Study of axial force and torque at drilling on ZTAL4Cu1 alloy

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Abstract: - The paper presents some aspects regarding the influence of cutting parameters on the accuracy and productivity in drilling operations. Some of these cutting parameters can have detrimental influence on the machining by drilling if they are in the domain that exceeds the rational or optimal values. Knowledge of magnitude of cutting parameters in drilling operations is essential for estimating the power requirement in order to have the optimum conditions for drilling operation. The axial force and torque are very important to be used at right magnitude because excessive torque can distort the workpiece or cause it to slip in the workholding fixture. The torque during drilling is difficult to calculate and for this reason in the paper we tried to find the relationship between different process parameters in order to have the optimum values of torque and axial force.

Key-Words: - machinability, torque, axial force, process parameters.

1 Introduction

Knowledge of the cutting forces is indispensable for the rational use of machine tools as it causes the efforts that require the machine tool and the tools used in machining process.

The study of the impact of the cutting forces on the whole removing material process serves to a great extent to obtain useful results related to the machinability of the materials.

Although the literature shows a series of works on the cutting forces of drilling with twist drills, most of these neglect the influence of the cutting speed to the size of the forces, which in the case of light alloys can lead to sensitive errors. In general, the axial force and torque are expressed in terms of the feed rate *s* and the diameter of the drill *D* or, depending on the dimensions deduced there from, namely the cutting thickness *a* and the cutting width *b* (Fig. 1).

$$P = C_1 \cdot s^{x_1} \cdot L^{y_1} \quad [\text{kgf}] \qquad (1)$$
$$M = C_2 \cdot s^{x_2} \cdot D^{y_2} \quad [\text{kgf}\cdot\text{cm}] \qquad (2)$$

or

$$P = D \cdot a^{w_1} \cdot k_{sp} \qquad (3)$$
$$M = b \cdot a^{w_2} \cdot k_{sm} \cdot l \qquad (4)$$

where:

$$b = \frac{D}{2 \cdot sin\chi},$$
$$a = \frac{s}{2} \cdot sin\chi .$$

C_1, C_2 - constants that characterize the material of the workpiece;
K_{sp} and k_{sm} - specific cutting force for a 1 mm^2 cut-out section in the direction of axial force, respectively on torque;
l = the arm of the P_z force.

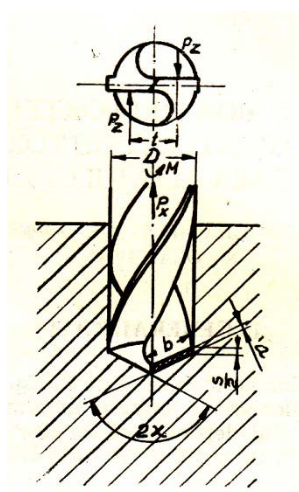

Fig.1 Axial force and torque at drilling operation.

As can be seen from the indicated relationships, the influence of the cutting speed on axial force and torque was not taken into account. If on the turning operation the influence of the cutting speed on the forces can be considered sufficiently clear, the data are still incomplete when drilling, indicating in some works only an insignificant influence of the speed in the range of 20-30 m / min.

For this reason, the paper aims at studying the variation of axial force and torque in drilling with twist drills, depending on the cutting parameters, namely: feed, the drilling depth, drill diameter, and the cutting speed for a zinc aluminum alloy.

2 Research Methodology

The tests were performed on 30 mm diameter cylindrical test specimens of pressure die cast ZTAL4Cu1 having the composition Al 3.5-4.3%, Cu 0.75-1.25%, Mg 0.03-0 , 06%, the remaining Zn.

Twist drill of high-speed steel having diameters between 13-20 mm was used. The thickness of the cutting edge was specific for the drilling of non-ferrous alloys, namely: point angle $2\chi = 140^0$ and helix angle $\omega = 35^0$. The drill sharpening was made using the imaginary cone method, without further sharpening.

Obtaining more precise results is conditioned by the existence of an identical geometry on all the tools used, since the geometric parameters' modifications introduce changes in axial force and torque. Thus, the magnification of the helix angle ω produces an increase in the angle γ, which leads to the decrease of the axial force and the torque, as a result of the decrease of the deformation work and the friction work on the rake face.

At values of over 40^0, the vibrations and large frictions occurring on the rake face which produce an increase of force and torque.

The decrease of the point angle χ leads to the increase of the P_z force component, thus of torque, but the axial force decreases. At low α angle values, the axial force and torque increase due to the increase of friction on the relief face. Finally, increasing the length of the main cutting edge with its unfavorable geometry involves increasing the axial force.

These were the reasons that conditioned a rigorously identical sharpening of the tools used to test.

Work was carried out in a feed range ranging from 0.13-0.31 mm /rev and for cutting speeds between 20-120 m / min.

The experimental results correspond to drilling in blind holes with length of $l = 1,5D$. In determining the axial force and torque values, a hydraulic dynamometer was used, the scheme of which is shown in Fig.2.

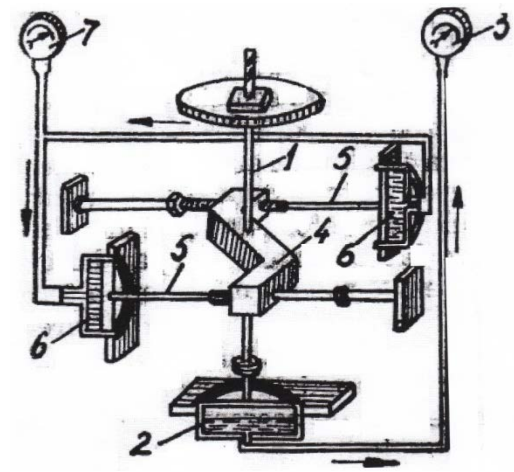

Fig.2 The schematic diagram of a hydraulic dynamometer.

The shaft 1, required by axial force and drill torque, acts on the hydraulic dose 2, and the manometer associated with this dose records a proportional pressure with the axial force. The drill torque is transmitted by the shaft 1 to the transverse bar 4 and hence by the levers 5 at the hydraulic doses 6. The manometer indications associated with these doses are proportional to the drill torque. For the two manometers calibration curves have been raised in [at] - [kgf], respectively [at] - [kgf · cm].

3 The test results

a) Influence of the feed

Accepting a variation of axial force and torque, according with the drill feed, drill diameter and cutting speed, given by the relations (5), (6), results that for drill diameter and cutting speed constant, the functions P = f (s) and M = f (s) will be represented as straight lines in logarithmic coordinates.

$$P = C_1 \cdot s^{x_1} \cdot D^{y_1} \cdot v^{-z_1} \quad (5)$$
$$M = C_2 \cdot s^{x_2} \cdot D^{y_2} \cdot v^{-z_2} \quad (6)$$

In order to determine the values of the x_1 and x_2 exponents for the investigated material, measurements of axial force and torque were made for a certain drill diameter and for the constant cutting speed, and the results in logarithmic coordinates were recorded.

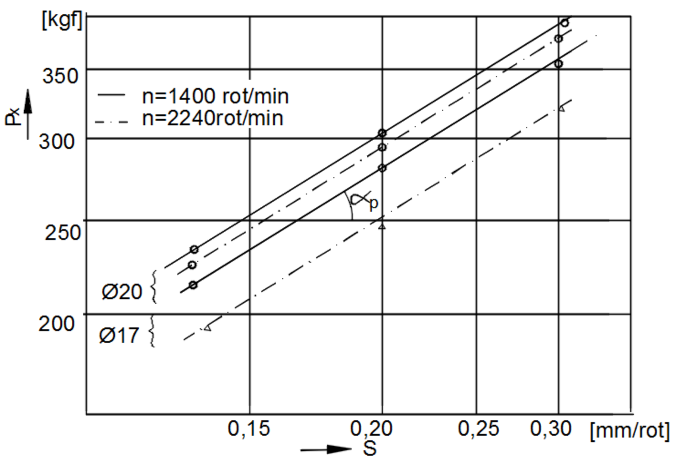

Fig.3 Variation of axial force depending on the drill feed.

It has also been verified by several series of measurements that the slope of the line obtained by the variation of the feed is not influenced by the size diameter or by the cutting speed at constant value th with which it is being worked.

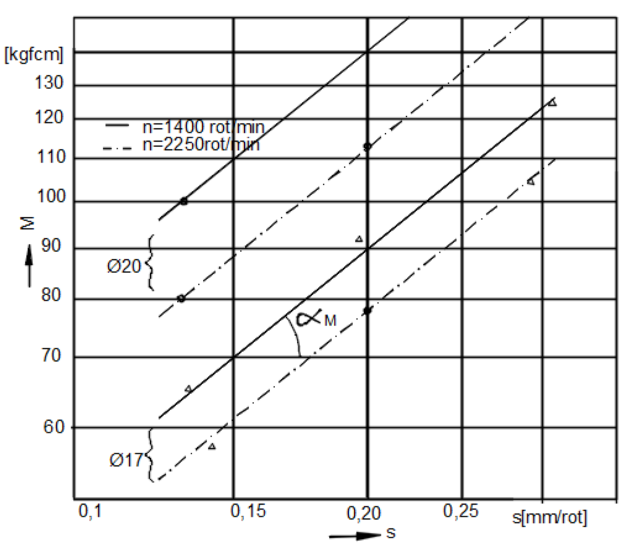

Fig.4 Variation of the torque depending on the drill feed.

The diagrams plotted in Fig. 3 and Fig. 4 allow the determination of the exponents, which in fact represent the angular coefficients of the lines of variation of the force and torque in logarithmic coordinates Thus, will result the following values:

$$x_1 = tg\alpha_P = 0.60$$
$$x_2 = tg\alpha_M = 0.83$$

b) Influence of the drill diameter

Working with a constant feed cutting speed, measurements were made for a series of drill diameters ranging from Ø13 ÷ Ø20 mm, with a progressive increasing variation of axial force and torque with drill diameter.

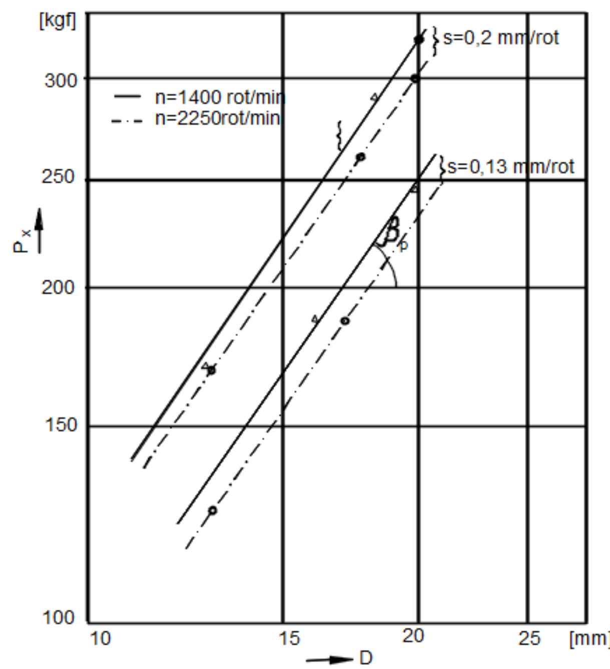

Fig.5 Variation of axial force depending on the drill diameter.

Even in this case, when changing the feed or the cutting speed with which the measurements were made, no influence on the slope lines of variation of force and torque according to diameter was found.

All the lines are parallel and the exponent of the diameter results:

$$y_1 = tg\beta_P = 1.\ 40$$
$$y_2 = tg\beta_M = 1.\ 72$$

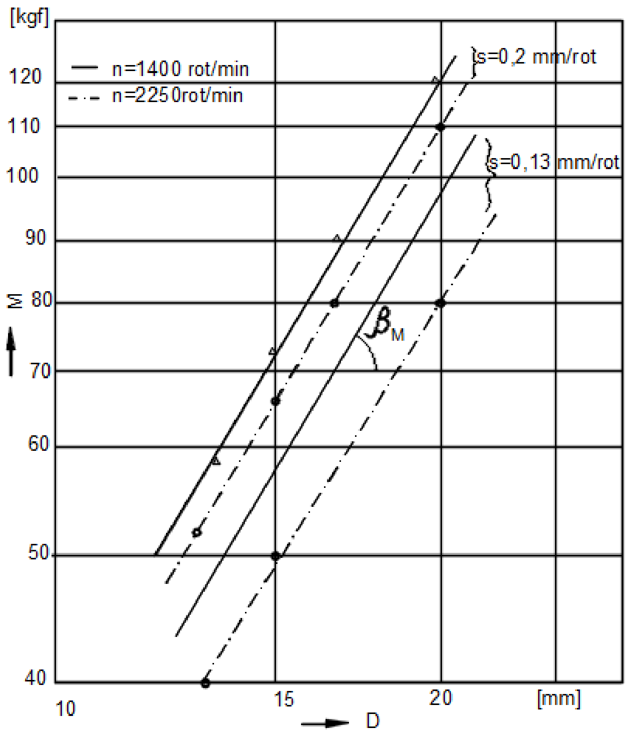

Fig.6 Variation of the torque depending on the drill diameter.

c) Influenece of the cutting speed

When investigating the influence of the cutting speed on the size of the axial force and torque, it must be taken into account that they result from the common effect of the main cutting edges, the chisel edge and the secondary cutting edges on the margins.

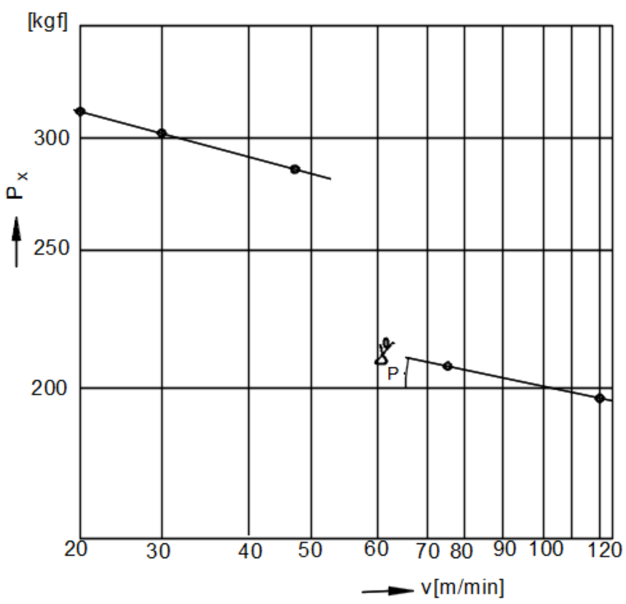

Fig.7 Variation of the axial force depending on the cutting speed.

The contribution of the chisel edge is characterized by the negative rake angle, through the reduced cutting speed to zero, through a difficult evacuation of chips, thus due to unfavorable cutting conditions. All of these factors lead to significant friction phenomena in the chisel edge area.

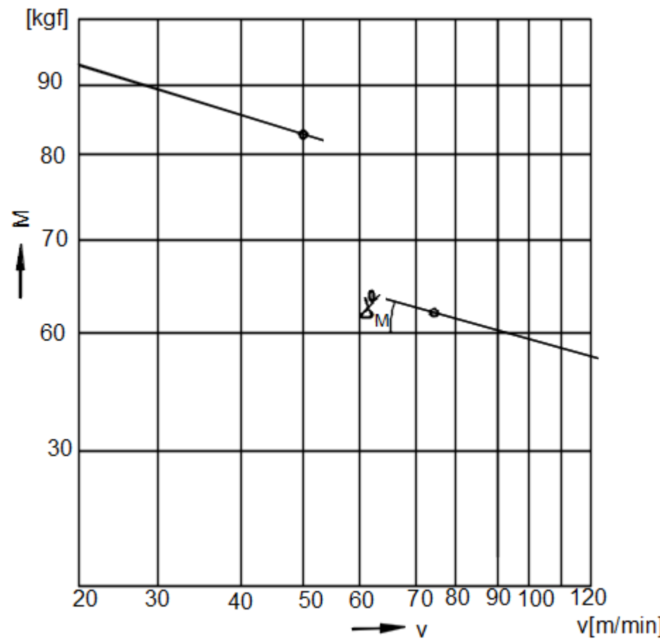

Fig.8 Variation of the torque depending on the cutting speed.

The contribution of the margin cutting edges is materialized primarily by increased friction, which increases as the depth of the groove is increased. Therefore, to obtain uninfluenced results from this friction on the margin cutting edges, all measurements were made for cutting lengths equal to $l = 1,5\,D$.

It is obvious that with the change in the cutting speed, the conditions in which the friction occurs change also, so there will be a corresponding variation of the axial force and the torque.

The experimental results highlight that for the researched material, two cutting speed domains in which the drilling is performed under different conditions, in both cases there was a decrease in the force and torque, when the speed increase.

In the range of cutting speed 20 ÷ 60 m / min, there are found high values of axial force and torque, due to the phenomenon of forming a build-up edge chips at these speeds. As such, in the processing of the material studied, this area of cutting speeds should be

avoided where its adhesion properties are very pronounced. It can be seen from Fig.7 and Fig. 8 that although the influence of the cutting speed on the axial force magnitude and the torque is less than the influence of the feed or of the drill diameter, it can not be neglected.
For the given cutting conditions, the coefficients were determined:

$$z_1 = tg\gamma_P = 0,\ 25$$
$$z_2 = tg\gamma_M = 0,\ 30$$

From the experiments carried out on the studied material, the following potential dependencies of the axial force and the torque results:

$$P = 42{,}6 \cdot s^{0{,}60} \cdot D^{1{,}40} \cdot v^{-0{,}25}\ [kgf] \qquad (4)$$
$$M = 115 \cdot s^{0{,}83} \cdot D^{1{,}72} \cdot v^{-0{,}30}\ [kgf \cdot cm]$$

e) Influence of the depth of the hole
As shown above, the measurements from which the results presented in the relations (4) were obtained were performed in all cases for hole lengths equal to 1.5 D, in order to eliminate the influence of the increasing friction force on the torque and axial force.

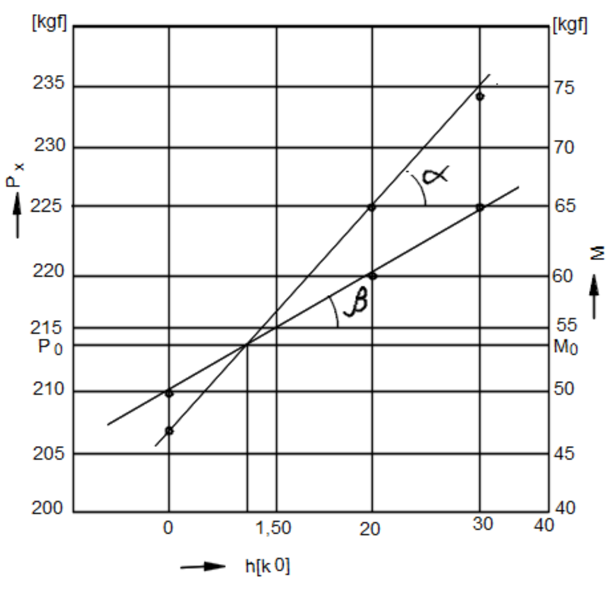

Fig.9 Variation of the axial force depending on the depth of the hole.

This influence was studied by measuring various depths of holes with diameter Ø17 mm using the cutting parameters: drill feed s = 0, 13 mm / rev and rotational speed of the drill n = 1400 rpm.
There was a linear increase in axial force and torque according to the depth of hole, following to the next relationships:

$$P_x = P_{x_0} \pm \Delta h \cdot tg\alpha \qquad (5)$$
$$M = M_0 \pm \Delta h \cdot tg\beta$$

where: P_{x_0}, M_0 are the axial force, respectively the torque for determinations made at the depth of the hole l = 1,5 D, Δh is the variation of the depth of the hole ($\Delta h = k \cdot D$).

4 Conclusions
For drilling operations is important to know the axial force and torque because these process parameters have a great influence in obtaining good accuracy and dimensional precision for the holes. These experimental data are available as an aid in designing and using drills and drilling equipment. Taking into consideration the elements of cutting as feed of the drill, diameter of the drill the cutting speed and the depth of the hole, we can have good information about the optimum cutting parameters that can be used to be sure that the holes that are produced correspond with required technical documentation.

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