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EXPERIMENTAL RESEARCH ON MEASURING CUTTING EFFORTS DURING ALUMINIUM ALLOYS DRILLING

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Abstract: *In the paper there is presented experimental research and results interpretation upon the measurement of the feed cutting force and cutting torsion moment in case of deep drilling of some aluminium alloys. There were used drills having the active part made of sintered metal carbides. The experimental stand, cutting regime parameters, obtained diagrams, their interpretation and corresponding exponential relationships are presented.*

Key words: *Experimental stand, Cutting efforts, Deep drilling, Aluminium alloys.*

1. INTRODUCTION

The experimental research had the aim to measure total feed cutting force and total torsion cutting moment in case of deep holes drilling [4, 5, 7, 8]. The reason to chose these cutting efforts measurement in order to study the cutting capacity [3, 9, 10] were two: first, they are the real efforts that load the technological system and second, their measurement is relatively easy to do, with an experimental stand which is very simple and reliable.

The experimental research was done on an original stand assembled on the milling machine for cutting tools TOS CELAKOWICE - Czechoslovakia, with the drill fixed in the spindle of the machine tool.

Measurement of the cutting efforts was done by means of a dynamometer, which uses stress gauges (Fig. 1).

The notations in Fig. 1 are the following: 1 - supporting shell; 2 - body; 3 - fixing bolt; 4 - measuring shaft; 5, 6 - screw and washer; 7 - radial ball bearing; 8 - flange; 9, 10 - screw and Grower washer; 11, 12 - screw and Grower washer; 13 - supports for workpiece.

On the measuring shaft, two complete Wheatstone bridges of stress gauges were fixed, one to measure the axial cutting force, the other to measure the torsion cutting moment. The measured values of the cutting efforts were set by means of an etalon mechanical dynamometer.

For the experiments, the following aluminium alloys were studied, in descendent order of hardness: ATSi12CuMgNi (135 HV), ATSi9Cu3Mg (125 HV), ATSi7CuMg03 (110HV). Each hardness mentioned in brackets was determined as average of 5 measurements for each alloy. It must be specified that there were more aluminium alloys that were studied (see Fig. 2), but in this paper we mentioned only those which had a homogeneous internal structure and lead to significant results.

The cutting tools that were used for the experiments to determine the machining ability of the aluminium alloys were drills enforced with metal carbides plates. These drills were manufactured by Carmesin S.A. Company, using HSS drills, in which the proper slot was machined and the proper metal carbide plate was fixed with silver alloy.

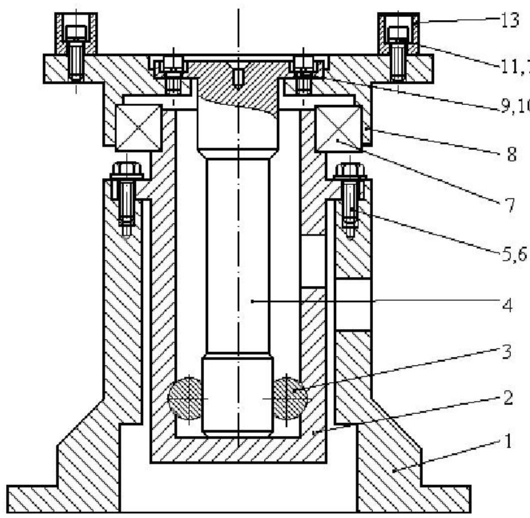


Fig. 1. Dynamometer.

Fig. 2. Aluminium alloy workpieces.

The used metal carbides plates were of P20 sort, rectangle, having a thickness of 2, …, 3 mm. After their fixture the drills were sharpened with the point angle of 118˚. Regarding the constructive geometry of the drills, two aspects must be mentioned: first, the rake face is plane and the rake angle is $\gamma = 5^\circ$ and second, the clearance face is conical, due to the conical sharpening method. The medium clearance angle is $\alpha = 15^\circ$ because the later experiments would use high feeds.

2. EXPERIMENTAL RESEARCH AND RESULTS

For the measurements of the axial cutting force and torsion cutting moment during the boring of aluminium alloys with drills enforced with metal carbides plates a factorial plan was set [1, 2, 6]. Because the function type of the cutting efforts was considered to be exponential Taylor type, the planned values of the cutting regime parameters were chosen depending on the available values on the machine tool. The plan is presented in Table 1.

After all measurements were done, 48 data files were obtained, one file for each planned experiment. Out of the 48 files, only 36 files will be presented, because one studied material (out of total four) had not a homogeneous internal structure, which lead to insignificant results. The obtained data, registered by means of computer data acquisition, were used to draw the variation of cutting efforts vs. time diagrams.

For example, Fig. 3 presents the diagram of the test A1 - for cutting force, B1 - for cutting moment.

The experimental results will be presented separately for each aluminium alloy, in Tables 2, 3 and 4.

As it was presented before, it must be found a complex exponential Taylor function, which will approximate as good as possible the experimental diagrams.

This means to determine the coefficients and exponents of the exponential functions considered as models:

$$F_a = C_F \cdot D^{x_F} \cdot s^{y_F} \cdot v^{z_F} \quad ; \quad M_t = C_M \cdot D^{x_{MF}} \cdot s^{y_M} \cdot v^{z_M} \quad .(1)$$

After calculations, the obtained values of the coefficients and exponents are presented in Table 5.

Table 1

Plan for experiments to determine cutting efforts at drilling (A1 - cutting force, B1 - cutting moment)

Variable → Test *FA*↓	Diameter *D*, mm	Spindle rpm	Feed speed f_v, mm/min
A1	6	1000	50
A2	6	1000	200
A3	6	2000	100
A4	6	2000	200
A5	12	500	25
A6	12	500	100
A7	12	1000	50
A8	12	1000	200
A9	8.5	1000	100
A10	8.5	1000	100
A11	8.5	1000	100
A12	8.5	1000	100
B1	6	1000	50
B2	6	1000	200
B3	6	2000	100
B4	6	2000	200
B5	12	500	25
B6	12	500	100
B7	12	1000	50
B8	12	1000	200
B9	8.5	1000	100
B10	8.5	1000	100
B11	8.5	1000	100
B12	8.5	1000	100

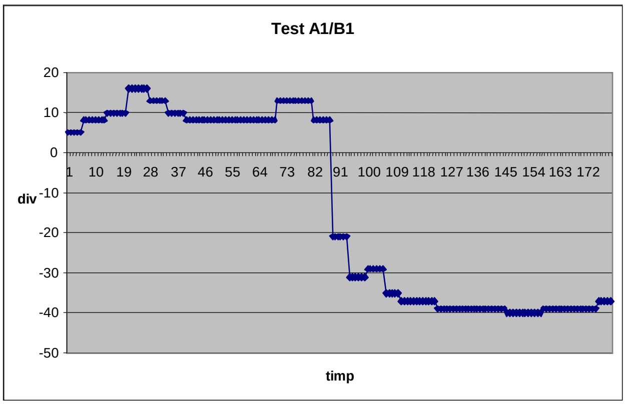


Fig. 3. Diagram cutting efforts vs. time for tests A1/B1.

Table 2

Experimental results for material 1 ATSi12CuMgNi

Variable →	Diameter	Spindle rpm	Cutting speed	Feed speed	Feed	Axial cutting force *FA*		Torsion cutting moment *MR*	
Test	mm	rot/min	m/min	mm/min	mm/rot	Div	daN	Div	daNmm
A1/B1	6	1000	18.849	50	0.05	16	11.36	40	7.176
A2/B2	6	1000	18.849	200	0.2	52	36.92	110	19.734
A3/B3	6	2000	37.699	100	0.05	20	14.2	40	7.176
A4/B4	6	2000	37.699	400	0.2	54	38.34	120	21.528
A5/B5	12	500	18.849	25	0.05	34	24.14	70	12.558
A6/B6	12	500	18.849	100	0.2	104	73.84	230	41.262
A7/B7	12	1000	37.699	50	0.05	34	24.14	80	14.352
A8/B8	12	1000	37.699	200	0.2	99	70.29	220	39.468
A9/B9	8.5	1000	26.703	100	0.1	42	29.82	90	16.146
A10/B10	8.5	1000	26.703	100	0.1	43	30.53	91	16.3254
A11/B11	8.5	1000	26.703	100	0.1	42	29.82	93	16.6842
A12/B12	8.5	1000	26.703	100	0.1	42	29.82	89	15.9666

Table 3

Experimental results for material 3 ATSi9CuMg

Variable →	**Diameter**	**Spindle rpm**	**Cutting speed**	**Feed speed**	**Feed**	**Axial cutting force *FA***		**Torsion cutting moment, *MR***	
Test	mm	rot/min	m/min	mm/min	mm/rot	Div	daN	Div	daNmm
A25/B25	6	1000	18.849	50	0.05	20	14.2	18	3.2292
A26/B26	6	1000	18.849	200	0.2	56	39.76	75	13.455
A27/B27	6	2000	37.699	100	0.05	21	14.91	20	3.588
A28/B28	6	2000	37.699	400	0.2	59	41.89	79	14.1726
A29/B29	12	500	18.849	25	0.05	42	29.82	37	6.6378
A30/B30	12	500	18.849	100	0.2	113	80.23	150	26.91
A31/B31	12	1000	37.699	50	0.05	48	34.08	40	7.176
A32/B32	12	1000	37.699	200	0.2	114	80.94	157	28.1658
A33/B33	8.5	1000	26.703	100	0.1	49	34.79	51	9.1494
A34/B34	8.5	1000	26.703	100	0.1	50	35.5	53	9.5082
A35/B35	8.5	1000	26.703	100	0.1	49	34.79	54	9.6876
A36/B36	8.5	1000	26.703	100	0.1	49	34.79	55	9.867

Table 4

Experimental results for material 4 ATSi7CuMg03

Variable →	**Diameter**	**Spindle rpm**	**Cutting speed**	**Feed speed**	**Feed**	**Axial cutting force *FA***		**Torsion cutting moment *MR***	
Test	mm	rot/min	m/min	mm/min	mm/rot	Div	DaN	Div	daNmm
A37/B37	6	1000	18.849	50	0.05	28	19.88	7	1.2558
A38/B38	6	1000	18.849	200	0.2	66	46.86	34	6.0996
A39/B39	6	2000	37.699	100	0.05	31	22.01	10	1.794
A40/B40	6	2000	37.699	400	0.2	71	50.41	38	6.8172
A41/B41	12	500	18.849	25	0.05	56	39.76	14	2.5116
A42/B42	12	500	18.849	100	0.2	133	94.43	69	12.3786
A43/B43	12	1000	37.699	50	0.05	60	42.6	17	3.0498
A44/B44	12	1000	37.699	200	0.2	140	99.4	74	13.2756
A45/B45	8.5	1000	26.703	100	0.1	61	43.31	20	3.588
A46/B46	8.5	1000	26.703	100	0.1	61	43.31	22	3.9468
A47/B47	8.5	1000	26.703	100	0.1	61	43.31	21	3.7674
A48/B48	8.5	1000	26.703	100	0.1	61	43.31	22	3.9468

Table 5

Experimental results processing (Taylor function coefficients and exponents)

No	***FA/MR***	**Tests**	**Material**	***C***	***x***	***y***	***z***
1	*FA*	A1-A12	ATSi12CuMgNi (135 HV)	19.533	0.931866	0.786033	0.076323
2	*MR*	B1-B12	ATSi12CuMgNi (135 HV)	10.925	0.936488	0.777504	0.063511
3	*FA*	A25-A36	ATSi9CuMg (125 HV)	13.972	1.056526	0.706443	0.087758
4	*MR*	B25-B36	ATSi9CuMg (125 HV)	8.111	1.007592	1.004101	0.101310
7	*FA*	A37-A48	ATSi7CuMg03 (110 HV)	15.577	0.985780	0.612864	0.106433
8	*MR*	B37-B48	ATSi7CuMg03 (110 HV)	2.807	0.937031	1.078658	0.264019

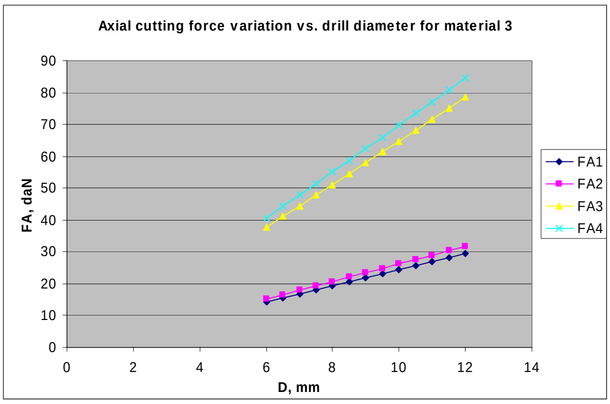
3. CONCLUSIONS

In the beginning it must be underlined that the before mentioned relationships can be used by the cutting tools manufacturer, in order to design and verify them. They also can be used by the machine tool manufacturer to design and verify the main and feed drives of the machine tool. Last, but not least, these relationships can be used by the manufacturing engineer to design a technological process.

Another aspect to be underlined is that the calculated values of the coefficients and exponents of Taylor functions, by their amount, confirm the following conclusions related to the influence of feed and cutting speed upon the cutting efforts:

The most important influence element upon the cutting efforts is the diameter of the drill. Its corresponding exponent has the greatest value of all. Influence of the drill diameter upon the axial cutting force for material 3 is shown in Fig. 4. The influence upon the torsion cutting moment is similar.

The most important influence cutting regime element upon the cutting efforts is the feed. It has much greater value of its exponent than the cutting speed's value. For



Note: Notations are as following:

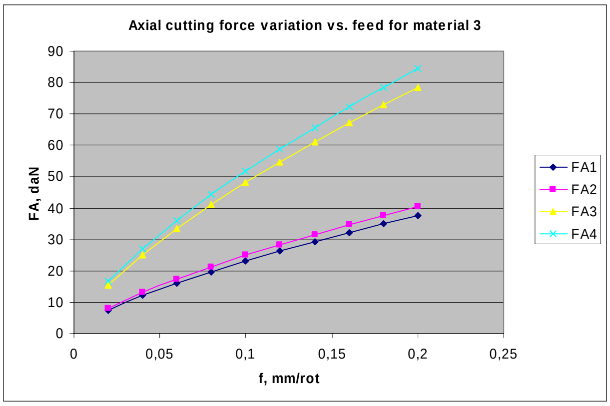
FA_1 V_c =15 m/min f = 0.05 mm/rot

FA_2 V_c =35 m/min f =0.05 mm/rot

FA_3 V_c =15 m/min f =0.2 mm/rot

FA_4 V_c =35 m/min f =0.2 mm/rot

Fig. 4. Axial cutting force variation vs. drill diameter.



Note: Notations are as following:

FA_1 V_c =15 m/min D = 6 mm

FA_2 V_c =35 m/min D = 6 mm

FA_3 V_c =15 m/min D = 12 mm

FA_4 V_c =35 m/min D = 12 mm

Fig. 5. Axial cutting force variation vs. feed.

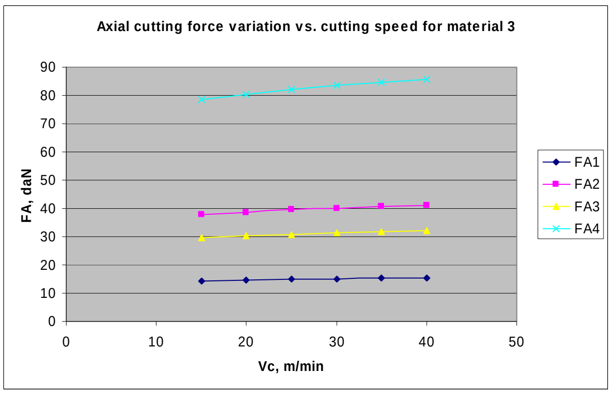


Fig. 6. Axial cutting force variation vs. cutting speed.

higher values of the cutting speed, the influence of feed diminishes a little (see Fig. 5).

When the cutting speed increases the trend of cutting efforts is to decrease. However, the values of the cutting speed exponents are very low (see Fig. 6).

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