Materials Engineering, Vol. 16, 2009, No. 4

PLASTIC DEFORMATION ON THE MACHINED SURFACE OF STEEL Cr20Ni10MoTi AT DRILLING

Jozef Jurko

Received 24th April 2009; accepted in revised form 9th July 2009

Abstract

Information about material machinability is very important for the machining technology. Precise and reliable information on the machinability of a material before it enters the machining process is a necessity, and this brings the verification of technological methods in practice. This article presents the conclusions of machinability tests on austenitic stainless steel according to EN-EU (ISO): steel Cr20Ni10MoTi. This article presents the conclusions of VEGA grant agency at the Ministry of Education SR for supporting research work and co-financing the projects: Grant work #01/3173/2006 with the title „Experimental investigation of cutting zones in drilled and milled stainless steels".

Keywords: *drilling, plastic deformation, machined surface, hardness.*

1. Introduction

Stainless steels are fundamentally subdivided by their chemical composition and metallographic structure, [2]. Austenitic steels are the most extensive and thus the most important category of stainless steels. Several kinds of these steels are known, which differ among themselves in their carbon, nickel, and sometimes in their titanium content. Titanium is an important element, which increases the steel's resistance to intercrystalline corrosion. Contemporary advancement of austenitic stainless steels is divided into the following three branches: several types containing no more than 0.03% carbon, the development of new types with added nitrogen as an active alloy, and the development of steels with an increased level of protection against corrosion. The basic alloying element in stainless steels is chromium. Its effect on corrosion resistance is increased in conjunction with other alloyed elements, mainly nickel, molybdenum and copper. Austenitic stainless steels are the most ductile of all steels. Austenitic steels have ductility that is fifty percent greater than ferritic steels, but handle heating more poorly. Specific electrical resistance depends on chemical composition and mechanical structure, to a lesser extent. Low thermal conductivity is a characteristic property of stainless steels, which is a function of chemical composition first and foremost. It is important to stress that each stainless steels would have to be described independently to note the extent of their characteristics and the effects that result from them. It is only possible to speak of the characteristics of stainless steels in specific measurements. Figure 1 illustrates the cross section of the Fe-Cr-Ni system with 70 % Fe and indicates the percentage of the components expected for these steels after equilibrium is achieved during reheating at high temperatures before deformation. Although the ferrite/austenite ratio changes with temperature, steel B always contains more austenite than steel A under similar reheating and deformation conditions.

2. Phenomenas in cutting zone at machining

Researching the cutting zone (the interaction between the tool, the work piece, and the cuttings) is to capture its state at the moment of the creation of the cutting (the so-called root of the chip). The process of cutting is the mutual interaction between the tool and the work piece, which is controlled by many phenomena. An understanding of the phenomena and domains involved arises from cutting zone experiments. Weber [8] states, that the depth of the shear level follows the formula $0.05\,h \leq h_{SP} \leq 0.1\,h$, where h is the thickness of the cut section and h_{SP} is the depth of the shear level. We observe elements from the cut layer in the shear layer that have been displayed (they melt the cutting wedge).

J.Jurko, doc. Ing. PhD. – Department of Manufacturing Technology, Faculty of Manufacturing Technology, Technical University of Košice, Štúrova 31, 080 01Prešov, Slovak Republic.

*Corresponding author, e-mail address: jozef.jurko@tuke.sk

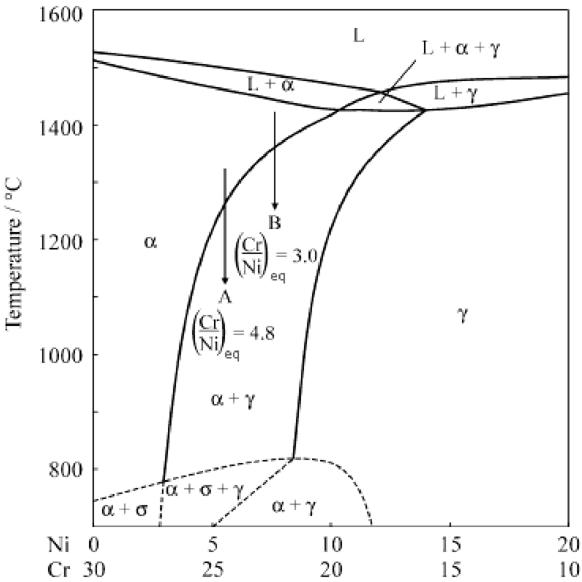

Fig. 1. Cross section of the Fe-Cr-Ni system with 70 % Fe

The thickness of the cut layer continually varies chip thickness h_1. Chip formation is described by Hencky and Zorev in book [3] through the theory of plasticity. The presence of strain lines in chip formation is depicted in Figure 2. The strain line field extended to the region of plastic deformation, the machined surface, and the cut layer (the chip). Strain lines (the so-called Lüders-Černov lines in book [3]) represent an extensive high-intensity deformation. Models of chip formation have been created by Weber [8], Oxley [5], Lee-Shaffer in book [3] and others based on the theory of plasticity and the use of strain lines. It is our opinion that chip formation most closely follows the method of Oxley [6], which even accounts for the element of time in chip formation.

2.1. Cutting zone at machining

Cutting zone" is a summary term from the region during cutting. To properly describe the cutting zone it is necessary to describe the regions and test parameters, [2], [3], [8], [9], [10].

1. Primary plastic deformation zone (primarily an examination of phenomena associated with the creation and formation of chips, with the effect of the components of cutting force-the state of strain deformation, the location of the angle of the shear level, chip compression, the temperature field, chip shape, chip formation and separation, the effect of the components of cutting force)
2. Secondary plastic deformation zone (primarily an examination of phenomena associated with friction and cutting wedge wear, and also with the generation of heat and temperature-the location of the grain angle, the contact length of the cutting wedge and the face plate, friction stress and scab creation (BUE), friction, the generation of heat and temperature, the mechanism of tool wear).

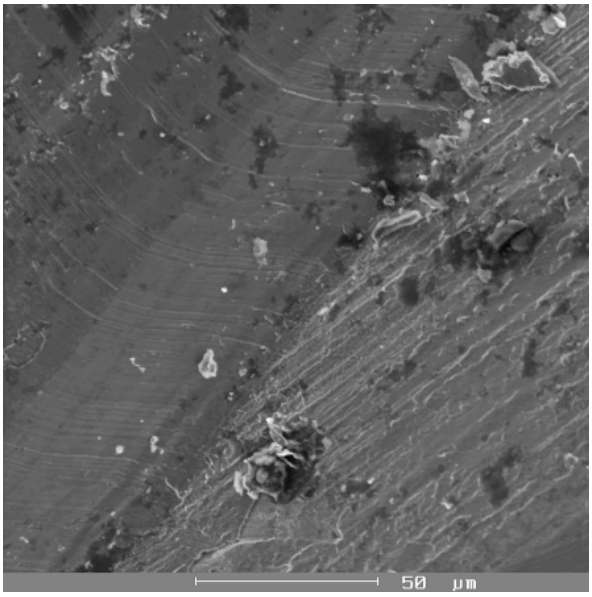

Fig. 2. Strain line field extended to the region of plastic deformation the machined surface, 35 m/min

3. Tertiary plastic deformation zone (primarily an examination of the phenomena associated with the shaping creation of the machined surface, its profile, morphology, qualities and inherited traits-contact of the machined surface and the worn side plate).
4. Cutting surface, its properties and integrity.
5. The gradually-deformed region of the cut layer.

3. Experimental part and description of achieved results

This article concerns with the evaluation of selected domains phenomena of stainless steel at drilling. The set-up used contained the following components: a VMF 1000 CNC machine, cutting tool -monolit screw drill from sintered carbide with progressive coats-TIAℓN, with diameter 8 mm. The materials to be machined were type of austenitic stainless steels with chemical composition listed in Table 1. The cutting process employed was axial dry machining (DM), and the cutting frequency was defined at intervals of v_c = 25 to 60 applied f = 0.05 ÷ 0.3 millimetres, and cutting depth a_P = 4.0 mm.

Tab. 1

Chemical composition (in wt. %)

Steel	C	Cr	Ni	Mo	Ti	Mn	P	S
Cr20Ni10MoTi	0.06	20	10	0.3	0.3	1.2	0.04	0.015

According to Dehlinger in book [3] strain hardening, which arises are a result of the total amount of strain (intrinsic) and external forces, tends to achieve marginal values towards the beginning of fatigue interruption. A variable load means that plastic deformations appear in small regions and fatigue cracks begin in the slip layers. For Oding, Cobkallo, Kuznetzova, Glikman and Techt in book [3] strain hardening represents only the first measurable stage of the process of fatigue. Austenitic Cr-Ni steels are, as a result of their higher ductility, more prone to surface strain hardening, which compared to construction steel can be up to 1.5 times as great. In a non-deformed state austenitic steels are not as hard as C45 steel, but in cases of great deformation they are greatly harder than ferritic-perlitic steel. Low thermal conductivity has a large significance in austenitic stainless steel drilling. It means the temperature which arises during the process of cutting on the touching plates of the cutting tool is poorly dissipated, which results in an increase in temperature on the touching plates, lowering the tools resistance to wear, reducing its longevity. This makes itself most apparent in the use of cutting tools made from high-speed steel, whose firmness and thus resistance to wear drops sharply at higher temperatures, as in Figure 3.

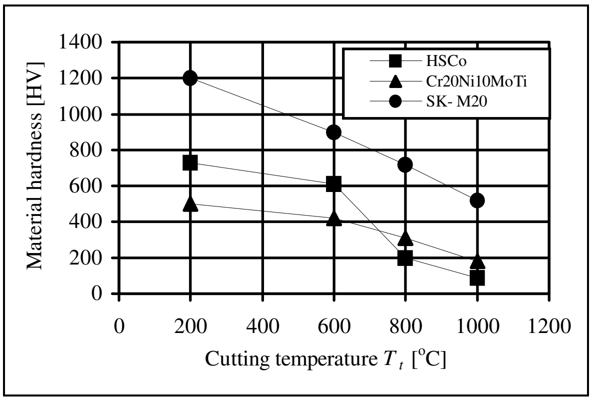

Fig.3. Influence of temperature on screw drill and chip material hardness HV 0.1
v_c = 35 m/min, f = 0,08 mm

Sintered carbide tools are not as sensitive to temperature on touching plates as high-speed steel, and can be used to attain higher performance, but in this case they have greater pressure stress, which directly influences the process of adhesive wear, [1], [5], [7] [10].

Every tool is damaged in the process of cutting. Wear mechanisms are activated in the cutting zone during the interaction of the elements of the cutting edge of the tool and the work piece, and under the influence of temperature. The mechanism of wear means the synergistic effect of factors that create a change in matter, a change in volume, i.e., a change in cutting edge dimension. Venkatesh [7] defines the region of wear for sintered. Figure 4 show a typical tool wear on the cutting edge and flank of tool.

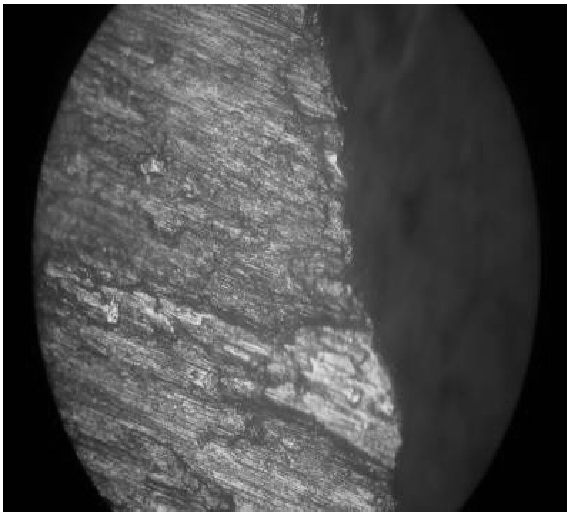

Fig. 4. Tool wear on the major cutting edge,
v_c = 35 m/min, f = 0.08 mm

When evaluating the quality of the machined surface, we measured the outer surface roughness parameters *Ra* [µm] stated in table 2. The acquired results are interesting in that for the defined cutting conditions we can achieve a quality machined surface after cutting with roughness parameters down to around 0.86 µm. Very good results were mainly achieved when cutting speed was 60 m/min and the feed was 0.08 mm per rev. or 0.1 mm per rev. Similar roughness in the outer surfaces of the individual type is not based on differences in the quality of the outer surface.

Tab. 2

Measures parameter values for outer surface roughness Ra in [µm]

		Cutting speed v_c [m/min]		
		25	35	60
Feed rate *f* [mm per rev.]	0.04	2.85	2.63	2.28
	0.08	2.46	2.44	0,86
	0.15	3.12	3.88	1.27
	0.3	4.56	4.02	3.89

The value of *Rz* (following ISO 4287, it is the upper limit of unevenness in outer surfaces) did not exceed a value of 5.5 µm. Figure 5 illustrates measure hardness past the machined surface. From measure of microhardness influence different evalues hardnees between the machined surface and the base material of steel *Cr20Ni10MoTi. Hardness on the machined surface is interval 265 to 280 HB. Hardness of steel (the base structure of steel Cr20Ni10MoTi is 190 to 215 HB.* Figure 6 illustrates plastic deformation past to amchined surface at drilling.

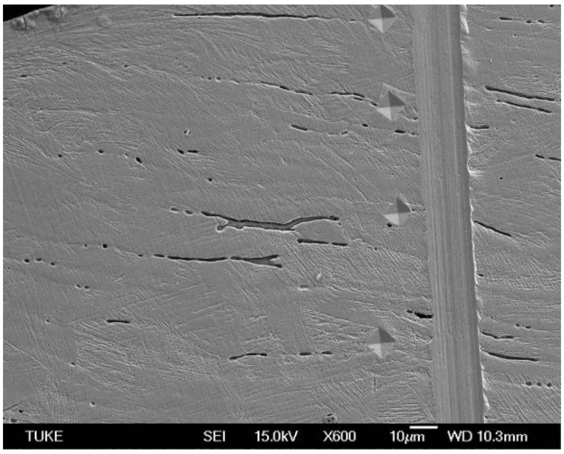

Fig. 5. Hardness measure by Vickers (HV 0.1) on the machinery CV 400 DAT, v_c = 35 m/min, f = 0.08 mm, magnituge 600x

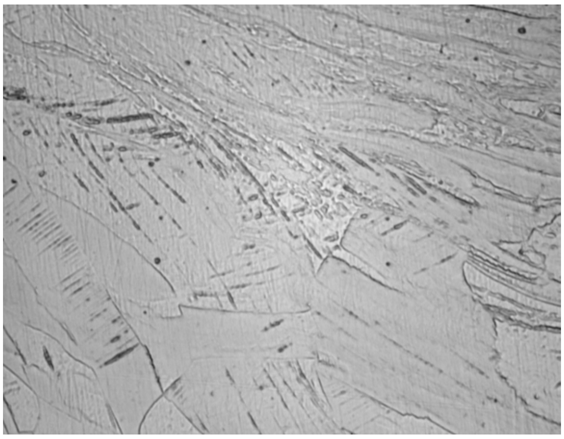

Fig. 6. Plastic deformation past the machined surface at drilling, v_c = 35 m/min, f = 0.08 mm, magnituge 1000x

4. Conclusions

It is important for both theory and practical applications that essential conclusions come from measurement and analysis. Results were acquired under laboratory conditions and performed in a tool shop. The conclusions are as follows: thermal analysis for the cutting process in the cutting zone, confirmation of surface strain hardening (change in mechanical properties) after cutting, for the cutting process, it is necessary to use a tool that has a large cross section so that it can sufficiently dissipate the heat formed from the cutting zone, the wear of cutting tools may also affect the selection of appropriate geometry, mainly the positive angle of the front of the tool as well as the required high surface quality of the tool's effective area, use vibration in the cutting process system to improve the process of removing shavings if allowed by the required outer surface quality after cutting, ensure the technological discipline of workers (maintenance of conditions contained in technical documentation).

Acknowledgements

This article presents the conclusions of VEGA grant agency at the Ministry of Education SR for supporting research work and co-financing the projects: Grant work #01/3173/2006 with the title „Experimental investigation of cutting zones in drilled and milled stainless steels".

References

[1] Jiang, L.; Hänninen, H.; Paro, J.; Kauppinen, V.: Active Wear and Failure Mechanisms of TiN-Coated High Speed Steel and TiN-Coated Cemented Carbide Tools When Machining Powder Metallurgically Made Stainless Steels. „Metallurgical and Materials Transactions" 9/1996, pp. 2796-2808.

[2] Jurko, J.; Lukovics, I.: Vŕtanie technologická metóda výroby dier. Zlín, Svidnícka tlačiareň Svidník, 2007, p. 191.

[3] Jurko, J.: Plastická deformácia v procese rezania. Prešov, Svidnícka tlačiareň Svidník, 2007, p. 132.

[4] Ohtani, T.: Cutting force characteristics in machining of hardened steel. Bull. Japan Soc. of Prec. Eng., (2):127-129, 1986.

[5] Oxley, P.L.B.: Mechanics of Metal Cutting. Int. conference in production engineering, Pittsburg, 1963, p. 50.

[6] Subramanian, C.; Strafford, K.N.; Wilks, T.P.; Ward, L.P.; McPhee, M.A.: Performance evaluation of TiN-coated twist drills using force measurement and microscopy. Surf. Coat. Technol., 62(1-3):85, 1983.

[7] Venkatesh, V.C.; Satchithanandam, H.A.: A Discussion on Tool Life Criteria and Tool Failure Causes. ANNALS OF THE CIRP, 29, 1, p. 19-22.

[8] Weber, H.; Loladze, T.N.: Grundlagen des Spanens. VEB Verlag Technik Berlin, 1986.

[9] Zaborowski, T.: Ekowytwarzanie. Gorzow Wlkp. : IBEN Gorzow Wlkp., 2007, p. 100.

[10] Yang, J.A.; Jaganathan V.: A New Dynamic Model for Drilling and Reaming Process, International Journal of Machine Tools & Manufacture, No. 42, 2002, p. 299-311.