1, 4]. The development of the VR techniques starts with simulating presentation of the still images with stereoscopy effect. The next step was creation of the helmets with special monitors build in - HMD (Head Mounted Displays). This leads to give user to percept not only a vision but also a sound via speakers builds into the HMD. By using the sensors the movements of the operators head could be combined with presented image so the visualisation become more immersive and give the observer features of being fully involved within the virtual scene. The next step was to create a whole body tracking systems usually based on exoskeleton mechanical structure (i.e. Gypsy Motion Capture System) but also on optical tracking with using special uniforms with markers. The important development was the ability to use force feedback features and solutions which simulated the human touch sensibility. The increase of calculation power of descent graphic cards gives an ability to render the virtual scene in a real time. All those solutions together are now very commonly used for support the designers in their daily work. The modern CAD and DCC (Digital Content Creation) software already allows to use some of the immersive technology within the regular options of the software such of modelling, texturing, parameterisation etc.

Virtual reality supports such activities like visualisation of CAD models for support the modelling process, comparing solutions and optimising the surface quality in early stages of the design process. By semi-photorealistic and physically correct visualisation of the surface, the designer can evaluate his own solutions even only on visual object without real life prototype [6]. The visualisation solutions are ready to present objects in 1:1 scale which is important to have a right perception of the designed elements.

Virtual reality systems nowadays often substitute real research stands used for visualization of researched physical phenomena as fluid and gas flow, thermodynamics processes or deformation due to forces. Virtual reality systems in this case are responsible for stereoscopic visualization that makes results of analysis more readable and accessible to the user (fig. 2).



Figure 2 - Use of VR in early design phase



Figure 3 - Ergonomical design in Virtual Reality system

VR systems also open up wide possibilities for modeling the ergonomic features of the products (fig.3). They have a number of features including collision analysis, identifying critical areas, animation, and making measurements of objects in the virtual world.

USE OF VIRTUAL REALITY SYSTEMS IN WORK STAND DESIGN

Tools based on the solutions of VR techniques can successfully be used in the design of work stands. In the case of mass production creation of ergonomic, comfortable work stands according to the anthropometric dimensions of man is very important.

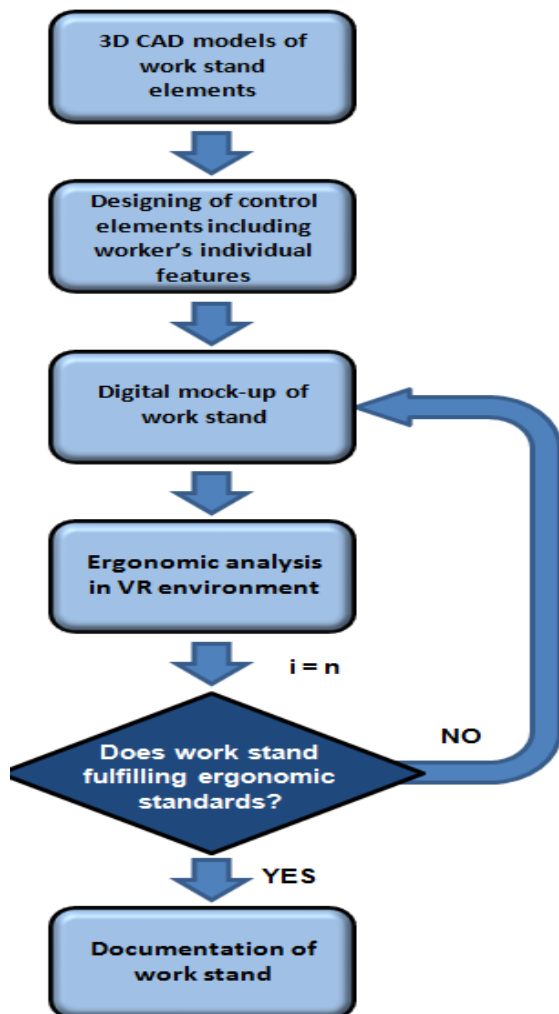


Figure 4 - Work stand design process using VR system

Proper designing of work stand must take into account not only human, but also such elements as equipment of work stand and its environment. The authors

proposed a new approach for the design of such facilities using virtual reality systems (fig. 4), taking all the previously mentioned requirements into account.

An example of the implementation of VR techniques in the design process can be a virtual model of spot welding work stand. The authors have developed an interactive simulation of a work stand using a specialized VR programming environment named EON Studio, developed by EON Reality. This simulation allows the user and the designer to verify the functionality of the work stand and helps to learn how to operate it. A detailed geometric model of the work stand has been prepared in CATIA V5, then the model was translated to EON Studio (fig. 5). Virtual spot welding work stand consists of:

- ❖ work table with clamps
- ❖ spot welding machine
- ❖ control panel
- ❖ welded elements
- ❖ virtual hand

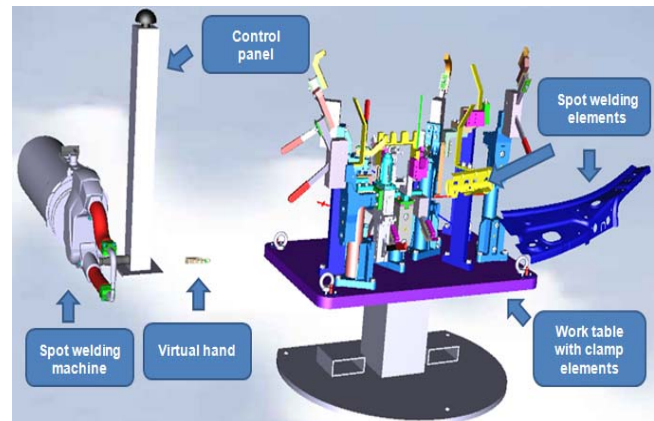


Figure 5 - Virtual work stand for spot welding

To ensure the opportunity of work conditions analysis, work stand simulation was enriched with interaction. A set of relations was created between objects of work stand, to simulate the operation of real welding work stand. The functions allows user to monitor and control elements of the work stand. By use of specialized equipment interaction and immersive effect has been increased. Control and manipulation of objects is realized via magnetic tracker system Polhemus Fastrack ® and the data glove recognizing gestures - 5DT Data Glove. The immersion effect is ensured by stereoscopic projection system - EON ICatcher or HMD helmet.

By using the tracking system user has the ability to control welding machine by hand and arm movement. With the data glove and appropriate gestures user is able to control the closing and opening welding clamps. Simulation enables collision detection of welding machine with elements of work stand and welded elements. Each contact of the welding machine with elements of the station is recorded, and the user is informed by a sound effect. Analysis allows specifying the location of a collision during the operation and allows selecting the optimal setting of welding machine to ensure the correct execution of

welds. Simulation of welding work stand also allows optimizing the welding process by eliminating unnecessary movements, determining the order and positions of welding machine.

Based on the virtual work stand it is also possible to perform MTM analyze, where the time of basic movements can be measured basing on simulated motions. Results of this analysis at the design phase allow detecting and eliminating design errors which with a standard approach could be observed only after construction of the work stand.

MODERNIZATION OF WORK STAND – CASE STUDY

The main aim of works was modernization of work stand for spot welding of elements of a car chassis pillar. These elements are part of the side wall of car chassis and are performed on two work stands Afo 10 and Afo 20 (fig. 6). Standard technological process which was needed for preparation of an element of pillar consisted of two operations - spot welding on first and second work stand. Between these operations gluing of single parts was performed.

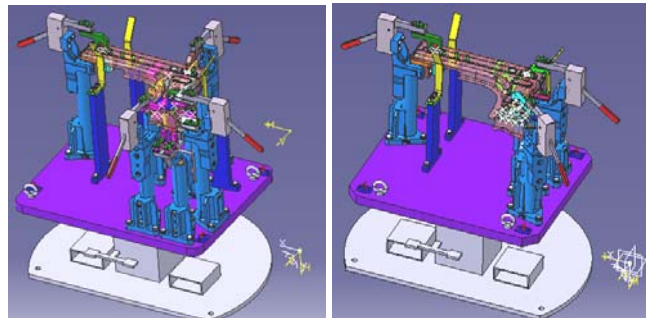
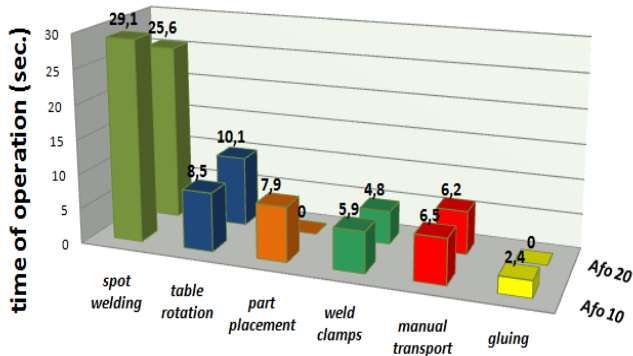


Figure 6 - Work stand for spot welding - Afo 10 i Afo 20

Main and the most important idea for modernization of the work stand was to design one integrated work stand on which all needed operation planned by technological engineer can be made. Such modernization should eliminate transport between work stands, reduce time needed to open and close weld clamps and decrease amount of rotation of work table during spot welding.

To specify work characteristic on work stands MTM analysis was performed (fig. 7).



work stand for spot welding - Afo 10 and Afo 20

Figure 7 - Time of operations on work stands Afo 10 and Afo 20

As a result of research efficiency of work stand estimate 695 pieces/day assuming 24h work. As the most important factors determining the efficiency of the work stand were transport between them and the process of opening and closing weld clamps. Therefore, when designing a new, modernized work stand the main focus was to minimize the time of these operations.

Design work related to the development of an integrated work stand was carried out using previously described virtual reality system. Construction of digital workstand has been established basing on studies conducted on the basis of the criteria. The integration of two separate workstands allowed eliminating time-consuming transport. Application of pneumatic clamps and reconstruction of the positioning units allowed reducing time needed for process of opening and closing weld clamps (fig. 8).

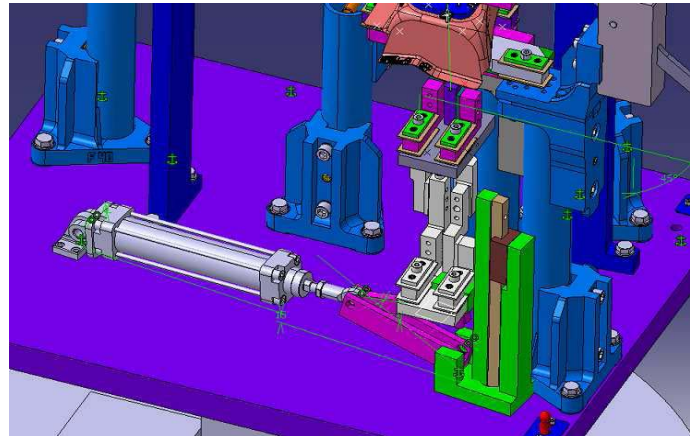
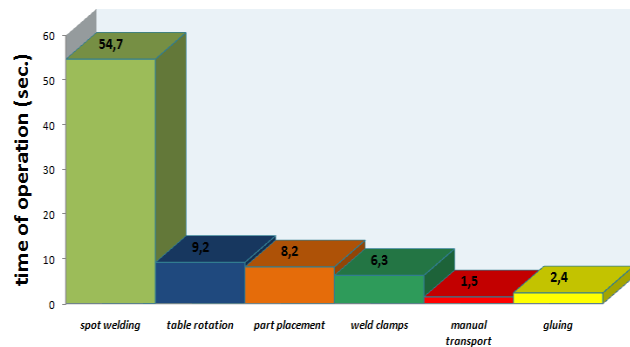


Figure 8 - Design of modified work stand

Use of virtual environment allows preparing interactive model of new designed work stand. Work simulation in virtual environment allows checking and detecting collision of spot welder with elements of work stand. Adequate relation between elements of work stands allows performing MTM analysis (fig.9), which results help to verify the amount of work and compare the rates before and after the modernization. As a result of the research work stand efficiency estimate on 897 pieces/day assuming 24h work, which was confirmed after the construction of modernized work stand.



work stand for spot welding - H22

Figure 9 - Time of operations on modified work stand H22

CONCLUSIONS

Design with use of VR allowed us to create a new, integrated work stand. Thanks to merging two separate work stands into one, significant labor and time reduction was possible. Improved functionality of work stand caused reduction of time needed for operations at work stand. Employees perform tasks with natural basic motions, which cause steady work, less fatigue and greater stability of the process. It is important to mention that proper design of such work stand would not be possible using conventional design techniques.

Use of VR technology allows including ergonomic aspects at the design phase of the new work stand, which increases the comfort of future work. Implementation of virtual analysis involving the designer and operator of the work stand allows easily intercepting and eliminating design errors, without need of building a physical prototype.

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AUTHORS & AFFILIATION

Maciej KOWALSKI¹,
Radosław PASZKIEWICZ²,
Przemysław ZAWADZKI³

¹⁻³POZNAN UNIVERSITY OF TECHNOLOGY, FACULTY OF MECHANICAL ENGINEERING AND MANAGEMENT, INSTITUTE OF MECHANICAL TECHNOLOGY, ul. Piotrowo 3, 60-965 POZNAN, POLAND

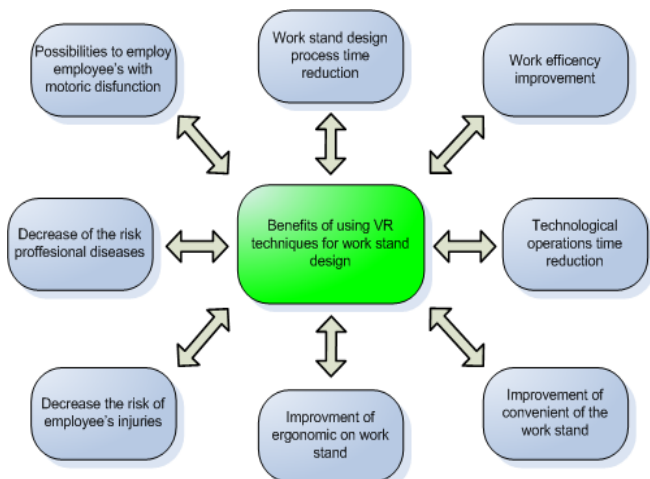


Figure 10 - Scheme of measurable benefits of using VR techniques for work stand design

This reduces the risk of occupational diseases and work accidents. An important advantage of the use of virtual technology in the design process is also the possibility to adapt the work stand for people with motion disabilities (fig. 10).

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ACTA TECHNICA CORVINIENSIS
- BULLETIN of ENGINEERING
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