Material machining for friction knots of moving parts for agricultural machines

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Abstract

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The study deals with the effect of the cutting parameters such as the cutting speed, feed and cooling on the quality of machined surfaces in the process of hole drilling for the sliding bearings used in agricultural technique. This effect has been studied on various metals such as copper, brass, dural and leaded bronze, which are commonly used for their friction knots of the moving parts for agricultural machinery. The results suggest the use in the design of collection parts, scything strips, as well as lifting equipment of agricultural technique, where particular linear and rotary movements of the friction parts are slow, as well as for the design of appropriate drilling procedures.

Keywords: friction knot; sliding bearing; cutting speed; cooling; quality of machined surfaces

Quality and efficiency of the agricultural equipment machining depend on the methods, devices and parameters that affect the work piece and so change its initial properties into those required. Finishing processes are also included, affecting the required shape, precision and surface of the component (Audy 2008, 2009).

Various machining procedures are used. Drilling process is one of the most used manufacturing techniques. Precision of the holes made and quality of machined surfaces after drilling can be additionally increased by subsequent roughing or reaming. The selection of the convenient drilling procedure can influence the manufacturing economics, machined surface quality, productivity and total technological cost of machining (Stephenson, Agapiou 2006). This effect is studied for various metals such as copper, brass, dural, and leaded bronze, which are commonly used for the preparation of the friction knots for the moving parts of agricultural machinery.

MATERIAL AND METHODS

Single-circuit detector Utilcell-M120 was used for obtaining the data on the changes of cutting forces in the process of drilling (Fig. 1). The crush element of this detector is made of beryllium-copper alloy made by the Utilcell Co., Barcelona, Spain.

The cutting force measured is the force acting on the arm, therefore it was recalculated for the real cutting force of the drill – following the equation:

$$F_z = \frac{2F_{nam} \times L}{D} \quad \text{(N)} \qquad (1)$$

where:

F_z – real cutting force (N)

F_{nam} – measured force (N)

L – distance between the detector and drill axis (mm)

D – diameter of the drill (mm)

Detector of temperature – a thermoelectric segment operates on the basis of Seebeck feature. Two

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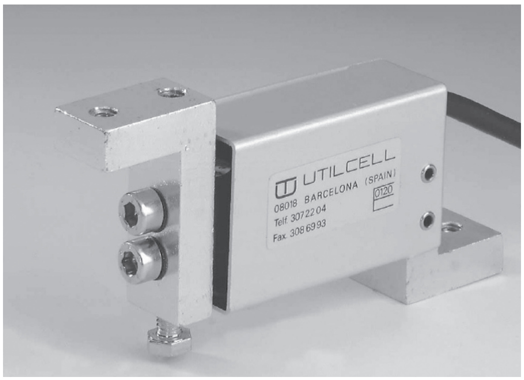

Fig.1. Detector of cutting force Utilcell M120 (Utilcell 2007)

line wires of different metals are linked on one end. If the ends of the circuit made have different temperatures, it incurs the proportional tension of temperature difference between them. The thermoelectric segment used in this study consists of two line wires of copper and of constantan (Stephenson, Agapiou 2006). The most accurate information about the temperature flow in the process of drilling can be obtained by measuring the temperature always at the level of the cutting spot. This position can be adjusted by displacement of the fixing holder on zero-sequence withdrawable part of the spindle. The position of the temperature detector is illustrated in Fig. 2.

Sample preparation

The samples were made of soft metals such as copper, dural, brass and leaded bronze for the effect assignment of the machining material type and cutting conditions on the process of drilling. Three samples were made of each metal, one for each particular rotation. All samples were in the shape of cylinder with the dimension Ø 30 × 30 mm. The precise measuring of temperatures was ensured by convenient surface quality. The samples were made by lathe-turning. The drilling was conducted without any cooling fluid.

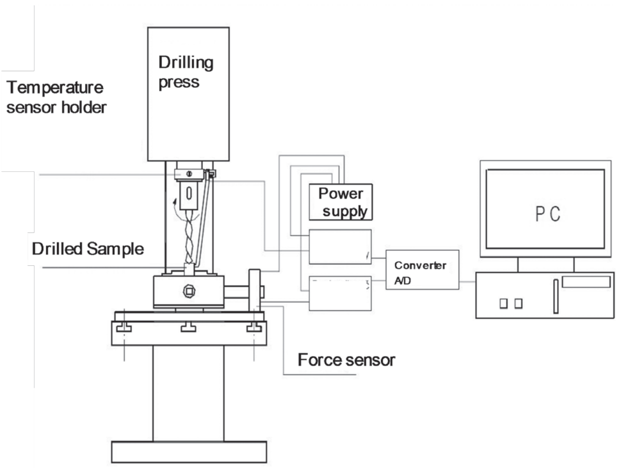

Fig. 2. Scheme of measuring device structure

Drill Poldi HSS 02 Ø 16 mm STN 22 1140 (1977) was used as the cutting tool; it had been made of high-alloy high-speed steel (Anonymous 2003).

Procedure of measuring

The rotation of 85 1/min was used for the first measuring. The feed was constant for the whole measuring process. Four snapshots were taken with thermography video camera throughout drilling. The first snapshot was taken when the drill reached the scope by whole cutting edge. The rest of snapshots were taken at periodical intervals. The last snapshot was taken in the position of close run out of the drill from the sample. Next two samples were measured at higher rotations of 150 1/min and 265 1/min. This procedure was repeated with other materials (Bátora, Vasilko 2000).

RESULTS AND DISCUSSION

Particular samples were measured within the parameters illustrated in Table 1.

The data on the average temperatures on the work-piece surface and cutting forces are illustrated in the following tables (Tables 2–5). The measured values were selected according to the gradation of the drilling tool track (Anonymous 2007).

Table 2 shows the data on the average temperatures on the work-piece surface and cutting forces for dural. The flow of the cutting forces in the dependence on the rotation change of dural is illustrated in Fig. 3.

Table 3 shows the data on the average temperatures on the work-piece surface and cutting forces for leaded bronze. The flow of the cutting forces in the dependence on the rotation change of leaded bronze is illustrated in Fig. 4.

Table 1. Applied parameters of drilling

	Rotation (1/min)	Feed (mm)	Cutting speed (m/min)
Sample 1	85	0.1	4.27
Sample 2	150	0.1	7.54
Sample 3	265	0.1	13.32

Table 2. Applied measured average temperatures and cutting forces for dural

Tool track (mm)	Sample 1		Sample 2		Sample 3	
	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)
0	22.9	0	28.5	14	32.0	0
3	27.8	3,489	36.1	3,099	37.4	3,465
6	35.4	4,524	40.1	3,994	43.3	4,490
9	42.0	3,277	49.7	4,110	50.3	3,576
12	48.5	3,609	54.1	3,133	56.5	3,821
15	51.0	3,446	58.9	3,677	61.8	3,301
18	54.7	4,750	58.9	2,912	65.3	3,215
21	57.7	3,754	61.8	3,056	69.2	3,162
24	59.5	3,735	64.1	3,508	73.6	3,191
27	59.5	4,096	67.0	3,277	76.3	3,499
30	51.6	1,554	54.7	4,009	54.7	10

Table 4 shows the data on the average temperatures on the work-piece surface and cutting forces for brass. The flow of the cutting forces in the dependence on the rotation change of brass is illustrated in Fig. 5.

Table 5 shows the data on the average temperatures on the work-piece surface and cutting forces for copper. The flow of the cutting forces in the dependence on the rotation change of copper is illustrated in Fig. 6.

Measured values of hardness

Table 6 shows the measured hardness of dural with all three samples measured. Hardness *Ra* in the dependence on the rotation of dural is illustrated in Fig. 7.

Table 7 shows the measured hardness of leaded bronze with all three samples measured. Hardness *Ra* in the dependence on the rotation of leaded bronze is illustrated in Fig. 8.

Table 8 shows the measured hardness of brass with all three samples measured. Hardness *Ra* in the dependence on the rotation of brass is illustrated in Fig. 9.

Table 9 shows the measured hardness of copper with all three samples measured. Hardness *Ra* in the dependence on the rotation of copper is illustrated in Fig. 10 (Žitňanský, Žarnovský 2010).

Geometry of drilled hole

The calculated values of ovality for each material studied are clearly shown in Table 10. Ovality was studied in the working plane A-A and B-B.

The basic prerequisite for the most suitable cutting parameters detection in drilling coloured met-

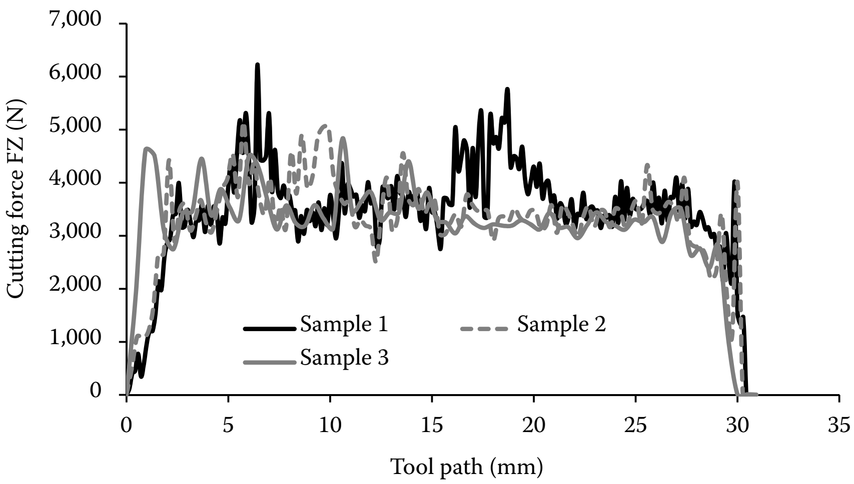

Fig. 3. Flow of cutting forces in dependence on rotation change – dural

Table 3. Applied measured average temperatures and cutting forces for leaded bronze

Tool track (mm)	Sample 1		Sample 2		Sample 3	
	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)
0	25.0	5	27.8	14	33.4	0
3	31.3	2,228	30.6	4,822	34.0	2,517
6	37.4	4,919	34.7	4,331	39.4	4,822
9	44.6	5,149.5	40.1	5,414	44.0	5,727
12	48.5	4,519	44.6	4,851	47.8	4,456
15	52.8	4,875	49.1	5,342	53.4	5,188
18	57.7	4,837	53.4	5,438	57.7	5,101
21	62.4	5,106	57.1	4,938	61.2	5,987
24	67.0	5,433	63.6	5,313	66.4	5,082
27	70.3	5,554	68.1	5,482	74.7	5,756
30	64.1	3,268	54.1	703	57.1	1,319

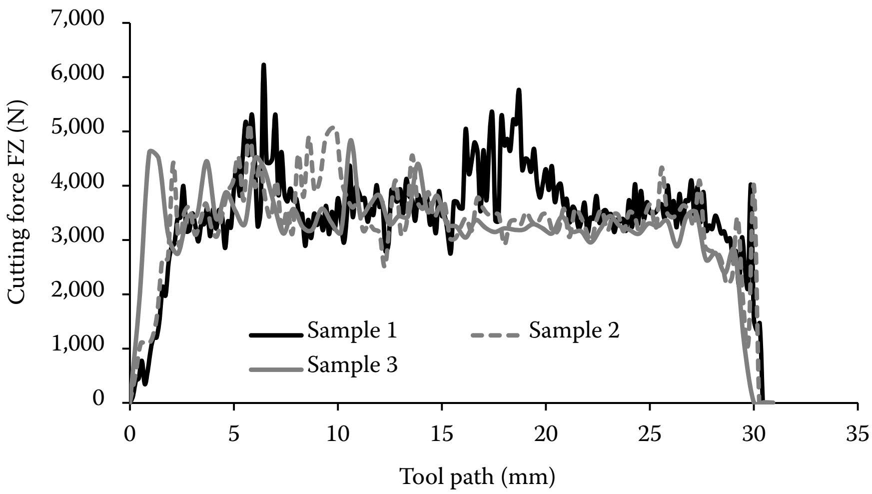

Fig. 4. Flow of cutting forces in dependence on rotation change – leaded bronze

Table 4. Applied measured average temperatures and cutting forces for brass

Tool track (mm)	Sample 1		Sample 2		Sample 3	
	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)
0	25.0	5	29.9	5	34.0	10
3	28.5	2,777	32.0	3,605	36.1	3,629
6	34.0	4,822	36.1	3,908	38.7	4,558
9	37.4	4,548	38.1	4,774	41.4	5,390
12	43.3	5,130	40.7	4,822	45.9	4,173
15	45.9	5,188	44.6	4,663	48.5	5,299
18	51.0	4,923	46.6	5,304	50.3	5,607
21	53.4	4,769	52.8	4,938	55.9	6,083
24	57.1	5,741	57.1	5,650	57.1	4,933
27	52.2	6,155	63.0	5,193	61.8	6,507
30	50.3	6,222	58.9	6,271	62.42	5,385

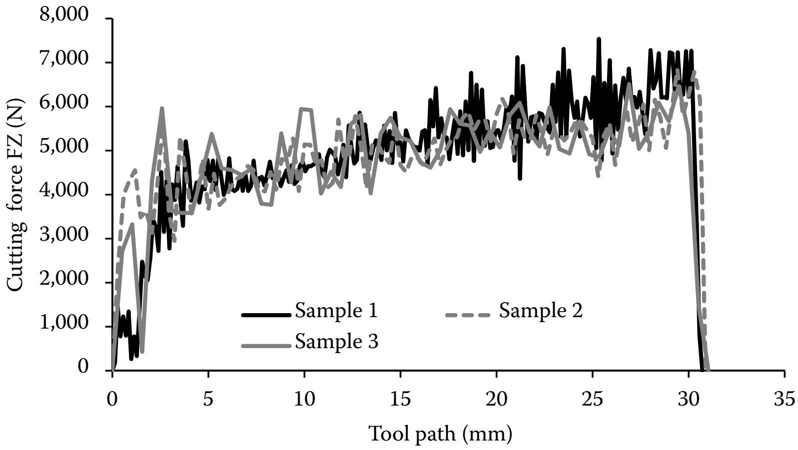

Fig. 5. Flow of cutting forces in dependence on rotation change – brass

Table 5. Applied measured average temperatures and cutting forces for copper

Tool track (mm)	Sample 1		Sample 2		Sample 3	
	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)	temperature (°C)	cutting force (N)
0	31.3	10	36.7	10	39.4	14
3	32.0	4,842	44.6	8,167	41.4	9,879
6	46.6	12,143	60.1	13,343	47.2	10,835
9	55.9	11,583	73.1	12,232	58.9	14,196
12	67.0	12,076	84.9	12,623	67.0	13,936
15	69.2	11,766	92.0	12,698	76.8	14,687
18	79.9	15,621	98.7	13,109	80.9	14,365
21	80.4	12,604	100.3	13,643	93.9	11,599
24	79.4	10,974	86.9	12,574	95.6	11,798
27	77.3	14,916	89.7	14,324	84.4	14,324
30	69.8	683	72.0	154	74.7	2,233

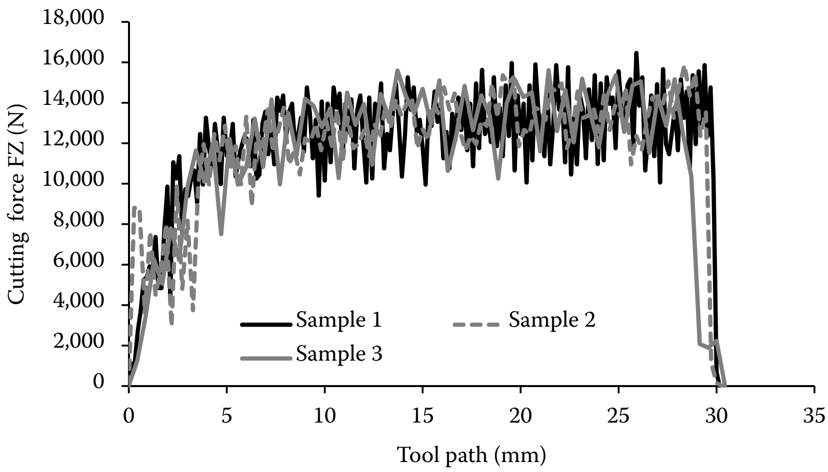

Fig. 6. Flow of cutting forces in dependence on rotation change – copper

als for friction knots of agricultural equipment was quality monitoring of the surfaces thus machined on the experimental samples. Quality of drilled holes was evaluated in accordance with the surface hardness, geometric precision, and conformity of the machined hole proportion with the drill diameter used. A rapid increase in cutting forces out of consideration to the average cutting force level was accomplished with dural samples drilling. It stayed around this value henceforth. The high-

Table 6. Measured values of hardness – dural

Parameter (μm)	Sample 1	Sample 2	Sample 3
Ra	2.02	1.33	1.72
Rq	2.45	1.61	2.03
Rt	12.4	7.3	9.4
Rv	8.7	5.5	7.3
Rz	6.1	3.9	5.1
Rp	4	2.5	3.7

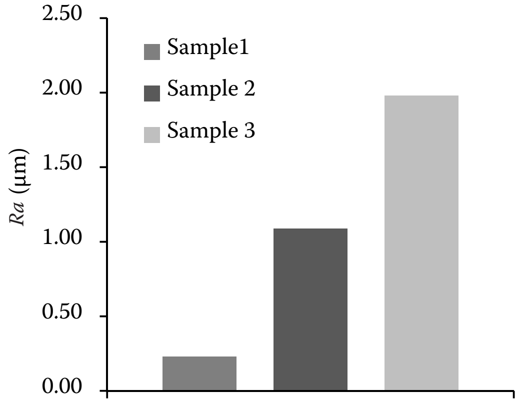

Fig. 8. Dependence of Hardness *Ra* on rotation – leaded bronze

Table 8. Measured values of hardness – brass

Parameter (μm)	Sample 1	Sample 2	Sample 3
Ra	0.83	0.7	0.95
Rq	1.3	0.88	1.13
Rt	8.3	5.2	5.6
Rv	4.2	3.8	4.5
Rz	2	2.5	3
Rp	1.6	1.4	2.1

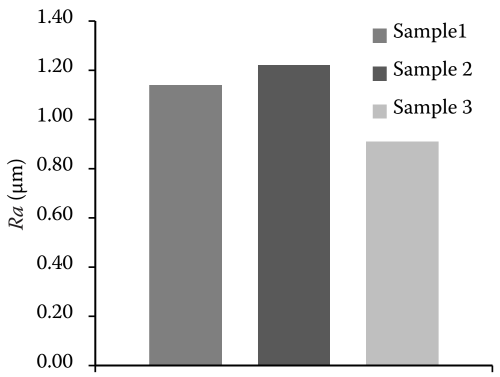

Fig. 10. Dependence of Hardness *Ra* on rotation – copper

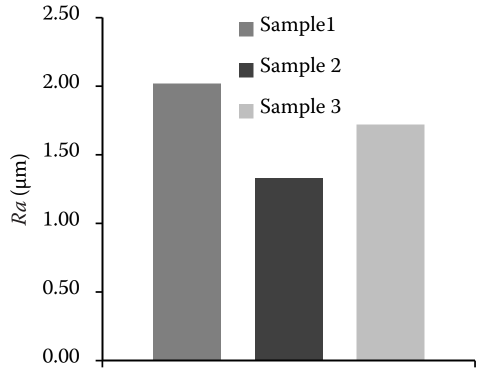

Fig. 7. Dependence of Hardness *Ra* on rotation – dural

Table 7. Measured values of hardness – leaded bronze

Parameter (μm)	Sample 1	Sample 2	Sample 3
Ra	0.23	1.09	1.98
Rq	0.27	1.34	2.33
Rt	2.6	6.1	10.1
Rv	1.4	5.1	8.2
Rz	0.8	4	6.4
Rp	0.5	1.9	3.2

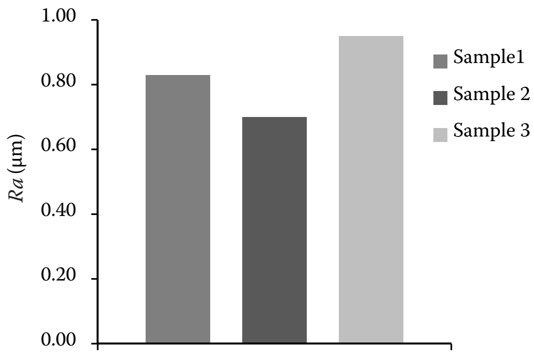

Fig. 9. Dependence of Hardness *Ra* on rotation – brass

Table 9. Measured values of hardness – copper

Parameter (μm)	Sample 1	Sample 2	Sample 3
Ra	1.14	1.22	0.91
Rq	1.49	2.26	1.39
Rt	10.5	17.4	10
Rv	6.4	6.6	4.6
Rz	4.1	4.4	2.7
Rp	3	3.1	2.7

Table 10. Calculated values of ovality

Plane (mm)	Sample 1	Sample 2	Sample 3
Dural			
A-A	16.09	16.09	16.11
B-B	16.13	16.12	16.12
Ovality	0.04	0.03	0.01
Leaded bronze			
A-A	16	16.01	16.01
B-B	16.01	16.02	16.02
Ovality	0.01	0.01	0.01
Brass			
A-A	16.02	16.035	16.02
B-B	16.04	16.04	16.03
Ovality	0.02	0.005	0.01
Copper			
A-A	16.39	16.39	16.257
B-B	16.37	16.355	16.3
Ovality	0.02	0.035	0.043

est deviations were obtained with the lowest cutting speed with the spindle rotation of 85 1/min. A higher stabilisation of the cutting forces was reached by cutting speed increment. Higher values of the cutting forces at a lower rotation could be caused by the mechanism of splinter production, when a higher plastic deformation was occasionally noted. This influenced also the degree of tool dullness and course of temperature. The highest cutting speed of 13.32 m/min caused the most abrupt temperature flow increment, when the resultant temperature flow measured on the spot of the cut increased almost linearly. The temperature was increasing from the beginning of the drilling process approximately evenly and then this trend of the temperature increase gradually deminished with a different cutting speed. The linear course of temperature at the highest rotation was caused by a more intensive production of the friction heat in short time, thus this heat could not be led away by the material quickly enough. The cutting forces and temperature decrement at the end of the drill track was as in all other drilled materials caused by the drilling surface decrement within running out of the drill from the material. The results suggest that with dural, the best values of surface geometry were reached at the rotation of 150 1/min with the cutting speed of .54 m/min. The best values of Hardness *Ra* = 1.33 µm were also reached by using these parameters. The lowest selected cutting speed of 4.27 m/min with the rotation of 85 1/min was marked in terms of hardness as the most suitable for drilling the leaded bronze sample. The quality of machined surface with Hardness *Ra* = 0.23 µm and very high geometry precision were reached by the use of these cutting parameters. This hardness was the highest one obtained among all coloured metals examined. The deviation from the set drilling proportion of the hole diameter of 16 mm was 0–10 µm. The cutting speed increment caused a significant hardness increment to 1.98 µm with the rotation of 265 1/min.

The cutting speed of 7.54 m/min with the average spindle rotation of 150 1/min was marked as the most suitable for brass drilling. The best values of ovality and hardness *Ra* = 0.7 µm were also measured at the cutting speed mentioned.

The best values of the copper samples-in hardness contrast to the other materials-were observed at the highest rotation of 265 1/min with the cutting speed 13.32 m/min. The lowest deviations from the hole drilling diameter set was also reached at the cutting speed mentioned. However, ovality was the worst with these cutting parameters. The lowest ovality of the machined hole was obtained at the lowest rotation (Žitňanský, Kročko 2001; Ružbarský, Tomáš 2006).

CONCLUSIONS

In the paper, the results are described of the drilling of different materials used for the manufacturing of agricultural machines moving parts. These materials include copper, brass, duraluminium and lead bronze. The same parameters were used in the drilling of all materials.

Based on the results achieved, we can conclude that the quality of drilled holes in particular material depends significantly on the cutting speed. Different effects of the cutting speed on the surface roughness and roundness were found. The lowest roughness values were achieved at different cutting speeds as those leading to the best roundness in the case of all materials in research.

References

Anonymous, 2003. Iljin Machinery Co., Ltd. Available at http://www.iljin-mc.co.kr/english/technology/quality.htm?qt=surface (accessed February 03, 2010).

Anonymous, 2007. Dimar Slovakia, Ltd. Available at http://mtf.dattex.net/modules.php?name=Downloads&d_op=getit&lid=28 (accessed April 25, 2009).

Audy J., 2008. A study of dry machining performance of the TiN, Ti (Al,N) and Ti (C,N) coatings and a type M35 HSS tool substrate material assessed through basic cutting quantities generated when orthogonal turning a Bisalloy 360 grade steel work-piece material. Annals of Faculty Engineering Hunedoara – International Journal of Engineering, *6*: 59.

Audy J., 2009. Study of coatings on experimental thrust and torque in drilling. Annals of Faculty Engineering Hunedoara – International Journal of Engineering, 7: 31–40.

Bátora B., Vasilko K., 2000. Obrobené povrchy (Cutting Surfaces). Trenčín, GC – Tech 2000, Inc.: 131.

Ružbarský J., Tomáš J., 2006. Some results of the turning of hardened steel without cooling. Acta Avionica, *8*: 87–90.

Stephenson D.A., Agapiou J.S., 2006. Metal Cutting Theory and Practice. Boca Raton, CRC Press.

STN 22 1140, 1977. Vrtáky skrutkové s kužeľovou stopkou. Základné rozmery (Taper shank twist drills. Basic dimensions).

Unticell, 2007. Untilcell. Available at http://www.utilcell.com (accessed Fabruary 10, 2010).

Žitňanský J., Kročko V., 2001. Vplyv podmienok dokončovania predvŕtaných dier na kvalitu vŕtaného povrchu a rozmerovú presnosť (Influence of drilled holes finishing conditions on drilling surface quality and accuracy of size). In: 6th International Scientific Symposium – Quality and Reliability of Machines. Nitra, SPU in Nitra: 101.

Žitňanský J., Žarnovský J., 2010. Effects of material and cutting conditions on the temperature of drilling measured by thermovision technics. Manufacturing Engineering, *9*: 34.

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