Ergonomic Design of Manual Assembly Workplaces

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Abstract

The manual assembly is still the most viable method of assembly for number of different applications where the overall product volumes are getting lower due to the frequent changes on a market. However, manual assembly is inconsistent and could vary if a workplace is not ergonomically designed. Design of the workspace may have significant impact on the overall product quality as well. The usage of the modern digital planning tools could greatly improve the final design of manual assembly workplaces. Some recently developed software tools have integrated functions for an ergonomic analysis of a digital plant layout model according to anthropomorphic data. A course that deals with assembly system design and planning should have integrated module for ergonomic analysis. In this work, suggestion for ergonomic planning of assembly systems is given, based on the development of one assembly system with the application of digital ergonomic tools.

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Introduction

Humans use skills, dexterity and judgment while they perform assembly operations. However, the quality achieved in this way is inconsistent. Nevertheless, a majority of assembly operations, performed in a regular assembly workstation, still can not be automated, or their automation would be prohibitively expensive. Assembly systems that could fit these demands should be flexible and easily reconfigurable. They have to be made according to ergonomic rules. Workers spend a lot of time performing same, repetitive operations. Any mistake during the development phase of an assembly system can cause further problems. Those problems are related not only to the functioning of assembly systems but also to the health of workers. The productivity of an assembly system, and therefore of the overall production system, can be amplified with better ergonomic planning. Operations in the manual assembly should be very carefully planed as well. Application of computer simulation allows virtual design and verification of an assembly system and its layout. This assembly system could further be investigated for compliance with the ergonomic rules. The ergonomic analyses, such as RULA (rapid upper limb assessment), are integrated in some of the software packages that could be effectively used in academia to expose undergraduate students to ergonomic workplace design. This approach would help students understand how important human factors are during the development of a production system.

Ergonomically Designed Assembly System

There are many social and economic benefits that can occur if the assembly systems are planned according to ergonomic rules. The economic goals that have been reported are cycle time reductions, increased productivity, reduced production costs, high returns on investment, increased flexibility, increased product quality, increased innovativeness, reduced human and system errors, decrease in lost work time, reduced sick leave, reduced injury costs and a drop in labor turnover. Social goals that have been reported are improved worker health, reduced physical and mental work load, less pain and complaints, more comfort, less injuries, improved safety, improved motivation, and better work satisfaction (Dul, 2004).

Wulff (1999) found that in a real situation related to a creation of a new system, design teams usually implement certain specific ergonomic criteria. However, some other general recommendations are usually not being implemented. Their study suggests that designers very often do not understand all ergonomic recommendations. They do not know how to apply these recommendations in the specific situations, and sometimes do not even consider them important. This can happen especially if ergonomic requirements are in conflict with other design requirements, which they find more important.

Recent studies show that there are problems related to the application of ergonomics knowledge in organizations (Slappendel, 1994). The workstations are not always designed according to ergonomic principles. Some studies have focused on the relationship between the available ergonomics data and the actions of individual designers. The ergonomic knowledge does not always get through to the designer (Wulf, 1999). Design engineers can have problems finding required ergonomics data. They can experience some difficulties while searching for relevant information in the ergonomics literature (Klein, 1986, Swierenga, 1990).

Digital Ergonomic Planning Tools

Application of digital manufacturing software could significantly reduce time required for planning (by some sources even up to 40 percent). Achieving this benefit requires both technology and business process improvements. These include using a more systematic and structured approach, introducing process automation, improving visualization and collaboration, and enabling manufacturing operation simulation. By having access to shared data, information search times can be reduced by as much as 80 percent. Product and process planners get feedback much earlier, reducing the time required for problem resolution (CIM Data, 2006).

Workplace design typically starts after an assembly sequence is determined. All assembly operations have to be grouped into assembly workplaces according to material flow, quantity and all necessary time considerations related to each assembly task (e.g. positioning, orienting, moving, joining, pressing, riveting, etc). A common mistake is that designer of an assembly workstation considers the average human dimensions as the only parameters for a design, whereas in reality workers' body dimensions have certain variability.

Ergonomic planning of an assembly system and process can be supported with computer based graphical simulation tools and appropriate models. The design process of an assembly system should call attention to the integrated approach in the product and process design. The same data about the product should be shared and used for manufacturing and also for analysis of various production activities including assembly task analysis, work studies, ergonomic workplace design, human task simulation and plant layout as well.

A human task simulation can be used for validation and optimization of the manufacturing processes before they are implemented on the shop floor. This can reduce overall manufacturing time and cost. Application of an integrated Product Lifecycle Management (PLM) environment can provide an easier implementation of all necessary changes to Bills of Process. In this way, managing and implementation of different processes can be more efficient. PLM environment can also make the reuse of data about assembly processes possible. That information can be accessible from the managed data environment. Design and layout information can be used to automatically generate shop-floor documentation.

Ergonomic Workplace Design

There are two main areas that have to be considered in order to achieve an assembly system in which the workers can perform their tasks comfortably. The first is design of workplaces that would fit anybody from the specific population sample in that specific company. A design of ergonomic chairs, tables and fixtures must have integrated function that can be readjusted for various body dimensions. The second is design of an assembly process that fits to predefined ergonomic rules. If some operations have more repetitive tasks, it is more likely that the worker can experience problems related to these repetitive motions. The weight of the parts that are going to be assembled is also an important factor that has to be considered while planning an assembly process.

Designing a workplace and an assembly system has to be done with ergonomics in mind. Every workplace should be investigated for compliance with the ergonomic limitations. A workplace has to fit every worker from a wide range of population sample. Everything that exists in a manual assembly system, including chairs, tables and fixtures, has to be designed in a way that allows readjustment to allow variability in body dimensions. Assembly movements are usually repeated during a long period of time, and therefore every specific operation has to be carefully analyzed before implementation on a real shop floor. Avoiding work-related discomfort and injury is an ultimate goal of any assembly system designer.

Integration of Ergonomic Design into Curricula

Digital planning tools, such as Dassault Systemes's DELMIA, have integrated tools for ergonomic workplace planning. Those tools include:

Human Builder, Human Measurements Editor, Human Posture Analysis, Human Activity Analysis, and Human Task Simulation. All these analysis tools are based on application of a human model in a virtual environment that represents real factory environment.

Digital simulation and planning tools can be integrated into the various design related courses. It is important for student to understand significance of keeping human factor in mind while planning an assembly sequence and system. Using these tools can enhance worker's productivity and assist in making improvements in a workplace setup even before it is physically built. An example of a digital workplace with a digital human model is given in Fig. 1.

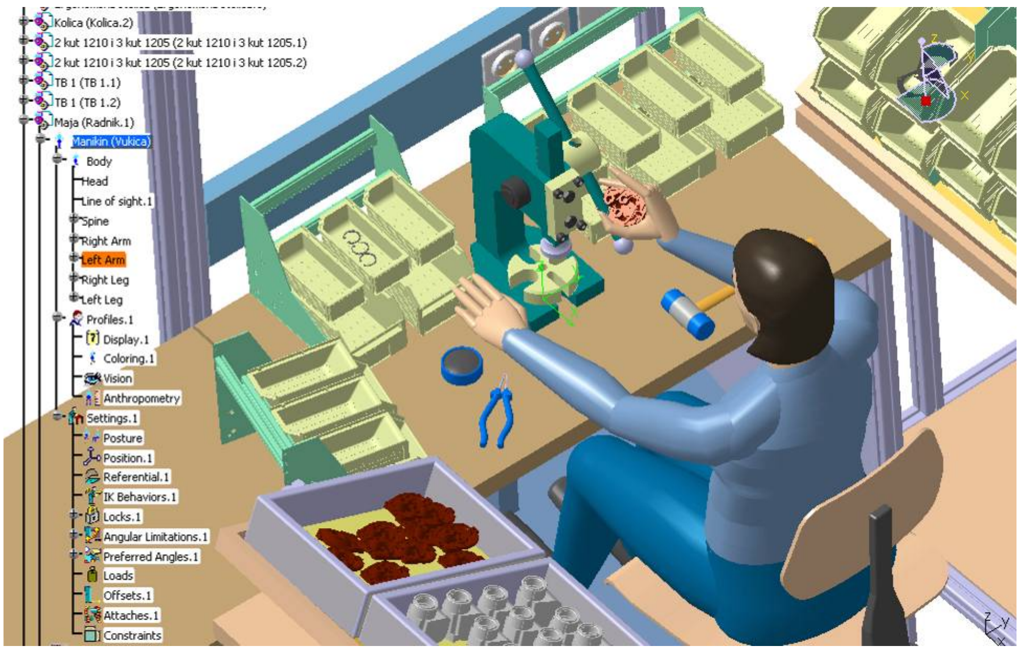

Fig. 1: A digital workplace with a digital human model

A digital model of a human body in DELMIA has 68 segments (Human Builder). They all have their own degrees of freedom, which is usually two or three. Every degree of freedom has its own range, from a minimum angle to a maximum angle. The minimum and maximum angle has the lowest score because working in those positions is the most uncomfortable for a worker. Some other angles have better grade. The most comfortable position gets the highest grade. Assembly operations should be planned so the human body segments are positioned somewhere in the highest score range possible. Digital ergonomic analysis examines the following risk factors: number of movements, static muscle work, force, working posture, and time worked continuously without a break. These factors, combined provide a final score that ranges from one to seven. The score "one" indicates that the posture is acceptable, and a score "seven" indicates that investigation and changes are required immediately. The score of a posture can be a parameter to determine if the workplace is appropriately ergonomically designed. An example of a virtual workplace with adjustable material shuttles is shown in Fig. 2.

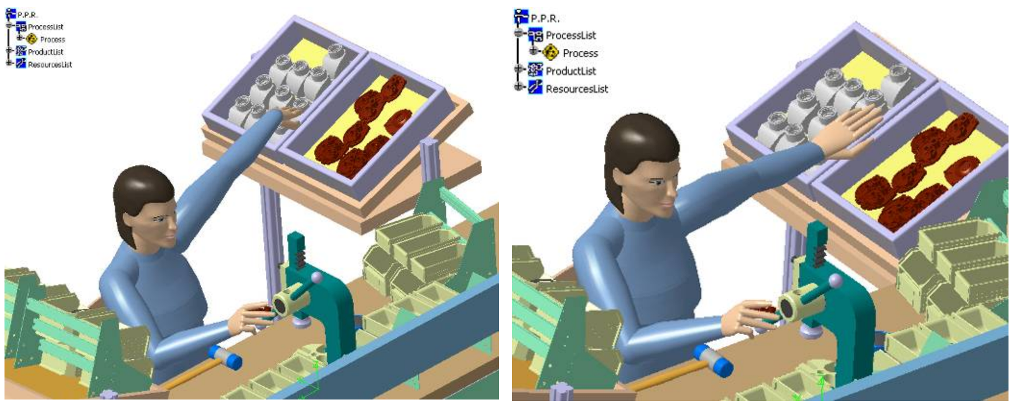

Fig. 2: A digital workplace with adjustable material shuttles

After the first design of a workplace is finished, it should be investigated how well it fits to the workers. A range of workers can be presented as digital models with different anthropometric measures. A good design is the one that can cover all wide variations in a worker's dimensions. Every module in an assembly system needs to have integrated function for readjusting if required. In this way, individuals can optimize their work environment according to their personal preferences. Every designer has a scope of what can happen in a workplace if a worker has specific anthropometric measures. However, comfortable postures of an individual worker cannot be apriory determined based on a general model which can lead to serious work-related disorders over the long period of time for. An example of one digitally planned and optimized manual assembly system is given on Fig. 3.

Fig. 3: Ergonomically planned manual assembly system

A virtual layout can enable easier planning of an assembly sequence. This kind of system can also provide knowledge capture of previous configurations of assembly system layouts. Virtual layouts can be reused for training of new workers, and also as valuable database for a future projects.

Conclusion

Digital tools can help students investigate an assembly system and perform analysis and optimization before the system is actually built. All workplaces have to be analyzed before their actual production since anthropometric data can vary greatly among individuals. Implementation of data regarding to ergonomic rules can be much easier if a designer uses a digital human model to investigate how the workplace would fit to a range of workers' dimensions. The students should be exposed to these simulation and visualization tools so they can see importance of considering human factors during manufacturing system design phase.

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