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EXPERIMENTAL DETERMINATION OF TORQUE FOR THE DRILLING OF AL7SIMG ALLOY

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ABSTRACT

The productivity of a machining process is closely related to the value of the cutting force. For the calculation of the cutting forces, a series of models have been developed to allow the determination of these forces according to the machined material and the specific conditions in which the process is carried out. Usually, for a better approximation of the value of the cutting force, the unitary specific cutting force is used, which depends on the machined material. For common materials, the values of specific unitary specific cutting forces are presented in the specialized literature, but for less frequently used materials, for example those with reduced machining properties, the respective values are difficult, sometimes impossible to find. In this paper it is intended to determine the unitary specific cutting force for an aluminium alloy with a high silicon content, recognized as difficult to machine. The determination of the value of this force is done starting from the measured values of the torsional moment at the drills.

KEYWORDS: drilling, unitary specific cutting force, torque.

1. INTRODUCTION

As it is known, machining involves detaching an area from the surface of the workpiece and removing it in the form of a chip.

Detachment of the nominal chip and its transformation into a proper chip is done under the action of a force exerted by the cutting tool, called chipping force [1,2].

In addition to this aspect, a series of authors dealt with the analysis of the stability of the cutting process by monitoring the forces that appear during it, [4,5] and the influence of the shape of the cutting edge on the forces and temperatures that develop during cutting [6-10].

A series of methods are used to determine the main component of the cutting force, the most well-known of which are the analytical method and the quasi-empirical method, [1-3].

The analytical method is based on the machined layer plastic compression model and uses the polytropic plastic compression equation [1]:

$$\sigma \times l^n = \sigma_0 \times l_0{}^n \qquad (1)$$

Where: σ – the stress caused by the principal component of the machining force;

σ_0 – the stress at which the first residual deformations appear;

l – the length of the non-detached chip subjected to the action of the cutting force;

l_0 – the initial length of the non-detached chip subjected to deformation;

n – constant dependent on the nature of the material and the shape of the chip section.

In the model shown, the non-detached chip is considered as an isolated specimen subject to compression.

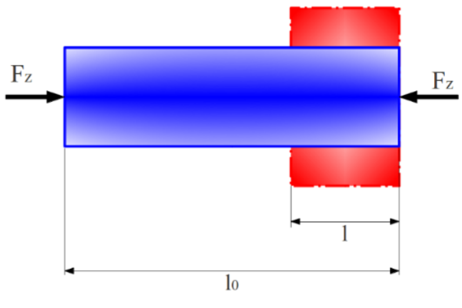

Fig. 1. *The model of the isolated specimen*

According to this model, the torque is calculated with the formula, [1]:

$$M_t = F_z \cdot z \cdot \frac{D}{4 \cdot 10^3} \ [\text{N}\cdot\text{m}]. \qquad (2)$$

In the equation (2), M_t is the torsional moment, F_z force on each of the main cutting edges, z the number of cutting edges of the drill and *D* the diameter of the drill. The cutting force depends on the specific cutting force through the relationship:

$$F_z = \frac{D}{2} \cdot s_d \cdot p_s \text{ [N]}, \quad (3)$$

s_d being the advance per tooth and p_s specific cutting force.

The specific force is determined with the equation:

$$p_s = \frac{p_{s1,1}}{a^z} \text{ [N/mm}^2\text{]}, \quad (4)$$

$p_{s1,1}$ being the unit specific force and *a* chip thickness, see also fig. 2.

Taking into account the equations (2), (3) and (4), for the torsional moment the following equation can be established:

$$M_t = \frac{D^2}{8 \cdot 1000} \cdot s \cdot \frac{p_{s1,1}}{a^z} \text{ [N·m]}. \quad (5)$$

If it is also taken into account:

$$a = s_d \cdot sin\kappa, \quad (6)$$

see also fig. 2, equation (5) becomes:

$$M_t = \frac{D^2}{8 \cdot 1000} \cdot s^{1-z} \cdot \frac{p_{s1,1}}{(sin\kappa)^z} \text{ [N·m]}. \quad (7)$$

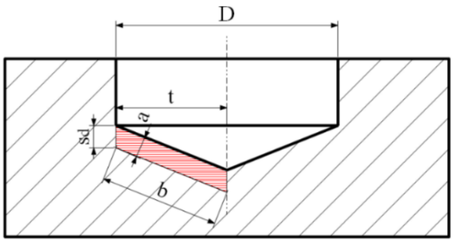

Fig. 2. *Undetached chip shape*

According to the equation (7), to determine the torque, it is necessary to know the specific unit cutting force and the characteristics of the cutting regime, respectively the advance *s* and depth of cut *D*/2.

In this paper, the experimental determination of the unitary specific chipping force is proposed, based on the measured values of the torsional moments in the case of drilling an aluminium alloy with a high silicon content, Al7SiMg.

2. EQUIPMENT USED AND WORKING METHOD

In order to be able to determine the parameters with the help of which the axial force and the torsional moment are calculated when drilling with a twist drill made out of high-speed steel (HSS) torque values were measured when drilling a hole Ø6 mm using various advance values (0.125; 0.16; 0.2; 0.3 mm/rot.).

The measurement was made with a dynamometer Kistler LabAmp 5167A and the machining on a milling center HAAS V1.

For each value of the advance, 3 determinations were made to be able to identify and eliminate aberrant results caused by external disturbing factors.

Next, the average value for the 3 cases corresponding to each value of the advance was considered.

The obtained results were processed using the Matlab program, using the module „Curve Fitting Toolbox".

3. DATA PROCESSING

For the 3 measurements, the average value of the torque was calculated, corresponding to the established advances, the results being presented in Table 1.

Table 1. *Values of torque*

f [mm/rot]	Mz [N·mm]	Mz_{med} [N·mm]
0.125	580.6	613.1
	633.3	
	625.2	
0.160	773.6	731.6
	618.0	
	803.2	
0.200	914.4	853.4
	860.9	
	785.0	
0.300	1214.3	1154.2
	1167.5	
	1080.7	

The results were entered in the "Curve Fitting Toolbox" module of the Matlab program. A "Custom" prediction model corresponding to the equation (7).

The value of the specific unit cutting force was obtained $p_{s1,1}$ = 489.5 N/mm^2 and the value of the exponent *z* = 0.273, with a confidence coefficient of 95%.

With these values, the magnitude of the torque is calculated for four values of the advance, for holes with a diameter of 6 mm.

The theoretical values obtained compared with the values obtained by measurement and the relative errors are given in Tabel 2 and fig. 3-6.

Table 2. *Measured vs. calculated values of torque*

f [mm/rot]	Mz [N·mm] measured	Mz [N·mm] calculated	Relative error [%]
0,125	613,1	610,8	0.37
0,160	731,6	730,8	0.11
0,200	853,4	859,5	0.71
0,300	1154,2	1154,1	0.008

The relative error for each advance value was calculated with the formula:

$$\varepsilon = \frac{\left|M_{z\_meas} - M_{z\_calc}\right|}{M_{z\_meas}} \cdot 100 \; [\%], \quad (8)$$

M_{z_meas} being the measured value of the torque and M_{z_calc} the value of this moment, result by calculation.

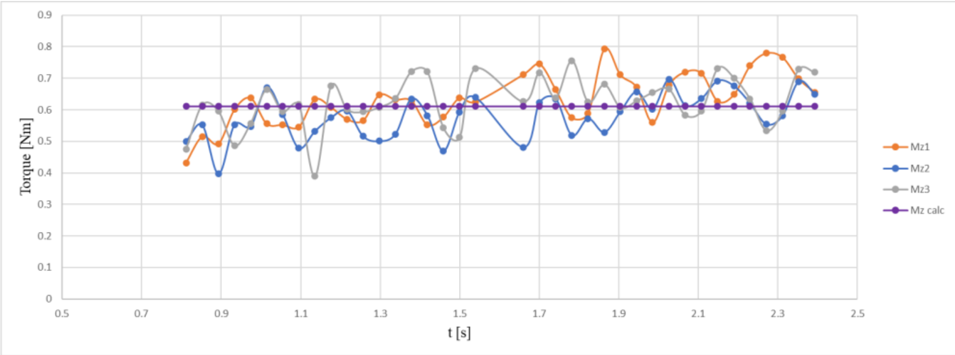

Fig. 3. *The measured and calculated torque values for s=0.125 mm/rot*

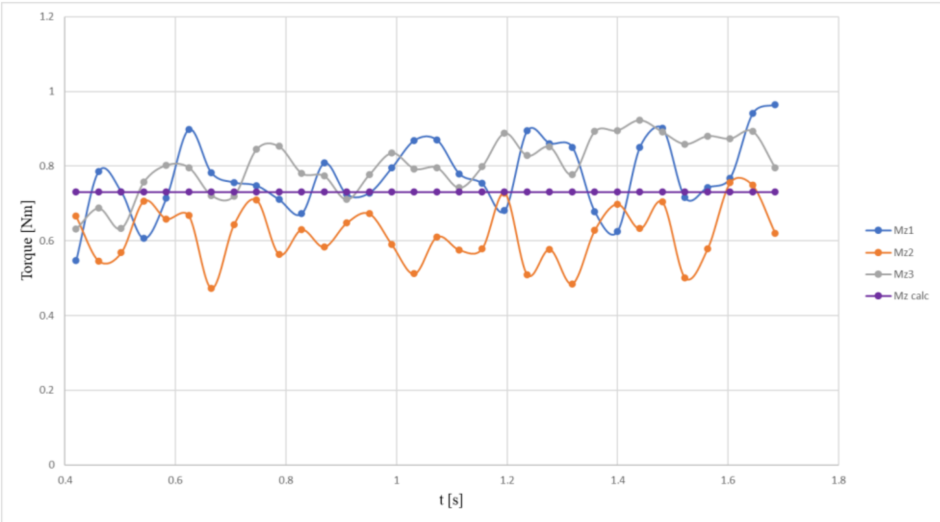

Fig. 4. *The measured and calculated torque values for s=0.160 mm/rot*

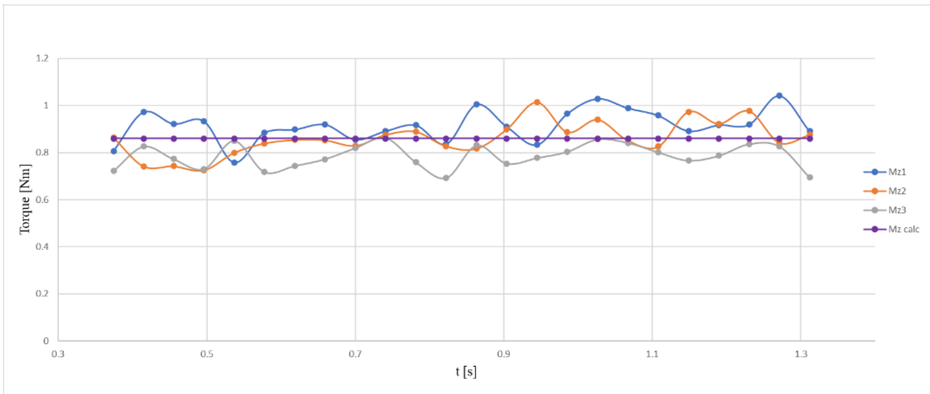

Fig. 5. *The measured and calculated torque values for s=0.200 mm/rot*

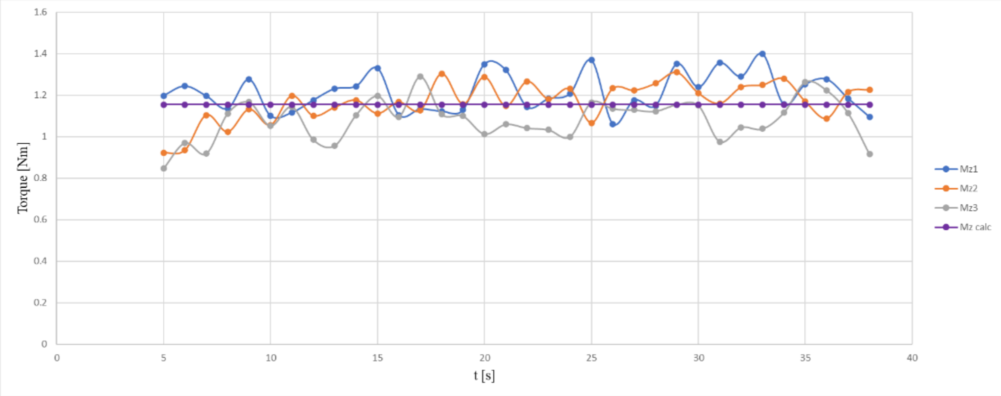

Fig. 6. *The measured and calculated torque values for s=0.300 mm/rot*

4. CONCLUSIONS

For the 3 measurements, the average value of the torque was calculated, corresponding to advances of 0.125; 0.160; 0.200 and 0.300 mm/rot, results presented in Table 1.

The proposed method allows the determination of the specific unitary cutting force, which determines the magnitude of the torque.

The obtained values are supported by the comparison with the values obtained by measurement, it being evident from fig. 3-6 that the calculated values are between the limits set by the measured values.

The method allows obtaining results that can be easily extrapolated in order to determine the axial force and the torsional moment when machining some materials for which the existing data in the specialized literature is insufficient or incomplete.

The method can also be extended in the case of other machining processes.

It is intended to carry out further research that will highlight the variation of the parameters calculated according to the diameter of the drill and the establishment of correction factors that take into account the machining conditions, respectively: the use of cooling fluid, the ratio between the diameter of the drill core and the outer diameter, etc.

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