„Improve“ and „Control“ Tools in Assembly of Micro Components: A Case Study

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The process of assembling micro components requires careful planning where precise and reliable data collecting is necessary due to a short production cycle time. After determining the shortages of the current data monitoring system, in this paper, by using the „Improve“ and „Control“ phases of DMAIC cycle, the development and later testing of a new tool for automatic capture and analysis of data obtained from the machine was done. SWOT analysis was used to establish the production site's and current manufacturing execution system strengths and weaknesses, opportunities and threats, which were then utilized to create the newly developed solution accurate and feasible. A tool calibration data was obtained on 9 machines in automotive company's micro component assembly unit. To confirm the accuracy of the data, a RunAtRate test was done on the machines, and by using hypothesis testing, the initial reliability of the new solution was determined. Further testing and comparison revealed that the newly proposed tool recorded 73-80% greater downtime and 40-50% more defective parts than the previously installed system. Accordingly, the usefulness of the proposed Lean Six Sigma tool is confirmed, and for periodic accuracy checks and further improvement, it is necessary to apply the PDCA cycle.

Key Words: *Micro Component Assembly, Improve, Control, Data analysis, Tool, Lean Six Sigma*

1. INTRODUCTION

The process of assembling the components, as the final step in the transformation of the product idea into a real functional object, most often requires careful planning in order to achieve the functionality of the product [1]. Namely, the manufacturing, quality inspection, and handling technologies in the manufacture of micro components are highly dependent on one another, which makes production cycle planning very complicated [2]. Furthermore, the absence of standardized procedures and interfaces makes planning much more difficult. The assembly of micro components, in addition to the problems of planning, also has the problems of technology that must ensure the required high precision [3]–[5], as well as the possibility of automating the process with minimal losses of time and materials [6]. In order to maintain the quality of the process, it is necessary to adapt the methods of quality assurance to the process, and instead of the classic final quality check, it is necessary to prevent the occurrence of quality deviation by analysing the various data supplied by production process and customer feedback [7]. Initiatives for quality improvement are supposed to be ground-breaking methods that produce results [8], [9]. Quality tools are an important instrument for improving business performance and they are classified into three primary groups according

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to their usage pattern by means of factor analysis and reliability testing: quality tools for reviewing current conditions, for analysing current conditions and for production planning and control, according to [9]. Regrettably, there are a lot of examples of inadequately thought out quality improvement initiatives that fell short of expectations [10], [11].

When it comes to data from the micro assembly process production planning, as the authors in [12], [13] states, there is often a problem with tools for precise collection of necessary data, and the reason for this is the sheer number of products, with usually a large number of small variations. Some papers [14], [15], that examined different branches of economy, including production, suggest that it is possible to use certain methods to reduce the number of data points and thereby even increase the precision of the analysis tools. However, as it has been mostly confirmed by theoretical models, in this paper instead of reducing the number of data points, the system is improved to provide accurate information, despite the large amount of data. For that improvement of the system the „Improve" and „Control" phases of the DMAIC (Define, Measure, Analyse, Improve And Control) cycle were used, as it proved to be the optimal approach in a large number of case studies [16]–[19]. Due to small number of studies dealing with the application of the DMAIC cycle in the process of assembling micro components [20], the motivation for this case study is to solve the problem of data reliability in a real system and to confirm the success of the proposed solution.

2. PROBLEM DESCRIPTION

As a suitable place for collecting data and performing the necessary experiments (monitoring), the sector that deals with the assembly of micro components was chosen for this research due to the fact that the cycle time of the selected machines is small, and the number of pieces/items of the product in the time interval is large, so accordingly the precise monitoring of operation and performance of machines is a challenge.

In this case study, there were 32 machines installed that work in 3 shifts, 5, 6 or 7 days a week. One worker per shift is responsible for the operation of each machine, and his task is to perform the basic adjustment of the machine's components so that the assembled product is accurate and functional, i.e., in accordance with the specifications set by the project. The process engineer is responsible for optimizing the assembly process, and in cooperation with the machine worker, from whom he receives information about the problems that occur on the machine, makes a decision to change the hardware or software part of the machine or change the work procedure of the worker, in order to reduce the frequency of the appearance of some undesirable problems. The efficiency of the machine is measured using the OEE index (overall equipment effectiveness), as this coefficient has proven to be reliable measure of machine operation [21]–[23]. In addition to being an operational metric, overall equipment effectiveness also acts as an indicator for process improvement initiatives taking place in the manufacturing sector [24]. Poor-quality pieces/items, which generally affect the reduction of the OEE index, due to their low price and economic unprofitability, are discarded from the plant as scrap, i.e., without refinishing. The MES system (Manufacturing Execution System) for production monitoring was installed in the sector, but the software and hardware are not adapted to the monitoring of machines for the assembly of micro components so the data, in the form in which the MES system represents them is unusable, which has been demonstrated in previous research using the SIPOC diagram and hypothesis test [13].

In this paper, the attention is directed towards the process of development and testing of a new tool for collecting, analysing and representing data from the production process.

3. METHODOLOGY

To begin the Improve phase of the process of increasing the quality of data collection, the first step was to analyse key system elements by using SWOT analysis and identify all strengths and opportunities that can be taken advantage of as well as weaknesses and threats that need to be adequately handled.

After that, in order to utilize the strengths and opportunities of the system, a new software tool is proposed and calibrated for optimal operation in the production system.

The performance testing of the new tool was performed in two parts in which the gathered data on the operation of the machines using the new tool and some other tool that is already applied in the system were compared. The data set for the first part of the performance test was created by direct monitoring the operation of several machines by an engineer at different periods during one working week using the Run At Rate method. The sample that was collected in this phase consists of 9 measurements that include data from about 30 hours of active direct monitoring and recording of all irregularities in the operation of the machines. The second part of the test was carried out over a period of two months, divided into two smaller periods of one month each in which samples were collected by analysing data on 9 machines that were manually entered into the existing database by machine operators.

At the end of each part of the test, a statistical test of the hypotheses was performed in order to confirm the quality of the new tool. Since the tested samples were collected at the same time on the same machines, those samples are considered dependent, so the Sign test and the Wilcoxon signed rank test were performed.

Several parameters were monitored during the observation, but the following objectives were set for hypothesis testing in both parts of the performance test:

- Validity of the number of well-made pieces (“good items”) of the product,
- Validity of the number of poorly made pieces of product (“bad items”), and
- Validity of the data on the duration of machine stoppages.

In the tests, the null hypothesis meant that there was no difference between the data groups, and the level of significance for rejecting it and adopting an alternative hypothesis was set at a coefficient of 0.05.

4. RESULTS

As the SWOT analysis shown in Figure 1 indicated, the production site has installed central MES system, that successfully communicates with PLC controllers on machines, but the method of processing gathered data is not useful and it needs calibration.

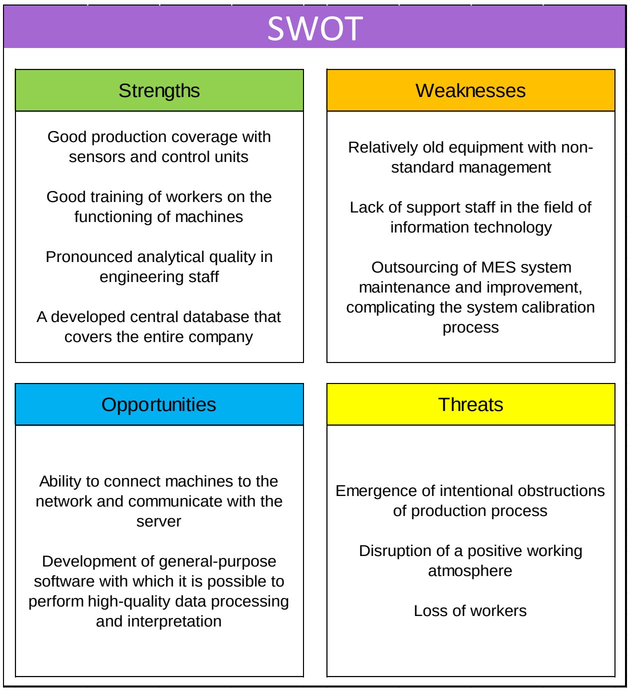

Figure 1 - SWOT analysis of a production site for data gathering process

Based on the available data and detailed live monitoring of the machine’s operation over a period of a few weeks, a prototype solution was proposed in the form of a tool developed within the framework of the Microsoft Excel program package. The new solution uses the data that the MES system automatically collects directly from the machine PLC, but processes it using different, more appropriate algorithms. The user interface of the new tool is shown in the Figures 2. and 3.

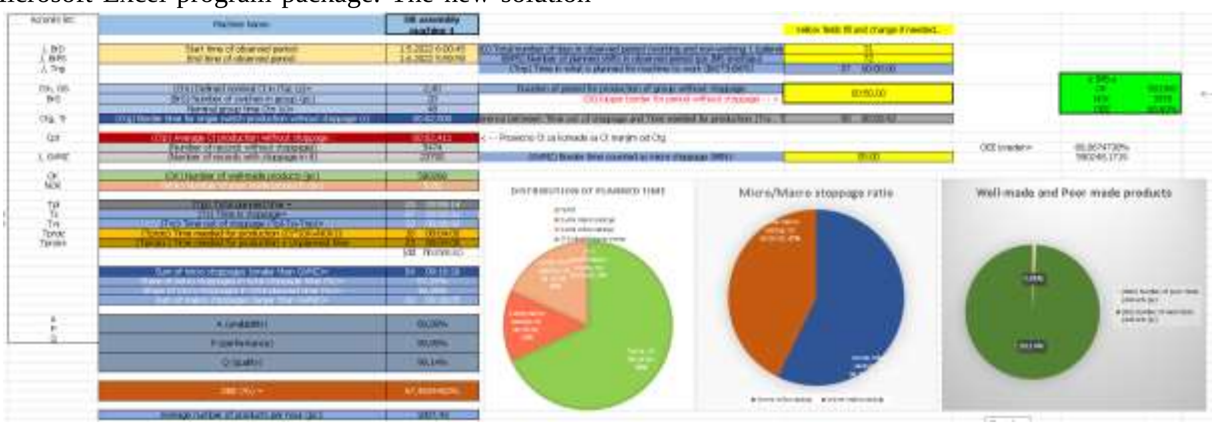

Figure 2 - Processed and displayed data in the new tool

Figure 3 - Additional tables and charts created in the new tool

After a test run and calibration of the software, a performance test was performed. The tests consist of cross-comparison of samples on number of well-made parts, number of poorly-made parts and duration of machine stoppages collected by manual method using direct observation on the machine (RunAtRate method), analysis of worker’s reports on the machine, and automatic method using direct communication with machine controllers.

The results of the first group of hypotheses testing of samples on all the above-mentioned attributes collected by the Run At Rate method and direct communication with the controller are given in Table 1.

Table 1. Results of Sign test and Wilcoxon signed rank test between RunAtRate method and PLC data

	Examined attribute	Number of measurements in the sample	Sign test Level of significance	Wilcoxon signed rank test Level of significance
PLC sample	Number of well-made items (“good items”)	9	0.508	0.139
R@R sample				
PLC sample	Number of poorly made items (“bad items”)	9	0.453	0.089
R@R sample				
PLC sample	Duration of machine stoppages	9	0.180	0.254
R@R sample				

The second group of tests examines the same elements of machine operation as the first group, only over two longer time periods of one month each. The samples were collected by analysing the data that the operators manually entered into the database and by direct communication with the machine controller.

Results of second group of hypothesis tests are shown in Table 2.

Table 2. Results of Sign test and Wilcoxon signed rank test between Manually entered and PLC data

	Examined attribute	Number of machines in the sample	Sign test Level of significance	Wilcoxon signed rank test Level of significance
PLC sample M1	Number of poorly made pieces (“bad items”) M1	9	0.039	0.011
Manual entered sample M1				
PLC sample M2	Number of poorly made items (“bad items”) M2	9	0.004	0.008
Manual entered sample M2				
PLC sample M1	Duration of machine stoppages M1	9	0.004	0.008
Manual entered sample M1				
PLC sample M2	Duration of machine stoppages M2	9	0.004	0.008
Manual entered sample M2				

	Examined attribute	Number of machines in the sample	Sign test Level of significance	Wilcoxon signed rank test Level of significance
PLC sample M1	Number of well-made pieces (“good items”) M1	9	0.508	0.594
Manual entered sample M1				
PLC sample M2	Number of well-made pieces (“good items”) M2	9	0.508	0.214
Manual entered sample M2				

5. DISCUSSION

As the SWOT analysis showed, a resource that can be put to good use in the production site is the large number of sensors present on the machines, as well as the possibility to connect the machine controllers with a central database where they will directly record work parameters at certain time intervals.

The suggested prototype solution was created in order to optimally use the available data from the central database and adequately process and clearly present it to interested parties. On Figure 2. it can be seen that new tool provides a list view of a large number of processed parameters, some of which are: total time in production, total time spent in stoppages, time spent in micro stoppages (shorter than the specified period), total number of well-made ("good”) parts in the observed period, and number of poorly made (“bad”) parts, as well as calculation of overall equipment effectiveness (OEE) coefficient with its elements (availability, performance, quality). The distribution of planned time between production time, long downtime and micro downtime is given in a pie chart, as is the ratio of short and long downtime and the difference between the number of well and poorly made parts. After this part of the tool, there are additional tables and charts, shown in Figure 3. that give information about number of well-made and poorly made parts and duration of downtimes by shifts, and by hours, as well as a sorted list of stoppages by duration.

The first group of statistical tests, the results of which are shown in Table 1, showed that the data collected and processed by the new tool do not differ from the data collected by the Run At Rate method, so it can be considered a faithful representation of the machines’ operation. The second group of tests, which examined the difference between the data accuracy of the new software and the previously applied manual reporting, showed that the data on the number of poorly made parts and the downtime on the machines differed statistically significantly, but there was no difference in the number of well-made items of products.

After performing performance testing, it was confirmed that the new solution is an improvement in the production site and that it contributes to the quality of the data collection process, which greatly facilitates quality control, as well increases the quality of the production process.

In order to maintain the accuracy and quality of the data, it is necessary to continue improving and controlling the newly designed tool, which should be done according to the PDCA cycle.

6. CONCLUSION

Previous research pointed out that there are numerous unsolved issues in process of planning in the assembly of micro components, and it is evident that in order to maintain the quality of the process, it is necessary to adapt the methods of quality assurance, such as DMAIC methodology. But, both in previous research and in practice, examples of that are rare.

The aim of this case study is to present the process of application of the key phases of the DMAIC methodology to a real and demanding production system, the Improve and Control phase, in order to increase the accuracy of the available data, make the assembly quality management process more efficient, and thus reduce the problems in planning and performing micro component assembly assessments.

As stated in [13], tools for manual collection of data on production performance, in addition to low efficiency in work, also lack reliability, which is unacceptable for the automotive industry. The old methods used in the observed production system resulted in between 14 and 52 percent of the machine's planned time being unknown. This paper proposes the new solution, which uses the data that the MES system automatically collects directly from the machine PLC, but processes it using different, more appropriate algorithms. Comparing the data value-wise, the newly proposed tool recorded 73-80% more stoppage time and 40-50% more bad parts. These data contribute to better Lean management, as well as to the quality of all processes in the system.

Further improvements can be made in the direction of hardware changes, in order to add new sensors or renew old ones, as well as the installation of more modern machine controllers that would have the ability to send a much larger variation of data to the main database, which would enable a much more detailed and complete analysis of the real situation.

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REZIME

ALATI „UNAPREĐENJA“ I „KONTROLE“ U MONTAŽI MIKRO KOMPONENTI: STUDIJA SLUČAJA

Proces montaže mikro komponenti zahteva pažljivo planiranje gde je neophodno precizno i prikupljanje pouzdanih podataka zbog kratkog vremena proizvodnog ciklusa. Nakon utvrđivanja nedostataka postojećeg sistema za praćenje proizvodnje, u ovom radu, korišćenjem faza „unapređenje“ i „kontrola“ DMAIC ciklusa, razvijen je i kasnije testiran novi alat za automatsko prikupljanje i analizu podataka. SWOT analiza je korišćena da bi se utvrdile snage i slabosti, pretnje i mogućnosti proizvodnog sektora preduzeća i trenutno korišćenog sistema za praćenje proizvodnje, koje su zatim optimalno iskorišćene da bi novorazvijeno rešenje bilo što tačnije i izvodljivije. Podaci o kalibraciji su dobijeni na 9 mašina u organizacionoj jedinici za montažu mikro komponenti. Da bi se potvrdila tačnost podataka, na mašinama je urađen RunAtRate test, a zatim je testiranjem hipoteza potvrđena inicijalna pouzdanost novog rešenja. Dalja testiranja i poređenja pokazala su da je novopredloženi alat zabeležio 73-80% više zastoja i 40-50% više neispravnih delova od prethodno korišćenog sistema. Shodno tome, potvrđena je korisnost implementiranog Lean Šest Sigma alata, a za periodične provere tačnosti i dalje unapređenje procesa prikupljanja podataka neophodno je koristiti PDCA ciklus.

Ključne reči: *sklop mikro komponenti, unapređenje, kontrola, analiza podataka, alat, Lean Šest Sigma*