

IMPROVEMENT OF THE MANUFACTURING PROCESS IN A METAL WORKING COMPANY THROUGH THE APPLICATION OF STATISTICAL METHODS

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Abstract

Standards for the quality management system require the application of statistical methods and techniques for measuring, monitoring and process improvement in business practice. The paper addresses the application of statistical process control in the die forging process in a metal working company. The objective of this paper is the quality improvement of forging process through the combination of several statistical methods and techniques to achieve synergy effect. First was applied Pareto analysis and cause and effect analysis, followed by creation of control charts for production process of die forged pieces. From our point of view quality improvement means to meet both the requirements of customer on mechanical features and to ensure stability of the process. The smaller the variability of the input factor is, the better is the process capability and therefore a higher quality of product is produced. Improving the process capability and reducing the variability of the product quality characteristics can be achieved by means of applying statistical methods. So can be determined the process variability, identified common and special causes of variability and in consequence to propose corrective actions. The application of chosen statistical methods has improved capability of the forging process, increased its efficiency and achieved further continuous development of production programme.

Keywords: statistical process control, quality improvement, variability, control chart, forging

1. INTRODUCTION

Quality is defined as totality of features and characteristics of a product or eservice that bear on its ability to satisfy or implied needs [1]. For improving the quality of products and processes in manufacturing company, it is necessary to use different tools and techniques, including statistical methods [2]. Using statistical process control organizations can optimize the manufacturing processes, ensuring the better product quality, better understanding of the relationships between process inputs and outputs, lower cost caused by nonconforming products and increased profit can be achieved through application of statistical methods in organization.

The objective of process improvement is to achieve the best possible quality characteristics of manufactured products. The quality of output from a process depends on the process capability, which is affected by several factors. Therefore the production process must be monitored from all possible points of view and any factors within the process. Improving the quality must be aimed at reducing process variability, respectively variability of input factors that can influence the process and so output characteristics of the quality.

2. CHARACTERISTICS OF THE MANUFATORING PROCESS IN THE COMPANY

The aim of project was to improve the quality of a particular product in the metal working company which deals with production and machining of die forgings for various industries. The process of forging and refining pin 352, made of low-alloy stainless chromium - molybdenum steel and designed for car production, was improved through use of the selected statistical methods.

Large production area of company enables an implementation of new technologies and equipment to further improve its products. The company is equipped with sophisticated technological, control and measuring equipment, ensuring our own design and subsequent production of forging tools There are manufactured FE

die forged pieces (closed die forging) of symmetric, circular shape or contour which, after mechanical processing serve as parts mainly for the automotive, agricultural, railway and construction industries.

Company has a quality management system (QMS) that covers all phases of the product life cycle and identified all the necessary processes involved. The purpose of QMS is to ensure that the product quality requirements are met in all processes, from order, through the process of pre-production and production stages, training employees to dispatch processes, respectively delivery of finished products and customer service.

The principle of continuous improvement is applied in all processes, so that the required quality of products is guaranteed and customer expectations are met. Indicators are designed for processes to monitor and set goals based on the evaluation of the process effectiveness. According to results of the evaluation and analysis the company's management define the measures for the achievement of planned results, continual improvement of processes and integrated management system. The analysis of data in the process of monitoring and measurement aimed at fulfilling the requirements of the product provides a controlling department as well as every department in the implementation of their processes. Important role plays using the appropriate statistical methods in analyzing data. In the company are now applied the following statistical methods:

- histogram,
- Pareto analysis,
- correlation diagram,
- flow chart,
- control chart,
- Ishikawa Diagram,
- methods for assessing the capability of processes, machines and measuring tools.

Measurement process capability is determined by total variation caused by random reasons influencing the process [3].

3. APPLICATION OF STATISTICAL METHODS IN THE MANUFACTURING PROCESS OF PIN 352

The company during the production process control shall cover all forgings; each nonconforming forging is properly registered. Nonconforming forgings are divided by type of error and evaluated using a Pareto analysis of these data once a month. The result is an assessment form, which includes:

- evaluation of internal nonconforming forging by type,
- internal report of nonconforming forged per year,
- external evaluation of nonconforming forgings.

For evaluating the amount of non-conforming forged over a long time period can serves the document Overview form about cost of the internal mismatched forgings. This comprehensive document provides information for evaluation about the amount of non-conforming products, but does not provide possibilities for the implementation of corrective and preventive actions in improving specific products or individual processes.

As part of the project was proposed a new method of analysis of non-conforming products - the pin 352 and also was proposed a method for monitoring and controlling the manufacturing process. The proposal for improving includes application of appropriate statistical methods. The production process of the pin 352 belongs among the core processes of the company. The pin 352 is a component for the automotive industry. Whole production process is divided into the following operations, with in-process quality control: the cutting of material, the heating to forging temperature, the fittings, the refinement, the blasting, and the output control.

In forging operation is introduced a statistical control within control where are used calipers to control forging dimensions. Measurement of product from withdrawn from the production line forging is every 30 minutes; every parameter should be measured periodically with calibrated meter. The measurement result is recorded in the table for data collection, and these measurements are evaluated in the control chart, which lists the size of the forging. If the measured values are within limits, the process is considered as stable. If the process is unstable, has to be carried out the interventions to adjust the parameters of fitting, e.g. adjust the amount of ram, replace the liner. Change made must be recorded in the table for data collection.

In the process of the pin manufacturing was previously applied the statistical control for a given parameter and it was assessed using the process capability. Based on the new requirements on the product quality provided to customers was necessary to implement the improvement process. Improving through activities to increase process capability and thus improve the quality of the manufactured bolts started with analyzing the conformity of the total quantity of products produced within one month.

For pin 352 has been processed the Pareto analysis based on measurements over a fixed time period during which it were manufactured products 1,000 pin 352 according to customer requirements. Results showed that from the total quantity produced were 80 forgings nonconforming, which represented 8% of all. Nonconforming forgings were categorized according to the type of error. Based on the data table was compiled the frequency of the defects used then for Pareto analysis. For a better understanding of the manufacturing process is given a more detailed description of occurred defects.

- A - Mechanically damaged products - slash which may arise when forging falling from the conveyor to the pallet and hit the edge of the forging, which is already in the palette. Since forgings are sizzling and heavy, so it created the chop.
- B - Defect when the material flows not exactly into the cavity (e.g., reason is there is it not enough material).
- C - Labelling means a rare problem that occurs when forging has a mislabeling.
- D - Tool - indicates that the error comes from the damaged forging tools.
- E - Defects caused by mistakes of operators.
- F - Low - mean defect when the piece below the permitted tolerance.
- G - Technological waste is produced during start until forging line achieves the right processing parameters.

Based on Pareto analysis were identified defects: B - defect when the material flows not exactly into the cavity forgings, G - technological waste and F - low forgings (see **Fig. 1**). Based on these findings were proposed and realized corrective measures, which should improve the overall quality forgings produced.

Another operation important in the production process is the refinement of pin 352 in the form of hardening and tempering. After finishing the refinement and cooling of forgings is the Brinell hardness measurement method using the HPO 3000-K/AQ hardness tester. Hardness measurement is performed on the first two pieces of the lot. Following the imposition of forgings for a variety of randomly selected 2 pieces, for which was measured hardness. Measurement is carried out after removal of about 0.05 mm thick layer. Customers defined the tolerance limits for the hardness of forging as follows: 283 to 345 HB.

New customer requirements were mechanical tests to check the mechanical properties of forgings, which are carried out on two pieces of 1 dose of input material and the forging of the minimum and maximum toughness. Where's the mechanical properties of forgings are met, it is likely that they should to be met also for other forgings.

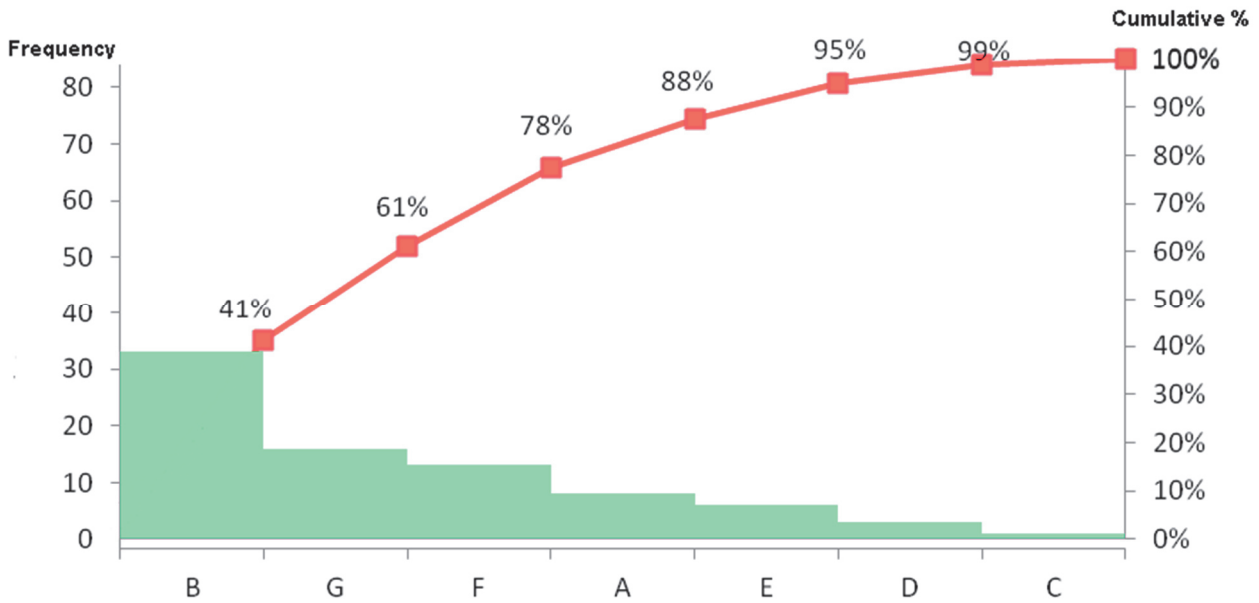


Fig. 1 Pareto diagram of nonconform forgings monthly

To improve process capability of the pin manufacturing was designed the statistical control for the output characteristic hardness. Using a control chart can be monitored process, regulated to be stable, thereby achieving the monitored characteristic, e.g. a hardness will be within established boundaries, and thus would have predicted variability. This will also ensure that the mechanical properties of produced forgings will conform to the requirements defined by the customer.

For the introduction of statistical control was used the control chart (\bar{x}, R) . It is most used for the statistical regulation and consists of the two diagrams, one of which is a characteristic position and indicates the level of the measured values, and the other is a characteristic variation, and indicates the variability of the values in the sample. Control charts indicate upper and lower control limits, and often include a central (average) line, to help detect trend of plotted values. Control charts can be constructed for many different types of indicators, whether univariate or multivariate. Control charts are simple to interpret [5, 6].

UCL and LCL for control diagram (\bar{x}, R) , were defined on the basis of data obtained by measuring the hardness of the forgings selected from a batch containing 500 pieces, which were made 20 withdrawals of 5 pieces.

UCL and LCL are calculated as follows:

- Upper control limit for the mean $UCL_x = \bar{x} + A_2 \cdot \bar{R}$ (1)
- Lower control limit for the mean $LCL_x = \bar{x} - A_2 \cdot \bar{R}$ (2)
- Upper control limit for variation $UCL_R = D_4 \cdot \bar{R}$ (3)

The values of coefficients A_2 and D_4 are tabulated values given in standard STN ISO 8258, and shall be based on the sample size, in this case, $A_2 = 0.577$ and $D_4 = 2.114$. Upper control limit for the mean is 342.57, lower control limit for the mean is 326.77 and upper control limit for variation is 28.96.

After calculating UCL, LCL is created the control chart X and R (see **Fig. 2**), all plotted values are within the control limits, which means that the process is stable, respectively statistically controlled. Calculated control limits can be considered as definitive and may be based on them to regulate the process.

The introduction of statistical control to check the hardness will ensure the stable process and that all requirements of the customer are met. Using the statistical control can identify significant impacts that cause instability in process and require the intervention process aimed at the implementation of correction actions.

Process being in statistical control means that the extent of variation of the output of the process does not exceed that which is expected on the basis of the natural statistical variability of the process.

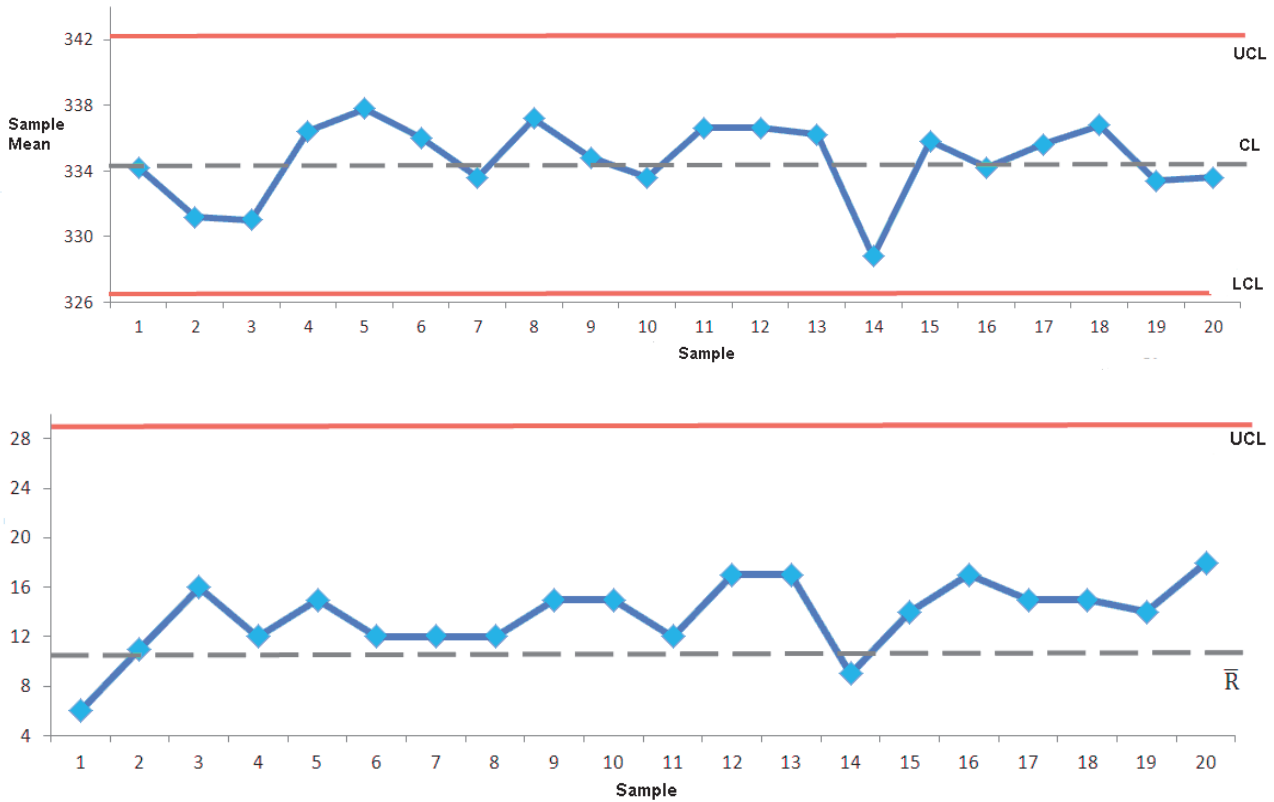


Fig. 2 Running of manufacturing process in the control charts (\bar{x} , R)

For the effective application of statistical control in manufacturing process, it is necessary to comply with the established procedure.

- After the manufacturing operation and cooling the forgings choose from first pallet from 5 pieces and then choose from other pallets randomly 5 pieces forgings.
- For forgings mill 0.05 mm layer away and measure the hardness with the hardness tester HPO3000K/AQ, ball with a diameter of intender 10 mm and applied force $P = 3\ 000\ N$.
- The measured values of hardness by Brinell ball after the measurement graphically indicate to the table to collect data for the forging.
- From the measured values to calculate the mean and variance, which are drawn in the prepared control charts.
- If the values are outside the regulatory boundaries to find the technologist and to perform a correction action in the process.

Correct and consistent application of statistical process control for the characteristics of hardness ensures control of the process stability. If the process is stable and it can be assumed that the forgings will meet the mechanical properties and should not be repaired. However, if not it is likely that the mechanical properties are not fulfilled. The hardness value is influenced mainly by chemical composition of the steel and heat treatment. Using control charts can be monitored and controlled a process, which in this case means to control the settings of the furnace are set correctly processing parameters on the appropriate conditions for the heat treatment of the material.

CONCLUSION

The aim of improving the quality in project was the introduction of statistical process control in manufacturing process of refinement in order to achieve a hardness of forgings, which will guarantee the desired mechanical properties. When the production process is stable, only conforming products are produced and customer special requirements are met. For the parameter hardness was determined the tolerance limits HB 283 and HB 345 by customer. As stated technologist if the hardness is 310 HB, it is assumed from experience that the mechanical properties will not fulfill. Application of statistical process control for refining will not only help to optimize the management of the manufacturing process of the pin 352 for the automotive industry and so must meet strict requirements, but is also means a benefit for that company. Efficient use of statistical methods leads to a reduction in production costs, the cost of poor quality, to higher satisfaction of customer requirements.

ACKNOWLEDGEMENTS

The paper is a part of VEGA research project No. 1/0448/13 Transformation of ergonomics program into the company management structure through integration and utilization QMS, EMS, HSMS.

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