Proceedings of the International Conference on Manufacturing Systems – ICMaS
Vol. 4, 2009, ISSN 1842-3183
University POLITEHNICA of Bucharest, Machine and Manufacturing Systems Department
Bucharest, Romania

PLASTIC DEFORMATION AND PHENOMENA IN ZONE CUTTING AT DRILLING OF STAINLESS STEEL

Jozef JURKO, Anton PANDA

Abstract: *In this paper, sintered stainless steel were machined with several kinds of conventional tools and newly developed tools, and the machinability was evaluated in relation to cutting force, cutting temperature, tool wear, tool life, surface finish and surface quality. Machinability was evaluated using various grades of high speed steels by drilling. A test method for evaluating tool wear under interrupted machining modes conditions and the associated machinability of work materials is presented. Systematic drilling involving a number of programmed tool interruptions resulting in different combinations of cutting and idle durations were used to develop a standard test method. The study indicated the critical role of the duration of the cutting cycle as well as the transient stage associated with tool entry and withdrawal upon the observed tool wear. How tool life in drilling can be improved considerably. Machining recommend-dations are given for drilling the stainless steels with austenite structure. The paper described the phenomena, which influencing on the twist drill by drilling holes. Research and development of the phenomena its very important for the next problem solution by drilling. The cutting part of twist drill is frequently the tool wear (for example fracture of cutting part) in the tool peak point and by chisel cutting edge. This is problems is very important and use for very difficult the machinability materials. The results of experimental verifying of the tools for the tool life of twist drill.*

Key words: *machinability, cutting, drilling, stainless steel, plastic deformation.*

1. INTRODUCTION

Machining is an important manufacturing operation in industry. Machining is the world's most common manufacturing process, with 15 to 20% of the cost of all goods being attributed. Machining may either be the primary manufacturing process as in the aerospace industry, or a secondary process as in the machining of castings, forgings, and powder metals. Most automotive castings are liable to be machined on up to 30% of their surfaces. Also, machining can be an indirect manufacturing process as in the production of press tools used in the stamping of automotive body panels. In the education of both technologists and engineers the basic mechanics of machining are explored. However, due to its nature, students should have exposure to the many variables that change with both workpiece and tooling materials, as well as the actual shop floor variables. This is important since they affect not only tool life but surface finish, component performance and material removal rates. Drilling was selected because most students who do not have a machining background will be familiar with a standard ″twist/jobber″ drill. Drilling is one of the oldest and most common machining operations.

The tools themselves have not changed much over the centuries, but the cutting materials and machine tools that employ them have. However, for its simplicity and commonality, the cutting geometries in drilling are extremely complicated and the process is terribly inefficient. Tool wear influences the quality of surface finish of the products produced and thus, if unnoticed, can cause high costs [10]. The economical tool life can not be benefited from without tool wear monitoring.

The problems of machinability materials narrowly are connected by your leave action wear of cutting edge. Wear of cutting edge is assistance combination of loading factors that affect of cutting edge [1, 12]. Tool life of cutting edge is impact all loading factors, that they have aspiration alter geometry of cutting edge. Wear is produced under interaction between cutting tool, workpiece and cutting conditions of machining. Mechanism wear is characterized abrasion elementary element boundary juncture coat and their disposal at concert pitch assistance abrasion forth cutting zone. General wear of cutting edge is generally results abrasion, plastic deformation and breakable breach. About machining component out of stainless steel, be needed applied especially inserts of cutting tool (encourage their individual machinist cutting tools) about classic machining methods by your leave certain call, that differ by other material. Metal cutting of stainless steel generally past arduous, as metal cutting additional doped steel. Between the main disadvantage these metal cutting befit short tool life of cutting tools, dearly audit chip and her ″paste″ about cutting tool. Stainless steel they have individual requirements, but require reach at it, that can a few brand stainless steel, between that requirements about metal cutting differ.

2. AUSTENITIC STAINLESS STEEL

Stainless steels are steels with a high degree of corrosion resistance and chemical resistance to most a wide range of aggressive chemicals. The corrosion resistance is mainly due to their high chromium content. Stainless steels normally have more than 12% chromium. Chromium makes the surface passive by forming a surface oxide film which protects the underlying metal from corrosion. In order to produce this film the stainless steel surface must be in contact with oxidizing agents. Stainless steels are classified as austenitic, martensitic or ferritic [4, 11].

Austenitic Stainless Steels: These are usually alloy containing three main elements Iron Chromium and Nickel (6% to 22%). These steels cannot be hardened by heat treatment. They retain an austenitic structure at room temperature and are ductile and have good corrosion resistance compared to ferritic stainless steel. They are at risk of intergranular corrosion unless heat treated to modify their chemical composition. In experiments will be a material X12CrNi 18 8, see Table 1, and definition structure by Fig. 1.

Ferritic stainless steel: This steel normally contains 11% to 30% chromium with carbon content below 0.12%. Other alloying elements are added to improve its corrosion resistance or other characteristics such as machinability. Because of the low carbon content ferritic stainless steels are not normally considered heat treatable. However there is some hardness improvement resulting from quenching from high temperatures. The carbon and nitrogen content of these steels must be maintained at low levels for weldability , ductility and corrosion resistance.

Martensitic stainless steels: These steels contain 12% to 17% chromium with 0.1 to 1% carbon. They can be hardened by heat treatment in the same way as plain carbon steels. Very high hardness values can be obtained for carbon levels approximately 1% using correct heat treatment. Small amounts of other alloying elements may be included to improve corrosion, resistance, strength and toughness.

Stainless steel X12CrNi 18 8 is attractive engineering material because of its outstanding properties such as corrosion resistance, weldability, high strength, and good form-ability. The basic properties of stainless steel have been studied and can be found in the materials the strain-rate effect plays an important role in plastic deformation of materials, several investigators have focused on the strain-rate effect for X12CrNi 18 8 stainless steel at low rates. Over the past decades, many researchers have indicated that the plastic deformation of materials under dynamic loading is very different from that under static loading. Dynamic plastic behaviour is often found during the metal-forming process, vehicular accidents, and unexpected foreign impacts. Products made from X12CrNi 18 8 steel are not infrequently subjected to dynamic loading. Although some investigators [1] have studied the impact and shock-loading behaviour of X12CrNi 18 8 stainless steel is dynamic plastic deformation, mechanical behaviour, and associated microstructural evolution are still insufficient.

Assume that austenitic stainless steel has a perfect lattice. If a plane of atoms slide over one another, this motion is called slip. These shear movements occur on defined crystallographic surfaces, called slip planes, and along specific slip directions. However, an equilibrium position can be re-established so that no stress is required to hold them. Hence as the load is released, the atoms do not return to their original positions, so it is regarded as plastic deformation. However, the theoretical stresses for slip in a perfect steel is much greater than in practice.

Table 1

Chemical composition of stainless steel X12CrNi 18 8

C	Cr	Ni	Mo	Si	P	S
0.08	18.0	8.0	2.2	1.0	0.030	0.030

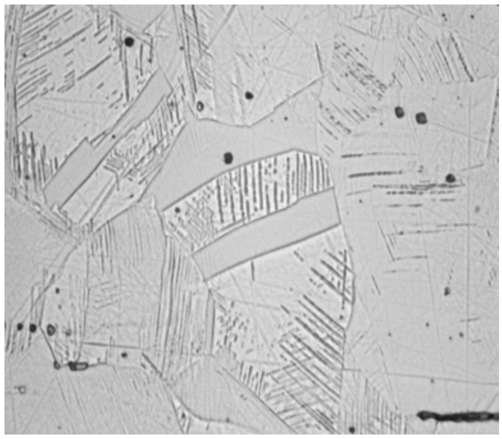

Fig. 1. Structure of X12CrNi 18 8 stainless steel.

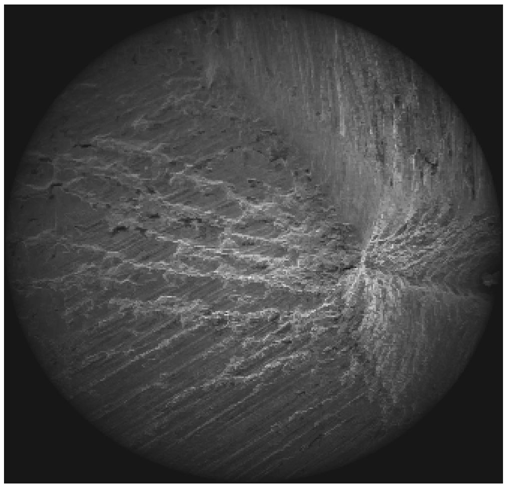

Fig. 2. Tension place in cutting part, mag. 100x .

3. ANALYSIS OF THERMODYNAMICAL PHENOMENAS BY DRILLING

Adhesive wear is often characterized as the most basic or fundamental subcategory of wear since it occurs to some degree whenever two solid surfaces are in rubbing contact and remains active even when all other modes of wear have been eliminated.

All cutting tools wear during machining and continue to do so until they come to the end of their tool-life, the life of a cutting edge is counted in minutes and today tool-lives are often less then the old, established mark of fifteen minutes, but often quite a bit more as well. It is the productive time available during which the edge will machine components to be acceptable within the limiting parameters.

The themodynamical phenomena are orientated on the problems of research of tensions on the tool Fig. 2 and definition the motion energy between interaction two materials influence.

4. DEFORMATION IN CUTTING ZONE

Stainless steel they have individual requirements, but require reach at it, that can a few brand stainless steel, between that requirements about metal cutting differ. Applied modern special implements enable reduce generality problems, connect with machining present band material, alternatively these mess enable absolutely cast out about their true app. Austenitic stainless steel are one from the main tip of stainless steels, that applied because machining fabrication component. Be due broad appliance and machined chiefly turning and drilling. Bases requirements about cutting tool because metal cutting of stainless steel in compare with another alloy steel are:

- advanced addiction at built up edge (BUE);
- drift at hardening of material.

These requirements we can chiefly eliminate true alternative inserts, videlicet band (ISO-M), that recommends generality world machinist of cutting tools. Action machining of stainless steel is dearly many a time accompanying birth BUE on the cutting edge, that make bucking tool life (currency) of cutting tool, affects brand of machined surfaces, give out at alteration dynamic characteristic of cutting process (cutting forces, cutting resistance,…), come-down action chip formation, Fig. 3, as well as affect about assurance machining.

In machining operations, mechanical work is converted to heat through the plastic deformation involved in chip formation and through friction between the tool and the workpiece.

Most of the analytical methods for steady-state temperature prediction in machining were developed based on Merchant's model for orthogonal cutting, which gives the shear and friction energy in terms of the measured cutting forces, tool-chip contact length, and chip thickness ratio. The heat generated during the metal cutting process where the work being done on the tool insert transforms itself in the form of heat.

5. EXPERIMENTAL PART

Drilling tests were carried out using a vertical machining centre equipped with 10 000 rpm, 16 kW spindle. The tests used and TiCN-coated high speed steel with cobalt (HSCo) drills with a diameter of Ø 10 mm, at a cutting speed of 30 m/min and feed rates of 0,1 and 0,2 mm/rev were used without coolant. All experiments was realized in practice by production disks from X12CrNi 18 8 steel. In SEM-images on the JSM 7000 F obtained with a 5 kV acceleration voltage at a working distance of 39 mm, the error in the magnification is ±4 %. The analysis deformation measurements were performed across the stainless steel from non-deformed material to machined surface (defined with hole surface).

On the cutting edge of presented HSCo drill with TiCN coating was SEM analyzed. It was found between TiCN-coating and X12CrNi 18 8 steel built-up edge (BUE) acts as an adhesive. Cutting speed 30 m/min and feed rate 0.1 mm/rev was used. From Fig. 4 influencing very intensive plastic deformation in place corner and stand point between interaction screw drill and workpiece.

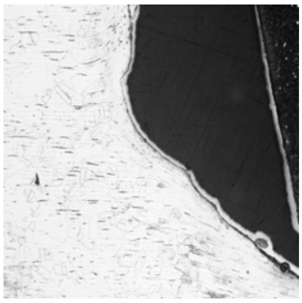

Fig. 3. Plastic deformation alongside machined surface of stainless steel by drilling, SEM, mag.100x.

Fig. 4. Plastic deformation alongside the machined surface of X12CrNi 18 8 steel .

The machinability of stainless steel workpiece with HIPed TiCN coating with HSCo steel drill was examined. The experiments showed that the tool wear mechanism affected by built-up edge formation on the cutting tool for TiCN-coated stainless steel was similar to that with conventional stainless steel. The interface plastic deformation material of X12CrNi188 steel was studied via SEM analyses. It was noticed that hardened during drilling process for both cutting parameters. The deformation of the chips has been studied and micro hardness alteration has been found because of work hardening and the diffusion of Fe into TiCN. Chromium rich layer forms on the steel during HIPing, when also iron diffuses into TiCN. The work hardening of TiCN observed in this study is due to the drilling. The increase of feed rate increases the depth of work hardened layer of TiCN coating. The interface between TiCN and steel is strong enough to withstand shear stresses caused by drilling forces and therefore the drilling process can be optimised according to difficult to machine base materials. The diffusion mechanism during HIPing and work hardening merits further investigation. This work also shows machinability of X12CrNi 18 8 steel and tool wear mechanism affected by BUE and deformation of stainless steel interface detected from chips.

Abrasive wear dominates the flank and crater wear of the HSCo tool edge. The grooved pattern is a combination of the scratching action of hard particles in the work material, and the protection against scratching offered by the hard phases in the tool material. Behind large tool carbides, seen in the chip flow direction, there are typical ridges of protected tool material. Abrasive wear is counteracted by a high yield strength (high hardness) and large carbide volume of the HSCo. Adhesive wear when viewed in low magnification the dominating wear mechanism of the milling tooth appears to be abrasive, i.e. a ploughing action of hard constituents in the work material (carbon steel). However, higher magnification reveals that it is rather a combination of abrasive and adhesive wear. This adhesive component, often referred to as mild adhesive wear, is a tearing of superficial HSCo material by high shear forces resulting in a slow drag of the surface layer and removal of small fragments in the direction of chip flow. If the tool is used to its upper limit of heat resistance, severe adhesive wear may result as a large scale plastic flow of surface material in the direction of the chip flow. Adhesive wear dominates the flank and crater wear of HSCo tools if the edges reach high temperatures, i.e. at high cutting speed. Adhesive wear is further promoted when cutting chemically aggressive materials. Both mild and severe adhesive wear are primarily resisted by the HSCo material through its high yield strength at elevated temperature (high hot hardness). The plastic deformation of HSCo tool edge is loaded beyond its yield strength and deforms by large-scale plastic deformation, resulting in edge blunting. Fatigue and fracture is see macroscopic fracture of the whole tool can occur but is a rather scarce event. More common is localized chippings of the tool edge. Normally, the tool suffers from a combination of two or more of these mechanisms, and it can be difficult to judge which is dominating. It is also indicated in the table how the different wear mechanisms result from a combined effect of properties of work and tool materials as well as cutting parameters. From the results obtained in the study, the following conclusions were drawn. The work hardening rate of TiCN coating chip is increased when feed rate is increased from 0.1 mm/rev into 0.2 mm/rev. The TiCN coating adhesion into stainless steel is not affected by diffusion of Fe into TiCN or Cr-rich layer in the steel. The drilling of TiCN coated stainless steel with appropriate cutting parameters is possible without severe tool wear. A cutting speed of 30 m/min and feed rate between 0,1 and 0,2 mm/rev with HSCo steel multilayer coated drills and through-spindle cooling should be applied. Tool wear mechanisms are affected by built-up edge (BUE) formation of TiCN and stainless steel on the TiCN coating of HSCo steel drill.

6. CONCLUSIONS

About machining of stainless steel needed adhere following commendation that are results experimental measured at laboratory and applied clause:

- needed act machining material attest;
- apply inserts ISO-M;
- secure consistence system machine-tool-workpiece-fixture;
- technological discipline maint manufacture engine.
- cutting tool exchange already about knock-down number of cutting edge;
- cutting tools cast a voice by your leave capacity conjunction because surety adequate consistence and efficacious conscription warm of cutting tool.

Tool wear monitoring is economically very important but technically a rather demanding task. In this paper an attempt has been made in order to reach further understanding of the dynamics that influence the drilling process and especially what happens when a drill is worn. A very simplified approach has been tested in the development of the cutting forces and modelling the influence of wear in these forces. Such factors as geometrical difference of the cutting lips, different kind of wear history of the lips, vibration at first natural frequency and excitation at harmonics of the speed of rotation have been taken into account in the development of the excitation force. The developed forces have been used for excitation of a simplified one degree of freedom model of the drill.

ACKNOWLEDGMENTS: This work was all together supported by the Ministry of Education of Slovak Republic (KEGA No. 03/7166/09).

REFERENCES

[1] Cook, N. (1975). *What is Machinability*. International Symposium on Influence of Metallurgy on Machinability, Deaborn Ohio, 1975, pp. 1–10.
[2] Bailey, J.A., Boothroyd, G. (1968). *Critical Review of Some Previous Work on the Mechanics of the Metal Cutting Process*, Journal of Engineering. for Industry, Trans. of the ASME 1, pp. 54–62.
[3] Dautzenberg, J.H. et all. (1983). *The Minimum Energy Principle for the Cutting Process in Theory and Experiments*, Annals of the CIRP, 32, 1, pp. 223–227.
[4] Chimušin, F.F. (1963). *Neržavejuščie stali*, Moskva, GN-TI, pp. 600.
[5] Jurko, J. (2005). *Drilling of Stainless Steels*, Prešov, D.A.H. Prešov, pp. 101.
[6] Kopalinski, E.M., Oxley, P.L.B. (1997). *Predicting the Effects of Cold Working on the Machining Characteristics*, Journal of Engineering for Industry, Trans. of the ASME, 109, pp. 257–264.
[7] Kramer, B. (1993). *Tribological Aspects of Metal Cutting.* Journal of Engineering for Industry, Trans. of the ASME 115, 3, pp. 372–376.
[8] Lee, E.H., Shaeffer, B.W. (1951). *The Theory of Plasticity Applied to a Problem of Machining*, Journal of Applied Mechanics, 73, 12, pp. 405–413.
[9] Nam, P. Suh (1980). *New Theories of Wear and Their Implications for Tool Materials*, Wear, 62, pp. 1–20.
[10] Oxley, P.L.B. (1963). *Mechanics of Metal Cutting*, Intern. Conf. in Production Engineering, Pittsburg, pp. 50.
[11] Rowe, G., Wolstencroft, F. (1971). *A Mechanical Approach to the Metallurgy of Metal Cutting*, Journal of the Institute of Metals, 98, 11, pp. 33–41.
[12] Šifrin, A.Š., Reznickij, L.M. (1964). *Obrabotka rezaniem žaropročnych i tatanovych stalej isplavov*, Moskva. Mašinostrojenie.
[13] Tipnis, V., Joseph, R.A. (1975). *Testing for Machinability*, International Symposium on Influence of Metallurgy on Machinability, Deaborn Ohio, pp. 11–30.
[14] Thomsen, E. G., Yang, Ch.T., Kobayashi, S. (1968). *Mechanics of plastic deformation in metal processing*, London, Collier-MacMillan Ltd., pp. 504.
[15] Uehara, K., Kanda,Y. (1981). *Fundamental Approach to the Thermal Crack of Cermet Cutting Tools*, Annals of the CIRP, 30, 1, pp. 222–228.

Authors:

Eng, Jozef JURKO, Faculty of Production Technology, Technical University in Košice with seat in Prešov.
E-mail: jozef.jurko@tuke.sk
Eng, Anton PANDA, Faculty of Production Technology, Technical University in Košice with seat in Prešov,
E-mail: anton.panda@tuke.sk