

THE APPLICATION OF PROBABILITY THEORY FOR DRILLING

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Boring is presented in the article as well as drilling, errors in the drilling shape and position, and their control. The position of the holes is determined. It is possible to give the position of the holes in many ways. We are analysing the measurement results with a statistical method in the article. For example, we use distribution analysis, that is we apply a standard χ^2 test to check if it is possible to define the measured variables according to a normal distribution. Finally, histograms and χ^2 tests enable us to make a conclusion considering the errors, and we also propose the correction.

Key words: boring, definition of position, statistics, histograms

Introduction

During the production of the components – particularly the hollow components – keeping the position tolerances as well as studying how the position errors in the finished bores evolve, and what kind of requirements are met, is very important considering the lifespan of the component. The position errors in the bores influence their function and assembly.

Under the position of the bores we mean how the hole occupies a position as compared to the geometrically limited surfaces, as well as what the position of bores is like as compared to each other. We characterize the hole with the position of its axis line. The latter one is provided with accurate measurements on the component drawings and the sizes are compared to a geometrically accurate central line – or surface or base.

The values of the position of the holes can be described on the drawing with a certain deviation, but it should be kept within the so called tolerance field. The value of tolerance is based on the standards selected on the basis of various shaping methods and the operating conditions of the workpiece.

Boring

Boring means shaping inner cylindrical surfaces with big tools (with drills, countersinks, reamers and with tap drills) or single edge tools. This way chipping procedures belong to the boring method that have one common feature, that is cutting tools with several edges rotate around their own axis and along its axis it makes a straight movement, which is identical with the pushing motion. In the course of boring the chipped surface is an inner cylinder or cone surface, plane and general rotation

surface. The above grouping can only provide us with general criteria for boring, and there may be exceptions there.

It is necessary to take the following aspects into consideration in the course of the preparation of the boring:

- the material of the workpiece;
- the technology of the operation;
- the selection of the tools;
- the selection of tool material;
- the selection of the machine tool and the consideration of its performance [1].

The operations of boring are as follows:

- drilling;
- sinking;
- reamer.

Drilling

Through hole drilling is the procedure when we make a hole into a standing or rotating brief workpiece. It is necessary to be careful that – despite the apparently simple operation – various errors may occur. This way, for example, in the case of a standing workpiece, the spiral drill can drill in an inappropriate way if the material of the workpiece is faulty. However, if the drilling is done into a rotating workpiece and the start falls into the rotation axis of the component, the spiral drill makes a uniaxial hole with an axis equivalent with the rotation axis of the workpiece, even in the case of a faulty material.

Shape and position errors (*Fig. 1*) may arise if we make a hole in a standing or rotating workpiece with a spiral drill. The error(s) may occur due to, for example, wrong harnessing or setting [1].

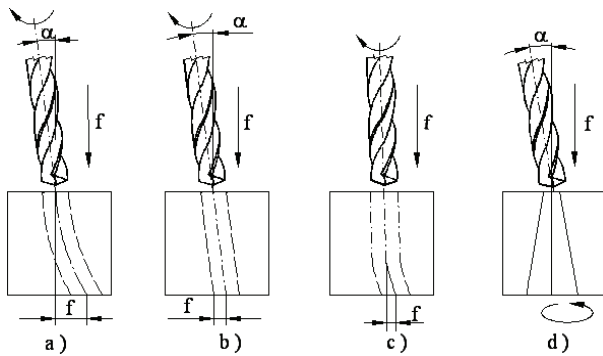


Figure 1: Shape and position errors during drilling

In picture (a) the axis of the drill and the direction of the feeding form a certain angle, the drill is subjected to a sideways pressure, so the hole will be a crooked.

In picture (b) the direction of the feeding and the axis direction tally, but the setting of the workpiece is wrong, the consequence of this is that the axis of the hole is aslope.

In (c) the axis of the drill and the direction of the feeding form an angle, and this time only one of the spiral drill edges chips, and the shape of the hole is wrong.

Picture (d) indicates the situation when the drill axis and the direction of the feeding forms an angle with the axis of the workpiece. The arising hole is tapered.

The main factors defining the accuracy of the hole:

- the quality of the substance to be holed;
- the diameter of the drill and the state of his edges;
- the state of the drill and a tool leg [3].

The definition of the position of holes

It is possible to determine the position of the holes in many ways.

Under the position of the bores we mean how the hole occupies a position as compared to the geometrically limited surfaces, as well as what the position of bores is like as compared to each other. We characterize the hole with its position of its axis line.

The latter one is provided with accurate measurements in the component drawings and the sizes are compared to a geometrically accurate central line – or surface or base (Fig. 2).

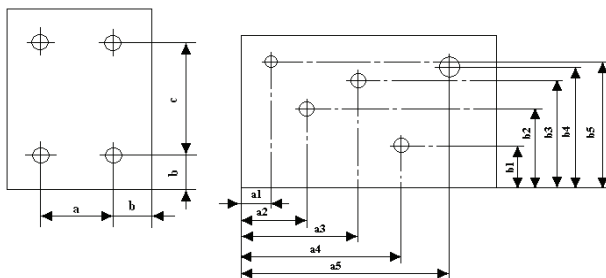


Figure 2: Rectangular scaling of holes

The values of the position of the holes can be described on the drawing with a certain deviation, but it should be kept within the so called tolerance field. The value of tolerance is described according to the standards

selected on the basis of various shaping methods and the operating conditions of the workpiece.

The control of the uniaxial of holes

If there is a component on which there are several cylindrical surfaces, and between them there is also a hole, uniaxiality plays a considerable role (coaxiality). Here we have to pay attention not only to the cylindrical surfaces, but also to the position of tapered and other surfaces as compared to each other.

In the course of the check-up we can speak about:

- uniaxiality (Fig. 3);
- deviation from parallelism;
- deviating of axes.

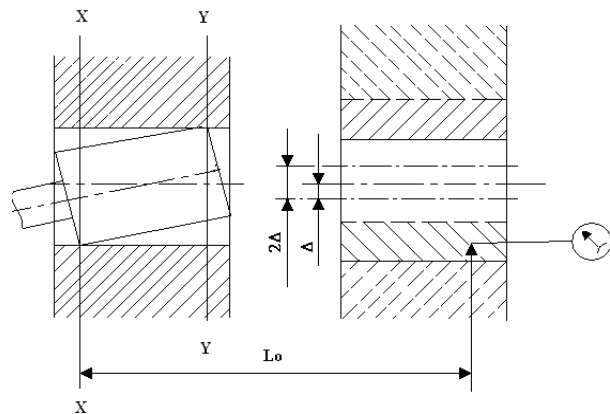


Figure 3: Checking the hole concentricity

Measurement methods should be chosen adequately. The basic principle of the measurement is that one of the cylinder surfaces (holes) is considered to be basic (this is the so called base), and we compare the deviation of the rest of the surfaces with it.

Main methods:

- A. the base is the component of the hole;
- B. we consider one of the hole diameters as a base, and we focus on it;
- C. we give accurate data referring to the hole axis in certain planes.

In the first case we place the hole of the component to be examined on the so-called compass tap of the measuring apparatus standing motionlessly in the case. It is important that there should not be a gap between them because this is an error source during the check-up of the additional surfaces. It spoils the accuracy of the measurement if the hole has a shape error. We make the workpiece revolve around the tap of the instrument in the course of the measurement and meanwhile – with other parts of the instrument – we fix the coaxiality for the surfaces and axes of the workpiece to be examined.

Within the 3rd method the orientation accuracy is growing in the recorded plane significantly, however, in the perpendicular plane we may expect smaller accuracy.

It is a modern method of measurement to use the coordinate gauge machine, with which we can check the surface where the tool (drill) enters the substance and

the one where it gets out of the surface. We can make a conclusion regarding e.g. the excentricity, which we cannot be measured with simple measuring devices [3].

Checking the hole diameters

The aim of all measurements is defining of the index-number.

During the measurement of a hole, as in the case of all solid shapes, it is necessary to consider not only one size, but several sizes.

A number of factors may cause the errors of the boring. I am examining the methods of boring in order that it would be more possible to choose the sources of dangerous errors out of several possible causes.

Boring is done with the help of MKC-500 type working centre. The equipment works with a program control. The machine tool working accuracy is IT6. I studied the component called arched arm (Fig. 4).

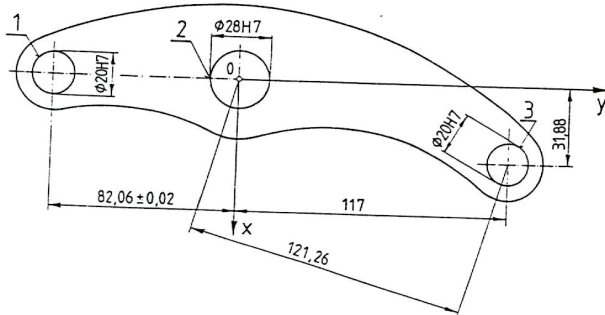


Figure 4: Arched arm

The technological plan of the arched arm:

- centre drilling, done with a standard centre drill with a diameter of 2.5 mm at all holes;
- multiple drilling happens with figural spiral drill (nominal size) -2 mm;
- sinking: (nominal size) -0.2mm;
- finisher shaping with the size being equal to the holes and tolerance (20H7, 28 H7), done with a traditional reamer;
- the edge breaking is done with a tapered countersink.

Based on the faulty workpieces and the examination of the technological process it can be stated that

- the error of the relative position of the holes may not be caused by the error of the device and the deficiency of a centre's accuracy;
- the insufficient hole protection may not cause the error of the hole diameter at painting, as there is no sign of it on the faulty pieces.

Thus, the two most frequent reasons can be unambiguously traced back to the types and lengths of the tools and the quality of the reamer. This way my further investigation considers only the two most important causes. Making a use of the measurements of all manufactured workpieces I apply statistical evaluation [2].

The statistical analysis of the data

The measurement results were expanded on the 162 workpieces used in the course of the experimental production.

The analysis of the data of the position of the holes

In Figs. 5 and 6 we can see data for the 5-6 and 6-7 holes in Y direction, while in Figs. 7, 8, 9 three holes in X direction are shown according to the descriptive statistical processing of error data. The statistical values necessary for the χ^2 test can be seen in Table 2.

Table 1: Measured values

class middle	40	32	24	16	8	0	-8	-16	-24	-32	-40
relative frequency	1	2	5	23	47	40	28	11	4	1	0

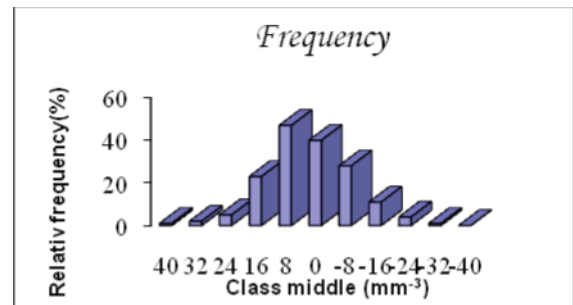


Figure 5. The evaluation of a difference measured in Y direction

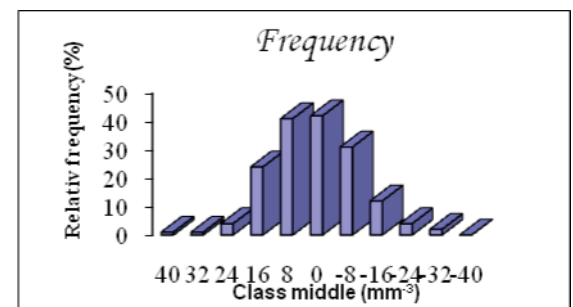


Figure 6. The evaluation of the difference measured in Y direction

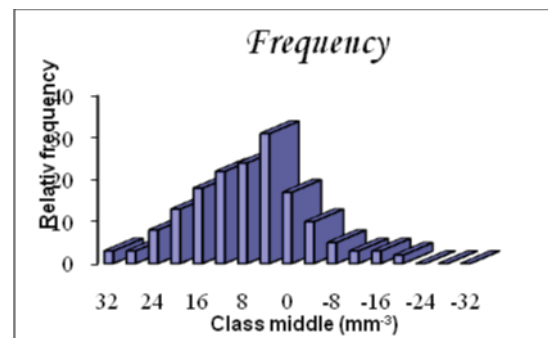


Figure 7. The evaluation of the difference measured in X direction

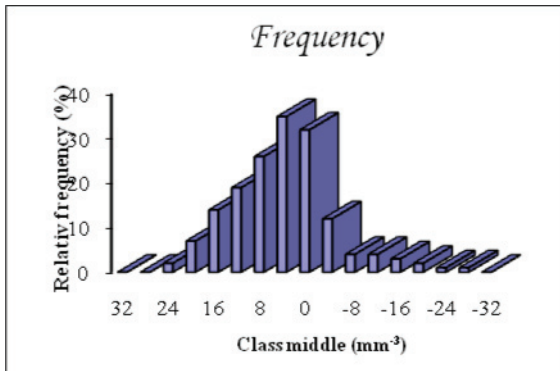


Figure 8. The evaluation of the difference measured in X direction

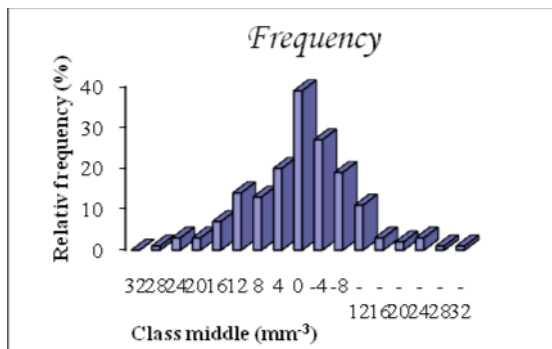


Figure 9. The evaluation of the difference measured in X direction

Table 2: The calculated features of the five diagrams

	n	X	R	s	A
Figure 5	162	2.71	68	11.7	-450
Figure 6	162	1.73	71	11.8	453
Figure 7	162	4	54	10.2	390
Figure 8	162	0.44	48	9	50
Figure 9	162	74	64	10	7.4

Table 3: the χ^2 data of the test

Class middle	Frequency	χ^2
-36.1 -28	1	0.1697
-28.1 -20	4	0.0492
-20.1 -12	11	0.1963
-12.1 -4	28	0.0526
-4.1 4	40	0.0988
4.1 12	47	1.5859
12.1 20	23	0.0123
20.1 28	5	1.605
28.1 36	2	0.0089
36.1 44	1	1.556

We apply a fitting test after defining the frequency distribution of the distances and graphical representation of holes, with the help of a statistical test – the χ^2 test (Table 3) –, so that the distances between the holes should follow a normal distribution.

The data are divided to k columns for the determination of the χ^2 test and the examination statistics is defined similarly to the previous method:

$$\chi^2 = \sum_{i=1}^k \frac{(O_i - E_i)^2}{E_i},$$

where O_i is the observed frequency for column i and E_i is the probable frequency of column i .

$\chi_{sz}^2 = 5.334 < \chi_{table}^2 = 15.1$; so the distribution is normal.

Considering the data about the machine, the apparatus and the circumstances of the shaping, and also taking the data in the tables into consideration, we can state that the big extent and scattering and the big number of waste products originating from the position of the holes are caused by the splay of the drill, asymmetric grinding and other factors linked to a tool.

Proposal for the correction of the quality

About the situation after the change we do not have additional data, but the number of faulty products deriving from this error is expected to fall to a level that there will be no need for any additional intervention.

Summary

We presented boring, as well as its steps and the check-up of the holes. We analysed the data of an experiment in a statistical way, which determined what error may arise during the shaping. After it we proposed the correction of the quality.

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