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A STUDY OF THE NATURALLY TREATED WORKPIECE HOW AFFECTS THE PERFORMANCE OF HIGH SPEED STEEL TOOL AND CARBIDE INSERTS

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Abstract

The overall aim of the study is to improve the tool body performance by use of an advanced steel grade with an optimized combination of all the demanding properties. Due to the high temperature conditions, the thesis concerns mostly hot-work tool steels increasing also the general knowledge of their microstructure, mechanical properties and machinability. Knowing the positive effect of sulphur on machinability of steels, the first step was to indentify a certain limit of the sulphur addition, which would not reduce the fatigue strength of the tool body below an acceptable level. In tool bodies, where the demand on surface roughness was low and a geometrical stress concentrator was present, the addition of sulphur could be up to 0.09 wt%. Fatigue performance of the cutting tools to a large extent depended on the steel resistance to stress relaxation under high dynamic loading and elevated temperatures. The stress relaxation behaviour, material substructure and dislocation characteristics in low-alloyed and hot-work tool steels were studied using X-ray diffraction under thermal and mechanical loading. Different tool steels exhibited different stress relaxation resistance depending on their microstructure, temper resistance and working temperature. Hot-work tool steels showed to be more preferable to low alloyed tool steels because of their ability to inhibit the rearrangement and annihilation of induced dislocations. High-temperature softening resistance of the hot-work tool steels was investigated during high-temperature hold-times and isothermal fatigue and discussed with respect to their microstructure. Carbide morphology and precipitation were determined using scanning and transmission electron microscopy.

Machinability of a prehardened hot-work tool steel of varying nickel content from 1 to 5 wt% was investigated in end milling and drilling operations. Machining the higher nickel containing steels resulted in longer tool life and generated lower cutting forces and tool/workpiece interface temperature. The difference in machinability of the steels was discussed in terms of their microstructure and mechanical properties.

Keyword: Coated carbide insert; coating Materials and Steel.

1. Introduction

Metal cutting is among the oldest and most important material shaping processes which is widely used in the automotive, railway, ship-building industries, aircraft manufacture, home appliance, electronics and

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construction industries, etc. It covers all chip-forming operations in which a thin layer of metal, the chip, is removed by a wedge-shaped tool from a workpiece. Turning, drilling, boring and milling are some of the most important machining operations employed in shaping and sizing engineering components. These operations are usually done on the machine tools using different cutting tools, drills and milling cutters. Metal cutting economics is to a great extent about the tool performance. Cutting tools represent only some percents of production cost but have a significant influence on the total economy. Changing to a tool with longer and more predictable tool life, the machine runs with fewer stops and the time consuming maintenance caused by tool replacement is decreased. The increased operational times directly result in better profitability by higher productivity and lower production costs.

Performance of indexable insert cutting tools is not only about the performance of cutting inserts. It is also about the cutting tool body, which has to provide the accurate positioning and secure support of cutting inserts under the tough working conditions. The new tool steel for cutting tool bodies, called MCG 4M, has been developed in the close cooperation between AB Sandvik Coromant, which is the world-leading tool producer, and Uddeholms AB, which is the world-leading tool steel producer. The new steel MCG 4M was specially designed to meet the tool producer demands to the next generation of cutting tool bodies. The name of the steel has been changed during the development process, therefore the MCG 4M appears under different designations such as HWX and MCG2006 in the enclosed papers.

Metal cutting process forms the basis of the engineering industry and is involved either directly or indirectly in the manufacture of nearly every product of our modern civilization. The cutting tool is one of the important elements in realizing the full potential out of any metal cutting operation. Over the years the demands of economic competition have motivated a lot of research in the field of metal cutting leading to the evolution of new tool materials of remarkable performance and vast potential for an impressive increase in productivity. Changes in work piece materials, manufacturing processes and even government regulations catalyze parallel advances in metal cutting tooling technology.

The most important elements in the design of cutting tools is the material construction and there judicious selection. The properties that a tool material must process are as follows:

- Capacity to retain form stability at elevated temperatures during high cutting speeds.
- Cost and ease of fabrication
- High resistance to brittle fracture
- Resistance to diffusion
- Resistance to thermal and mechanical shock

Tool materials have improved rapidly during the last sixty years and in many instances, the development of new tool materials has necessitated a change in the design trend of machine tools to make full use of the potentialities of tool materials for high productivity. Progress from carbon tool steels, high speed steels and cast alloys to carbides and ceramics has facilitated the application of higher speeds at each stage of development. With the advent of carbides and ceramics radical changes have taken place in the design of tool holders and cutters and the concept of the throw away tipped tool where the insert is held mechanically and is discarded after use represents a major advance in the metal removing technology of modern times.

Till 1900 machining was performed by plain carbon tool steel, shortly after 1900 high speed steel was introduced this has undergone many modifications giving rise to several types of HSS. The next notable improvement came with the introduction of cobalt bonded sintered tungsten carbide. However shortage of tungsten has led to the development of many non-tungsten cutting tool materials. Ceramic tools exhibit very high hardness and wear resistance facilitating the use of higher cutting speeds. UCON a new tool material consisting of columbium, tungsten, titanium permits 60% increase in the cutting speed when compared with tungsten carbide. Cubic Boron Nitride with hardness next to diamond which is claimed to give speed 5 to 8 times that of carbide can be used to cut hardened materials. Polycrystalline diamond bonded to tungsten carbide substrate has been successfully employed for machining non-ferrous materials.

Traditional tool materials such as HSS continue to undergo substantial improvement in there properties through suitable modifications in their composition by optimizing the processing technique as well as incorporating various surface treatments. As a result of these technological advances HSS are still in use having surviving competition from carbides and ceramics. Carbide because of the ability to retain its strength and hardness at very high temperatures, to withstand cutting speeds 6 or more than 6 times higher than tools of HSS and the economical price has become a logical choice of many cutting industries. However with the incorporation of suitable surface treatments, its service life as well as its properties can be enhanced even more.

Figure 1. Modern indexable insert cutting tools for drilling and milling.

2. Literature review

In this paper, machinability of AISI 316 austenitic stainless steel was investigated using cryogenically treated and untreated high-speed steel (HSS) twist drills. Machinability of AISI 316 austenitic stainless steel was evaluated in terms of thrust force, tool life, surface roughness, and hole quality of the drilled holes. Experimental results showed from 14% to 218% improvements for treated tool lives. Thrust force, surface roughness, and hole quality are better with treated drills when compared with untreated drills. These improvements were mainly attributed to formation of fine and homogeneous carbide particles and transformation of retained austenite to martensite. Microhardness and microstructure observations verified these formations.

The tool life performance of multilayer hard coatings was evaluated for machining of spheroidal graphite cast iron. TiCN+TiC+Al2O3+TiN and TiCN+TiC+Al2O3+TiN multilayered coatings with different thicknesses were fabricated on WC substrates using high temperature chemical vapor deposition (HTCVD). These cutting tools with hard multilayered coating systems were used in the longitudinal turning of spheroidal graphite cast iron under the cutting conditions encountered in the work. To investigate the tool life performance in cutting tools coated by HTCVD, cutting experiments were performed using a CNC turning bench with 3 different cutting tools having multilayered hard coatings and an uncoated insert with square edges, and a type of spheroidal graphite cast irons. The tests were done under various combinations of speed, feed, and depth of cut. Tool life based on flank wear was considered to compare the 3 cutting tools. Tool performance was evaluated with respect to tool wear, surface roughness, and cutting forces at 4 different cutting speeds in the range 125-200 m/min.

Current experimental studies have yielded that cutting speed, using carbide cutters, has no significant influence on surface roughness obtained for machining the α-β Titanium alloy Ti-6Al-4V. This paper presents results of experimental investigations carried out on the widely used titanium alloy Ti-6Al-4V using variable cutting speeds as well as different cutting tools at a constant feed rate and depth of cut. The effects of varying cutting speeds on the tool life have been analyzed by inspecting the surface roughness of the machined samples and the tool wear observed during machining. As the cutting speed increases, the tool life drops off very rapidly and at higher cutting speed the chips start to ignite because of high heat generation at the cutting zone which is mainly caused by the low thermal conductivity of titanium alloys as postulated. Consequently higher cutting speeds may be used to dramatically reduce the production costs, but the currently available cutting tools will have a very poor tool life. According to this study, it has been identified that the uncoated carbide tool life is comparatively better than that of coated ones at lower cutting speeds whereas the coated ones are preferable at higher cutting speeds. It is expected that the metal manufacturing industries will be highly benefitted by this outcome in selecting the appropriate cutting tool as well as cutting speed according to their desired surface finish and tool life.

The performance of Carbide tools was studied to investigate the tool life and wear behavior at various machining parameters. Coated and uncoated carbide tools were used in turning tool steel AISI D2 bar with hardness of 25 HRC. Machining test were performed in dry cutting condition at various cutting speeds and feed rates. Taguchi's design of experiment was employed to accommodate the machining parameters of various cutting speeds and feed rates. Result show that the wear progression for both types of carbide tools experienced three stages of wear rate, namely: initial, gradual and abrupt stages of wear mechanism. Slow wear rate and uniform flank wear observed at low feed rate of O.05mmlrev.Generally coated tool performed better as compared to uncoated tool. A good surface finish and longer tool life were achieved using coated tool.

A study was undertaken to investigate wear of coated and uncoated carbide end mill cutters (K20). This study was done on austenitic stainless steel (SS316L) with the use of combination of different speeds and feeds. 4 μm thick coating of AlCrN which is done by PVD method on carbide tools proved to better when machining is done on SS316L, as compare to uncoated tools. Wear as well as surface roughness is found to be increased with the help of coated tools. For surface roughness feed is found to be the most dominant factor at constant depth of cut. Al based coatings provide chemical inertness, hardness and good wear résistance due to the formation of Al2O3 layer on the tool surface at high temperatures. ISO criterion (0.3 mm flank wear) was used to measure the tool life of end mill cutters. Almost double tool life is achieved for coated tools as compare to uncoated one, may be due to fact that coatings provide better wear resistance even at high temperature at cutting zones which is due to high speed cutting. The combination of high speed and high speed was found to be the worst combination as far as flank wear is considered, as at high speeds higher stresses are developed on tool and tool edge. Good surface finish is observed for coated tools, specifically when combination of high speed and low feed is used. SEM analysis is done so as to investigate tool wear of end mill cutters. Finally it was found that uncoated carbide inserts cannot be used to machine SS316L at high speeds and feeds, and coating of AlCrN is proved to be suitable for the same.

There are different types of cutting tools in use for machining various materials for the multiple operations in order to produce components. The manufacturers of these components expect to improving their productivity, quality of the components and longer life of the cutting tools. Similarly the customers also expect the quality and durability of the product at competitive price. The tool manufacturers also aims at producing quality tools to with stand for higher cutting forces, thermal resistivity with more wear resistance and to give longer life of the tool, to produce better surface finish product and maintain desired dimensional accuracies of the product. For the past several years the materials of the cutting tools are the same, but due to continuous improvements in enhancing the life of the cutting tools, different methods/process are in progress for producing the tools. The cutting tool manufacturers with their rich R&D experience and continuous innovations, carrying on their production activity to meet the challenges of the market demand. In this paper the analysis is made for the performance of various coated carbide cutting tools in machining the steel AISI 1018. In this review, the machining performance of coated tungsten based cemented carbides, were investigated during finish turning of AISI 1018 steel under dry conditions. The coatings are of TiN, Al2O3TiN/Al2 O3,TiC/Al2 O3/TiN and nano composite coating respectively. For comparison, uncoated cemented tungsten carbides are also tested under the same cutting conditions. The coated tools exhibited superior wear resistance over the uncoated tool. The TiC/Al2 O3/TiN coated tool had the lowest flank wear. The Al2 O3, coated tool showed superior wear-resistance over the TiN/Al2 O3 coated tool. The TiN coated tool showed the least wear resistance with respect to the other coated tools. The coated tools produced lower surface roughness compared to the uncoated tool. The TiC/Al2 O3/TiN coated tool produced the lowest surface roughness of all the tools tested.

Steel selection factors and limitations

Steel selection for tool bodies is essential for the functionality and manufacturability of a tool. analyzing the common damage mechanisms and working conditions of cutting tool bodies, there are several important properties influencing the usability of the cutting tool bodies. First of all, the tool body steel requires an adequate level of fatigue strength to stand the dynamic stresses imposed during use. In addition, the steel needs high strength and hardness to stand the stresses and chip wear. Moreover, the steel should keep strength at higher temperatures and over the whole life time of the tool body, i.e. have high temper resistance and high hot hardness to avoid plastic deformation and wear in service. The detailed analysis of the cutting tool producer needs has led to the conclusion that machinability is also essential, as machining of the steel represents a large fraction of the production cost of a cutting tool.Its complex shape with flutes and insert pockets, thread holes and small and deep holes for cooling channels requires time-consuming and advanced machining operations. Moreover, because of demands on the dimensional accuracy, the cutting tool bodies are also preferred to be machined in the prehardened condition that makes the machining more difficult.

Materials

Tool steels are used for tools, dies, and moulds that shape, form, and cut other materials. Tools perform such operations as forging, cold work, die casting machining, etc. Because of their special properties, tool steels are also employed for structural parts as machine elements, shafts, bearing, gears, etc., in demanding environments as high loads, wear and high temperatures. Within tool steels, there are various classifications, which can be based on alloying, application or heat-treatment. According to the AISI classification system, tool steels are arranged into nine main groups: water-hardening tool steels (W), shock-resisting tool steels (S), oil-hardening tool steels (O), air-hardening tool steels (A), high-carbon high-chromium tool steels (D), mould steels (M), hotwork tool steels (H), tungsten and molybdenum high-speed tool steels (T and M).

In high-alloyed tool steels, as high-speed steels, there is a great risk for segregation of alloying elements, and the powder metallurgy is the process to be used. Firstly, as in the conventional steel making, scrap is melted and the steel chemical composition is adjusted. Instead of casting, the steel is then sprayed out into droplets, which solidify on the way down in the argon-filled container. The steel powder is collected in a cylinder of low-carbon steel, which is then submitted to hot isostatic pressing for consolidation. After that, billets are hotworked to final dimensions and soft annealed. Tool steel heat treatment to working hardness involves austenitizing, quenching for martensite formation, and tempering. The goal of this processing is to produce a microstructure of tempered martensite with dispersed alloying element carbides.

Tool steels used in this study

The first one was the most commonly used for tool body application SS2541 (Swedish Standard) or the AISI P20+Ni. THG2000 (Uddeholm designation) was the other tool body steel chosen for the studies, which was the chromium hot-work tool steel AISI H13 modified for improved machinability. QRO90 (Uddeholm designation) was the special low chromium hot-work tool steel with very high elevated-temperature strength, included as a reference for comparison when testing the high-temperature properties. Finally, MCG 4M (Uddeholm designation, called HWX in Paper II and MCG2006 in Papers III and V) was the hot-work tool steel, newly developed within the project for tool bodies, with leaner balance of carbide alloying elements and added nickel for improved machinability and long-term high-temperature properties. The sulphur content in the MCG 4M was max 0.03 wt% as in the two others tool body steels.

Steel grade	C	Si	Mn	Cr	Ni	Mo	V
SS2541	0.37	0.3	0.70	1.4	1.40	0.2	0.06
THG2000	0.39	0.9	0.40	5.3	0.15	1.2	0.90
MCG 4M	0.30	0.3	1.20	2.3	4.00	0.8	0.80
QRO90	0.38	0.3	0.75	2.6	0.15	2.3	0.90

Table 1. Chemical composition of the steels, wt %.

Experimental details:

Cutting tools:

High speed steel

High speed steels owe their name to the fact that they were originally developed for high speed metal cutting. The properties of high resistance to wear and heat high initial hardness of about 60 to 65 RC at service temperature of 600 to 650 ºC and the economical price of HSS have made them a logical choice of many cutting industries. This finds applications as turning tools, twist drills, counter bores, taps and dies, reamers, broaches, milling cutters, hobs, saws, etc. The perfect combination of alloying elements and the domain of heat treatment processes confers excellent hardness and wear resistance properties allied to good toughness.

Back rake angle	0°
Side Clearance Angle	10°
Side Rake Angle	10°
Principal Cutting edge Angle	90°

Table 2. Description of single point HSS tools

Tungsten carbide

Tungsten carbide has been proved to be much more efficient than HSS when machining hard materials such as steel itself. Due to its extreme hardness, tungsten carbide is largely used in the manufacture of cutting tools as cheaper and more heat resistant alternative to diamond. This is useful when machining tough materials and may leave better surface finish on the parts.

The cutting tools used were squares inserts with cheap breakers of two different grades: SNMG120412MP (Kennametal) and SNMS12048 (Kennametal). The inserts were clamped onto a tool holder with a designation of PSBNR2020K12D5L (WIDAX).

Metallographic examination:

Metallographic study basically includes the following:

Optical micro- (micro structure) examination

This is defined as the method of studying microstructure constituents (grains, phases, micro pores, etc) by means of a metallurgical microscope. In order to carry the analysis first the samples were polished using emery paper of four different grits. This was followed by mirror finishing by polishing the samples on velvet cloth which is mounted on a rotating disc. After this these samples were etched with 2% nital and dried in air. Microstructure examination was carried out using an optical microscope.

Scanning Electron Microscope (SEM) examination

Scanning electron microscope creates images by using electrons instead of light waves while conventional microscopes use a series of lenses to bend light waves and create magnified image. The SEM shows very detailed three dimensional images at much higher magnification. The images obtained from this are black and white only as this does not work on the principles of light waves.

X-Ray Diffraction (XRD) analysis

It is a versatile non destructive technique that reveals detailed information about the chemical composition and crystallographic structures of natural and manufactured materials.

3. Conclusions

Performance of cutting tool bodies can be greatly improved using advanced steels such as hot-work tool steels as tool body materials. Using hot-work tool steels, fatigue performance of tool bodies can be greatly improved as hot-work tool steels have better resistance to residual stress relaxation at elevated temperatures. Using hot-work tool steels, tool performance can be enhanced as softening resistance of hot-work tool steels is more pronounced than the low-alloyed steels. Machinability of hot-work tool steels can be improved by alloying. The addition of sulphur up to a certain limit is allowable without reducing the fatigue strength of tool bodies. Increasing nickel content in hot-work tool steels up to 5 wt% resulted in the significant improvement of the steel machinability in end milling and drilling operations.

From all the above literature and conclusions of other research papers I am much more interested to work on this above topic.

References

[1]Adem Çiçek, Ilyas Uygur, Turgay Kıvak and Nursel Altan Özbek, Machinability of AISI 316 Austenitic Stainless Steel With Cryogenically Treated M35 High-Speed Steel Twist Drills, *J. Manuf. Sci. Eng.* 134(6), 061003 (Nov 01, 2012)

[2] Recep Y˙I˘G˙iT, Fehim FINDIK, Erdal C¸EL˙IK, Performance of multilayer coated carbide tools when turning cast iron, Turkish J. Eng. Env. Sci.33 (2009), 147 – 157.

Vol.2 Issue.3,
March 2014.
Pgs: 14-27

[3] K.B. Ahsan, A.M. Mazid, R.E. Clegg, G.K.H. Pang, Study on carbide cutting tool life using various cutting speeds for α-β Ti-alloy machining, Central Queensland University, School of Engineering and Built Environment, Rockhampton, Australia.

[4] Mr. Mahesh. J. Patil, Investigation in Tool Life of Coated and Uncoated Carbide Tools in Turning, PfOCfJ6dings01 2nd National Conference TIME 2010.

[5] Sonawane Gaurav, V. G. Sargade, Comparative Performance Evaluation of Uncoated and Coated Carbide Inserts in Dry End Milling of Stainless Steel (SS 316L), International Conference in Computational Intelligence (ICCIA) 2011 Proceedings published in International Journal of Computer Applications.

[6] M. Narasimha, R. Reiji Kumar, Achamyelehaemro Kassie, Performance of Coated Carbide Tools, The International Journal Of Engineering And Science (IJES), Volume-2 Issue- 6 , Pages 47-54, 2013.