Journal of Material Science and Mechanical Engineering (JMSME)
p-ISSN: 2393-9095; e-ISSN: 2393-9109; Volume 5, Issue 4; October-December, 2018, pp. 172-176

http://www.krishisanskriti.org/Publication.html

A Study on Wear Analysis of Mixed Ceramic Cutting Tool

S. I.A. Qadri, G.A. Harmain and M.F. Wani

Mechanical Engineering Department
National Institute of Technology, Srinagar
E-mail: qadrisyedirshaad@gmail.com

Abstract—*In this study, the effects of cutting speed on tool wear when machining Inconel 718 nickel-based super alloy has been experimentally investigated. A series of turning tests were conducted to analysis the cutting performance of mixed oxide ceramic cutting tool which has triangular shape. The cutting forces and tool wear are discussed. Metal removing process(plain turning) is carried out for three different cutting speeds(145,230and 360m/min) while 0.3mm depth of cut and 0.19mm/rev feed rate are to be constant. The cutting speed has significant effect on tool wear. The experiment results showed that crater and flank wears are usually dominant wear. Minimum flank wear is seen at low cutting speeds while crater is seen at high cutting speeds. Further, the increase in cutting speed, the resultant cutting forces has tendency to decrease with increase of cutting speed gradually.*

Keywords*: Inconel 718, Mixed Oxide Inserts, Scanned Electron Microscope, Computerized lathe Tool Dynamometer, Flank Wear; Crater wear.*

1. INTRODUCTION

Inconel 718, which is a nickel based super alloy and different from other alloys, has been widely used in the aircraft and nuclear industry due to its exceptional thermal resistance and the ability to retain its mechanical properties at elevated temperatures over 700^0C [1–3]. The advanced material, called "Super Alloy" is designed for high temperature applications and at the same time maintain very high strength to weight ratios generally known that nickel base super alloy is one of the most difficult material to machine[3,4]. The poor machinability of Inconel 718 is associated with the following factors: the tendency of nickel base alloys to galling and welding especially on the tool rake face, the tendency to form built-up-edge (BUE) at lower speed conditions, the presence of hard abrasive carbides in their microstructures that can accelerate the tool wear, and their relatively low thermal conductivity (22.3% lower than that of Steel CK45). These characteristics are at the expense of the high temperature properties of super alloys used in aero engines such as high creep and corrosion resistance as well as elevated temperature strength.[5]The microstructure of Inconel 718is comprised of an austenitic face centered cubic (FCC) matrix phase, which is a solid solution of Fe, Cr and Mo in nickel together with other secondary phases. The main strengthening phase is the precipitate gamma double prime. This phase consists of uniformly distributed body centered tetragonal(BCT) disc-shaped particles (of composition Ni3Nb) that are coherent with the parent matrix. Inconel 718 is often used in a solution treated and aged condition, this involves a solution treatment at 970^0–1175^0C, followed by a precipitation treatment at 600^0–815^0C. The heat treatment results in a microstructure of large grains containing the precipitated phase and a heavy concentration of carbides at the grain boundaries. The difficulty of dislocation motion through this microstructure is responsible for the high tensile and yield strength of the material. The microstructure only degrades significantly when held at temperatures higher than its ageing temperature for extended periods. During long-term exposure to moderate temperatures (~650^0C)the particles increase in size but coherency is not lost. As the temperature is further increased strength begins to decrease with time due to growth of the particles and consequential loss of coherency [6].Inconel 718, a high strength, thermal resistant alloy, and is mainly used in the aircraft industries. Due to the extreme toughness and work hardening characteristic of the alloy, the problem of machining Incone1 718 is one of ever-increasing magnitude. The main factors that affect the performance of a cutting tool whilst machining the super alloys are: (i)high hardness; (ii) wear resistance; (iii) chemical inertness; and (iv) fracture toughness [7]. Nickel-base super alloys are normally machined with WC–Co grades with cutting speeds of the order of 50 m min_1. With the introduction of sialon materials, it is possible to increase the cutting speed by a factor of five, and more recently silicon carbide whisker-reinforced alumina tools have made it possible to machine at cutting speeds of up to ten times those used with cemented carbide [8]. Ceramic tools are suitable with regard to the first three properties even at high cutting speeds. However, their fracture toughness is much lower than that of the other widely used tool materials such as high-speed steel and carbides [9].Narutaki et al. have investigated the influence of the cutting speed on the wear of ceramic tools when machining Inconel 718. They have observed that the notch wear (VBN) at the depth of cut line was the biggest problem. SiC whisker reinforced ceramic tools showed the least fluctuation of VBN. All of the ceramic tools were found to have the maximal VBN around a cutting speed of 100 m min_1. The performance of whisker ceramic was better with respect to notch wear at a cutting speed of under 300 m min_1. However, when the speed exceeded400 m min_1, the Al2O3–TiCshowed the smallest wear compared to the other ceramic tools. Moreover, Al2O3–SiCandSi3N4 tools suffered large flank wear at a cutting speed of 500 mmin_1. The effect of feed rate on tool wear at a cutting speed of 300 m min_1. At the feed rate of 0.32 mm rev_1, notch wear and the average flank wear were large for both of the ceramics.[10]

By using ceramic inserts, the cutting speed could be increased from 183 to 381 m/min. Theother machining parameters such as feed rate of 0.20mm/rev and depth of cut of 0.38 mm remained the same. Machining of hardened steel was done using zirconia toughened alumina ceramic cutting tool and Ti[C,N]mixed alumina ceramic cutting tool. Hong Xiao [11]conducted tool wear studies on various ceramic tools and observed that oxide and mixed ceramic tools are more suitable for machining hardened steel than other ceramic tools, because of their superior flank wear resistance. Brandt [12] observed that mixed alumina ceramic tool has better flank wear resistance due to higher hot hardness and greater thermal conductivity than oxide alumina ceramic tools, while machining hardened steel. Brandt and Mikus [13]observed that the crater wear of alumina based ceramic tools while machining steel was predominantly dependent upon superficial plastic deformation, and this deformation was greatly affected by chemical reaction with the work piece material. Bhattacharyya et al. [14] found that the tools based on mixed ceramics give better performance than those based on oxide and nitride ceramics, while machining cast iron. Richards and Aspin wall [15] observed that the tool life of mixed alumina ceramic tool was severely limited due to excessive depth of cut notching, while machining Nickel based alloys. Wayne and Buljan [16]Inconel 718, a high strength, thermal resistant Nickel-based alloy, is mainly used in the aircraft industries. Due to the extreme toughness and work hardening characteristic of the alloy, the problem of machining Incone1 718 is one of ever-increasing magnitude.

This paper discusses the effect of cutting conditions on the machinability of Incone1 718.

According to literature review, the reported works were focused mainly on work hardening effect, surface integrity, tool life and surface quality of Inconel 718 machined with any one tool material.

Therefore, the aim of present experimental work is to study the influence of cutting speed on tool wear mechanism and cutting forces with dry cutting conditions on one of the cutting tool mixed oxide based on ceramic material with 70%Alo^{2}O3 and 30%TiC.

2. EXPERIMENTAL DETAILS

2.1 Materials and methods

The Work piece of round shape of Nickel alloy-718 material (35 HRC) of 50mm diameter and 400mmlength was selected as sample for experimental purposes. The experimental work of turning tests were carried out on Kirloskar center lathe machine 1550. The specification of lathe machine which includes Height of the centers 165mm, swing over the bed 305mm, spindle speed range 45 to2000 RPM, feed range 0.4-0.08rev/mm and main motor 5HP. Furthermore, In this study, Sandvick make ceramic cutting triangular insert was used.

The chemical analysis of used sample was measured on the HITACHI (modelS-3600) Scanned Electron Microscopic as follows is given table 1. Further, the microstructure of nickel based alloy-718 is shown in fig1.

Quantitative Results for: Base(743)

Element Line	Weight %	Atom%	Formula
Al K	0.16	0.34	Al
Ti K	0.57	0.69	Ti
Cr K	16.14	17.96	Cr
Mn K	0.24	0.25	Mn
Fe K	17.68	18.31	Fe
Ni K	60.69	59.80	Ni
Nb L	2.49	1.55	Nb
Mo L	1.57	0.94	Mo
Ta L	0.46	0.15	Ta
Total	100.00	100.00	

Table 1: Chemical Composition of Inconel Nickel base super alloy 718 measured on SEM HITACHI (S-3600)

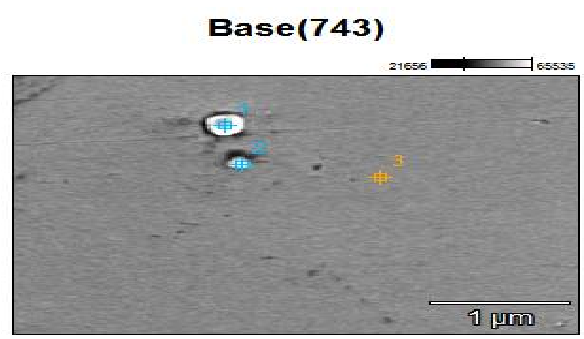


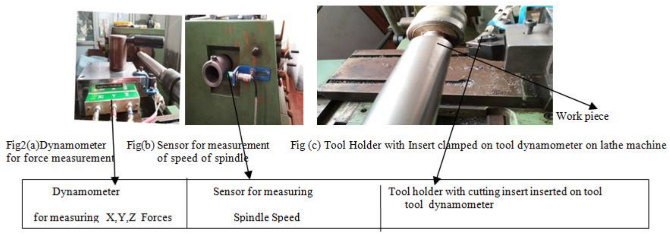
Fig1:- Microstructure of Nickel base alloy - 718

The nomenclature of samples and used cutting tool insert geometry with tool holder type of Lathe machine is given in table 3.

Table 2: Work material Inconel 718 properties, tool geometry and tool holder nomenclature

Work material		Working Tool Geometry	
Work specimens	Inconel 718	Tool holder	Multiple lock Negative triangular tool holder
Hardness	35HRC	shape of inserts	Triangular
Size	50 x 400mm	rake angle	-10^0
Density	8.19 g/cm³	clearance angle	^{0}0
Young's modulus	206GPa	Plan approach angle	30^0
		Nose radius	0.8mm
Machine Tool Kirloskar center lathe machine 1550			

The ceramic cutting insert of mixed Oxide(6050) [SANDVICK] clamped on Multiple lock Negative triangular tool holder was used for turning tests.



The process parameters were selected as three different cutting speeds 145,230 and 360m/min respectively. The feed rate and depth of cut were used constant 0.19mm/rev and 0.3mm respectively. The lathe machine was equipped with a computerized Tool Dynamometer designed and developed by :Real Scientific Engg Corporation (www.realtechnologies.co.in) for measurement of force components Fx, Fy and Fz as shown in fig 2(a)The computerized tool dynamometer was in such a way designed and fabricated to monitor and highlight the actual spindle speed of machine spindle. feed(machined length of tool)along with the test duration time. To assess the actual cutting spindle speed a sensor is attached with the main spindle of the machine as shown in fig 2(b))and tool holder was clamped in the slot provide in the tool dynamotor for machining and recording the cutting tool forces as shown in fig2(c).. At the end of the each test surfaces of the specimen has been examined. Observation on the cutting tool tips were carried out by means of Scanning Electron Microscope equipped with an EDS system.

3. RESULTS AND DISCUSSIONS

3.1 Study of Cutting Forces

The forces acting on the tool are important aspect of machining. Knowledge of the cutting forces is needed for the estimation of power requirements, the adequately rigid design of machine tool elements, tool-holders, and fixtures, for vibration free operations. Cutting forces are categorized in into three components i.e. the radial thrust force (Fx), feed force (Fy), and tangential cutting force(Fz).Usually, the tangential cutting force is the largest of the three components, though in finish turning the radial thrust force is often larger, while the feed force is minimal.

While recording the cutting forces during using of mixed oxide cutting tool the all the forces decreases when cutting speed increases from 145 to 230 and 360m/min. The thrust force (Fx) decreases from 125N to 75N with increase of cutting speed, whereas the feed forces (Fy)increases with increase of cutting speed from145 to 230rpm/min from 200N to 275N and the decreases again upto200N with increase of Cutting Speed from 230 to 360m/min .

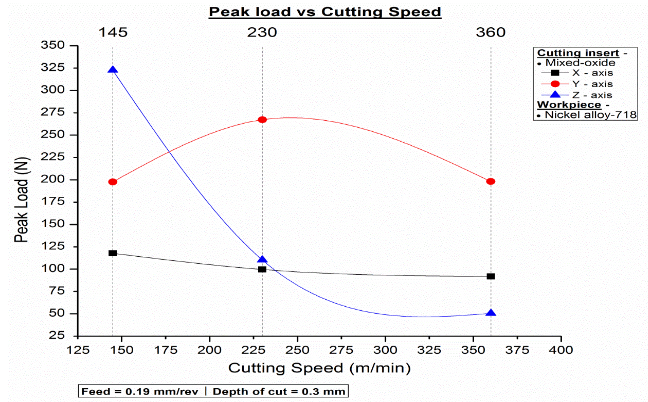
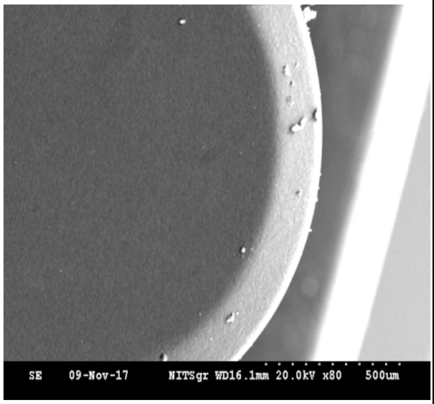
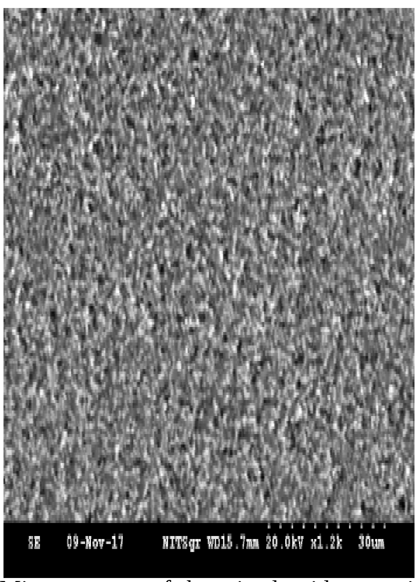
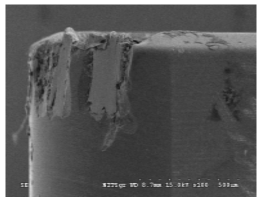
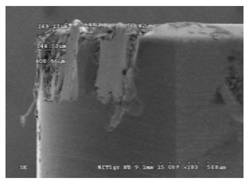
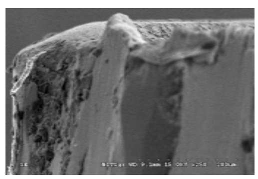
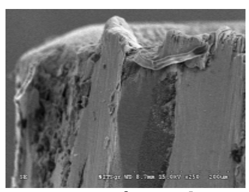
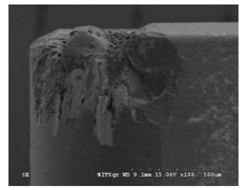
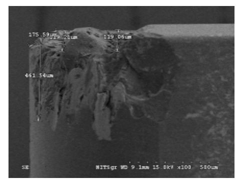
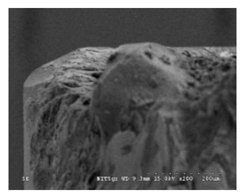
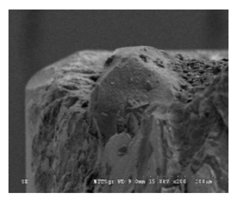
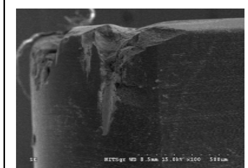
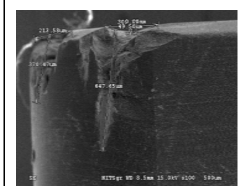
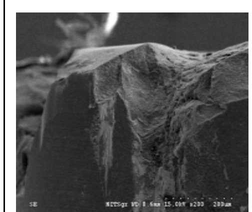
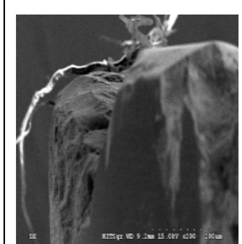


Fig. 3: Effect of cutting speed on three dimensional cutting forces

Similarly, the tangential cutting forces (Fz) decreases drastically from 325N to 50N with increase of cutting speed from 145m/min to 360m/min. In the result, the cutting forces recorded as shown in figs 3 , it showing that Mixed Oxide cutting tools exhibited lower cutting forces at higher cutting speeds.

3.2 Study of Tool Wear

During machining, the cutting tools are subjected to severe forces and temperature which causes tool wear and therefore, it is necessary to study the tool wear mechanism during machining for the determination of cutting conditions .Tool wear during machining of nickel alloy-718 is vital problem which needs to be addressed by using of optimized process parameters with proper tool geometry.

Mixed –Oxide Ceramic Based Cutting Insert Before machining (Shape and Microstructure)	Mixed –Oxide Ceramic Based Cutting Insert After machining Cutting Speed 145m/min, 0.3mm depth of cut and 0.19mm/rev feed rate	Mixed –Oxide Ceramic Based Cutting Insert After machining Cutting Speed 230m/min, 0.3mm depth of cut and 0.19mm/rev feed rate	Mixed –Oxide Ceramic Based Cutting Insert After machining Cutting Speed 360m/min, 0.3mm depth of cut and 0.19mm/rev feed rate
  Microstructure of the mixed oxide ceramic based cutting insert.	    Duration of machining 180 seconds	    Duration of machining 180 seconds	    Duration of machining 180 seconds

4. CONCLUSIONS

After the preliminary experimentation, it can be concluded that spindle speed, significantly affect the output parameters while tuning nickel based super alloy-718 material(HRC35) using ceramic cutting tool.

The cutting speed has significant effect on tool wear. The experimental results showed that crater and flank wears are usually dominant wear. Minimum flank wear is seen at low cutting speeds while crater is seen at high cutting speeds. The flank wear, crater wear and notch wear are higher on machining, which is due to the hardness of nickel alloy. The conclusions of in this experimental tests of turning of Inconel 718with mixed oxide ceramic inserts were observed that flank wear, crater and notching are main cause of the wear of mixed oxide ceramic inserts.

REFERENCES

[1] Richards N, Aspinwall D. Use of ceramic tools for machining nickel basedalloys. Int J Mach Tool Manf 1989;294:575–88.

[2] Khamsehzadeh H. Behaviour of ceramic cutting tools when machiningsuperalloys. Ph.D. thesis, University of Warwick; 1991. p. 125.

[3] Ezugwu EO, Machado AR, Pashby IR, Wallbank J. The effect ofhigh-pressure coolant supply. Lub Eng 1990;479:751–7.

[3]Sims CT.In:Sixth Plan see Seminar Book:1968.

[4]Gessinger GH.Powder Metllurgy of Super Alloys.London:Butter-Worth:1984.

[5] R.J.S. Pigott, A.T. Colwell, Hi-jet system for increasing tool life,SAE Quart. Trans. 6 (3) (1952) 547–566.

[6] E. Bradley, Superalloys: A Technical Guide, ASM International, MetalsPark, 1989, ISBN 0-87170-327.

[7] K.J. Szeszulski, A.R. Thangaraj, K.J. Weinmann, On the CuttingPerformance of Whisker-Reinforced Ceramics Machining Inconel, Winter Annual Meeting of ASME, Fundamental Issuesin Machining ASME, Dallas, TX, USA, 1990, pp. 97–113.

[8] G. Brandt, A. Gerendas, M. Mikus, WEar mechanisms ofceramic cutting tools when machining ferrous and non-ferrous alloys, J. Euro. Ceram. Soc. 6 (5) (1990) 273–290.[9] B. North, Ceramic Cutting Tools, SME Technical Paper, SME,Dearborn, Michigan, MR86-451, 1986.

[10] N. Narutaki, Y. Yamane, K. Hayashi, T. Kitagawa, High-speedmachining of Inconel 718 with ceramic tools, CIRP Annals. 42(1) (1993) 103–106.

[11] Hong X. Wear behaviour and wear mechanism of ceramic tools inmachining hardened alloy steel. Wear 1990;139:439–51.

[12] Brandt G. Flank and crater wear mechanisms of alumina basedcutting tools when machining steel. Wear 1986;112:39–56.

[13] Brandt G, Mikus M. An electron microprobe and cathodoluminescencestudy of chemical reactions between tool and work piece when turning steel with alumina-based ceramics. Wear 1987;115:243–63.

[14] Bhattacharyya SK, Ezugwuand EO, Jawaid A. The performanceof ceramic tool materials for the machining cast iron. Wear 1989;135:147–59.

[15] Richards N, Aspinwall D. Use of ceramic tools for machiningnickel based alloys. Int J Mach Tools Manufact 1989;29:575–88.

[16] Wayne SF, Buljan ST. Wear of ceramic cutting tools in Ni-basedsuper alloy machining. Tribol Trans 1990;33:618–26.