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The modernization of the production system of the selected type of synchronizer ring

Jolanta B. Krolczyk[1,*], *Stanislaw* Legutko[2], and *Piotr* Bialek[2]

[1]Opole University of Technology, Faculty of Mechanical Engineering, 76 Proszkowska Street, 45-758 Opole, Poland
[2]Poznan University of Technology, Faculty of Mechanical Engineering and Management, 3 Piotrowo Street, 60-965 Poznan, Poland

Abstract. The aim of the work focuses on the modernization concept of the production system of the selected type of synchronizer ring. The synchronizer rings are applied in the gearboxes of the vehicles in order to synchronize the gears. The range of this work includes the analysis of the previous production system and identification of its specified elements affecting the limitations of productivity or additional costs. As a result of analysis, the set of innovative solutions, enabling the better exploitation of company resources, have been presented.

1 Introduction

Contemporaries manufacturers are making efforts to obtain or maintain their position in a competitive environment [1]. More efficient production by reducing production errors, increases the total companies' productivity [2]. The main problem companies are too high cost of the final product caused by defects [3-4]. Several methods and techniques successfully have been used to reduce the production defects and optimization of product [5-9].

One of the primary objectives of a company is manufacturing of products with high quality, which can satisfy the consumer’s needs. The quality of products is strongly affected by the selected technological input parameters, condition and properties of a machine, as well as the process dynamics [2, 10]. The modern company should produce in the short time and in the low level of costs. Fulfilling all of the above mentioned conditions allows the competetiveness of the company. Nowadays, selling the products with high quality is insufficient. The introduction of the product to the market in the shorter time than the competitors is thus essential.

The application of Cax computer techniques enables the partial automation and robotization of manufacturing processes in order to improve the productivity, stablility, and the elimination of shortages, as well as safety improvement of the employees. Robots and manipulators substitute the human in the realization of processes which require the large physical effort or include the hazard, like in example: welding, casting, assembly [11]. The application of Cax techniques is in favor of popular JIT (Just-in-time) strategy,

* Corresponding author: j.krolczyk@po.opole.pl

implemented in the companies [12-14]. The selection of the appropriate managament strategy is a difficult task and requires comprehensive analysis of the actual company's management system.

The aim of the work focuses on the modernization concept of the production system of the selected type of synchronizer ring. The synchronizer rings are applied in the gearboxes of the vehicles in order to synchronize the gears. The range of this work includes the analysis of the previous production system and identification of its specified elements affecting the limitations of productivity or additional costs. As a result of analysis, the set of innovative solutions, enabling the better exploitation of company resources, have been presented.

2 The description of the technological process

The analyzed manufacturing process of the synchronizer ring has been carried out in the company, which is specialized in the production of forged elements and forgings made of non-ferrous alloys and steel. Above 40% of products is intended to the export to the European countries and USA. The company is medium, according to the size. The manufactured forgings are formed by the hot drop forging with the application of modern apparatus and tools. The mass of the produced forgings (after the removal of fash) is in the range of 0,025 to 3,0 kg and the maximal diameter is of 220 mm.

The synchronizer's ring is the axis-symmetrical product with the length to diameter ratio L/D≤0,5. Therefore, it can be classified as bush or disc. In this kind of parts, the external and internal cylindrical surfaces are being machined [15]. The important issue is also the limitation of roundness errors occurring during the manufacturing process. The manufactured rings are formed as forgings in the range of diameters from 90 mm to 250 mm. The rings made of preforms are forged in the specially formed tools. Forgings are subjected to the heat treatment and preliminary machining without the finishing. Nowadays, the company manufactures the 100 types of rings to the following companies: Mercedes Benz, Scania, MAN and IVECO. The exemplary synchronizer rings are depicted in Fig. 1. The synchronizer ring is made of 16MnCr5 steel, intended to carbonization, which is characterized by the high ductility and hardness of the outer surface.

Fig. 1. The exemplary synchronizer's rings of the gearbox.

The blank is a preform made of steel supplied by the outer supplier. The first operation involves the preform turning on the semi-automatic turret lathe. During this operation, the following surfaces are being cut: face, outer diameter and chamfer. One in ten of semi-finished products is being measured by the calliper. Figs. 2 and 3 present the preforms, namely: before and after the turning. The semi-finished product is then drop forged on the LKM 1000 press. The preform is being heated in the heater for the 75 seconds, and then is formed in the die under the press' impact (Fig. 4). The dimensional control with the calliper is carried out for the one in ten of semi-finished products.

The next operation in the ring's manufacturing process is the fash removal, which is created during drop forging. This operation is conducted on the stand equipped with CNC

TZC-32 lathe. After the fash removal, the rings are transported to the OWT – 400 rotor-tape cleaner. This process is carried out with the cleaning agent's stream.

The rings after the cleaning are normalized. This process is applied in order to obtain the homogenous fine-grained structure, the improvement of product's mechanical properties and unify the structure and properties of the steel products in the mass production. Heat refining lasts for the 6 hours and 20 minutes. The rings are being heated for the 3 hours to the 910° C then kept in the constant temperature for a 1 hour and finally cooled down for the 2 hours and 20 minutes to the room temperature.

Fig. 2. Preform before turning.

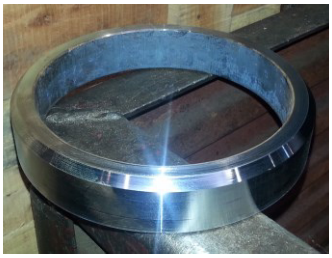


Fig. 3. Preform after turning.

Fig. 4. Forging.

The next operation is ring calibration on the calibrating press PH-750. This process creates the oval shape of the ring and forms the external teeth, which are not being machined in the subsequent production process stages. This operation is necessary, because of customer's requirements regarding the shape errors of product. The control measurement of teeth with the use of calliper is carried out by the employee. The calibrated rings are further subjected to turning on the TZC-32 stand. During this operation, the teeth external diameter and face are machined in the finishing conditions. However, the internal diameter is bored in roughing conditions. The additional treatment during this operation is the burr removal from the teeth external diameter by the brush. Figure 5 presents the ring before and after the turning.

Fig. 5. The ring before machining (left) and after machining (right).

Because of the longest machining time of singular product and a large number of dimensions to control, this operation is particularly important during the whole manufacturing process. Therefore, the work on this stand requires high experience enabling the fulfilling of production norm. The roundness control, carried out on special device, includes the each of manufactured parts. Moreover, the employee controls the one in ten of products, in accordance to specially designed instruction.

The next operation is finish turning of chamfer and conic on the WEMAS DZ 270 stand. Because of the short time of the machining, which amounts to about 12 seconds, this is the one of the more difficult processes for the operator. The ring is clamped in the specially designed chuck enabling the precise machining. The construction of the chuck allows the stable clamping of the element, without the influence of the adverse circumferential forces causing the deflection. The operator during the boring process controls the roundness of the each ring on the specially designed measurement device. The one in ten of products is being checked according to the special instruction – similarly to the previous operation.

The machined rings are transported to the stand on which the maintenance (by the drowning in the fluid) is carried out. The parched rings are packed up and transported to the warehouse. The quality control is carried out on the specialized CMM machine (Fig. 6) and profile meter (Fig. 7).

Fig. 6. Coordinate measurement machine WENZEL.

Fig. 7. Profile meter.

3 Modernization concepts

3.1 The identification of system's elements limiting the productivity and generating costs

Modernization of production system is based on its sustainable improvement by the upgrade. It can involve the changes regarding the applied technology or the work organization. The primary objective of modernization is the improvement of productivity and products' quality.

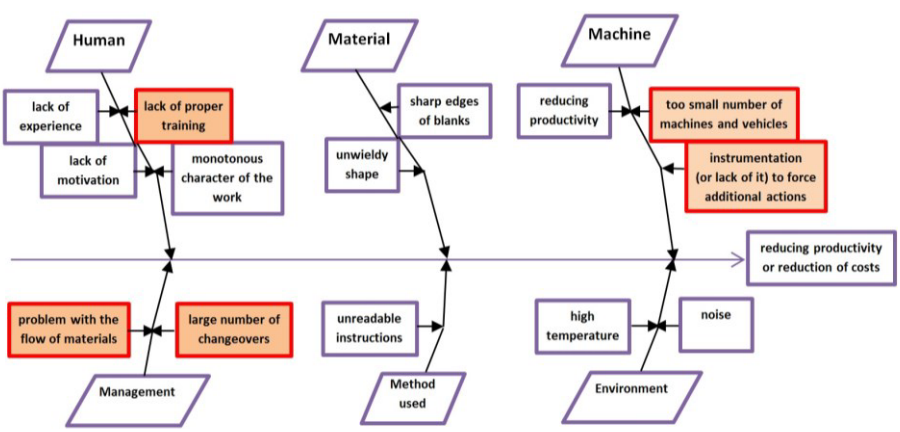


Fig. 8. Ishikawa diagram depicting significant factors limiting the productivity.

An example of the tool enabling the identification of problems occurring in the specified system is the Ishikawa diagram. The Ishikawa diagram depicting significant factors limiting the productivity of the analyzed synchronizer ring production system is presented in Fig. 8.

3.2 Modernization concepts

The first modernization proposition is related to the upgrade of LZK 1000T press' induction heater. Preform is placed in the induction heater in order to prepare it to the forging. The heating process lasts for 75 seconds.

The stand is equipped with two heaters, which allows the simultaneous preparation of two preforms, while forging the third one. The solution which enables the process time shortening and therefore the productivity improvement is the exchange of the heater and application of the newer one with the shorter heating time. The application of the specialized inductor's construction which simultaneously heats the external and internal preform diameter would allow the reduction of a heating time by a 50% in comparison to the actual method. The another solution can be the purchase of an additional heater with a higher power.

The second proposal is upgrading the equipment of lathe TZC-32 with chip conveyors. The lathe is used to remove burrs and roughing processes. Operator working on this machine has to periodically remove chips into a special container. This process takes about one minute. It is repeated twice within an hour on the burr removal stand - but during roughing operations - once an hour. Typically, an operator working in a particular slot controls both machines at the same time. The use of chips cartridgebox can save the time associated with chip removal on a scale of 16 -30 minutes per shift.

Another proposed amendment concerns additional holes in the WEMAS DZ 270 lathe's chuck. During the machining of the ring, the phenomenon of accumulating the coolant and chips inside the chuck and the insert's grooves has been noticed. The effect of this phenomenon was a problem with the preparation of the machine for the cutting of the each subsequent part. Inaccurate cleaning of the chuck caused the deflection of ring's axis toward the tool's axis and as a result the generation of a lack resulting from exceeding the permissible value of a roundness error and burr formation.

The solution to the above problem is to drill three holes in the chuck for removing the cooling fluid by the action of centrifugal force during machining of the ring. It would allow the removal of chips using compressed air, which significantly shortens the preparation time of machine. Processing of the product on the WEMAS stand takes about 12 seconds, while preparing the machine takes about 35 seconds and includes cleansing the chuck and clamping the work piece.

This means that the machine capabilities are used only in about 25%. Based on the analysis of a preparation time of a similar ring with the application of cleaning with the compressed air, it was estimated that the implementation of the above solution would shorten the cycle up to 40%.

During the analysis of the production system a problem has been noticed with the flow of resources between stands. During the each shift, the production department is supported by only one forklift. The operator of the trolley supports a variety of processes which affects the production delays. The use of an additional vehicle would avoid the losses resulting from delays in the delivery of the necessary semi-finished products for all stands of the production department.

The need for an additional training of employees to control and reduce the number of changeovers has been also observed. An important issue concerning the permanent improvement of the production system is to minimize the number of defects generated by the company.

The analysis conducted by the Quality Control Department shows that the most common deficiencies are resulting from the machining errors. They can be the result of the inappropriate selection of technological parameters or improper inspection by an operator at a given stand. The solution might be to carry out more detailed training in the use of measurement tools.

Another type of failure are the defects and cracks in the forging process. They arise particularly when starting a new order, when the optimal process parameters are not identified. The solution to the problems associated with forging and adjustment of machine tools is to reduce the number of changeovers. Where possible, the production should be organized in such a way that the batch of products was as long as possible. The above concepts of modernization are aimed at increasing the efficiency of the production system and minimizing the number of deficiencies. Due to the lack of detailed data on the number of units produced and the number of deficiencies, as well as individual times in operations, the authors have estimated effects on the basis of research conducted in the company.

The heater used currently in the process of forging heats the preform at the internal diameter side. The innovative solution of simultaneous heating of the inner and outer parts of the preform would shorten the process by the 50%.

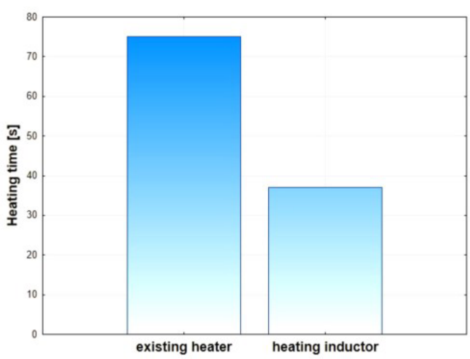


Fig. 9. Shortening heating time.

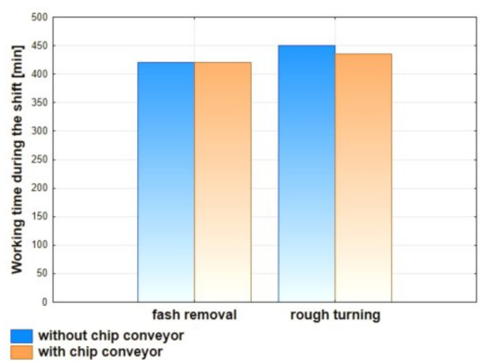
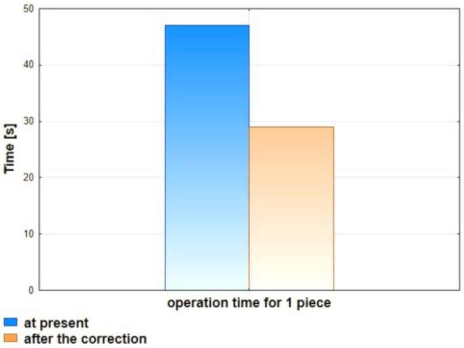


Fig. 10. Estimated extension of time in positions removal of fash and rough turning.

Figure 9 presents the estimated benefits of using this solution.

The existing equipment of TZC – 32 lathe's stand forces the employee to chip removal from the machine, which induces the downtimes of the machine ranging from 16 to 30 minutes per shift. The use of chip conveyor enables to save this time, thereby increasing the efficiency of the stand. The estimated benefits are shown in Figure 10.

The current use of the WEMAS DZ 270 machine's capabilities is approx. 25%. Implementation of the solution described above, involving the execution of additional holes in the chuck of WEMAS DZ 270 lathe would shorten the time to prepare the chuck and increase the efficiency of stands by almost 40% (Fig. 11).



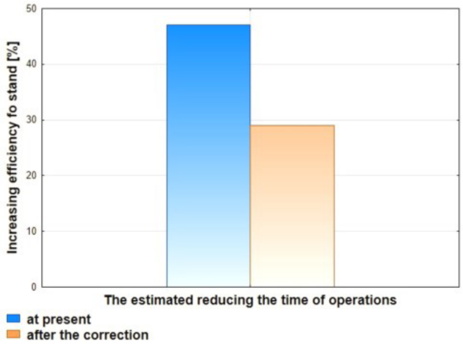


Fig. 11. The estimated benefits of using the modernized design of the handle.

4 Conclusions

1. Efficiency of the LZK 1000T stand, where the forging operation of preforms is performed, is limited by the generator of heaters. Because of the possibility of failure, the heating time is prolonged. The solution is to buy new heaters, which allows faster preparation of preforms for processing.
2. From the observation of TZC-32 stands it can be concluded that the employee spent 16 to 30 minutes per shift on the process of removing chips from the machine. The use of chip conveyor in these machines would save time and increase the production quantity of rings.
3. On the basis of research conducted by the authors it can be concluded that the introduction of changes into the design of the WEMAS lathe's chuck would shorten the manufacturing time of the ring up to 40%. The removal of cooling fluid through the additional holes, during the machining of ring would enable faster chuck's cleaning and better exploitation of machine's capabilities.
4. Modernization of the production system may also include organizational issues. The authors proposed the execution of more detailed training in the use of measuring tools and reduce the number of changeovers. The purpose of these changes would be to reduce the number of defects and improving the quality of manufactured products.
5. An important issue that covers the entire production system of the enterprise, is the flow of material between the stands. The decision to purchase an additional vehicle to support the production department must be preceded by detailed studies on the viability of such an investment.
6. During the fash removal operation on the TZC-32 stand, the frequent cutting tool's cracking at the irregular intervals has been observed. This demonstrates the high instability of the cutting process. One should carry out a study to compare whether more is preferable to apply the high cutting parameters, or increase the tool life.

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