THE VERIFICATION OF AXIAL FORCES AND TORQUES IN DRILLING BY THE NONCOATED CUTTING TOOLS AND DRILLS WITH PVD TIN COATING

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Abstract: The main aim of this scientific paper is to assess the contribution of surface layers of bearing steel by determining the experimental measurement of cutting forces in the drilling technology with the drilling cutting tools made of uncoated high speed steel and also with coated by the PVD method. This experimental paper is a continuation of the solutions of grant VEGA no. 1/9428/02 titled "The technological heredity of the machined surfaces - surface integrity". The first chapter of this scientific study discussed about the possibilities and technological challenges in drilling of bearing steels. The second chapter discusses about technological characteristics of cutting process and cutting forces. In the third and fourth chapter is described the measurement of cutting forces in drilling by the piezoelectric Kistler dynamometer. This paper, together with published results is a basis that will enable optimizing the quality of drilling production process, automotive parts of their dominant functional areas. The process of drilling was carried out in triaxial CNC milling machines with post iTNC530 HEIDENHAIN control systems. During drilling through dynamomatra were measured axial cutting forces and torques.
Keywords: cutting forces, drilling, PVD coatings, dynamometer KISTLER, HEIDENHAIN iTNC530

1. INTRODUCTION

The main aim of this experimental paper is to study and analyze the experimental measurement of the axial cutting forces and torques at drilling of specimen part made from bearing steel TYPE2 (STN 14 140). This measurement was successively analyzed and experimentally verified on selected sample material 45x100x300 mm outside the cut milling (for experimental measuring of the axial cutting forces and torques during the drilling process and measured and results designated with the piezoelectric KISTLER dynamometer (Fig.3).

Drilling technology is a part of the manufacturing process, which is based on the use of energy delivered by the machine tool, which is an activity (for the interaction with machinery and cutting tool) is formed workpiece (part) in the desired shape, dimensions and surface quality by taking a certain amount of cutting tool material [10].

Application materials for the cutting tools are defined by their physical, chemical, thermal and mechanical properties [6].

The term does not include only a machining process or a description of how to make machinery component removal of excess material, but also clarifying and explaining existing factors and phenomena in the machining process. Drilling is therefore also its scientific, not only practical part. Therefore, we are talking just about the theory of machining as well as experimental methods. The theory provides hypotheses that are experimentally verified and the verification of the hypothesis becomes a theory validation.

In theory aside the agreed convention for marking and cutting action of cutting forces, as well as forces that associated with an internal resistance of the cutting material [13].

One of the management strategies for business success in the market is a strategy of continuous improvement of production quality through the implementation of quality management and continuous improvement. Improving product quality then affects not only the production processes, but also post-production activities [7].

One of the main process engineering company is a manufacturing process that can be improved, including through implementation of new technologies and production processes in drilling to activities related to experimental measurements of axial cutting forces and torques in drilling technology.

Cutting force is tied to the relative movement between tool and workpiece. As relates to the resistance to motion, it cannot be regarded as a constant variable in time [2].

Research on cutting forces in machining of metals is not only practical but also theoretical importance. Theoretical knowledge of the cutting forces to refine theories about the cutting process. In practice, again knowledge of the importance of cutting forces for design tools, the selection of cutting conditions, calculations and design of machine tools etc. [12].

Links between technology and machining surface quality, building on their functionality in the future must cover the entire technological world, they show ways to deal with ever-increasing demands on product quality and offered use of reserves resulting [1].

2. CNC DRILLING TECHNOLOGY

Cutting properties of high-speed twist drills without coating, and also with wear resistant PVD coatings are mutually compared by measuring the mean values of axial (feed) F_f cutting forces and torque Mc, impassable when drilling holes to a depth of $L = 3 \cdot D$, using intensive cooling emulsion. Drilled test sample material was used on 14 dimensions 45x100x300 140.3 mm, with surface machining by milling technology. Mechanical properties of material are $R_m = 895$ MPa, $R_{p0,2} = 798$ MPa, $A_{05} = 15,2$ %, $HV_5 = 278$ [5, 9].

In the process of experiments were used twist drills of high speed steel type HSSCo5=19 855, DIN 338, ø 6mm, without coating, and cross cut–sharpening drills type C, furthermore drills made of z high speed steel HSSCo5 = 19 855, DIN 338, ø 6mm, with surface treatment − N, sharpening type C drilling tools made from high speed steel HSSCo5 = 19 855, DIN 338, ø 6mm, with PVD TiN coating, sharpening C, and then drills type DIN 338–N, sharpening the cutting edge of the transverse width $š_p = 1,3$ mm, cylindrical collar for circuit š = 0,8 mm, with the same geometry, but made from HSSMo5= STN 19 830.

Experimental drilling and measurement was realized on vertical CNC machine tool FV 25A CNC with P=15 kW performance, and with HEIDENHAIN iTNC530 control system (Fig. 1). Speed range of the machine is n_{max}=6000 min⁻¹, range of feed rates v_f =1÷2000m·min⁻¹, rapid traverse v_f =6000 mm·min⁻¹. How cool was used semi-synthetic coolant emulsion CIMSTAR 560 5%, with amount Q = 10÷30 dm³·min⁻¹ (L·min⁻¹), with external supply. Recommended cutting conditions for drilling workpiece material were as follows. Cuting speeds v_c = 13,4 – 16,9 – 21,1 – 33,9 m·min⁻¹. Frequency of rotation :n = 710 – 900 – 1120 – 1800 min⁻¹. Feeds f = 0,03 – 0,05 – 0,08 – 0,12 mm. Feed rate v_f = 33,6 až 134,4 mm·min⁻¹.

The direct capture components of cutting forces are most frequently used piezoelectric dynamometer. It is possible to measure one, two, or three components of cutting force or torque [3].

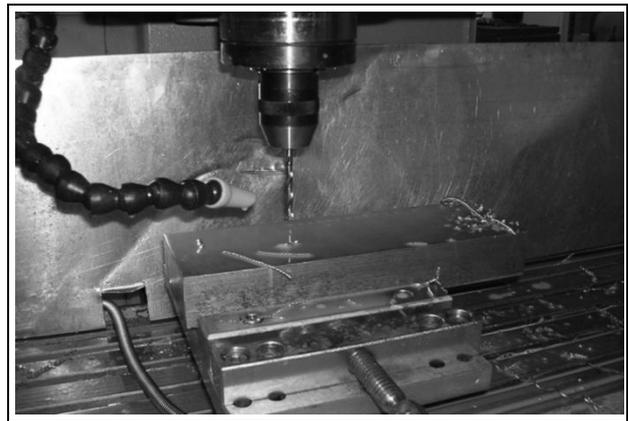Fig. 1. Overview of the vertical CNC milling machine FV 25A

Fig. 2. Piezoelectric dynamometer KISTLER 9272 B

Fig. 3. Device for measuring the axial cutting force (F_f [N]) and torque (M_c [Nm]). An overview of quaternary piezoelectric dynamometer KISTLER 9272 B completely computer controlled, a charge amplifier type KISTLER 5011 A

3. EXPERIMENTAL MEASUREMENT

The main aim was to determine the load measuring drill of ø6 mm and drilling process analysis using mathematical-physical models on computer. Experiments measuring F_f and M_c builds on previous drilling conducted experiments in determining the durability of drills followed HSSCo5 (O-N-TiN) at different cutting speeds but constant feed f = 0.08 mm and cooling E 5% (Q = 1.0 dm³ . min⁻¹) to the FV25 CNC machine (Fig. 2).

3.1 Experiment I

During the tests, we drilled of Ø6 x 21 mm holes into the material steel type 14 140.3 was first being aware of the dependence F_f = f (f), and M_c = f (f) at constant cutting speed v_c = 21.1 m . min⁻¹, ie with n = 1120 min⁻¹, using a cooling and a change following feeds: f = 0.03 to 0.05 - 0.08 to 0.12 mm. Mean values of measured axial forces F_f [N] when drilling Ø6 x 21 mm holes into the material 14 140.3 (TYPE2), for different values of the shifts, which are listed in Table1. Mean values M_c torque [Nm] drilling Ø6 x 21 mm with cooling in 14 140.3 steel material, with different feeds are shown in Table 2.

Drill Feed f [mm]	Drilling with coolant CIMSTAR 560- E5 %			
	O_{10} − HSS 55	N_{10}	TiN_7	HSS 30
0,03	206	304	171	435
0,05	324	439	242	570
0,08	484	591	351	750
0,12	707	778	466	1011

Tab. 1. Mean values of axial cutting forces F_f [N] at drilling, at various values of feed motions

Drill	Drilling with coolant CIMSTAR 560 -E5 %			
Feed f [mm]	$O_{10} - HSS\ 55$	N_{10}	TiN_7	$HSS\ 30$
0,03	0,70	0,80	0,60	0,75
0,05	0,86	0,95	0,82	0,92
0,08	1,30	1,41	1,17	1,42
0,12	1,86	2,04	1,62	2,00

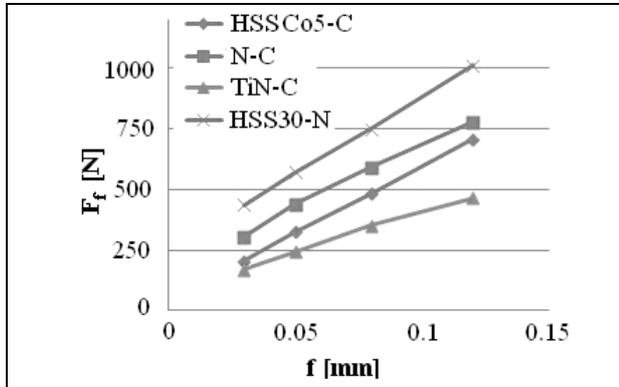Tab. 2. Mean values of torques M_c [Nm] at drilling, at various values of feed motions

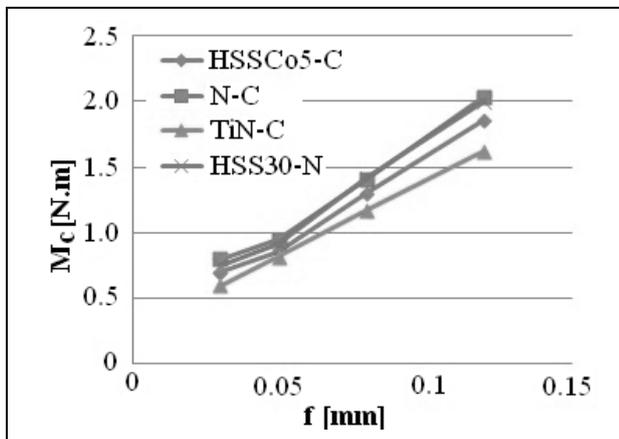Fig. 4. Course of axial force F_f for drill ø 6 mm at various feeds

Fig. 5. Course of torque M_c for drill ø 6 mm at various feeds

A comparison of uncoated HSS drilling cutting tools HSSCo5 and HSSCo30 is based on the HSS 30 = 19 830 N sharpening with increasing axial forces caused by 43 to 100% and increase torque by $7 \div 9\%$. Nitrided drills exhibited in this case, durability is very low, and after only four holes were drilled wear $VB_{max} = 0.4 \div 0.6$ mm. The course of the axial (feed) forces F_f and torque to drill Ø6 mm x 21mm holes with uncoated (O), ion nitriding (N) and PVD TiN coating cutting tools in different feeds is shown in Figure 4 and also in Figure 5.

3.2 Experiment II

Measuring of axial cutting forces F_f [N] and M_c torque [Nm] at a constant feed motion rate f = 0.08 mm, that the normative recommended cutting conditions for drilling were Ø6 mm, but at different cutting speeds in the range: v_c = 13.4 to 16, 9 - 21.1 to 33.9 m . min^{-1} (n = 710 - 900 - 1120 to 1800 min^{-1}). Mean values of measured axial cutting forces F_f and torques M_c drilling ø6 x 21 mm of 14 140.3 material at a constant feed motion rate f = 0.08 mm and changing the cutting speed, using cooling for various coated and uncoated drilling cutting tools are listed in Table 3 and table 4. While changing the torque M_c [Nm] drilling Ø6 x 21 mm of 14

140.3 material at a constant feed rate f = 0.08 mm and changing the cutting speed are monitored for drills presented in Fig. 6 and 7. Experiment conditions: f = 0,08 mm = const., $_{f1}$ = 56,8 mm·min^{-1} at n_1 = 710 min^{-1}, v_{f2} = 72 mm·min^{-1} at n_2 = 900 min^{-1}, v_{f3} = 89,6 mm·min^{-1} at n_3 = 1120 min^{-1}, v_{f4} = 144 mm·min^{-1} at n_4 = 1800 min^{-1}.

Drill	Drilling with coolant CIMSTAR 560-E5 %			
v_c [m·min^{-1}]	$O_{10} - HSS\ 55$	N_{11}	TiN_7	$HSS\ 30$
13,38	454	469	390	867
16,9	452	463	381	824
21,1	450	462	368	782
33,9	447	458	343	763

Tab. 3. Mean values of axial cutting forces F_f [N] at drilling

Drill	Drilling with coolant CIMSTAR 560-E5%			
v_c [m·min^{-1}]	$O_{10} - HSS\ 55$	N_{11}	TiN_7	$HSS\ 30$
13,38	1,60	1,53	1,48	1,63
16,9	1,43	1,37	1,40	1,44
21,1	1,31	1,22	1,20	1,35
33,9	1,12	1,18	1,11	1,16

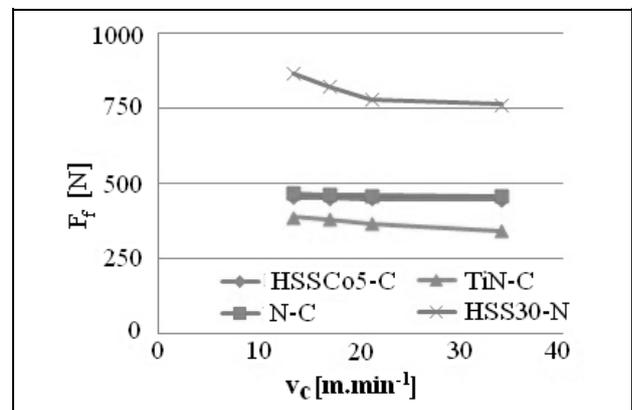Tab. 4. Mean values of torques M_c [Nm] at drilling

Fig. 6. Course of axial force F_f for drill ø 6 mm at various feeds
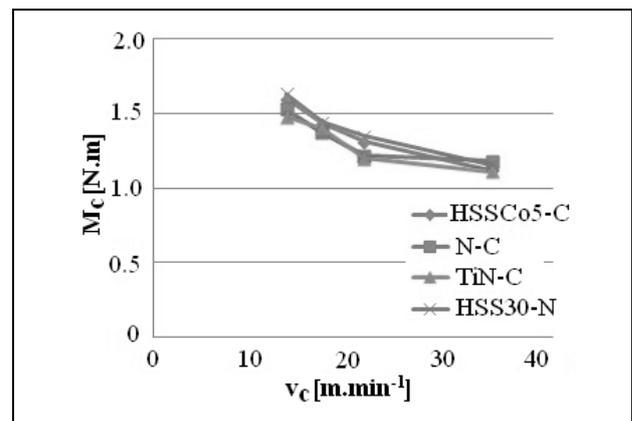

Fig. 7. Course of torque M_c for drill ø 6 mm at various feeds

4. THE EVALUATION OF RESULTS

As is shown in a graph of average values F_f and M_c according to the feed rate, at v_c = 21.1 m . min^{-1} (Table 1 and 2), this dependence of linear regression process, e.g. both increase with increasing shift (Fig. 4, 5), and fall (Fig. 6, 7). The coated drill cutting part, in accordance with the dependence T = f (v_c), Ff sizes are larger than uncoated drill HSSCo5, due to more wear and tear to the cutting edge delamination after only 4 holes drilled.
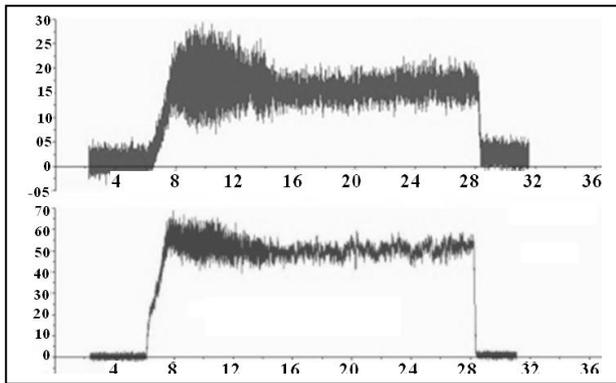
Fig. 8. Course of axial force F_f (up) during drilling with drill with sharpening type C (horizontal axis – time, vertical F_f and M_c)[5]

The smallest F_f and M_c were measured with PVD TiN coated drills, with minimal wear after 4 to 8 drilled holes. The greatest value of the axial force F_f and M_c were measured during drilling with uncoated drill HSSMo5 = 19 830 with N-shaped sharpening, ie the transverse width of the cutting edge s_p = 1.3 mm. At cross cutting edge increases the axial forces more than 43% to 76% over uncoated drill with a C-shaped cross multiple section and M_c increase of 7 ÷ 9%. Dependences of F_f M_c with drill bit sharpening C is shown in Fig. 8. The difference is in the variation of axial force and torque at the beginning of collaring the bit into the material at the start of drilling. At the beginning of drilling (collaring the bit) with N sharpening, there is a greater increase in vibration and dynamic axial force F_f and especially torque M_c compared with drill sharpening C. Even in experiments II, when changing F_f and M_c subject to change cutting speed (v_c) at a constant feed rate f = 0.08 mm shows that the smallest value of F_f and M_c are in PVD TiN coated drill and the largest drill in uncoated HSSMo5 = 19 830, with sharpening N (transverse width of cutting edge s_p = 1.3 mm compared to 0.3 mm in cross-sharpening C). Proper writing methodology was created, which would be able to define the communication ways between single devices during machining process [4].

The total cutting force induced by the action of the cutting tool to the workpiece is called the symbol F. For the analysis of power relationships cutting process, the resulting cutting force F breaks down into relevant components. During the act of machining the workpiece cutting force F, which is the vector can be separated into individual components [11].

5. CONCLUSION

Practical experiments of the measurement of axial cutting forces F_f and torques M_c confirmed,the fact, that the surface of coated drills to test our worn down to VB_{max} = 0.6 mm after drilled of 4 holes while the tool coated with TiN was finish after 8 holes with no measurable wear on surface of cutting tool.

The practical benefit is the finding that in bearing steels machinability is attained by R_a good and improves with increasing the hardness (strength). Effect of cutting speed of change of tangential cutting force F_c was not measured. That opens the way for further research in this area, to optimize the process of CNC drilling machine parts from bearing steels in the production of their dominant functional areas.

On the basis of experience, we can state that the system of quality management processes is beneficial only if it is constantly improving. It is necessary to improve all activities and anything that can improve a company based on the constantly changing needs of the real experience and customer demand that is continuously gathering customer feedback and satisfaction regarding their views on the process improvement [7].

Timely communication with customers and experience we can ensure a smooth launch of new standards, as the arrival of new technologies and systems with you and automatically gives them a very positive change [8].

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