# The Influence of Assembly Workplace Layout on Ergonomics

VÁCLAV ŠTEFAN, KAMENSZKÁ ADRIANA
Institute of Production Technologies
Slovak University of Technology, Faculty of Materials Science and Technology
Jána Bottu 2781/25, 917 24 Trnava
SLOVAKIA

*Abstract:* - Assembly is an important element in the production process. It largely influences the quality of the product and especially the time required to produce the final product. Studies in the field of assembly show that as technology advances, it is necessary to use new improvements at each stage of production, which includes the assembly stage. The aim of every enterprise should be to make the best and most economical use of all the resources at its disposal, on the one hand, and to increase productivity, on the other. Nowadays, ergonomics must be taken into account when solving problems or rationalizing assembly, since most assembly operations are carried out manually. In the theoretical part of the document, the assembly process is described together with the factors that influence it, focusing on manual assembly and its impact on ergonomics. The practical part describes an experiment carried out with the aim to increase the ergonomics of workers and to make the assembly process more efficient at an assembly workplace in a selected industrial enterprise through pre-arrangement of the workplace.

*Key-Words:* Assembly Process, Manual Assembly, Ergonomics, Workplace Design, Layout, Experiment

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## 1 Introduction

The assembly process consists of assembly operations of joining components into units (assembly nodes, groups) and final products [6][3].

It is realized in a specific technically and economically expedient sequence. From the point of view of organization, assembly can also include preparatory, auxiliary, and service activities. These not only support the assembly process, but also rationalize it. Assembly processes are carried out according to predetermined rules and take place in specific technical, technological, organizational and economic conditions [7].

If the assembly process needs to ensure successful goal-directed behaviour, its goal-directed design is already essential. If the assembly process already exists, it needs to be innovated or rationalized. For this reason, a thorough knowledge of the various factors that influence the assembly process and its design is important. It is also necessary to take into account the interactions and interrelationships between the different factors. The assembly process is strongly influenced by factors that can be summarized in 5 groups [9]:

1) Properties of the object of assembly/assembled product – dimensionality, weight, complexity, etc.
2) Production conditions – in particular the level of preparation of design and technological documentation, the total number of pieces, the length of the period, the seriality
3) Workforce – number of workers, demands on their expertise, physical and mental workload
4) Work resources – types, number, level of automation
5) Process organization and management – applied organizational form of assembly, division of labour, etc.

In addition to the factors mentioned above, automation also has a significant impact on the assembly process. According to the degree of automation, the assembly process can be divided into [1]:

- Manual Assembly
- Mechanised Assembly
- Automated Assembly

The basic structural unit of assembly processes is the assembly operation, which is carried out at the assembly site. The organisation of assembly processes has a strong influence on the realisation of assembly. The main task of the organisation is to ensure the appropriate temporal, spatial and material progression of the assembly process [14].

The big trend today is to increase assembly efficiency through automation, but many companies still have a number of assembly tasks that require human input. This means that even in today's "automated age" there is still manual assembly [10].

# 2 Ergonomics in Manual Assembly

## 2.1 Manual Assembly

Manual assembly is the traditional, in some cases (from a technical and economic point of view) necessary way of joining components, assemblies and units. In manual assembly, a worker assembles previously manufactured components and/or sub-assemblies into a complete product or product unit. This type of assembly uses mainly the energy of the worker's hands. Manual assembly has the following characteristics [3]:

- the use of simple fixtures,
- use of universal assembly tools,
- alignment of the parts to be joined,
- economical handling and transport of handled parts,
- ergonomically optimal workplace of the worker.

The work activity that is carried out in such workplaces is characterized by monotony and work at a forced work pace. Simply put, the worker is not free to choose the work pace and his/her activity is subordinated to the rhythm of the work process and/or the rhythm of other workers in the process [11].

The trend in designing or innovating assembly workplaces is precisely the ergonomic aspect, which addresses the interaction of the worker and his working environment to increase work productivity, efficiency and, last but not least, work safety [13].

## 2.2 Ergonomics

Ergonomics is a field focused on human factors and describes the scientific consideration of working conditions, particularly with respect to the physical and mental characteristics of human operators, abilities, limitations, and needs [8].

The main goal of ergonomics is to preserve human health, i.e., his physical, mental, and social satisfaction, to create optimal conditions for the performance of his work and to ensure his well-being at work. In addition to these factors, the use of ergonomic principles also has a positive impact on economic indicators. These are directly influenced by a reduction in the cost of sick leave, accident rates, an increase in a person's performance capacity and, consequently, an increase in labour productivity [4]. According to the authors Gilbertová & Matoušek, a person's executive capacity is affected by [2]:

a) sensory capacity – includes primarily the function of sight and hearing
b) mental capacity – its basis is the intellectual level of a human
c) human adaptation to working conditions – it is influenced by several factors, such as the type and content of work activity, the risk associated with work, the work and rest regime and the social climate at the workplace

As we mentioned in the previous section, there are still many assembly activities that must be performed by a human. Figure 1 shows the elements of the working system that affect the level of manual assembly from an ergonomic point of view [12].

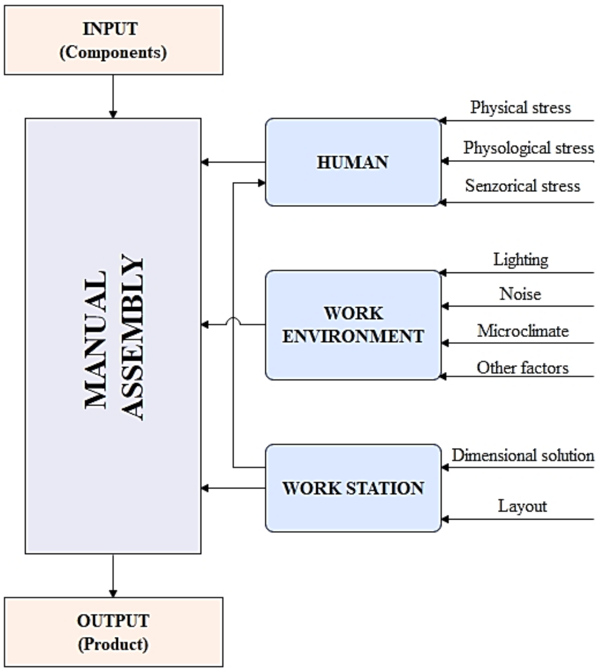


Fig. 1 Elements of a Working System [12]

When designing or upgrading assembly processes and workplaces with regard to manual assembly, the following areas must be addressed from a human perspective [11]:

- organisation of working movements - elimination of complex and strenuous movements
- physical and psychological stress at work
- work and rest regime

- dimensional and spatial arrangement of the workplace - elimination of redundant walking of the worker, shortening of travelled paths

It is the area of dimensional and spatial arrangement of the workplace that can largely affect the ergonomics of the assembly worker in the form of excessive walking during the assembly process.

# 3 Description of the Current State of the Assembly Workplace

## 3.1 Assembly Workplace Layout

The subject of the experiment is the assembly workplace of piston valves, which are part of the construction of hydraulic dampers. The assembly workplace concentrates on manual assembly and can therefore be classified as one of the more dimensionally compact workplaces. The workplace consists of 5 sections:

1. Section for part pre-assembly
2. Section for part crimping
3. Lubrication section of the component
4. Final part testing and packing section
5. Expedition

The overall layout of the assembly workplace along with the workplace elements are shown in Figure 2, which represents the layout of the workplace.

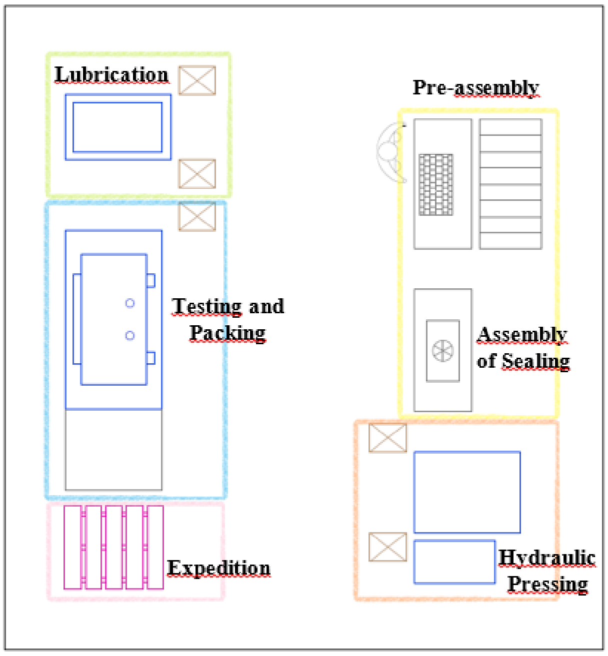


Fig. 2 Layout of the Assembly Workplace

The pre-assembly section consists of two workbenches. On the first table, connected to the rack, manual pre-assembly of the part is carried out according to the BOM. The second assembly table houses the equipment for assembling the gasket.

The pressing section is equipped with one hydraulic press, on which 3 pressing operations of the part are performed in sequence. The assembly section includes two auxiliary trolleys on which the parts are placed before and after the pressing operation.

Next is the lubrication section, which houses the equipment by means of which the lubrication of the part of the component is carried out. This part of the component is very important and necessary for the complete assembly of the valve and its functionality.

The last section where the assembly operation is carried out is the section of testing and packaging of components. The first part of the section is the equipment that is needed to test and check the functionality of every single assembled component. The second part of the section is the workbench on which the functional parts are packed into boxes of a certain number of pieces.

## 3.2 Description of the Component Assembly Process

The assembly process begins with the first operation, namely the pre-assembly of the component on the first assembly table. The worker removes the prescribed number of components from the boxes according to the BOM and inserts them successively on the individual pins of the assembly pallet. The assembly pallet is a plastic tool of certain dimensions from which 10 pins protrude. These pins are used to 'thread' the components one by one according to the type of component. Assembly is always carried out on one pallet only, with a capacity of 10 components. After the first operation, the worker moves with the pallet to a second table, where a seal is applied to each stacked part. The seals are assembled with the aid of the machine.

In the next part of the assembly, a worker with a pallet of pre-assembled parts passes to the pressing section. The pressing operation is carried out on one piece of equipment and is divided into:

- Pressing operation I. – Crimping
- Pressing operation II. – Hard characteristic
- Pressing operation III. – Fine characteristic

Each pressing operation is different, depending on the jigs used and also the pressing pressure settings. Therefore, it is necessary that the entire pallet, i.e. 10 pieces, goes through each pressing operation. The worker then changes the jigs, adjusts the equipment and proceeds with Pressing operation II.

However, Pressing operation II. and Pressing operation III. do not follow directly after each other. After the Pressing operation II. is performed, the worker with the pallet moves to the next assembly section, namely the Lubrication Section. This assembly operation involves the application of lubricant to a critical component of the part. The lubricant is applied to the component by a special automatic device.

After this operation, the worker returns to the Pressing Section to complete the last pressing operation of the part.

The whole assembly process is completed by final testing and packaging. The individual components are tested on special test equipment. The equipment tests the oil flow through the valve. This operation is important from a quality point of view. Every single assembled component is tested on the equipment to meet all quality principles. The parts are then packed by a certain number of pieces into boxes that are moved for shipment - palletized.

## 3.3 Definition of the Issue of Current State

Based on the information from the enterprise and the observation made during operation, the following details of the assembly site were summarized:

- the assembly workplace is set up for two-shift operation, with each shift lasting 7.5 hours = 450 minutes of networking time,
- the production of one shift is set to 140 pieces of manufactured parts,
- each component goes through a total of 5 sections and 7 assembly operations,
- the parts go through the process on pallets = pallet capacity is 10 parts,
- the worker goes through the entire assembly process a total of 14 times to meet the shift production quota.

Following the literature review of the paper and the stated objective of the experiment, the focus of the above-mentioned requisites is on the total path travelled by the worker during the work shift, which is directly affected by the layout of the assembly workplace. Figure 3 shows the layout of the assembly workplace, which illustrates the paths between each operation that a worker must complete to accomplish the complete assembly process. The assembly process paths are marked in sequence, following the established assembly sequence.

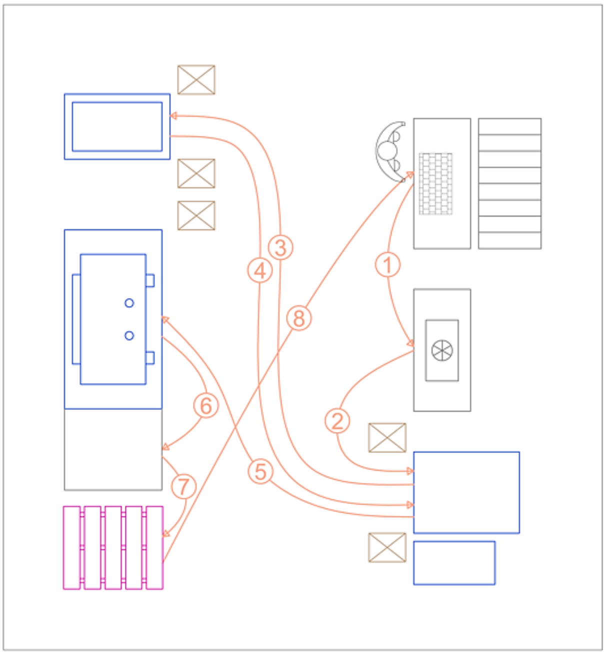

Fig. 3 Layout of the assembly workplace with paths

In terms of ergonomics, the number of steps was observed and analysed, and the length of the routes in meters were determined by mathematical calculation. In the calculation, we considered an employee step length of 1 step = 0.7 m, which was obtained by calculating the arithmetic average of the step lengths of five different employees. The obtained and recalculated values of the individual assembly workplace routes in meters and number of steps per shift in the current state are shown in Table 1.

| Path Number | Start | Finish | Current State [Steps] | Current State [Meters] |
|---|---|---|---|---|
| **1** | Pre-assembly | Assembly of Sealing | 3 | 2,14 |
| **2** | Assembly of Sealing | Hydraulic Pressing | 4 | 2,69 |
| **3** | Hydraulic Pressing | Lubrication | 9,5 | 6,66 |
| **4** | Lubrication | Hydraulic Pressing | 9,5 | 6,66 |
| **5** | Hydraulic Pressing | Testing | 6 | 4,32 |
| **6** | Testing | Packing | 2,5 | 1,85 |
| **7** | Packing | Expedition | 1,5 | 1,19 |
| **8** | Expedition | Pre-assembly | 8 | 5,75 |
| **Overall** | | | **44** | **31,26** |

Tab. 1 Current State of Workplace

### 3.4 Conclusion from the Analysis of the Current Situation

In the current chapter, we have analysed and described the current state of the piston valve assembly workplace. Based on the information from the company and the observation made by us, it can be concluded that not only time is lost in the assembly process at the workplace, but especially the redundant walking of the worker is caused by the inefficient layout of the workplace.

## 4 Assembly Workplace Design

In order to ensure that the current state of the assembly workplace was made more efficient from an ergonomic point of view, certain changes and measures had to be introduced. The most significant change that would go a long way towards achieving the stated objective in the workplace is the use of a different type of assembly workplace or a modification of the layout of the assembly workplace. This assertion is proven by the experiment carried out.

### 4.1 Experimental Setup

The following design is made to eliminate the number of worker steps and thus make the workplace ergonomics more efficient. The future state of the workplace layout is visualized in a similar way to the current state.

In Figure 4, a layout for the future state of the piston valve assembly site is developed. The workplace is re-arranged, with the change in layout depending on the sequence of the different operations of the assembly process.

In order to verify the correctness and functionality of the incorporated changes, the rationalization tool - the Spaghetti Diagram - has been re-used in the proposal. Subsequently, an individual pathway analysis was performed, Table 2. The evaluation criteria were the same as in the current state, both the number of steps travelled, and the length travelled in meters.

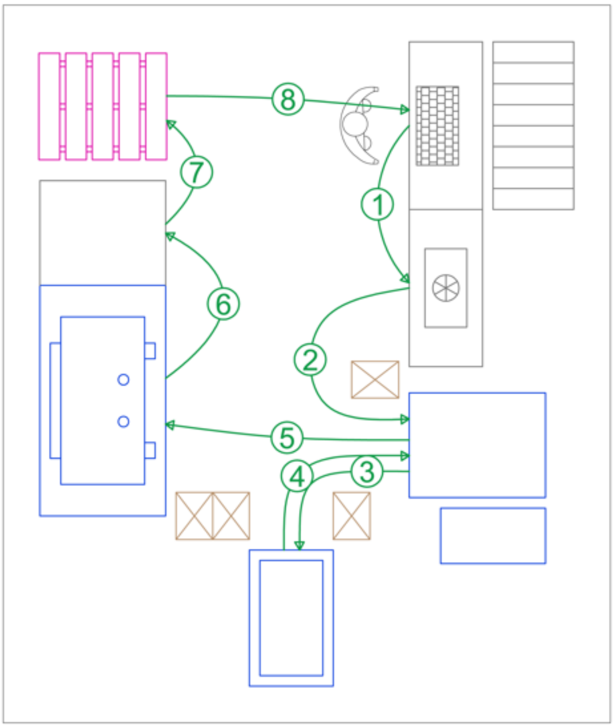


Fig. 4 Layout for the future state with paths

| Path Number | Start | Finish | Future State [Steps] | Future State [Meters] |
|---|---|---|---|---|
| 1 | Pre-assembly | Assembly of Sealing | 2,5 | 1,66 |
| 2 | Assembly of Sealing | Hydraulic Pressing | 3,5 | 2,59 |
| 3 | Hydraulic Pressing | Lubrication | 2,5 | 1,62 |
| 4 | Lubrication | Hydraulic Pressing | 2,5 | 1,62 |
| 5 | Hydraulic Pressing | Testing | 3,5 | 2,33 |
| 6 | Testing | Packing | 2,5 | 1,85 |
| 7 | Packing | Expedition | 1,5 | 1,19 |
| 8 | Expedition | Pre-assembly | 3,5 | 2,32 |
| **Overall** | | | **22** | **15,18** |

Tab. 2 Future State of Workplace

### 4.2 Evaluation of the Experiment

Having analysed the proposal, we have concluded that the incorporation of the proposed changes will achieve the expected positive change in the workplace. If the proposal is applied, there will be a reduction in the number of steps and also a 47.5% reduction in worker routes. This change can

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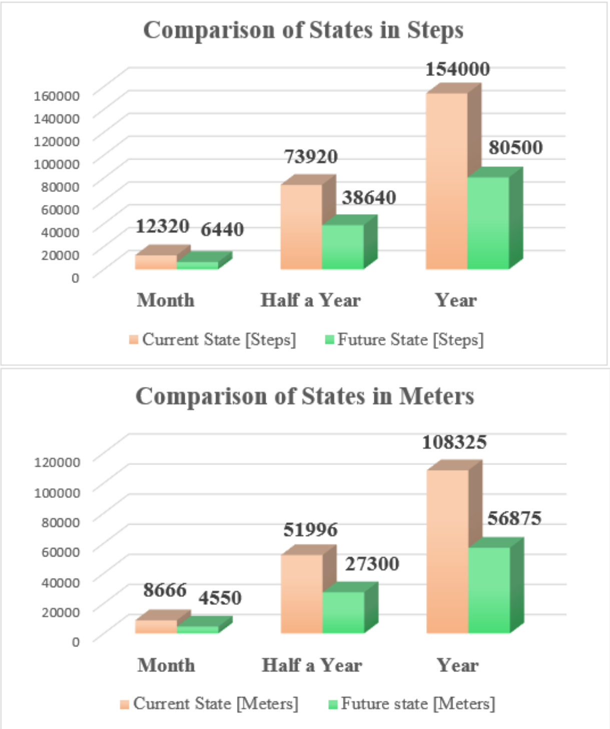
translate into a saving of approximately 51 kilometres in an ideal production year. The comparison of the individual routes in meters but




also the differences in the number of steps of the current and future state are visualized through the graphs in Figure 5.

Fig. 5 Comparison of Current and Future State

## 5 Conclusion

Manual assembly is a work activity that causes physical and mental strain on the worker. It should be a priority for every company to reduce this burden. In order to achieve ergonomic efficiency, appropriately chosen ergonomic measures can create conditions in the workplace in which the worker is able to perform at an increased level and at the same time contribute to an increase in labour productivity. One measure is to make the assembly workplace more efficient.

The aim of the experiment was to increase the ergonomics of the worker at the workplace and to make the assembly process more efficient through the pre-arrangement of a manual assembly workplace in a selected industrial enterprise.

One of the rationalization tools called Spaghetti diagram was used to analyse the current situation and to verify the correctness of the assembly workplace design. By using the diagram appropriately, the assembly workplace and the assembly process itself can be analysed and efficient and inefficient routes can also be identified.

Using the diagram, the wastage in the current state at the assembly site was identified. Consequently, changes to the workplace layout were proposed and implemented with a view to improving ergonomics. The final part involved verifying the functionality of the design in practice. Thus, based on the results of the verification, it can be stated that the new layout and routing eliminated redundant walking of employees by up to 47.5%, thus ensuring process efficiency and increased ergonomics at the selected assembly workplace.

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## Contribution of individual authors to the creation of a scientific article (ghostwriting policy)

The authors Štefan Václav and Adriana Kamenszká prepared both the theoretical and practical parts of the article together.

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