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IMPROVING THE QUALITY OF FINAL PRODUCT BY POKA-YOKE SYSTEM ON ASSEMBLY WORKSTATION: A CASE STUDY

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Abstract. *Contemporary lean oriented organizations strive to improve the quality of final product, increase customer satisfaction and reduce customer complaints. One of the possible solutions to achieve continuous improvement of traditional assembly workstation is the implementation of innovative Poka-Yoke system. Poka-Yoke system has the role that guides the operator step by step through the assembly process and, on this way, increases quality of the final product and decreases errors in production processes. In this research paper authors proposed modular assembly workstation, integrated with a Poka-Yoke system on which the research was conducted. The main aim of this research paper is to show that the implementation of the Poka-Yoke system reduces operator's error and increases the quality of the final product during the performance of monotonous, repetitive assembly tasks.*

Keywords: *Assembly workstation, Defective parts, Good parts, Operator errors, Poka-Yoke system, Quality of final product*

1.INTRODUCTION

In order to remain competitive in a turbulent market environment, contemporary organizations must adapt to the high demands and expectations of customers through the production of unique personalized products of the highest quality (products without defects and additional repairs) at lower costs. Product quality is monitored through the number of customer complaints or costs related to complaints, costs in internal processes, costs of modifications of product, costs which are referred to the waste generated during the production process, the percentage of bad products quality, etc.

Industry 4.0 introduces and develops new tools and advanced innovative manufacturing technologies (Romero et al., 2019) aiming to continuous improvement of product process (throught digitalization and automation with a human touch) and this further results in increased workers` productivity and increasing of product quality and reducing human error at an early step (Lazarević et al., 2019). On the other hand, Industry 5.0 promotes human-centric approach and huge production with low defects and maximum efficiency (Xu et al., 2021).

One of the main problems that occurs on assembly workstations during the performance of monotonous, repetitive assembly tasks is the operator's error, which occur due to a drop in attention and concentration. The number of errors made by operators during installation increases with increasing complexity and variety of components, increasing the steps to be performed or if installation requires specific operator skills and qualifications. Also, human errors often occur due to negligence, loss of attention and concentration, mental fatigue of the operator, etc. A special challenge is the improvement of effectiveness and reducing operator`s errors on prefabricated workstations where workers perform repetitive, tedious and physically demanding assembly activities. One of the possible solutions to achieve continuous improvement of production processes is the implementation of innovative Poka-Yoke system on traditional assembly workstation. Poka-Yoke system has the role that guides the operator step by step through the assembly process and on this way increases quality of the final product and decreases operator errors.

The motive for writing the paper lies in the fact that a review of the literature revealed that a very small number of scientific research papers have been written in which the benefits of implementing a Poka-Yoke system on prefabricated workstations have been pointed out. Therefore, there is room for further advanced research in this area.

2. METHODOLOGY

Workplaces where the operators assemble parts, components, subassemblies into the final product are one of the representative workplaces where complete digitalization cannot be carried out. The reason for this lies in the fact that these workstations produce complex final products in small quantities with great variability. In order to produce the final product of the appropriate level of quality, it is necessary that the assembly activities are performed correctly.

The higher level of quality can be achieved by reducing the number of products of poor quality, reduction of excessive processing of products, reduction of waste during the production process and reducing customer complaints. Numerous studies have concluded that decreasing of concentration of the worker is the main cause of occurrence of many errors. According to (Young, Stanton, 2001) mental workload and stress are the main contributors to human errors in a workplace. (Rabby et al. 2019) considers that cognitive load negatively affects workers attention, memory ability and reasoning ability. Operator errors reduce the quality of final products and cause economic losses due to defects and additional repairs or corrections. The most significant defects that occur due to human errors during manual assembly tasks include the lack of individual parts and components, improper assembly and assembly of the final product from the wrong components, non-compliance with the order of combining components and parts, etc (Kurhade, 2015). Quality control carried out by operators after installation is not sufficient to prevent the occurrence of defects. So, it is necessary to partially automate assembly workstation by low cost solution like Poka-Yoke system.

Operator errors can be reduced and in some situations eliminated by using a Poka-Yoke system that has the role of guiding the operator through the assembly process and inform him what next steps to take. The Poka-Yoke system represents low-cost solution which enables the prevention of errors at the source by detecting and eliminating abnormal conditions. Flashing green lights on the storage containers for parts and components guide the operator through the assembly process and show which parts and components to use at which time to prevent the risk of mistakes. Operators guided by the Poka-Yoke system take the components from the appropriate container with the stored components and parts, where the display lights up green. In this way, there is no need for operators to think about which component to take next or look for components for a longer period of time if there is a drop in concentration. This ensures that the installation activities are carried out correctly.

Application of Poka-Yoke system in assembly processes is shown in research papers (Ahire et al., 2014; Sachin et al., 2015; Estrada et al., 2008). Fasth-Berglund and Stahre (2013) proved that the application of the “pick to light” system, which is based on the Poka-Yoke system contributes to reducing errors and improving the quality of the final product during performing assembly activities.

3.CASE STUDY

The experiment was realized on a proposed innovative modular assembly workstation, in which Poka-Yoke system is implemented (Savković et al., 2022). Unlike the traditional workstation, the proposed one is designed in accordance with the lean principles, main ergonomics principles and adapted to the needs and requirements and individual characteristics of the operator. In new assembly workstation all components storage containers are arranged according to lean principles and taking into account that the zones of the handling area are different for each person. On this way bending, stress and stretching of the body are eliminated. In the new proposed workstation, in which Poka-Yoke system is implemented, the operator follows the operation instruction to pick up the parts and combine them. In this way, the assembly process is carried out step by step in sequence until the product is finished. Poka-Yoke sensors also show how many parts/components are left in the container and when to refill the material. Three male participants, aged between 19 and 27 years participated in the experiment (picture 1.). All three participants are mechanical engineering students. Participants in the experiment first received initial instructions, and after that, they performed assembly activities for 15 minutes. Before the start of the experiment, the participants listened to a relaxing music for 5 minutes.

The experiment goal was to assembly the finished product by inserting blue wires from the container into a part made of Plexiglas and closing the switch according to the diagram displayed on the monitor (2

D or 3D images). Participants followed the flashing green lights on the Poke- Yoke system and took the necessary components according to pre-determined instructions.

The experiment was realized in two sessions. In the first session, the participants realized assembly activities in 75 parts, while in the second session they realized assembly activities in 60 parts. The experiment was conducted twice, i.e. without and with the application of the Poka-Yoke system. Between sessions, participants had a short break of 15 minutes. The experiment without the application of the Poka-Yoke system and the experiment with its application were not performed on the same day.

Picture 1. Participant performs an experiment on a proposed modular assembly workstation, in which Poka-Yoke system was built

4. DISCUSSION AND RESULTS

Table 1. shows the percentage of good parts before applying and using the Poka-Yoke system. The data shown in this table refer to the first session. Table 2 shows an identical analysis, but for the second session.

Table 1. Percentage of good parts in session 1 – before and after application of Poka-Yoke system

	Percentage of good parts before applying Poka-Yoke system	Percentage of good parts with Poka-Yoke system
Participant 1	44.0%	80.0%
Participant 2	34.7%	78.7%
Participant 3	41.3%	77.3%
Mean value	**40%**	**78.7%**

Table 2. Percentage of good parts in session 2 – before and after application of Poka-Yoke system

	Percentage of good parts before applying Poka-Yoke system	Percentage of good parts with Poka-Yoke system
Participant 1	46.7%	71.7%
Participant 2	41.7%	71.7%
Participant 3	35.0%	75.0%
Mean value	**41.1%**	**72.8%**

From Tables 1. and 2. it can be concluded that the participants in both sessions had less than half of the good parts when it comes to working without the Poka-Yoke system. By applying the Poka-Yoke system, somewhere around 3/4 of the parts are done well. Also, based on the obtained data, it can be concluded that certain parts were problematic for all participants and that the number of such parts is not negligible. After conducting this research, it was concluded that the quality of the final product was improved, percentage of good parts with implementation of Poka-Yoke system is increased by 31.7%.

Table 3. shows the percentage and number of parts that the participants did incorrectly without the application of the Poka-Yoke system, as well as the result of the application of the Poka-Yoke system to the considered parts.

Table 3. Analysis of defective parts those are common to all participants

	Session 1	Session 2	The whole experiment
Parts that none of the participants did well	29 (38.7%)	26 (43.3%)	**55 (40.7%)**
The number and percent of parts was well realized by only one participant using the Poka-Yoke system	7/29 (24.1%)	3/26 (11.5%)	**10/55 (18.2%)**
The number and percent of parts was well realized by two participants using the Poka-Yoke system	7/29 (24.1%)	8/26 (30.8%)	**15/55 (27.3%)**
The number and percent of parts was well realized by all three participants using the Poka-Yoke system	11/29 (37.9%)	9/26 (34.6%)	**20/55 (36.4%)**
The number and percent of parts that none of the participants realized well even with the application of the Poka-Yoke system	4/29 (13.8%)	6/26 (23.1%)	**10/55 (18.2%)**

As can be seen from the table 3. somewhere in around 40% of the parts all participants made a mistake without applying the Poka-Yoke system. Also, it can be clearly seen that after the application of the Poka-Yoke system, the number of defective parts decreased, i.e. that even more than a third of the considered parts were well done by all three participants. However, in less than a 1/5 of the parts, even in the new experiment (along with Poka-Yoke), none of the participants managed to do well. Insight into the data from the records, it was determined that the significant majority of these parts refer to 3D models, i.e. more complex parts.

Based on the conducted experiment, it can be concluded that a significant percentage of parts were problematic for all three respondents. This is actually the case when not using the Poka-Yoke system. In the same situation, about 25% of the parts were well done by all three participants. This means that about 35% of the parts were done incorrectly by one or two participants. Therefore, although it can be seen from the attached tables 1. and 2. that the authors had a relatively similar result (percentage), they still differed in the structure of good parts. Therefore, it is not possible to clearly determine the pattern and reason why participants make mistakes.

When it comes to experimenting with the application of the Poka-Yoke system, the situation is changing for the better. Participants on average have about 3/4 of good parts, so the structure of mistakes is slightly equalized. As already mentioned, it can be clearly established that all respondents have significant problems with 3D, i.e. complex parts, which could not be done well even with the help of the Poka-Yoke system. Those parts should be subsequently analyzed and the causes that lead to such errors should be determined and resolved. Also, the search for the necessary components and parts has been eliminated, the installation of the wrong components has been eliminated and reduced.

4. CONCLUSION

The focus of this scientific research paper is to point out the benefits of introducing a Poka-Yoke system on a proposed prefabricated assembly workstation. The contribution of this research is reflected in the comparative analysis of percentage of good parts in two scenarios - during traditional manual performing assembly activities without Poka- Yoke system and during the assembly process led by Poka-Yoke system on the proposed new workstation and taking into account the number of defective parts and final product quality.

Future research directions are related to the performing of advanced research in which the model will be tested on a larger sample of participants and the influence of various factors (eg. time) will be analyzed.

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