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Possibilities of Use of Statistical Methods in the Technology of Broaching of Internal Contoured Surfaces

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Abstract: *The technology of broaching the inner shaped surfaces makes it possible to increase production in the production process. The tools are called broaching mandrels. Broaching tools are shaped tools that have a series of cutting teeth arranged one behind the other, in which the value of the diameter itself increases more and more. Broaching tools have more cutting edges. The final shape of the inner shaped surface is produced in one rectilinear movement of the broaching tool. The use of broaching technology is suitable in series production. The technology of broaching of internal shaped surfaces represents the technology of chip machining of metals and the use of statistical methods makes it possible to monitor the influence of the broaching process on other parameters. This has advantages in solving the experiment, the research itself and in solving the assignment or customer requirements. As a quality management tool in established series production, it is appropriate to use statistical process control methods. The experimental parts were welded parts of two parts, one part was a sheet metal stamping and the other part of the weldment was a round-shaped hub, which is inserted into the central hole of the sheet metal stamping. In the broaching experiment, the influence of the broaching process on another defined weldment parameter of two parts was statistically monitored. Statistical methods are suitable for experimental tests, technical preparation of series production and evaluation of the results of experiments.*

Keywords: *Broaching, profile shape, statistical methods*

1 INTRODUCTION

The use of technology of broaching he inner shaped surfaces of workpieces means the production of the inner shape, which is machined on parts with a through-hole. This hole *d* is usually made in a previous manufacturing operation using drilling or turning technology. The resulting force of broaching consists of the sum of the forces acting on all the engaging teeth [1] represents the resultant broaching force, shown in Figure 1. The cutting speed represents the speed of the main movement and is denoted by v_c [2]. Direct movement of the drawing tool through the workpiece opening leads to the desired internal shape. The broaching process has a negative contour of the broaching tool on the workpiece [3]. In series production, this shape is most often in the form of a profile shape [4]. Profile calibres and regulating gauges is suitable to use for measuring the profile shape. It is suitable to use statistical methods to determine the effects of the process of broaching the inner shaped surface on other defined workpiece parameters.

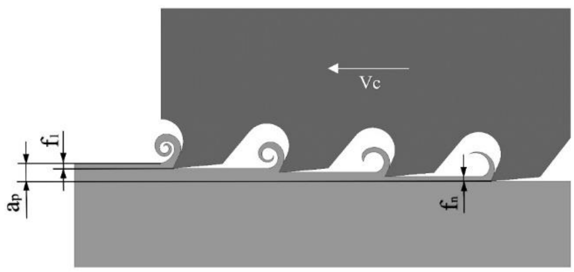

Fig. 1. Principle of work of the broaching tool
v_c – main cutting speed, a_p – depth of cut, f_1, f_n – feed on individual teeth

Example of a shaped surface after the broaching process is shown in Figure 2.

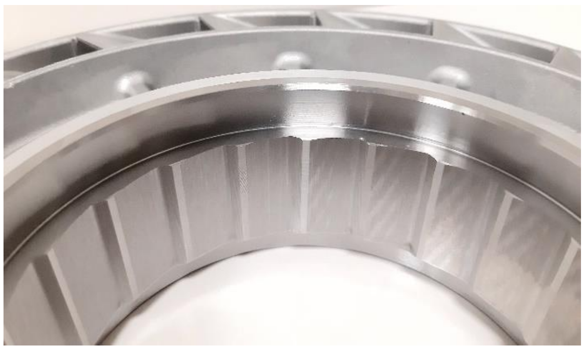

Fig. 2. Workpiece after the process of broaching the inner surface

In this particular case of the tested workpiece, the surface roughness after broaching was defined. The given workpiece surface was induction hardened in next technological process.

2 STATISTICAL METHODS

There are many statistical methods of process control. We will show selected statistical methods in the next part of the article. We will present an example of the application of the statistical method of process control on a process of technology – broaching of the inner profile surface. Form of a profile shape is shown in Figure 3. Technology of broaching is used in mass production, so it is appropriate to use statistical methods to evaluate it, because we get quite a lot of input data. It is the large amount of data that determines the use of statistical methods.

Fig. 3. Workpieces after broaching with a profile shape

To ensure measurements in the series production process, measuring profile calibers are used, which have profiles for good pieces and also for unsuitable parts. Example of a profile measuring caliber is shown in Figure 4.

Fig. 4. Profile measuring caliber

In the serial production process of broaching, for the first pieces, adjusting pieces, meters with measuring watches are available to ensure control measurements, where the measurement itself is made between measuring balls or measuring rollers. Test pieces and first pieces produced by the technology of internal broaching of shaped surfaces in practice either in measuring laboratories on 3D coordinates or on measuring SCANmax devices. It is important to set up an inspection procedure for testing and new workpieces. The control procedure is compiled as part of the overall planning. It is used for the testing production and before serial production. The control procedure serves as a prescription for the inspection of dimensions of the broached parts and the parameters of the process of broaching the internal shaped surfaces in the testing phase or prototype phase. The right choice of data collection, control procedure and measuring devices are important when using statistical methods and the evaluation itself in the process of broaching.

2.1 Six Sigma Method

The Six Sigma method is used to improve processes and quality in production processes. It was originally developed by company Motorola. This approach to process improvement was already known in the 1980s. The main goal of Six Sigma is to minimize process losses and this method uses statistical methods. This method assumes that there can be a maximum of 3.4 failures per million pieces produced, which is the goal of the Six Sigma method. The focus of this method is to minimize process variability while looking for factors that need to be addressed and are responsible for it. Lean deals with the slenderness of processes, the focus of Six Sigma is on their variability. This method includes the following solution procedures - DMAIC and DFSS. The DMAIC principle is used to improve the -existing production processes. The DFSS principle is used in the design and solution of new processes [5].

2.2 DMAIC Method

This method contains 5 phases in order to successfully implement changes or project management in order to improve the existing process: D – Define, M – Measure, A – Analysis, I – Improce, C - Control [6]. The KAIZEN methodology [7] means continuous process improvement.
The DMAIC method is suitable for solving tasks and problems in order to improve processes. In the SIPOC form [8], Table 1 shows the DMAIC method for solving the process of broaching the inner profile shape.

Table 1. Overview of workpieces processes in a form of SIPOC

SIPOC				
Six Sigma SIPOC Form				
S	**I**	**P**	**O**	**C**

The designation SIPOC means: Supplier - S, Input - I, Process - P, Output - O, Customer - C.

Software applications are used to support the statistical evaluation [9] of processes (research, experimental and production). These include the possibility of statistical evaluation. They are powerful evaluation tools and contail and offer the possibility of other functions, it is used e.g. MiniTAB software[11, 12].

2.3 Monitoring of the machine and process capability

It includes the implementation of statistical process control and machine capability monitoring. By process capability we mean the evaluation of process performance according to the specifications that are measured. The capability indicator expresses ability. capability.

Terms:

- Machine / process capability – means the ratio of tolerance and production accurance.
- Systematic factor – means an irregular occurrence (e.g. broken tool, etc.).
- Random factor means constant variance. It includes a certain part of the total variance (e.g. the raw materials have a fluctuating quality).

Expression of machine / process capability monitoring evidence is in Table2. Contains test types, capability indicators and methods.

Table 2. Machine/process capability indicators

Test type	Methods	Capability indicators
Short-term test	Machine capability	C_m, C_{mk}
Short-term test	Preliminary process capability	P_p, P_{pk}
Long-term test	Continuous process capability	C_p, C_{pk}

The expression of process and machine capability is realized on important features and parameters, or on the basic of customer requirements.

There are several main influencing factors:

- Material,
- Environment,
- Machine,
- Humen,
- Method.

The influence of factors is different – it is systematic or random. When analyzing the process, it is important to take the influence of factors into account for unsatisfactory test results.

Fig. 5. Broaching tool for profile shape

The expression of the influence of the broaching process on other parameters is shown on a specific test. The broached shape is a profile shape. An example of a broaching tool showing the finishing teeth for a profile shape is shown in Figure 5.

Tested part – it is a weldment of a pump welded from two components. A sheet metal stamping: outer diameter D1 = 300 mm, an inner hole D2 = 53 mm, and a hub, which is inserted into the central hole of the sheet metal stamping and are welded together. The component parts are welded. In the hub, there is a through hole for extending a profile shape having a module 32, as shown in Fig. 6. Broached hub has JIS G4051 S48C material. A 7B66 broaching machine and a cutting speed of 3,5m/min were used for the broaching test. ECOCUT 715 [10] cutting oil was used for the broaching test.

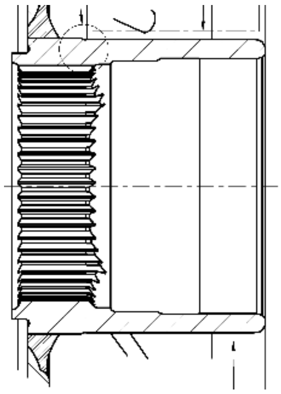

Fig. 6. A broach of the internal contoured surfaces

In our particular case, the parameters from Six Sigma SIPOC – Form represent the following:

- S – Supplier: turning, welding, hardening
- I – Input: workpiece (dimensions, chemical composition, mechanical properties of the material)
- P – Process: process of technology of broaching of internal contoured surface (profile shape)
- O – Output: broached workpiece, geometric dimensions
- C – Customer: turning

The capability indicators C_m and C_{mk} are used in the evaluation test. The critical parameter of the part is the diameter D = $48h10_{(-0,1)}$. The assessed parameter has the following characteristics:

- it is an inner diameter,
- its dimension is relatively large D = 48 mm,
- it is a tolerated dimension,
- the tolerance is h10 which represents a deviation of -0.1 mm for the lower limit.

50 pieces of measured components is the tested dose. As mentioned above, the workpieces to be broached were welded two pieces. Thus, the welding technology also introduced certain inaccuracies into the final product. Capability is shown graphically in Figure 7.

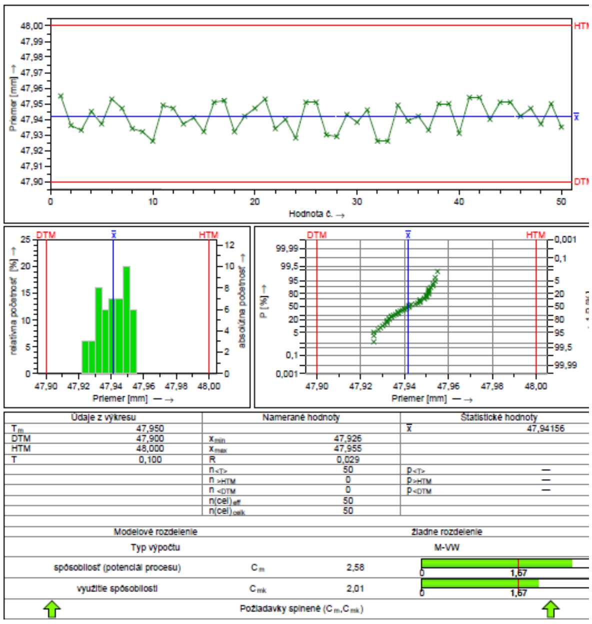

Figure 7. Assessment of capability indicators C_m and C_{mk}

For the capability indicators C_m and C_{mk} applies that: $C_m/C_{mk} \geq 1{,}67$.

The result of the assessed capability indicators in this particular case shows that $C_m = 2{,}58$ a $C_{mk} = 2{,}01$ and the requirements were met.

CONCLUSION

Broaching the internal profile surfaces allows us to achieve high productivity in the production process and the technology is suitable for series production. It is used mainly in engineering and also in the automotive industry. In the production processes of metal machining, the use of statistical control of the production process is generally widespread. Statistical methods are a suitable tool for solving customer requirements. They are a powerful tool in optimizing cost reduction and also in conducting your own research.

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