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Research Article

Experimental Study on Tool Parameters of Al_2O_3 in High Speed Machining

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Abstract

In this project work, experimentally modeling of dry high speed machining at cutting speed range of 80 to 600 m/min using Al_2O_3 turning insert. Studied the turning process parameters (cutting speed, feed rate and depth of cut) for mac hining of EN-24T alloy steel with an cutting tool Al_2O_3 & Carbide turning insert at cutting velocity range between 80 t o 600 m/min (450 to 3000 rpm) with feed rate of 0.1 to 05mm/rev and depth of cut of 0.1 to 0.5 mm. Experiments we re repeated for -6°, 0° and +6° rack angles of Al_2O_3 tool. Performed simulation of turning operation using Finite Eleme ntal Method (FEM) techniques at the same cutting speed, Feed rate and depth of cut ranges for the +6° tool and cuttin g forces are measured from FEM analysis. Experimental Performance of Al_2O_3 tool was compared with Carbide tool a nd validated with FEA analysis. Calculated percentage of variation of cutting forces of experimental and FEA results o f Al_2O_3 tool.

Keywords: *High speed machining, measurement of cutting forces, machining of EN24T steel, Al_2O_3 tool*

1. Introduction

Among the most effective and efficient modern manufacturing technologies, high speed machining (HSM) is employed to increase productivity while simultaneously improving product quality and reducing manufacturing costs. Depending on work and tool materials as well as tool life requirements, the cutting speed used in HSM is often 2–50 times higher than those employed in traditional (relatively low speed) machining. Due to its high material removal rate and short product cycle time, HSM has received steadily growing applications in recent years in many industrial sectors, such as defense, aerospace, aircraft, automotive, and die- and moldmaking (N. Fang 2008).To improve the productivity and reduce the cost of manufacturing, one of the popular choices is to go with high speed machining. High speed machining involves very high strain rates.

Advances in ceramic processing technology have resulted in a new generation of high performance ceramic cutting tools exhibiting improved properties. Improvements have been made in tool properties such as fracture strength, toughness, thermal shock resistance, hardness and wear resistance. These developments have now enabled the ceramic tools to be used in the machining of various types of steel, cast iron, non-ferrous metals and refractory nickel based alloys at high speed. Aluminum oxide is widely used as ceramic cutting tool material and it is strengthened by the addition of particles like zirconium oxide, titaniumcarbide, and titanium nitride to improve the properties (Senthil Kumar, 2003).

Ceramic cutting tools have an advantage in the machining of hard work piece materials at high speed. The variation of main cutting force with cutting speed on machining EN 24 steel (45HRC) using Ti[C,N] mixed alumina ceramic cutting tool is presented in Figure. It can be noted from the figure that the cutting forces of the ceramic cutting tool decreases with cutting speed.

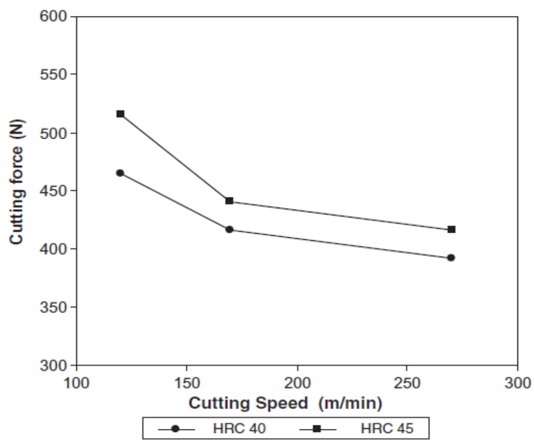

Fig. 1 Comparison of main cutting force with cutting sp eed on machining EN 24 steel with 40HRC and 45 HRC using Ti[C,N] mixed alumina ceramic cutting tool.

The decrease of cutting force with respect to cutting speed when using Ti[C,N] mixed alumina ceramic

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cutting tool shows that this type of ceramic cutting tool can machine the work piece material with high speed and at low cutting forces. The lower cutting forces, result in a lower distortion of work piece, which improves the surface finish while machining with the ceramic cutting tools and particularly by using Ti[C,N] mixed ceramic cutting tools (Senthil Kumar, 2003).

[Charles W 1988],These ceramic composite cutting tool materials are being used primarily for machining of hard materials like cast iron, steel, stainless steel in their hardened conditions, refractory metals like nickel-based alloys and composite materials. The need for finish machining operation like grinding can be eliminated by using these ceramic composite cutting tools. It was reported that switching from coated carbide tools to composite ceramic tools had resulted in a 2.5 times improvement in tool life plus faster metal removal rate when machining automobile axle hubs made out of malleable iron

[Yang Zhenchao, 1997] was simulated The turning process of Inconel 718 by the commercial general purpose machining software Advant-Edge and the influences of cutting speed, feed and cutting depth on cutting force and temperature are analyzed. In the experimental range, the cutting forces decrease with cutting speed increasing, and increase with feed and cutting depth increasing. The influence of cutting depth on cutting forces is significant.

2. Experimental set-up and methods of cutting force measurements

Table 2 summarizes the experimental set-up, where a total of 64 orthogonal high speed turning experiments were performed on a CNC turning center (PMT 801-2518 375BC).

Table 1 Details of Al_2O_3 tool used in the experiments.

Details of tool material	Alumina Ti[C,N] mixed tool
Composition	Al2O3 +TiCN
Insert Specification	TNMGAB30
Density	4.25 g/cm^3
Vickers hardness	1930 (HV30)
Young's Modulus	400 GPa
Fracture toughness	4.5 MPa√m
Thermal conductivity	20 W/mK

Table 2 Experimental set-up

Category	Value
Work material	EN24T Alloy steel
Workpiece diameter	55mm
Tool insert	TNMG AB30 (Teague Tec)
Tool material	Ceramic (Al_2O_3 +TiC)
Rack angles	-6°, 0°& +6°.
Tool edge radius	0.4 mm
Tool holder	MTJNL2525M22
Cutting speed	86, 173, 259, 345, 432& 518 m/min
Feed rate	0.1, 0.2, 0.3, 0.4, 0.5 mm/rev
Depth of cut	0.1, 0.2, 0.3, 0.4, 0.5 mm
I/P power to the	7.5kW

The cutting experiments involved Carbide tool and Al_2O_3 with rack angle -6°, 0°& +6°. Six levels of cutting speeds, and five levels of feed rates & depth of cuts. No cutting fluids or coolants were employed in order to facilitate the collection of the cutting force data.As shown in Table 2, the employed cutting speeds (86–518 m/min) were at least three times higher than those used in traditional machining of the two work materials.

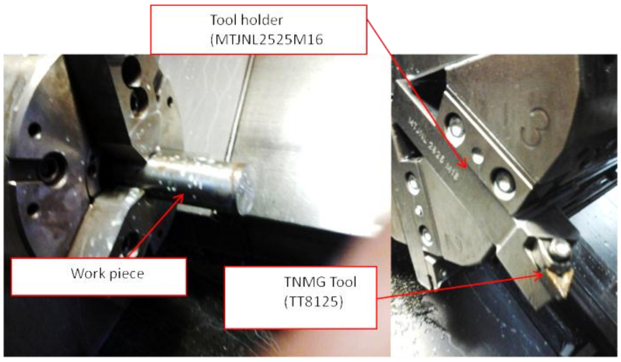


Fig. 2 shows the experimental set up on CNC turning center.

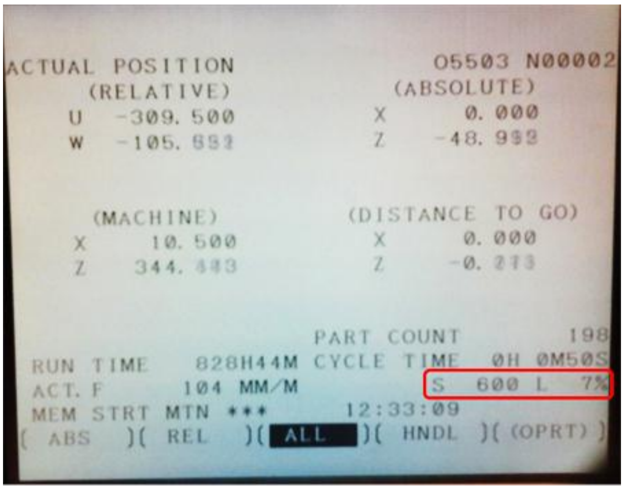


Fig. 3 Photographic view of CNC machine FANUC system output screen display

2.1 Measurement of cutting forces

As the tool start progress into the tool, reaction forces will act on the tool edge radius. These forces transferred to the spindle and FANUC system convert this forces into percentage of load on the machine (power consumed).The following formulas are used to calculate the cutting forces from the output of CNC FANUC system display.

Work done = power (P) needed for turning
= $(F_c \times V_c/6000)+(F_D \times V_c/6000)+ (F_f \times V_c/6000)$ (1)
Since there is no radial movement of tool in turning,

there is no work done by the radial component of force.

$P = (F_c \times V_c/6000)+(F_f \times V_c/6000)$ (2)

$P = (F_c \times V_c/6000)$ (3)

Where Force is in Newton and V is in m/min,

F_c = Tangential forces, F_D = Radial forces in

F_f = Feed forces

3. Finite Element Analysis modeling

The simulation of turning operation on EN24Tsteel using Al_2O_3 tool with +6° rack angle has been performed using Finite element method techniques. Abacus 6.12 version CAE software is used. 3D geometry of work piece and tool are created in the abacus and are as shown in the fig. 4.

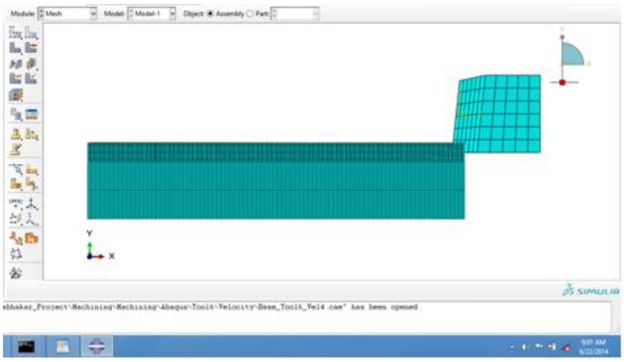


Fig. 4 Assembly view of work piece and cutting tool.

A tetrahedral mesh is used which is an 8-node linear tetrahedron with Abacus designation C3D8R, the DOF of each node is 3. The mesh properties as shown in the table 3. The work piece is fixed in the all linear motion and rotation motions and the tool is allowed only x-direction translation motion. Fig.5 shows the boundary condition of work piece and cutting tool.

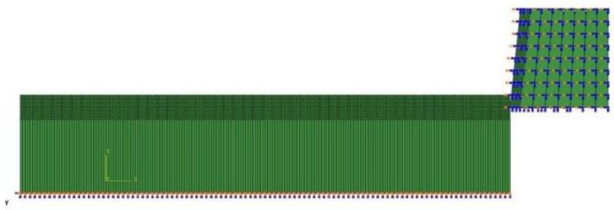


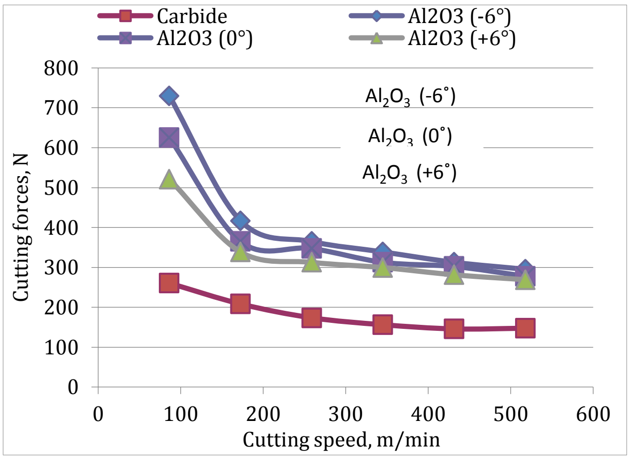
Fig. 5 Boundary conditions of work piece and cutting tool

4. Results and Discussion

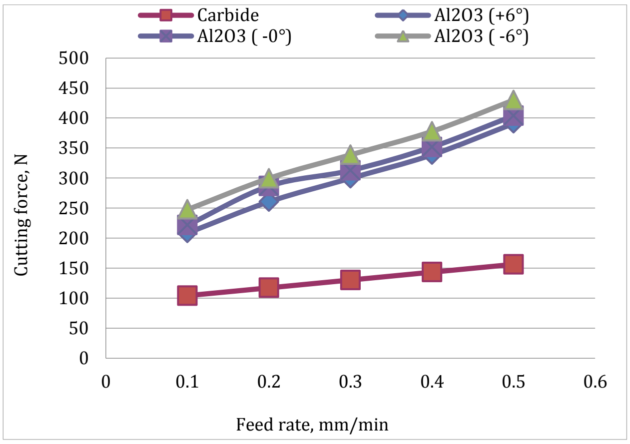
In the present investigation, analysis of cutting forces during the turning of EN24 steel using carbide and Ceramic tool insert with -6°, 0°& +6° rack angles has been carried out on CNC turning center. Also, simulation of turning operation for EN24 steel by finite element method has been carried out for ceramic tool. The results of Al_2O_3 & Carbide tool from experimental set up have been compared and the Al_2O_3 experimental results have been validated with FEA results.

4.1 Comparative study of experimental results

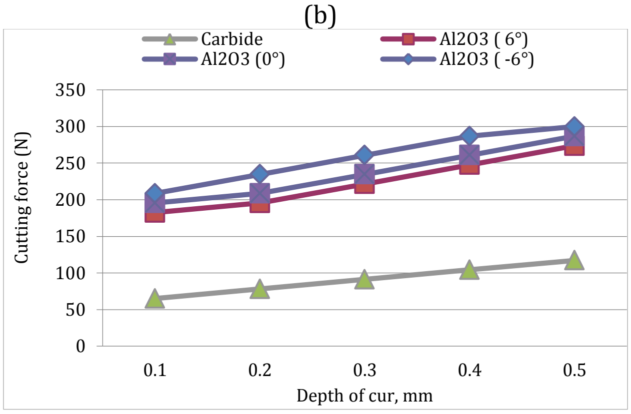
Fig. 3 shows the comparison for variation of cutting forces with respect to cutting velocity for carbide and Ceramic tool. The behavior of cutting forces for both the tools is similar and magnitude of cutting force for ceramic tool is higher because of dry machining. From the figure 6 (a), it is noticed that, for Al_2O_3 tool the cutting forces are reducing significantly during the speed range of 80 to 180 m/min and after that gradually reducing.



(a)



(b)



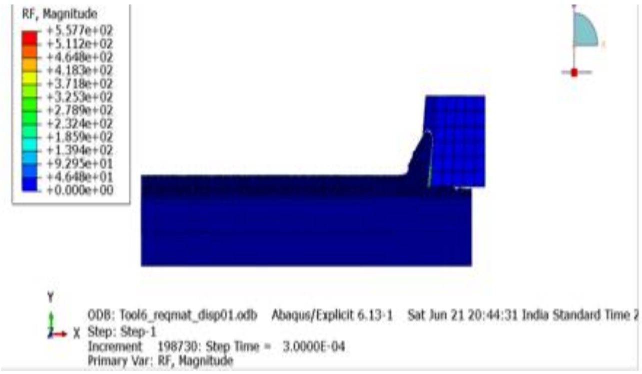
(c)

Fig. 6 Variation of cutting forces with respected to (a) cutting speed, (b) Feed rate & (c) Depth of cut

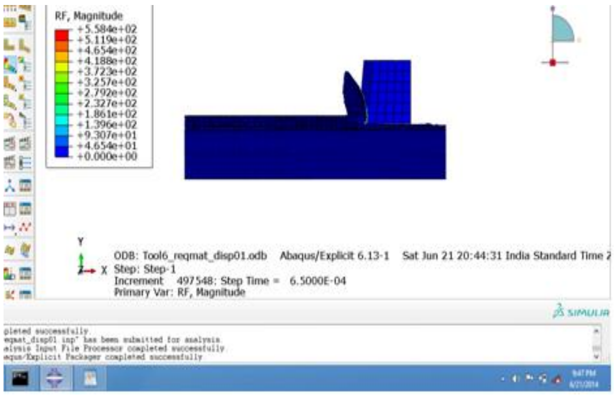
The magnitude of cutting forces for carbide tool is less comparatively because of dry machining. As commonly it is notices that the magnitude of the cutting forces are decreasing as the rack angle increases from -6˚ to +6˚. This is because of the force exerted by chip on the cutting tool edge/face is less as the rack angle increases from negative to positive.

4.2 Validation of Al_2O_3 Experimental Result with FEA results

The results obtained by FEA are noted and plotted the graphs as shown in figures. Here the forces extracted by FEA are compared with forces extracted from experimentally for the process parameters of cutting speed 86 to 512 m/min (450 to 3000 rpm), feed rate 0.25 mm/rev and 0.5 mm respectively.



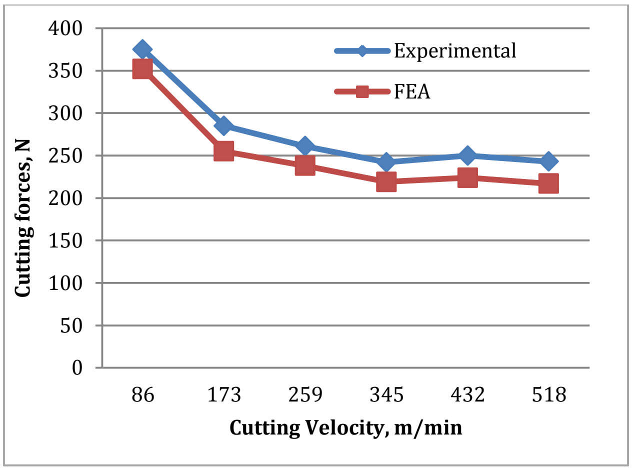
(a)



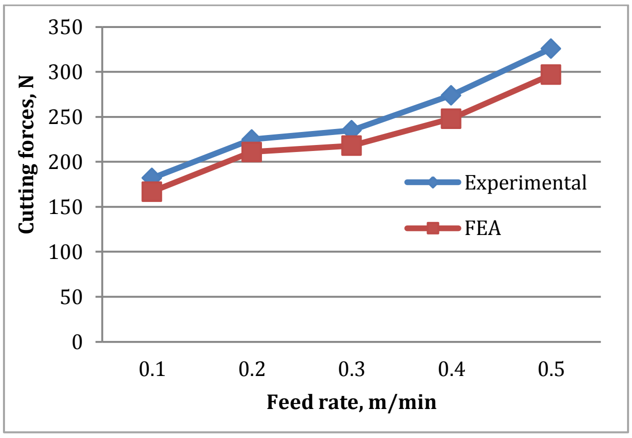
(b)

Fig. 7 Screen image of FEM results for Cutting velocity, 86 to 518 m/min, feed rate 0.25, rev/min & cutting depth, 0.5mm. (a) Cutting forces after 3sec of tool travel. (b) Cutting forces after 6 sec of tool travel

Considering this result, it is observed that the experimental result is similar to the FEA analysis. There is some deviation in the value cutting forces, this deviation may occur due to the some possible measurement errors in experimental test, such as machine operating experience, setting of process Parameters, manufacturing defects in specimen, eccentricity present at the time of machining and due to chip out or tool fractures and frictional forces between tool and work piece.



(a)



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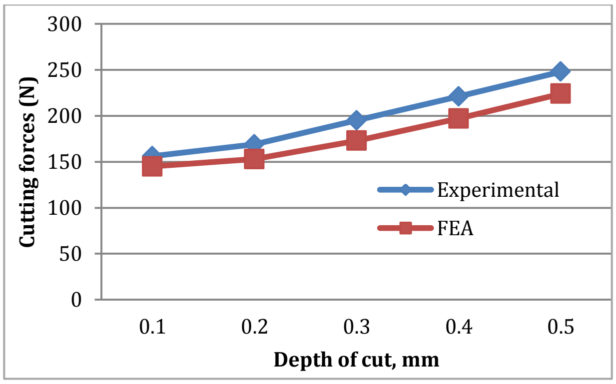

(c)

Fig. 8 Comparison of cutting forces from experimental & FEA results with respect to (a) Cutting speed, (b) Feed rate & (c) Depth of cut.

4.3 Percentage Deviation of cutting forces from experimental & FEA results of Ceramic tool

As part of validation of experimental results of Al_2O_3 tool, cutting forces values which results from experimental and FEA results are tabulated and calculated percentage of deviation between both the values.

Table 3 cutting speed Vs Cutting forces for Al_2O_3tool with +6° rack angle

Cutting velocity, m/min	Cutting forces ,N		% of variation
	Experimental	FEM	
86	375	352	6.13
173	285	255	10.53
259	261	238	8.81
345	242	219	9.50
432	250	224	10.40
518	243	217	10.70

Table 4 Feed rate Vs Cutting forces for Al_2O_3tool with +6° rack angle

Feed rate, m/min	Cutting forces, N		% of variation
	Experimental	FEM	
0.1	182	167	8.24
0.2	225	211	6.22
0.3	235	218	7.23
0.4	274	248	9.49
0.5	326	297	8.90

Table 5 Depth of cut Vs Cutting forces for Al_2O_3tool with +6° rack angle

Depth of cut, mm	Cutting forces, N		% of variation
	Experimental	FEM	
0.1	156	145	7.05
0.2	169	153	9.47
0.3	195	173	11.28
0.4	221	197	10.86
0.5	248	224	9.68

Conclusion

The high speed turning operation of EN24T steel alloy using Al_2O_3 cutting tool with different rack angles is conducted on CNC turning machine and the influences of cutting speed, feed and cutting depth on cutting force are analyzed. In the experimental range, the following conclusions are based on the results above:

1) An increase in the cutting speed leads to a gradual decrease in the cutting forces. It should be noted that the cutting conditions employed did not favor any material adherence on tool cutting edge. It is observed that the forces (N) decreased quickly in the interval 80–180 m/min, and reduced by 34.0%, however, these drops are only 20.6% between 180 and 520 m/min
2) The results presented on Fig. 6 (b)show the evolution of the cutting forces according to the feed rate. If the feed rate increases, the section of sheared chip increases because the metal resists the rupture more and requires larger efforts for chip removal.
3) It is observed that the cutting force increases with cutting depth increasing because of the area of cut per tooth increasing.
4) Based on experiments conducted with three different rack angles, it is noticed that cutting forces on tool is decreases as the rack angle increases from negative to positive
5) From Fig. 8, it is validated that the behavior of experimental results is similar to the FEA analysis. There is some deviation in the value cutting forces, This deviation may occur due to the some possible measurement errors in experimental test, such as machine operating experience, setting of process parameters, manufacturing defects in specimen, eccentricity present at the time of machining and due to chip out or tool fractures and frictional forces b/w tool and piece

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