Design of the Assembly workplace considering the Ergonomics

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Abstract

The main aim of this article is to design an assembly workplace for a socket hub. The first part of the article describes conducted analysis of assembly and disassembly of the socket hub. On the basis of the done analysis, the assembly process was worked out. Considering to serie production, 4 different assembly workplaces were designed for piece, small series, serial and serial production with the cooperative robot involved. The simulation of ergonomic conditions of the first two variants was done assembly process using software Siemens Tecnomatix Jack 8.4. The proposed workplaces were assesed considering the ergonomics workplace, taking into account the acceptable and conditionally acceptable position of the employee. The result of the work is a technical-economic comparison of the workplaces based on the evaluated workplace ergonomics with an emphasis on increasing the labor productivity.

Keywords: assembly workstation, Siemens Tecnomatix Jack 8.4, ergonomics

1. Analysis of the subject of assembly

The main purpose of this article is to design an assembly workplace for a socket hub. In the first part, the analysis of assembly and disassembly of the socket hub was carried out. On the basis of the analysis, four different designs of the assembly site were developed with regard to the series production. For the first two variants simulation of ergonomic conditions was performed, and the workplace was assessed from the point of view of ergonomics with regard to the acceptable and conditionally acceptable position of the employee.

The subject of the assembly was a socket hub. This is a classic, commonly available, plug-in socket that allows you to divide the power supply and connect up to three appliances at the same time (see Figure 1).

Figure 1. *Socket hub EMOS E2010*

The first step was to analyze the disassembly of the socket hub. The socket hub was split to the components, which were measured, and a 3D model was created for each part. The socket hub technical drawing was created from the 3D model. For the sake of clarity, only the main socket dimensions are shown in the enclosed drawing (see Figure 2 below).

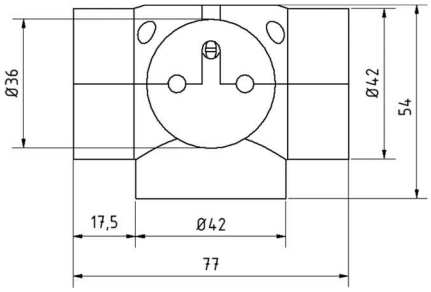

Figure 2. *Drawing of the basic dimensions of the socket hub*

Based on the socket hub analysis, a piece list has been established (see Table 1), which is supplemented with graphic views of all socket hub components. Each of the components is marked with a suitable letter according to the material and the serial number.

Table 1. *Socket hub piece list EMOS E2010*

Označení součásti	Název	Počet kusů	Náhled
P1	Spodní plastový kryt	1	
E1	Měděný vodič	1	
E2	Měděný vodič	1	
E3	Měděný vodič	1	
P2	Vrchní plastový kryt	1	
S1	Šroub M2x8	4	

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2. Design of the assembly process

The basic requirement for the workplace was its flexibility and ergonomics of the employee's working positions. Flexibility is essential because of the frequent change of the montaged object and the variability of the assembly operator. An important parameter of the workplace layout was the ergonomic risk parameters of the worker's position during the assembly. In total, four different variants of the assembly workplace were developed.

The first type of assembly workstation was designed for manual piece assembly, the second for small series manual assembly, and two other variants were designed for serial production. In the last variant for serial production, human cooperation robot was used.

2.1 Simulation of ergonomic conditions

The Tecnomatix Jack 8.4 simulation software was used for simulation and visualization. In this program a layout was developed for all the mentioned variants of the installation workplace. In addition, two different physiological models of operators (see Figure 3) were created. To focus on a wide range of people, the first figure was a tiny woman and the second figure was a tall man. The size of the people was set according to the available NHANES database, which is part of the program database.

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	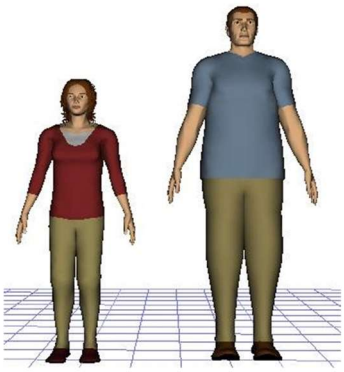	
Výška	149,7 cm	188,2 cm
Váha	50,2 kg	125,1 kg

Figure 2. *Parameters of created figures*

In the SW a simulation of manual and small series simulation were performed, for which the acceptable, conditionally acceptable and unacceptable positions of the worker from the point of view of ergonomics were evaluated. Body, head (neck), upper limbs, wrists, elbows, knees and feet positions were evaluated. Ergonomic positions were evaluated according to the Government Decree No. 361/2007 Coll. using the NV361 module in which all of the above parameters can be evaluated.

2.2 Manual assembly for piece production

The main criterion for the design of the workplace for manual piece assembly was the variability of the equipment. Due to the frequent change of the product assortment. A prerequisite is the installation of only a few sets of socket hubs. Emphasis is placed on the versatility of the equipment used in order to be used for other assembly or other activities in the company.

Designed equipment (see Figure 4) for this workplace is a height-adjustable table, ergonomic height-adjustable chair and a pallet located on both sides. On the left pallet are the components necessary for the socket hub assembly and the right pallet is designed for folding assembled socket hubs.

Figure 3. *Workplace placement before assembly*

Prior to the installation in this workplace, the worker must supply the workstations himself from the stockpile. All the necessary components are placed on the pallets, which must be appropriately positioned on the worktop (see Figure 5). There are prepared lower and top plastic covers on the left side of the work table (for the worker). On the right, empty boxes are located for assembled sockets. Small copper wires and screws are located in the center of the smaller boxes. Each component has its own place and is exactly 27 times in one set (carrier). A universal hand screwdriver was selected to tighten the screws.

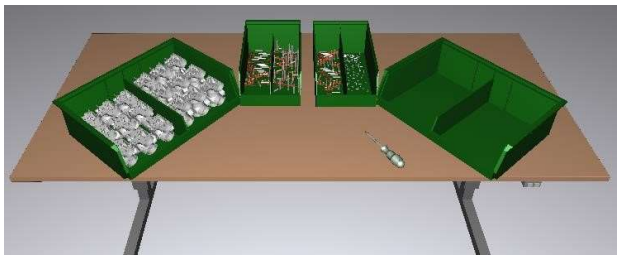

Figure 4. *Location of components for piece production*

2.2.1 Simulation of the manual assembly workplace for piece production

The results of the workplace simulation revealed several workplace imperfections. Copper wires and screws partially extend beyond the worker's reach, this may lead to health problems over the longer term. Several unacceptable positions of the head and neck were also revealed. In particular, too much of a rotation of the head when removing plastic parts from the crate and unacceptable head inclination when inserting the wires into the plastic cover. Most often, the wrists reach the critical position during manual assembly when inserting the parts into the plastic cover and screwing the screws (see Figure 6) for wrist rotation.

Figure 5. *Sample of unacceptable wrist position*

2.2.2 Evaluation of piece production workplace

At the workplace of the piece production, the worker often gets into an unacceptable position. The workplace is not suitable for a long-term use. The calculated assembly time is 100 seconds according to the simulation. Removal of freely positioned, non-oriented copper wires could increase the assembly time. The advantage is the low cost of the workplace (see Table 2) and versatility, which will ensure the possibility of further use for another piece assembling. The workplace is suitable for assembly a small number of socket hubs up to 100 pieces.

Table 2. *Initial costs for piece production workplaces*

Unit	Estimated price [Kč]
Height-adjustable table	15 000
Height-adjustable chair	10 000
Screwdriver	150
Set of crates	700
Total	**25 850**

2.3 Manual asssembly for small series production

In the variant of manual assembly for small-series production, the employee only deals with the assembly of the socket. Storage and collection of crates is provided by another authorized worker. During assembly the main requirement was once again the versatility of the workplace and improved ergonomics of the work positions.

The basic designed equipment (see Figure 7) is an ergonomic chair and a height-adjustable table. To ensure greater clarity, one crate was used for each component. Part of the workpiece is an electric screwdriver that eliminates wrist rotation and specially designed tool for holding a socket.

Figure 6. *Deployment of small series production workplace*

2.3.1 Ergonomics of small series production workplace

Copper contacts are placed in the grooves in the crates to avoid interlocking and damage. This method reduces the final assembly time by facilitating the collection of components and eliminating the need for orientation of the contacts to the correct position.

The crates are supported so that they are tilted towards the worker. By re-positioning and tilting the crates, all crates are within the reach of the worker (see Figure 8). The special tool is positioned in the ideal position for frequent work movements.

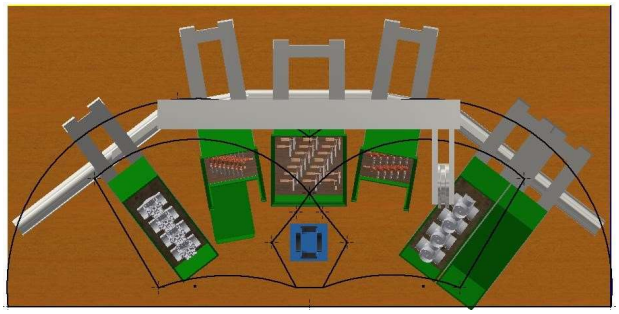

Figure 7. *Reach distance for small series production*

From the point of view of the working position in this workplace, it is not necessary to pull the head (see Figure 9) into an unacceptable position when removing the components from the edge crates. By using a special tool to hold the plastic cover, the employee can use both hands to work, eliminating unacceptable wrist positions. The product has been reduced to an inappropriate position when the head (or throat) is lengthened. Likewise, using an electric screwdriver reduces the strain on the wrist area. height-adjustable table. The employee gets in an unacceptable position when picking up an electric drill. The solution is to reduce the height of the structure on which the drill is mounted. An unacceptable wrist position occurs also when removing the screws from the left part of the crate.

Figure 8. *Acceptable head and neck position*

2.3.2 Evaluation of small series production workplace

At the workplace of small series production, the worker gets into an unnatural working position only rarely. Most of the unacceptable positions were eliminated by new spacing, tilting crates and the use of the special tool.

The appropriate orientation of the copper contacts, the aligned plastic covers in the carrier and the electric screwdriver to tighten the screws reduces the assembly time of one piece. The supply time for the workplace, which was performed by another employee in this variation, was lost. With the exception of a special tool for holding plastic covers, the workstation is fully versatile and can be used for other small assemblies.

The socket assembly time calculated based on the simulation is 55 seconds. The cost of the assembly plant is CZK 58,500. (see Table 3). The workplace is suitable for fitting up to 5000 pieces of socket hubs.

Table 3. *Initial costs for small series production workplaces*

Unit	**Estinated price [Kč]**
Height-adjustable table	30 000
Height-adjustable chair	10 000
Fixcture for holding socket hub	3 000
Electric screwdriver	13 000
Grooved plates for copper contacts	2 000
Crates	500
Total	**58 500**

2.4 Assembly for serial production

The assembly plant for serial production was designed for up to six operators. The workplace is based on a manual workplace for small series production. The main innovation in the workplace is the conveyor, after which the individual components are transported. In front of the conveyor there is a work area on which special tools are placed to hold plastic parts.

Designed equipment for this workplace (see Figure 10) are ergonomic chairs, electric (or pneumatic) drills for tightening bolts and footrests for lesser employees. Unable to use a height-adjustable table, therefore an adjustable footrest was used.

Figure 9. *Deployment of the serial assembly workplace*

2.4.1 Ergonomics of serial production workplace

Due to the complexity of the simulation and the similarity of workplace placement with the previous variant, no ergonomics of working positions was simulated. The option is based on a small series production workplace, and therefore we expect similar results in employment positions. A suitable seating position for smaller workers is provided with a height-adjustable chair and a footrest (see Figure 11).

Figure 10. *Workplace solutions for people of varying heights*

Crates with components are almost all within range for the worker (see Figure 12). The special holding tool is placed in the ideal position for frequent movements.

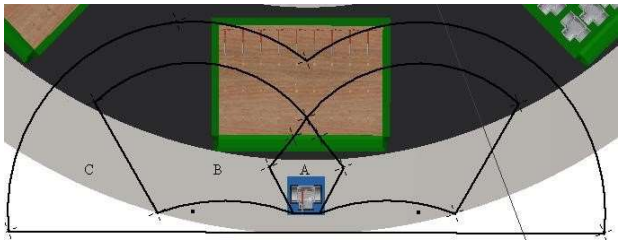

Figure 11. *Reach distance of the serial production workplace*

2.4.2 Evaluation of serial production workplace

Based on the assumption of similarity to the small-scale production variant, simulation of the assembly process was not performed.

The advantage of serial assembly is greater clarity and the possibility of placing the drill in a more suitable position. The extension of the installation time is unacceptable. Using a step conveyor, it is necessary to introduce the line timing according to the longest operation (5.4 s). This will increase the assembly time to 64.8 seconds. The cost of the entire workplace is around CZK 1,400,000 (see Table 4).

Table 4. *Initial costs of a serial production workplace*

Unit	Estimated cost [Kč]
Design of assembly workplace	1 000 000
Roller conveyor	200 000
Set of a crates	1 200
Wooden grooved plates for copper contacts	3 000
6 x Height-adjustable chair	60 000
6 x Footrest	12 000
6 x Fixcture for holding socket hub	18 000
6 x Electric screwdriver	78 000
Total	**1 372 200**

2.5 Cooperative assembly workplace for serial production

The last variant is the cooperative workplace for serial production. A cooperative robot was involved to speed up the assembly and improve ergonomics. The proposal was based on a manual production workplace for small series production.

The proposed workplace equipment (see Figure 13) is a rotating table with two plastic holders. The basic element of this assembly workplace is the use of the collaborative robot called YuMi, which places the copper conductors in the lower plastic housing. Furthermore, ergonomic chairs, electric drill, vibratory screw feeder, and construction for holding crates.

Installation begins with the worker inserting the plastic cover into the special tool. Then rotates the rotating table towards the robot. The robot places the copper contacts and the table rotates back to the operator. The operator attaches the upper part, the socket hub rotates, assembles with the screws and sets socket between finished products.

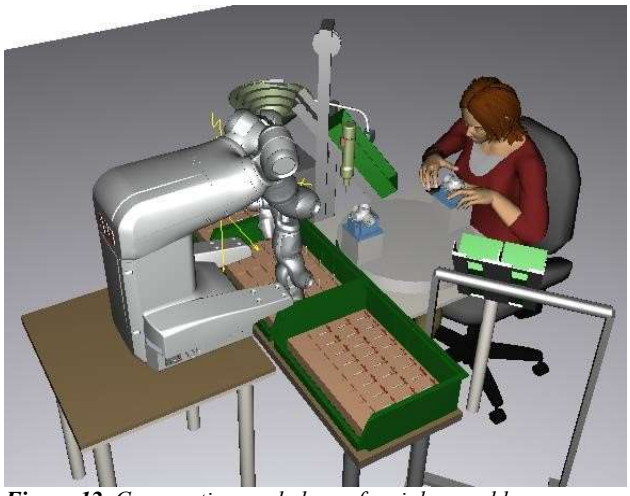

Figure 12. *Cooperative workplace of serial assembly*

2.5.1 Ergonomics of the cooperative workplace

Due to the similarity with the workplace of small series production, no ergonomics of work positions was simulated. We assume the same job results as the workplace we were based on. The height of the workspace suits the high operators. Smaller employees can set the optimum working position by using a height-adjustable chair and a footrest. The crates are folded, oriented towards the worker and located at its ideal range (see Figure 14).

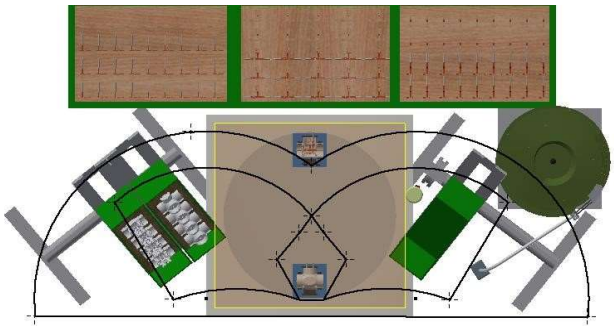

Figure 13. *Reach distances of the cooperative workplace*

2.5.2 Evaluation of cooperative workplace

This option is based on a small series assembly workplace. In addition, a vibrating screw feeder is used to eliminate wrist rotation. One of the assembly part is made by a robot that inserts copper contacts into the lower plastic cover. The robot significantly reduces the workload of the worker.

The assembly time of one piece is 40 s and the cost of the cooperative workplace is around CZK 1,250,000 (see Table 5).

Table 5. *Initial costs of the cooperative workplace*

Unit	Estimated cost [Kč]
Robot Yumi od ABB Group	1 000 000
Rotating table	100 000

Construction for crates	10 000
2x Fixcture for holding socket hub	6 000
Vibrating screw feeder	100 000
Height-adjustable chair	10 000
Footrest	2 000
Electric screwdriver	13 000
Set of crates	1 800
Wooden grooved plates for copper contacts	3 000
Total	**1 245 800**

3. Technical and economic assessment

Based on the results of the simulations, the comparison of the ergonomic positions (see Figure 15) of the worker for manual piece and manual small series assembly was processed. Ergonomics of the workplace for small series production is considerably better in terms of working positions than the workplace ergonomics for piece production. In case of piece production, the worker often gets into an unacceptable position, while in the small-scale only when grabbing the drill and removing the bolts from the crate.

The socket assembly time at the manual small series production plant is nearly twice as low. Only the acquisition costs seem to be better for the piece assembly (see Table 2 and Table 3).

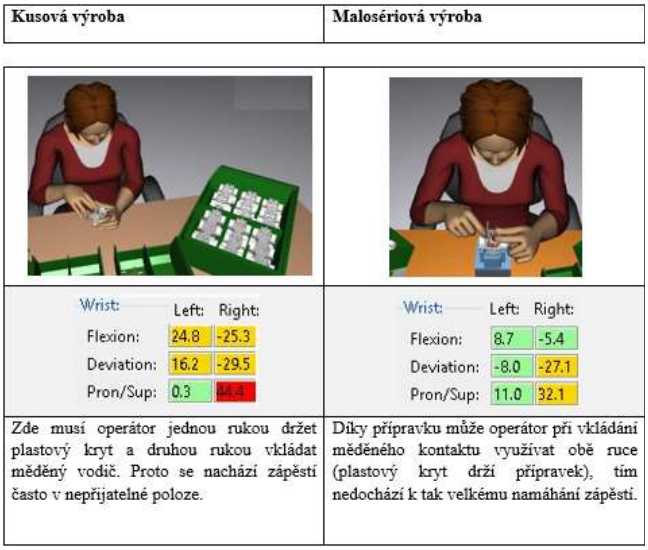

Figure 14. *Comparison of piece and small series assembly*

The workplace with mechanized serial assembly is clearer and is designed for up to 6 people at the same time. However, due to the conveying of the conveyor, time of assembly one piece is extended. The disadvantage is the significantly higher cost of the workplace.

In the cooperative workplace, the remaining unacceptable positions are reduced due to the better positioning of the electric screwdriver and the use of the vibratory screw feeder. The collaborative robot reduces the workload of the worker and reduces the time for the installation of one socket. The disadvantage is the high cost of the robot, which is not surprising. However, collaborative robot YuMi is very flexible and can be easily used later for other applications.

4. Conclusion

On the basis of the analysis, the designs of assembly workplaces for piece and small series production were made. For all workplaces the installation procedures and the description of the workplace equipment were prepared. Simulation and assessment of acceptable and unacceptable operator positions were created in the software Siemens Tecnomatix Jack 8.4. The initial costs were estimated for all workplaces.

In the final part, the workplace of piece and small-lot assembly was compared in terms of ergonomics of the working position.

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