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Analysis of Specific cutting energy in High Speed Turning of Inconel 718 by using Ceramic Tools

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ABSTRACT – *The paper presents an experimental investigation of specific cutting energy of super alloy Inconel 718 during high speed turning using advanced ceramic grade KYS25 and KYS30 inserts with two different nose radii. The effect of machining parameters on cutting ratio was investigated in dry machining. As cutting speed increases specific cutting energy decreases hence less forces are required to shear work piece material in shear zone.*

Keywords: *High speed machining, Advance ceramic tools, Specific cutting energy, Inconel 718.*

I. INTRODUCTION

Nickel based alloy, Inconel, 718 is extensively used in an aerospace engine, gas turbine, space vehicle, rocket engine, nuclear reactor, submarine and petrochemical devices [1].The components assembled in these devices are subjected to extreme stress and temperature condition. This necessitates the component with high degree surface integrity which is vital need for better performance, reliability and longevity of the machined parts during service. The machining forces have an important share in the generation of stresses and temperature in the machined surfaces and hence, it is important to know the machining parameters, which reduce the cutting forces and generate favorable surface characteristics [2].

Inconel 718 is machined using coated carbide, ceramic and CBN cutting tools. Due to short life of carbide cutting tools, the ceramic inserts are finding promising result while machining these alloys. These are possible due to improved properties of the ceramic tools such as fracture strength, toughness, thermal shock resistance, hardness and wear resistance. These developments made the ceramic tools to withstand temperature produced in high speed cutting of Inconel 718.Besides reduction in cutting forces and improved surface finish as compared to that of plain and coated carbides makes them suitable for machining at higher cutting speeds. [3].The paragraph below highlights the few prominent studies of machinablity of Inconel 718 using ceramic insert. Narutaki et al [4] observed that the SiC-whiskered ceramic insert showed best performance in respect of notch wear at cutting speed under 300m/min and Tic added alumina ceramic tool showed small tool wear as compared to carbide tools. Ezugwu [5] used pure oxide and mixed oxide ceramic tools to study the extent of surface damage on machined surface under optimum cutting condition. A rhomboid shaped and round inserts were used during experimentation. Machining with the mixed oxide ceramic tools generally produced better surface finish than with oxide ceramic because of their improved hot hardness, fracture toughness and wear resistance. Li and wang [6] focused on cutting speed influence on tool wear and tool life. They reported that the Sialon grade ceramic insert with square and round shape proved better for high speed machining of Inconel 718. Coelho et al [7] studied the performance of similar insert subjected to modification on edge geometry form on tool wear, surface roughness and temperature during high speed turning of speed nickel based alloy. They found that round inserts made of alumina based ceramic C50 are the best in terms of tool wear and flank wear. Ceramic tools shown lower temperature on the rake face during machining compared to PCBN. Ezugwu et al [8] focused their study on cutting force and tool wear during machining of Inconel 718 using round shaped whisker reinforced ceramic insert. They observed that lower forces are generated at high coolant supply pressure due to improved cooling and lubrication at cutting interfaces. Nalbant [9] discussed the effect of cutting speed on tool wear and tool life when machining of Inconel 718 using square and round ceramic insert. They observed that that square type inserts shows good performance compared to round inserts at low cutting speed and round type insert are good at high cutting speed. Muammer and Altin [10] studied the effect of cutting speed and edge geometry on cutting force. They reported that lowest cutting main cutting force are obtained square insert SNGN 120712 and highest cutting forces are observed on RNGN 120700 ceramic tools, which depends on tool geometry. Bushly [11] experimentally observed the effect of cutting parameters and coolant condition on damage to the machined surface. The literature review shows that the work undertaken using advance ceramic tool under dry cutting condition is inadequate. In this investigation super alloy Inconel 718 is machined by using advanced SIALON grade ceramic CVD coating KYS25 and KYS30 rhomboid shaped inserts having different nose radii. The main objective of this research is to study the influence of machining parameters on cutting force using experiment and to find the suitable tool geometry and the optimal cutting conditions in order to achieve higher mach inability.

II. EXPERIMENTAL SET UP

Machining tests are carried out on a CNC turning lathe(Make-Micromatic Model-Jobber XL) with capacity of 5.7 KW and maximum spindle rpm of 5000 as shown in figure .The three force components F_c, F_t and F_f are measured online during turning of Inconel 718 with a sensitive three component kistler dynamometer (Model-9257 BA) with built in charge amplifier. Data acquisition was made through the charge amplifier and a computer using dynoware software. Specimen of Inconel 718 are prepared in the dimension 30 x150mm and then used for experiment. Chemical composition of work material is given in Table 1.

TABLE 1.CHEMICAL COMPOSITION OF WORK MATERIAL

C	Mn	Si	Cr	Ni
0.03100	0.2300	0.1600	18.1200	52.2300
Co	Mo	Nb	Al	Fe
0.3300	2.9700	5.100	0.7100	19.400

In this experiment SIALON ceramic having three different nose radii with rhomboid shaped inserts are used. They are specially designed for high temperature application material. Their geometry is shown in Table 2.Tool holder PCLNL2525M12 ISO with ‘’p’’ clamping is used having is rake angle 5^0 clearance angle -6^0 and approach angle $95^{0.}$

TABLE 2. GEOMETRY AND MATERIAL OF THE CUTTING TOOL INSERTS:

Material	Nose radius	Grade	ISO Designation
SIALON CERAMIC	1.2mm	KYS25CVD	CNGA120412E
SIALON CERAMIC	1.6mm	KYS30	CNGA120416E

(a) CNGA120412E

(b) CNGA120416E

Fig1. Cutting tools used for experiment

Figure 2.Experimental set up of CNC lathe

III. EXPERIMENTALLY DESIGNED MATRIX:

Mainly for Inconel 718 industry has recommended cutting speed in range of 100 to 400 m/min in high speed cutting range for ceramic cutting tool. Hence, keeping this in mind as well as reference of research literature the turning parameters for this project work (cutting speed, feed and depth of cut) are selected. Parameters chosen for the experimentation are shown in the table.

Table 3.1 Test condition used for evaluation of machining performance

Expt. No	Input factor for 1.2 and 1.6 mm nose insert		
	Cutting speed m/min	**Feed rate mm/rev**	**Depth of cut mm**
1	150	0.05	0.5
2		0.10	0.5
3		0.15	0.5
4	250	0.05	0.5
5		0.10	0.5
6		0.15	0.5
7	400	0.05	0.5
8		0.10	0.5
9		0.15	0.5

IV. Result and discussion

Table 4.1

Ex. No	Insert	Cutting speed m/min	Feed rate mm/rev	Width Aw	Thickness Ao	Cutting ratio	Chip reduction co-efficient	Sp. Shear energy
1	1.2	150	0.05	1.08	0.42	0.12	8.33	6.36
2	1.2	150	0.10	1.26	0.22	0.44	2.27	1.8
3	1.2	150	0.15	1.14	0.37	0.40	2.5	2.22
4	1.2	250	0.05	0.92	0.2	0.25	4	3.11
5	1.2	250	0.10	1.098	0.18	0.55	1.81	1.07
6	1.2	250	0.15	1.92	0.26	0.57	1.75	1.10
7	1.2	400	0.05	1.11	0.2	0.25	4	1.73

8	1.2	400	0.10	1.22	0.18	0.53	1.88	0.52
9	1.2	400	0.15	1.06	0.37	0.40	2.5	1.65
10	1.6	150	0.05	1.12	0.11	0.46	2.17	2.8
11	1.6	150	0.10	1.19	0.17	0.58	1.72	1.10
12	1.6	150	0.15	1.32	0.25	0.60	1.66	1.15
13	1.6	250	0.05	1.19	0.09	0.54	1.82	1.05
14	1.6	250	0.10	1.41	0.19	0.52	1.93	1.62
15	1.6	250	0.15	1.45	0.28	0.53	1.88	1.34
16	1.6	400	0.05	1.62	0.13	0.38	2.63	1.30
17	1.6	400	0.10	1.15	0.2	0.50	2	0.96
18	1.6	400	0.15	1.32	0.22	0.68	1.47	0.74

4.1 Analysis of specific cutting energy

Table 4.2 Effect of nose radius at cutting speed 150 mmin^{-1} on specific shear energy

	Nose radius(mm)		Feed rate mmrev^{-1}	Depth of cut (mm)
	1.2	1.6		
Specific shear energy GN/m^2	6.36	2.8	0.05	0.5
	1.8	1.10	0.10	0.5
	2.22	2.14	0.15	0.5

Table 4.3 Effect of nose radius at cutting speed 250 mmin^{-1} on specific shear energy

	Nose radius(mm)		Feed rate mmrev^{-1}	Depth of cut (mm)
	1.2	1.6		
Specific shear energy GN/m^2	3.11	2.18	0.05	0.5
	1.07	1.05	0.10	0.5
	1.10	1.62	0.15	0.5

Table 4.4 Effect of nose radius at cutting speed 400 mmin^{-1} on specific shear energy

	Nose radius(mm)		Feed rate mmrev^{-1}	Depth of cut (mm)
	1.2	1.6		
Specific shear energy GN/m^2	1.73	1.3	0.05	0.5
	0.52	0.96	0.10	0.5
	1.65	.0.74	0.15	0.5

Table 4.5 Effect of nose 1.2 mm radius ^{1} on specific shear energy

	Nose radius 1.2 (mm)			Feed rate mmrev^{-1}	Depth of cut (mm)
	V1=150m/min	V2=250m/min	V3=400m/min		
Specific shear energy GN/m^2	6.36	3.11	1.73	0.05	0.5
	1.8	1.07	0.52	0.10	0.5
	2.22	1.1	1.65	0.15	0.5

Table 4.6 Effect of nose 1.6 mm radius ^{1} on specific shear energy

	Nose radius 1.6 (mm)			Feed rate mmrev^{-1}	Depth of cut (mm)
	V1=150 m/min	V2=250 m/min	V3=400 m/min		
Specific shear energy GN/m^2	2.8	1.05	1.3	0.05	0.5
	1.1	1.62	0.96	0.10	0.5
	1.15	1.34	.0.74	0.15	0.5

Table 4.7 Specific shear energy on number of observations

No Observations	Specific shear energy GN/m^2	No Observations	Specific shear energy GN/m^2
1	6.36	10	2.8
2	1.8	11	1.1
3	2.22	12	1.15
4	3.11	13	1.05

5	1.07	14	1.62
6	1.1	15	1.34
7	1.73	16	1.3
8	0.52	17	0.96
9	1.65	18	.0.74

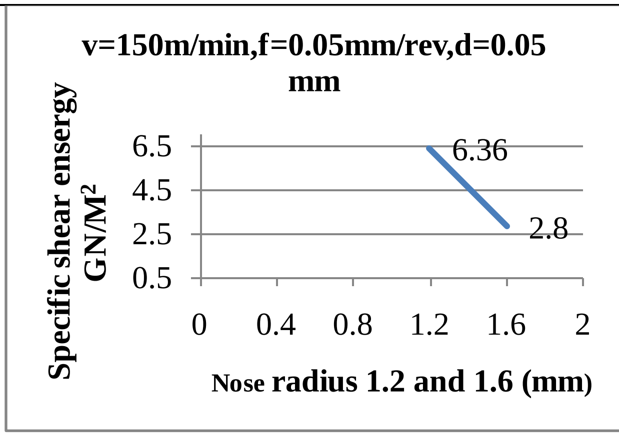

Figure 4.1 (a) Effect of nose radius on specific shear energy at cutting speed at 150m/min and feed rate 0.05mm/rev

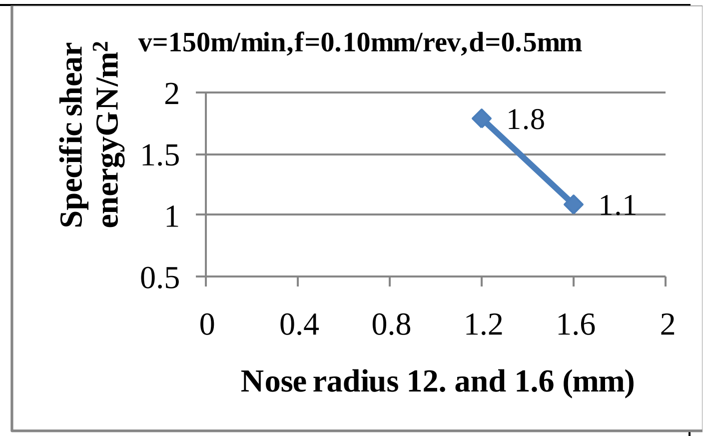

Figure 4.1(b) Effect of nose radius on specific shear energy at cutting speed 150m/min and feed rate of 0.10mm/rev

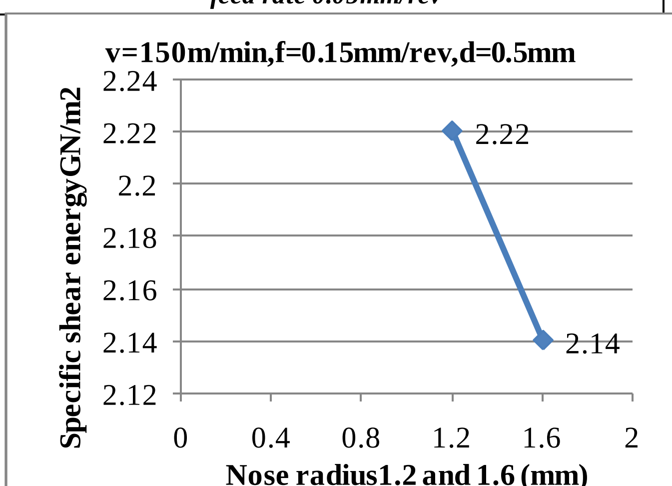

Figure 4.1(c) Effect of nose radius on specific shear energy at cutting speed 150 m/min and feed rate 0.15mm/rev

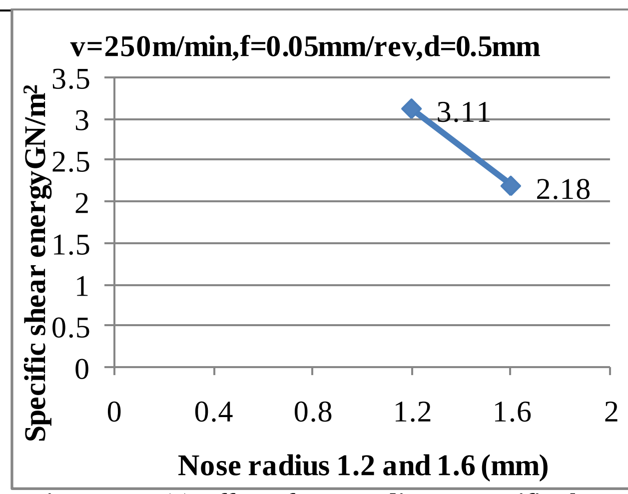

Figure 4.2 (a) Effect of nose radius on specific shear energy at Cutting speed 250m/min and feed rate 0.05 mm/rev

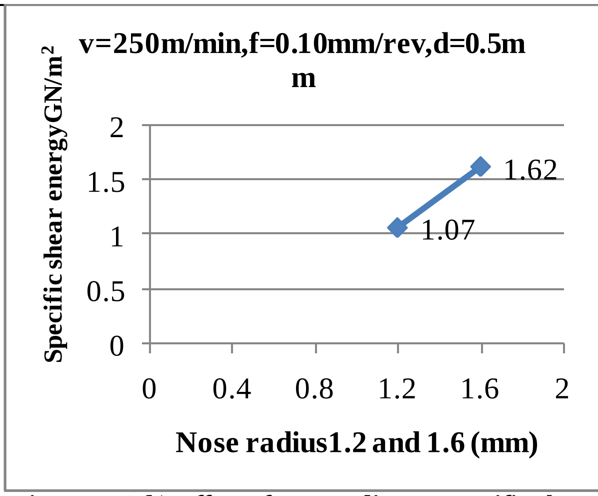

Figure 4.2(b) Effect of nose radius on specific shear energy at cutting speed 250 m/min and feed rate 0.10 mm/rev

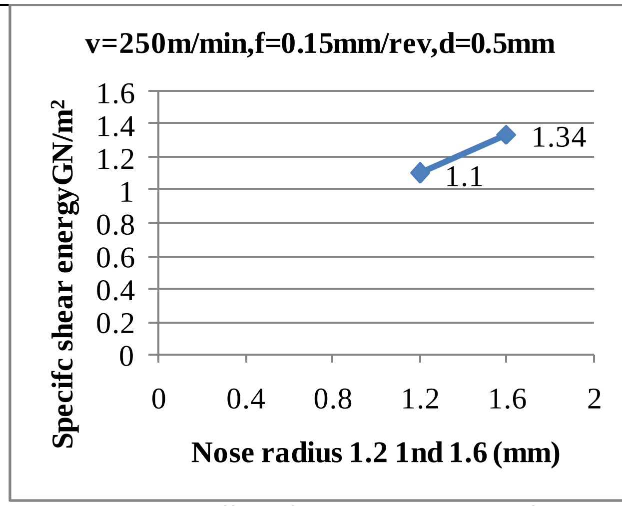

Figure 4.2 (c) Effect of nose radius on specific shear energy at cutting speed 250 m/min and feed rate of 0.15mm/rev

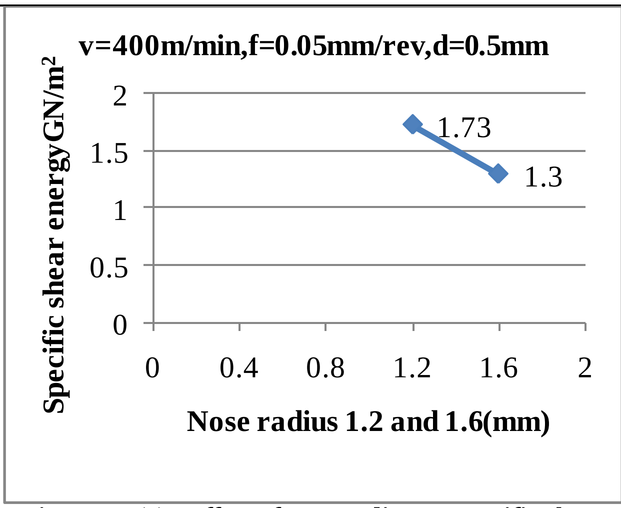

Figure 4.3(a) Effect of nose radius on specific shear energy at cutting speed 400m/min and feed rate 0.0 5mm/rev

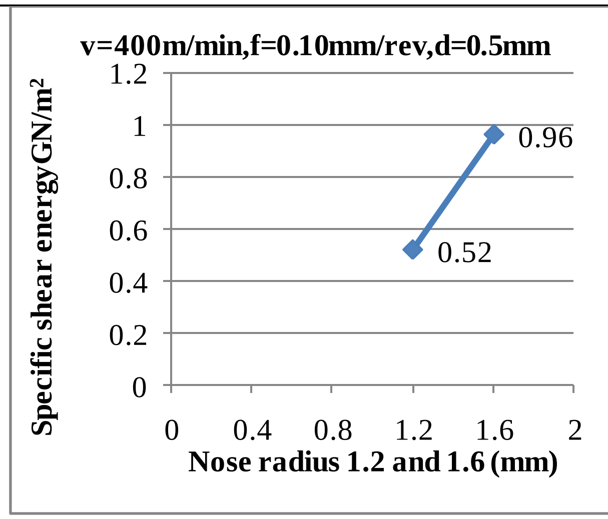

Figure 4.3(b) Effect of nose radius on specific shear energy at cutting speed and feed rate 0.10mm/rev

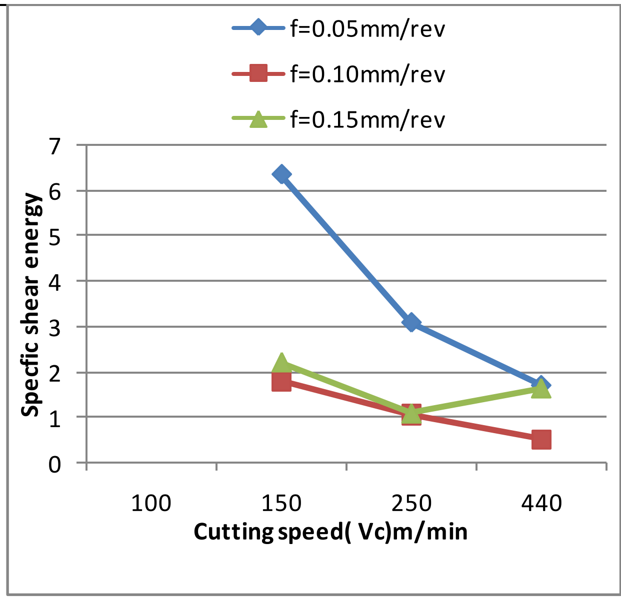

Figure 4.4 (a) Effect of cutting speed on specific shear energy using 1.2 mm insert at different feed rate f=0.05,0.10,0.15 mm/rev respectively.

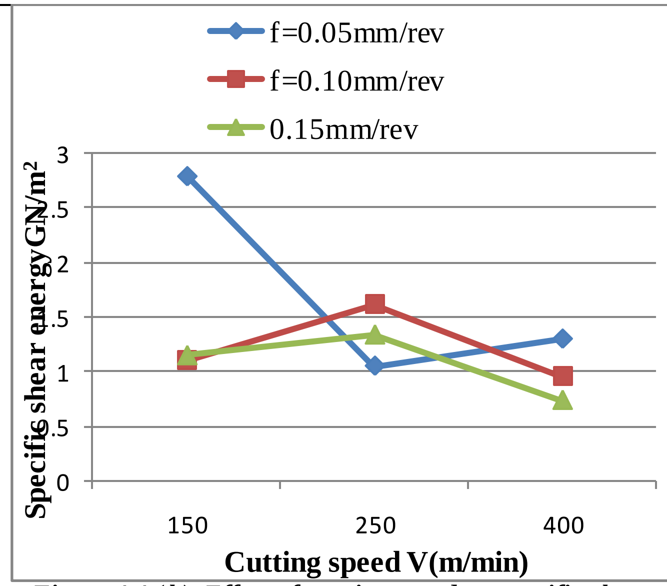

Figure 4.4 (b) Effect of cutting speed on specific shear energy using 1.6 mm insert at different feed rate f=0.05,0.10,0.15 mm/rev respectively.

V. CONCLUSION

This experimental work involves analysis of specific cutting energy in high speed turning operation on Inconel 718 using ceramic insert. The following conclusions are yielded.

- The insert 1.6 mm nose radius show good performance as compared to 1.2 mm nose radius insert in high speed turning of Inconel 718.
- Due to wide area of 1.6 mm nose insert less forces are required to shear work piece material and hence less energy required to shear work piece material and better surface integrity is obtained.
- Increasing in cutting speed from 100 to 400 m/min decreasing in specific cutting energy is observed. Increasing cutting speed causes increase in temperature in shear zone, which reduces material strength and hence less energy required to shear work piece material.

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