ANALYSIS FOCUSED ON PROCESS CAPABILITY IN THE FLANGE PRODUCTION

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Abstract

Process capability analysis is a part of the statistical process control, which is designed to monitor and regulate the process. The aim of statistical control is to maintain the manufacturing process at a level so that produced products have the required quality and meet the customer requirements. The contribution provides a closer look on the capability of flange forging process for the automotive industry. In the automotive industry there are strict requirements on product quality, therefore it is necessary that all manufactured products meet the specified quality requirements. In the case study is introduced the analysis of factors influencing the process capability in flange manufacturing. Based on the findings from conducted analysis it is to expect an improvement of the forging process capability based on proposed measures.

Keywords: Quality improvement, process capability, flange production, forging

1. INTRODUCTION

The quality of produced products depends on the manufacturing process, respectively on manufacturing operation. Improving the quality is part of the quality management, which focuses on increasing the ability to fulfill the required properties. It includes activities aiming to achieve a higher level of quality compared to previously [1, 2].

There is some variability in the monitored quality characteristics in any production process on the basis of that the process capability can be expressed. The process capability is the ability to produce products that meet customer requirements. If the process is capable, then the required quality of the manufactured products can be achieved and the customer requirements are met and it is possible to reduce the control and therefore to reduce the control costs.

Determination of the process capability is based on the statistical process control of monitored quality characteristics. Capability index is used as a quantitative form for expression the quality level for a given parameter, respectively quality characteristics. It is necessary to obtain the required number of measurements and then to calculate the coefficient, which figures out the level of process capability.

It is to consider that it is important for determination of the process capability a way of obtaining the raw data and compliance with determinating conditions. The process must be in a state of statistical control and the monitored quality characteristic must have a normal distribution. In the case of incapable process it is necessary to suggest and implement corrective actions to improve the process.

Knowing the process capability is important for planning as well as for improving the quality. It provides an evidence for producer and also customer that the product is produced in stable conditions, to ensure stable compliance with the prescribed criteria [3].

The aim of this paper is to describe the determination of process capability in flange forging process. On the basis of the capability indices, the process was considered as incapable and therefore the causes were analyzed and proposed measures for improving the process capability.

2. DETERMINATION OF THE FORGING PROCESS CAPABILITY IN FLANGE PRODUCTION

The main production program of the company includes forgings, heat treatment of semi-finished products and forging tools production. Company promise guarantees within the certified quality management system to the customer from automotive industry that manufactured products have high quality standard and the company meets the specific requirements of the automotive industry. These requirements are specified within international standard, such as VDA 6.1 standard applied in the automotive industry. The company makes effort to meet the specifications of this standard, particularly in assuring the capable process. Our project deals with the flange production for a foreign customer (see **Figure 1**), its production is the largest series production program in the company. In the final control is primarily controlled the flange thickness, and it is performed 100 % quality control. If the company delivers some nonconforming products to the customer, it would affect also relations with customers and the financial results.

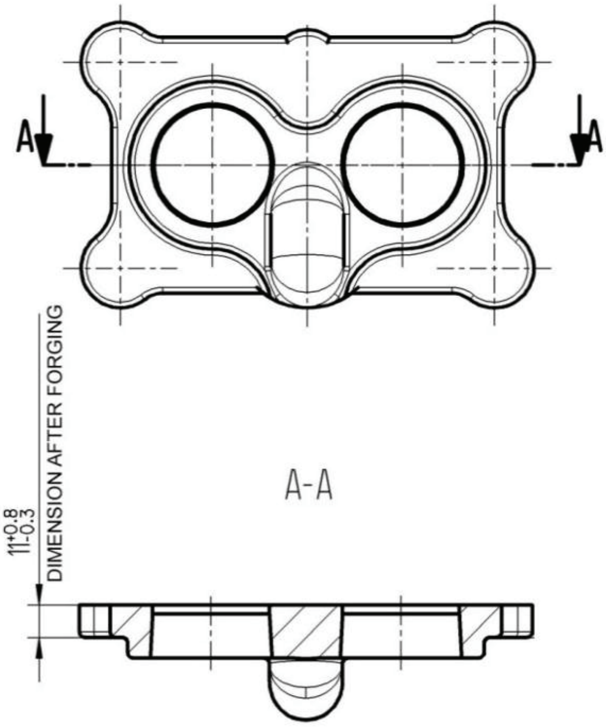

Figure 1 Flange

Forging is a key process in the flange production and the process capability might be assessed regarding requirements for the flange thickness. Following activities were realized in accordance with the standard procedure for improvement of the forging process:

1. Objective determination

Objective is that, on the basis of the calculated and proven capability c_{pk}, the supplier might be able to indicate the customer continuing compliance with the product quality and 100 % quality control of manufactured products in the process would be not essential. Another expected benefit might be the cost reduction for output control after implementation of selective control.

2. Data collection

Firstly, for the process capability specification it should be assumed that the production process is under statistical control. The evaluation of process capability standardly uses capability indices based on the assumption of normal distribution of the monitored quality characteristic [4, 5]. This precondition was met; since the statistical control was proceed in forging process. It is necessary to have a larger number of values in a specified manner for calculating the process capability indices.

The flange thickness is reckoned as an important quality characteristic for a given component (see **Figure 1**), it should have a value 11 + 0.8 to - 0.3 mm. For the process capability calculation was controlled the flange thickness. Measurements were made by worker using a digital caliper rounding values to two decimal places. In presented case study the sample size n = 5 and it takes into account the control costs and fact that it is a serial production. The flange is a full-form product and control samples were collected from a single source, e.g. closed die forging press. It was taken to control the last 5 pieces of manufactured components within the control range. Control interval was specified 1 hour. Five flanges were selected randomly every hour from all manufactured products to check their thickness. The measured values of thickness are recorded into the collection card.

3. Verification of the normal distribution

Ratio calculation of the process capability is based on a normal distribution; therefore it had to be carried out the analysis of values obtained within the flange thickness control. According a roughly bell-shaped histogram for the process, it can be stated that the frequencies allocation of measured values thus the quality characteristic is normally distributed (see **Figure 2**). In this case, the process is caused by no significant effects, so the process is under the statistical control and it can follow the capability evaluation of process. The specification of the measured values distribution can also be performed by testing. In our case it was implemented parametric test goodness of fit, which also confirmed that the set of values has a normal distribution.

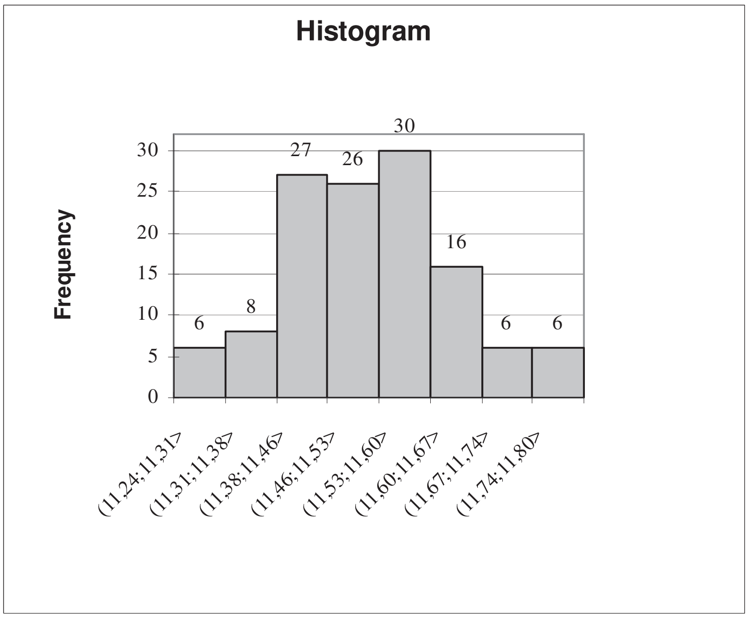

Figure 2 Histogram

4. Calculation of the capability index

Several indicators can be defined for expressing the process capability, most used are capability indices c_p and c_{pk} The manufacturing process is considered as capable, if the coefficient or critical factor reaches a value greater than 1.33. Ratio calculation of process capability is based on a comparison of variability expressed by prescribed tolerance limits and actual variability of observed quality characteristics which is calculated from the measured values. For calculating the capability indices it is necessary to know the tolerance limit, the average value of measured data and the selection standard deviation, based on which to determine the actual variability.

For the flange thickness was specified dimension $11\ ^{+0,8}_{-0.3}$ mm, i.e. that upper specification limit *USL* is 11.8 mm and lower tolerance limit of *LSL* is 10.7mm. Sample mean, calculated from the measured values, is 11.521 mm and the standard deviation, which was determined on the basis of the selection standard deviation s, is 0.114 mm.

$$c_p = \frac{USL - LSL}{6\sigma} = \frac{11.80 - 10.7}{6 \cdot 0.114} = 1.61 \qquad (1)$$

Where: *USL* - upper specification limit;
LSL - lower specification limit

Based on the calculated value of coefficient, which is 1.61, it can be concluded that the forging process is capable. Capability index $c_{p,}$ also called process potential index, or process capability ratio, takes into account the overall process variability, but does not take into account the displacement of the median compared to the prescribed level T, which is the flange thickness 11 mm. This includes the critical factor c_{pk} defined by Montgomery [7] as the measurement of the actual capability in the process. Index c_{pk} takes the process centering into account. In other words, c_{pk} deals with the case of a process with mean μ that is not centered between the specification limits.

The capability index C_{pk} can then be calculated as:

$$c_{pk} = \min\left\{\frac{USL-\bar{x}}{3\sigma};\frac{\bar{x}-LSL}{3\sigma}\right\} = \min\left\{\frac{11.80-11.521}{3\cdot 0.114};\frac{11.521-10.70}{3\cdot 0.114}\right\} = \min\{0.82;\, 2.40\} = 0.82 \quad (2)$$

The process capability is assessed by the smaller of the calculated values, i.e. in this case c_{pk} =0.82. So we can state that the forging process is actually not capable. The abovementioned indices are suitable for determination of the process capability in case of symmetrical tolerances. To express the forging process capability of flange with asymmetric tolerance for thickness are proposed coefficients c_{pm} and c_{pmk}

$$c_{pm} = \frac{USL-LSL}{6\cdot\sqrt{\bar{s}^2+(\bar{x}-T)^2}} = \frac{11.80-10.70}{6\cdot\sqrt{0.114^2+(11.521-11.00)^2}} = 0.34 \quad (3)$$

$$c_{pmk} = \frac{\min(USL-\bar{x};\bar{x}-LSL)}{3\cdot\sqrt{\bar{s}^2+(\bar{x}-T)^2}} = \frac{(11.80-11.521)}{3\cdot\sqrt{0.114^2+(11.521-11.00)^2}} = 0.15 \quad (4)$$

Calculated values of coefficients c_{pm} and c_{pmk} emphasize further that the process is uncapable [8]. In the case if the final distribution is not normal; it is appropriate to use the quantile method, which is based on an appropriate model of the distribution. Calculation is then following:

$$c_p = \frac{USL-LSL}{x_{0.99865}-x_{0.00135}} \quad (5)$$

$$c_{(p)k} = \min\left\{\frac{USL-\bar{x}}{x_{0.99865}-x_{0.5}};\frac{\bar{x}-LSL}{x_{0.5}-x_{0.00135}}\right\} \quad (6)$$

Since using the test goodness of fit confirmed that a set of measured values is normally distributed and given objective of the project was mainly to propose measures to improve capability of the forging process, the calculation of these coefficients are not indicated in article.

5. *Evaluation of process capability*

According coefficient c_p = 1.61, it can be defined the process is within the tolerance. The c_p is much bigger than 1.33, so compliance of capabilities can be considered as very good. The critical factor capability c_{pk} unlike the coefficient c_p, takes into account the shift of the mean from the prescribed level. Calculated c_{pk} is 0.82 in this case. The forging process capability is described best by c_{pm} = 0.34 and c_{pmk} = 0.15. One can assume that the production process is not capable and it is not able to meet the requirements of customer.

3. ANALYSIS OF INFLUENCES ON THE CAPABILITY OF THE MANUFACTURING PROCESS

According results it can be stated that the manufacturing process is not capable, so it is necessary to analyze what effects this process. The graphic representation of the measured values (see **Figure 2**) shows that most of the measured values are close to the upper tolerance limit. This situation needs to be addressed it can be used a cause and effect diagram - Ishikawa diagram. The CE-diagram shows the factors, causes that affect the forging process of the flange.

Firstly, the process is affected by the setting of the machine. One can regulate the stroke and clearance. The stroke is the distance between the top and bottom of the die, between which is the parting line. If a stroke is small, it leads to the production of forgings, which have a smaller thickness than the prescribed nominal value. If the stroke is large, the thickness is bigger. Incorrectly adjusted clearance will cause a product deformation. Furthermore the dimensions of forged flange can be effected by machine vibration, its occupancy, or if the machine works during all three shifts, or there is an interruption of the production process. Then the machine settings can change and thus may cause a scrap production. An important part of the machine is a die that defines the shape and dimensions of the forging. Improperly designed, deformed, wear, cracked die and die heated to inappropriate temperatures can cause the production of non-conforming flanges. Another factor, influencing the manufacturing process result, is the material for the flange production. The material can be incorrectly labeled or its chemical composition does not match the label. For a flange forging process is very important thickness. The forging thickness is influenced by the temperature for preheating the material. If the temperature is not appropriate, the material is not sufficiently flexible and forging thickness has not the prescribed value. Also the time of the forging process is one of the main causes performing in the technological process. It is important that the material is forged just such a time when the temperature guarantees its adequate formability. When the forging time is extended, the temperature may change so that the material is the formability is getting worse. Another factor is the operating staff of the machine, which would have to intervened in the process whenever is detected any deviation from the desired state. If the operator does not carry out the intervention in the production process, it could cause no capable production process.

4. MEASURES FOR THE FORGING PROCESS IMPROVEMENT

The cause's analysis in forging process pointed out that it is necessary to propose some corrective action for improvement. Through realized corrective measures can be achieved the required process capability and one will be able to prevent the production of non-conforming flanges. Following guidelines are essential to be observed for achievement of the required process capability:

- Ensuring the proper setting up and control of the machine every time when starting operation.
- Regular maintenance and inspection of the machine and if any anomalies are detected, immediately realize corrective measures.
- Keeping the written records about the controls and repairs, the records is to be placed near the machine in order to be able at any time to look into it.
- Control each die condition before the start of forging.
- Keeping records about the number of produced units for the die, when approaching the limit of its working life to ensure timely delivery of new or fixed die.
- Control the temperature on the regular basis, if necessary, make the corrections.
- Supplying material only from a manufacturer that provides a quality guarantee and with an implemented quality management system.

Analysis in the company outlined that the machine and the human factor is to consider as the most important source of nonconformity in the manufacturing process from all operating conditions having effect on thickness of the flange, and thus the process capability. As it was mentioned, for quality improvement it is necessary measurement, monitoring and continuous improvement in the manufacturing process, in our case study a flange forging. The important precondition is that the quality control should be systematic and independent.

5. CONCLUSION

Quality is the deciding factor for customers choosing from several products and therefore the quality is a tool to recruit and to retain a market share in the current market competition. Creating an effective program of the quality improvement can be a tool for increasing productivity and for reducing costs. Each company might to optimize, manage and improve the processes directly related to customer requirements or processes affecting the process effectiveness. It is important to ensure that the ongoing processes meet all requirements in all stages of the production. Identification of nonconforming processes at the earliest stage leads to corrective action and thus to improvement [8].

An important precondition of the production process is the continued stability, which can be reached by means of the statistical control. From what have been mentioned in the case study analysis of process capability in flange production, it is possible to be inferred, that using statistical methods include a wide range of tools that are used mainly for investigating the stability and the process capability. Mentioned methods help companies to make stable the manufacturing process and reduce the manufacturing costs.

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REFERENCES

[1] NENADÁL, J., NOSKIEVIČOVÁ, D., PETŘÍKOVÁ, R., PLURA, J., TOŠENOVSKÝ, J. *Moderní management jakosti: principy, postupy a metódy.* Praha: Management Press. 2008. 380 p.

[2] MELOUN, M., MILITKÝ, J. *Kompendium statistického spracování dat.* Praha: Karolinum, 2012. 766 p.

[3] TEREK, M., HRNČIAROVÁ, Ľ. *Štatistické riadenie kvality*. Bratislava: Ekonomická univerzita, 2004. 234 p.

[4] PLURA, J., NEPRAŠ, K., KLAPUT, P. The influence of skewness of the monitored quality characteristics distribution on the process capability analysis results. In *METAL 2014: 23rd International Conference on Metallurgy and Materials*. Ostrava: TANGER, 2014.

[5] KOTZ, S., JOHNSON, N.L. Process Capability Indices - A Review. *Journal of Quality Technology*, 2002, vol. 34, no. 1, pp. 2-19.

[6] MONTGOMERY, D.C. *Statistical Quality Control: A Modern Introduction.* 6th ed. Hoboken: J. Wiley & Sons, 2012. 768 p.

[7] JAROŠOVÁ, E., NOSKIEVIČOVÁ D. *Pokročilejší metódy statistické regulace procesu.* Praha: GRADA Publishing, 2015, 296 p.

[8] MATEIDES, A., ZÁVADSKÝ, J. *Ako zaviesť systém riadenia kvality podľa STN EN ISO 9001:2001 v organizácii.* Bratislava: EPOS, 2005, 212 p.