ERGONOMIC DESIGN OF WORKPLACE

Tajana LUŠETIĆ, Maja TRSTENJAK, Predrag ĆOSIĆ

University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture
Ivana Lucica 5, Zagreb, Croatia

Abstract

Even though a lot of jobs are lost due to big changes that came with new technologies and automatization, never before have people paid such attention to designing ergonomic workplaces. This way companies want to improve production and ensure the safety of their workers. There is also some software which can help with designing workplaces with human models. Jack Siemens is one example of this kind of software. This software Jack and principles of ergonomics were used in the company Končar-MES d.d. in one assembling workplace. Two proposals to optimize this operation were using conveyor and a rotating-lifting table.

Keywords: ergonomics, design of workplace, work and time study optimization

1. INTRODUCTION

Today's feature is the growing domination of automation and the new production and technological conditions are set before the industry to transform production activities. The dynamic development of new technologies and the investment in new machines, devices, tools and equipment sets the need to find solutions and create conditions that will ensure the humanization od work. There has always been an urge to organize and perform a job that will result in less fatigue and energy losses. Ergonomics is a scientific area where with multidisciplinary researches of technique, technology and environment on the human and with the interdisciplinary ergonomic approach, are attempted to reconcile the relationships in the human-job system with the aim of humanizing work [1].

2. ABOUT ERGONOMIC DESIGN OF THE WORKPLACE

Ergonomics is the science raised from ever present ambition of humans to optimize their efforts in achieving their objectives. Part of that ambition is focused on optimal designing of the workplace, also by taking into account the capabilities and limitations of the worker. Thus, making the best use of space through optimum placement of equipment, integrating the human factor into workplace design, and effectively aligning the workplace into the surrounding environment are identified objectives of workplace design ergonomics.

Ergonomics can have a strong impact on any organization and there are following benefits while applying it [2]:

1. Reduced cost by decreasing injuries occurrence of the workers,
2. Improved productivity is the result of the better designed workplace which ensures good posture, less exertion and fewer motions of the workers,
3. Better quality because poor ergonomic leads to frustrated and fatigued workers that don't do their best at work,
4. If an employee does not experience fatigue and discomfort during their workday, this can result in decrease of absenteeism, improved moral and increased employee involvement,
5. Better human performance because of safe and health culture created in the organization.

Workplaces should be designed so that most people can safely and effectively perform the required tasks. There are certain criteria that need to be taken into consideration while developing and an ergonomic workplace such as reaches, anthropometric size/dimensions, muscle strength/capability and visual capabilities. When laying out a production workplace or office area there are some general recommendations that need to be followed [3]:

- Services needed by several people should be placed in a central location.

- The communication needs of different operations should be evaluated, and people or workplaces should be located to maximize communication.
- Lines of sight and other visual requirements for operations should be kept clear. For example, it is important to be able to see from a control console to manufacturing equipment.
- Noisy, heat-producing, odor-producing, or visually distracting operations should be modified or located to minimize their effects on other operations.
- The work area should be arranged so the product can flow through it, preferably in one direction, with minimal re-handling.
- Workstations should be designed to permit people a minimum separation of 122 cm, with 244 cm being more desirable.
- Postural flexibility and change should be provided. A person should not be restricted to a workplace in such a way that he or she cannot change posture during the shift.

The most important categories of workplaces are sitting, standing and sit/stand [3]. Sitting workplaces are used in situations when all items needed in the short-term task cycle can be easily supplied and handled within the seated workspace, and those items do not require the hands to work at an average level of more than 15 cm above the work surface. Weights, that are being handled with, need to be less than 4.5 kg and also when workers are doing assembling or writing tasks for the majority of the shift they need to be in a sitting position. Standing workplaces are used in situations if there is no knee clearance for the seated operation, if objects that are being handled weight more than 4.5 kg. They are also used when reaches are frequent and high, low or extended such as those in front of the body, and whenthe operations, that have to be done, are physically separated and require frequent movement between workstations. In the pictures below, are given examples and measurements for sitting and standing workplace.

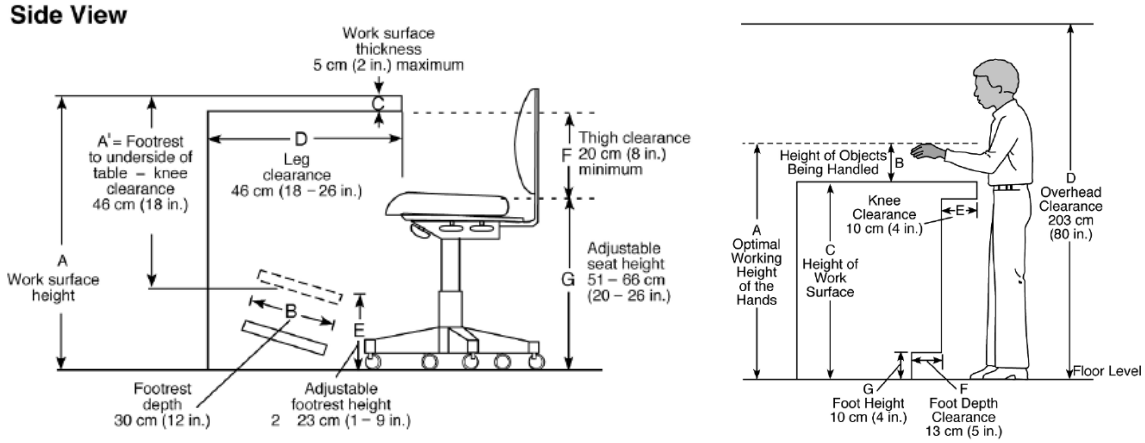

Figure 1 – Recommended dimensions for a seated workplace and recommended standing workplace dimensions [3]

3. SOFTWARE APPLICATION SIEMENS PLM JACK

There are lots of softwares for giving solutions on how to design an ergonomic workplace. One of the most popular software is Jack Siemens. This software offers ergonomic aspects of manual operations during early stages of designing products and manufacturing processes by improving safety, efficiency and comfort of the workplace environment using digital human models [4]. These human models represent a wide range of worker population, as well test existing designs for multiple factors, including injury risk, user comfort, reachability, line of sight, energy expenditure, fatigue limits and other important human parameters. Using Jack can save time and reduce costs by enabling improvement of the product quality and process feasibility in the early product lifecycle.

Figure 2 – Task Analysis Toolkit [4]

3.1 Tools and Methods

Some of the benefits of the software are:

- Human interaction during the design, build and sale stages of the product lifecycle is inevitable, and Jack helps with assessing the human element throughout the whole product lifecycle
- Jack saves time and money while enabling creation for more human-friendly designs
- Jack provides a complete environment for all ergonomics and human factors needs, offering a comprehensive suite of analysis capabilities
- It can uncover human performance and feasibility issues early in the design process, allowing for big savings from a small investment
- Jack enables to effectively communicate issues and visualize potential solutions

The Jack solution provides the latest human simulation capabilities including:

- Task Simulation Builder, which enables to use high-level commands to instruct the human model in the 3D, virtual product and work environment. This capability facilitates quick animation and scenario development. Once a task sequence has been defined for the human model, there can be test of what-if scenarios by swapping in human figures of different sizes, by moving objects in the environment or by changing the weight of an object. Human postures and motions are automatically recomputed to reflect the updated scene. The simulation even provides ergonomic reports and time estimated based on standard time tables.
- Human posturing techniques, which enable to quickly and accurately posture the human models with minimal input. Jack boasts some of the most sophisticated. methods for figure manipulation and posture prediction available on the market today, including the ability to predict posture based on hand force exertions.
- Smooth skin human modeling, which employs deformable mesh technology to represent visually and anthropometrically accurate body shapes.
- Advanced hand modeling, which provides a premier solution for representing hand anthropometry and other hand modeling features.
- Customization capabilities, which include an easy-to-access scripting/programming interface to create analysis and interface add-ons that can be used to extend and custom-fit Jack to one's business needs (many of these customizations are openly made available to the Jack user community).

4. CASE STUDY-AN EXAMPLE IN FACTORY ELODA

An implementation of work study and ergonomics has been done in Končar-MES d.d. The purpose of the case study was reducing the lead time for assembling an electromotor.

Končar-MES Inc. is a Croatian company which manufactures electromotors (three-phase motors, single-phase motors, brake motors, flame-proof motors and servo motors), fans and electrical drives. They have a developed, flexible manufacturing program that is supported by the development and advancement of technology and production processes that achieve their goals and can accommodate different customer and market demands. To achieve their goals, they have a developed mission, vision and strategy by which their production and product development are in accordance with the latest European standards, enabling them to continually develop and business stability through satisfying specific customer needs. They pay great importance to the quality of their own products by investing in the new technologies and organizing and motivating employees, resulting in a reduction in production costs.

Time, for assembling ten pieces, was taken with the software SimData (Figure 3) which allowed collecting time from multiple workstations and gave analysis and graph data during and after collection [5]. The assembly of 10 ordered engines takes place on the table and the worker performs a separate process on each of the 10 products before switching to another process.

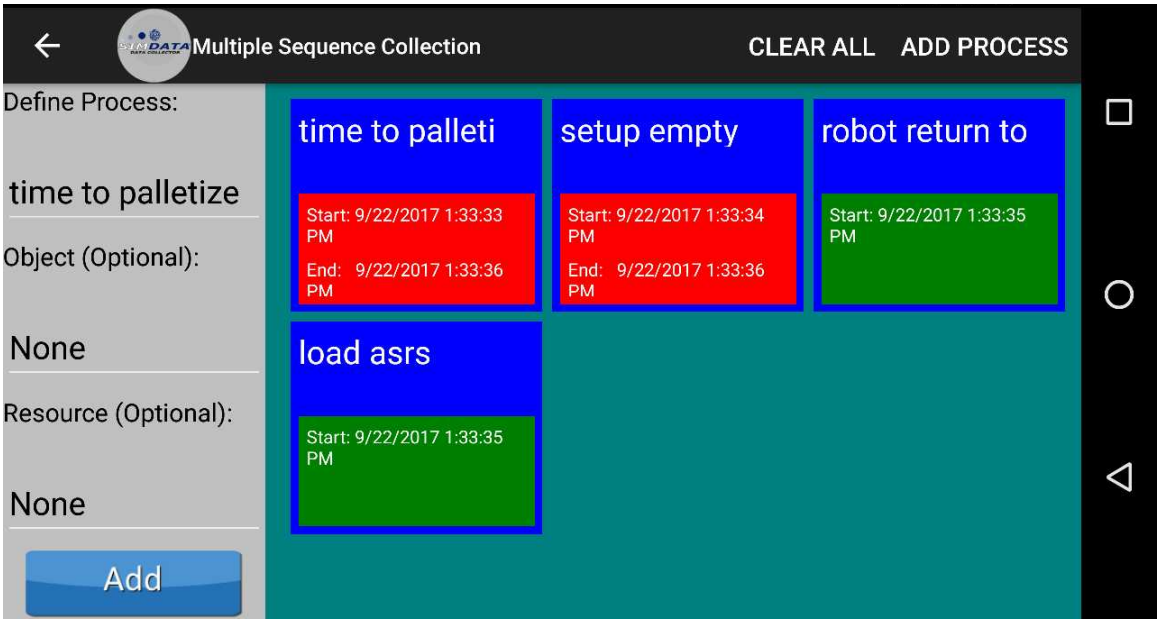

Figure 3 – SimData software [5]

All the necessary parts for motor assembling such as screws, rotor, spring, fan, casing are located near the worker. They are neatly arranged on the table next to or on a trolley near the work desk. As the trolley can ride, the worker is able to approach them when needed, and thus reduce unnecessary movements. For the analysis of ergonomic principles in the Jack Siemens program, dimensions of the workbench, auxiliary table holders, trolleys for certain parts such as fans, rotor, bearing shields and casings, dimensions of the auxiliary desk for easier operation of individual operations, and wheelchair dimensions storage of finished products. Given the different operations, there are different strains and loads on the workers.

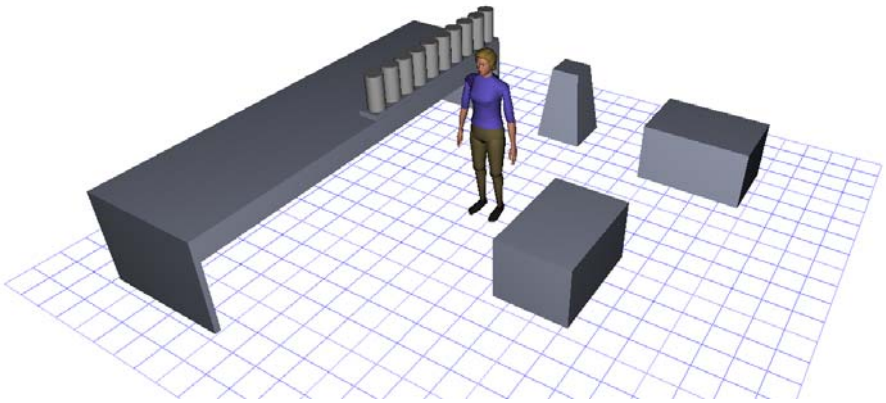

Figure 4 – Display of the workplace in Jack Siemens

After doing a simulation where the worker walks to the table and picks ups the electromotor and puts them on the cart behind them, software offered some of their analysis like Task Analysis Toolkit which gave us the lower back analysis and Ovako Working posture Assessment System (OWAS). The compression force on the lower back, which happens when the worker in putting down the product, was 1707 N. That force is lower than the standard one which is 3000 N after The National Institute for Occupation Safety Health (NIOSH). This number tells us that there is a possibility of injuring the lower back (Figure 5).

Figure 5 – Lower back analysis

OWAS identifies the most micron work postures for the back, arms and legs and the weight of the load handled. Whole body posture is described by these body parts with a four digit-code. The code for this simulation was 4121. All possible positions are divided into four categories that show the need for ergonomic changes. The previous simulation falls into the number two category according to which the position of the body can have adverse effects on the musculoskeletal system.

Since not all parts of the body are equally loaded, Jack offers estimated time of recovery in seconds (Figure 6).

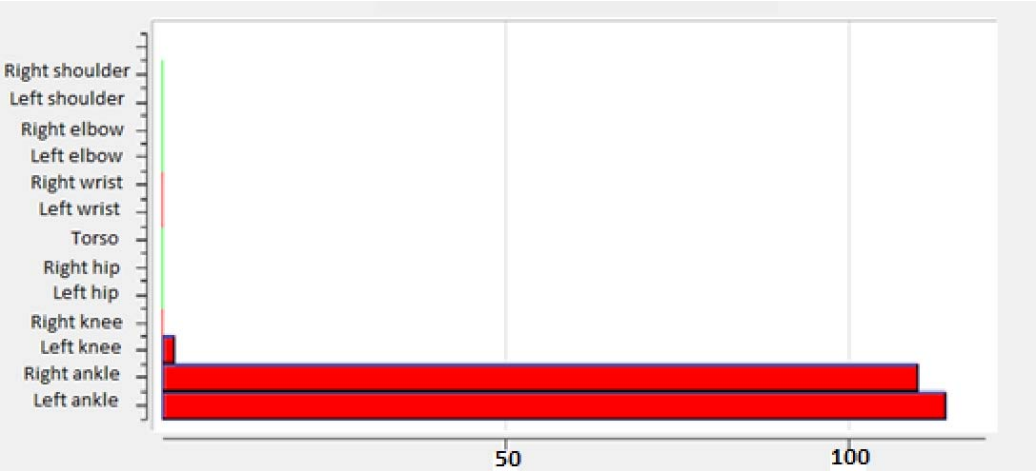

Figure 6 – Estimated time of recovery in seconds

The most difficult task in this simulation was walking from the table to the cart and vice versus, ankles are the parts of the body that carry the biggest load so for them time of the recovery is the longest.

After arranging the workplace in a simulation Jack also calculated the time for every action that happened like walking to the table, picking the product and leaving it on the cart and the same process again (Table 1).

Table 1 – Calculated time in Jack Siemens

Task	**Time (sec)**
Taking the first product	3,23
Putting the first product	5,44
Taking the second product	6,8
Putting the second product	6,43
Taking the third product	5,06
Putting the third product	5,11

To reduce this time, they could use conveyor right in front of the table. This way the worker wouldn't have to walk which would result in reducing this time (Figure 7). Every products, on the tables that are nearby, have to be put on a conveyor to go to the quality control area, so they have to put this product also but only later. So this would also be financially profitable.

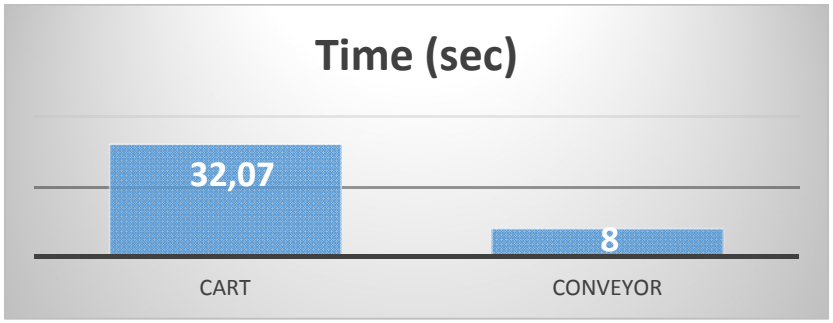

Figure 7 - Difference between using carts and conveyor on the table

32,07 is the time for picking up three products and putting them down on the cart. 8 seconds is the time we get when we eliminate the time for walking which is the biggest waste. The lead time was reduced by 75%.

Optimization of the workplace is more difficult to introduce precisely because of different body positions and the affordability of certain solutions. A possible solution is the introduction of a rotating-lift table (Figure 8). They are used when there is a request for access to multiple pages. It enables greater effectiveness and productivity of workers by removing the need for reaching, uncomfortable body positions, and reducing the likelihood of repeated injuries associated with such actions. They are widely used in assembly because they allow workers access to numerous products or tools. Additional benefits include minimizing the space required for the workplace and reducing possible collision hazards.

Figure 8 – Example of a rotating and lifting table **[6]**

5. CONCLUSION

Application of ergonomic principles and recommendations are important because they reduce physical stress, illness, facilitate task execution, and enable rapid information exchange in the work environment. With the measured time of the operation of assembling, we have an insight of the longest operations and possibilities of reducing their time if it is possible. We can reduce time by redesigning the workplace in a more ergonomic way so that workers don't have to do some unnecessary actions and for this case it was taking parts from the cart, walking to every product, walking to the storage for some parts and putting the final product on the cart. Two given proposals were having a conveyor on the table. Worker would then put the final product on it and wouldn't have to walk to the cart which would result in reducing the time of this operation. Second proposal is assembling products on the rotating and lifting table since for every operation the position of the worker is different, so are the strains and loads for the body. With this proposal, the work of the worker could be facilitated. By using software Jack, we can determine strains and loads on the body in a simulation with human models. Finally, by virtual analysis of workplace prior its physical design we can foresee possible shortcomings that are relevant for proper workplace design.

6. REFERENCES

[1] D., Taboršak: *Studij rada*, Orgadata, Zagreb, 1994.
[2] *Workplace Ergonomic 101*, ergo-plus.com/workplace-ergonomics/.
[3] *Kodak's Ergonomic Design for People at Work*, Second Edition, The Eastman Kodak Company, 2004.
[4] *Jack User Manual*, Version 8.2, 2014 Siemens Product Lifecycle Management Software Inc., 2014.
[5] *SIMDATA*, Data Collection, www.createasoft.com/Products/Time-and-Motion-Studies-Software.
[6] *Lift Products* Inc., www.liftproducts.com/lifttables/stainless/roto-max-ss.html.
[7] Salvendy, G.: *Handbook of Human Factors and Ergonomics*, 4. Edition, Jonh Wiley &Sons Inc, 2012.
[8] Singh; L. P.: *Work study and ergonomics*, Cambridge University Press; 1st edition, 2018.