Parametric Optimization of Cutting Force and Temperature During Hard Turning of Inconel 625- A Review

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Abstract

In this review paper the results of an experimental investigation about the effect on Inconel 625 during hard turning using cubic boron nitride (CBN) based ceramic cutting tool. Turning experiments were carried out at different cutting speeds, feed rates and depth of cut. Tool performance was evaluated with respect to temperature, cutting forces generated during turning. The effect of cutting speed, depth of cut and feed rate on cutting forces & temperature during hard turning of Inconel 625 was experimented and analyzed by using taguchi method. Than optimize the cutting force & temperature using analysis of variance (ANOVA) technique.
Keywords: Hard Turning, Inconel 625, CBN Cutting Tool.

I. Introduction

A. *TURNING PROCESS*

Turning is the removal of metal from the outer diameter of a rotating cylindrical work piece. Turning is used to reduce the diameter of the work piece, usually to a specified dimension, and to produce a smooth finish on the metal. Often the work piece will be turned so that adjacent sections have different diameters. Turning is the machining operation that produces cylindrical parts. In its basic form, it can be defined as the machining of an external surface:

- With the work piece rotating.
- With a single-point cutting tool, and
- With the cutting tool feeding parallel to the axis of the work piece and at a distance that will remove the outer surface of the work.

Taper turning is practically the same, except that the cutter path is at an angle to the work axis. Similarly, in contour turning, the distance of the cutter from the work axis is varied to produce the desired shape. Even though a single-point tool is specified, this does not exclude multiple-tool setups, which are often employed in turning. In such setups, each tool operates independently as a single-point cutter.

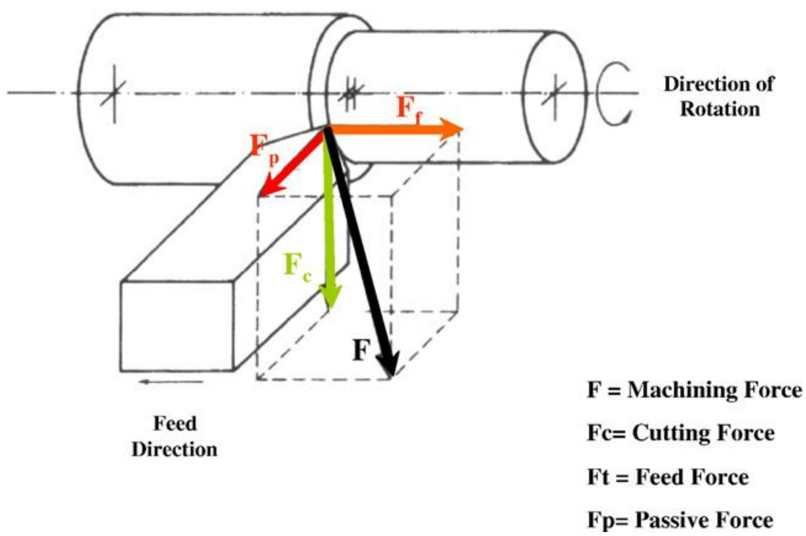

Fig. 1: Schematic Draw of The Machining Forces Components In A Turning Operation

B. PROCESS PARAMETERS

The three primary factors in any basic turning operation are speed, feed, and depth of cut. Other factors such as kind of material and type of tool have a large influence, of course, but these three are the ones the operator can change by adjusting the controls, right at the machine.

1) *Cutting speed*

The cutting speed is the rate of cutting on the main motion. When the work piece rotates once, a certain length (cutting length) passes by the cutting edge of the circumference of the work piece. It is expressed in meter per minute (m/min), and it refers only to the work piece. Every different diameter on a work piece will have a different cutting speed, even though the rotating speed remains the same.

$$\boldsymbol{v}=\frac{\boldsymbol{\pi}\times\mathbf{D}\times\mathbf{n}}{\mathbf{1000}}\ \text{m/min}$$

Here, v is the cutting speed in turning,

D is the initial diameter of the work piece in mm and N is the spindle speed in RPM.

The cutting speed cannot be chosen random. If the cutting speed is too low, the machining time is too long; if it is high, the cutting edge loses its hardness due to strong helping-up. The cutting edge wears out quickly and must often be reground.

For the determination of cutting speed, the following points have to be observed.

- Material of the work piece
- Material of the turning tool
- Cross section of chips
- Cooling
- Design of the machine

2) *Feed*

It is the rate at which the tool advances along its cutting path. The feed of the tool also affects to the processing speed and the roughness of surface. When the feed is high, the processing speed becomes quick. When the feed is low, the surface is finished beautiful. There are 'manual feed' which turns and operates a handle, and 'automatic feed' which advances a byte automatically. A beginner must use the manual sending. Because serious accidents may be caused, such as touching the rotating chuck around the byte in automatic feed.

On most power-fed lathes, the feed rate is directly related to the spindle speed and is expressed in mm (of tool advance) per revolution (of the spindle), or mm/rev.

$$Fm = f.\ N\ \text{mm/min}$$

Here, Fm is the feed in mm per minute, f is the feed in mm/rev and N is the spindle speed in RPM.

Increase feed reduces cutting time. But increased feed greatly reduced the tool life. The feed depends upon factors such as size, shape, strength, and method of holding the component, the tool shape and its setting as regards overheating, the rigidity of the machine, depth of cut.

3) *Depth of Cut*

Depth of cut is practically self-explanatory. It can be defined as the thickness of the layer being removed (in a single pass) from the work piece or the distance from the uncut surface of the work to the cut surface, expressed in mm.

$$\mathbf{d_c} = \frac{\boldsymbol{D-d}}{\mathbf{2}}\ \text{mm}$$

Here, D and d represent initial and final diameter (in mm) of the job respectively.

It is important to note, though, that the diameter of the work piece is reduced by two times the depth of cut because this layer is being removed from both sides of the work.

Other factors remaining constant, the depth of cut varies inversely as the cutting speed. For general purpose, the ration of the depth of cut to feed varies from 10:1.

II. LITERATURE REVIEW ON PLATEN OF INJECTION MOLDING MACHINE

(1) Machinability investigations in hard turning of AISI D2 cold work tool steel with conventional and wiper ceramic inserts, Paulo davim, V.N. Gaitonde and S.R. Karnik, Int. Journal of Refractory Metals & Hard Materials 27 (2009) 754–763.

In this paper researcher have done machinability aspects the machining force (Fm), power (P), specific cutting force (Ks), surface roughness (Ra) and tool wear (VC) has been measured during hard turning of high chromium AISI D2 cold work tool steel with different CC650, CC650WG and GC6050WH ceramic inserts with linear increasing depth of cut. It has been using response surface methodology (RSM) based mathematical models have been developed to analyse the effects of depth of cut (0.2, 0.4 and 0.6 mm) and machining time (5, 10 and 15 min) with constant 80 m/min and 0.10 mm/rev on machinability.

The experiments have been planned as per full factorial design (FFD) and the adequacy of the models has been tested through analysis of variance (ANOVA) Based on the experimental results and parametric analysis. It have been found that CC650WG wiper ceramic insert is perform better in reference of surface roughness and tool wear while CC650 is better in minimizing of machining force, power and specific cutting force.

(2) *Nanocrystalline diamond coating tools for machining high-strength Al alloys*, J.Hu, Y.K. Chou and R.G.Thompson, International Journal of Refractory Metals & Hard Materials 26 (2008) 135–144

This paper reported the Nanocrystalline diamond coatings were produced using a microwave plasma-assisted CVD (chemical vapour deposition) process and deposited on common tungsten carbide tools. The NCD (nanocrystalline) tools were investigated in machining high-Si Al alloy at a range of machining conditions with tool wear and cutting forces examined and analyzed by varying speed (3 and 10 m/s) and feed (0.2 and 0.8 mm/rev) and constant depth of cut 1 mm at two stage with different tool MCD,PCD,NCD.

In addition, commercial CVD diamond coating and PCD (poly crystalline) tools were also tested and compared against the NCD tool performance. Moreover, an FE model was developed to study the stress modifications in diamond coating tools after the depositions and during machining at different conditions.

(3) Tool wear and machining performance of cBN–TiN coated carbide inserts and PCBN compact inserts in turning AISI 4340 hardened steel, Abhijit S. More, Wenping jiang, W.D. Brown and P.Malshe, Journal of Materials Processing Technology 180 (2006) 253–262

This paper reported on Hard turning experiments based on full factorial design of experiments on hardened AISI 4340 steel (HRC = 53) using cBN–TiN coated inserts and commercially available PCBN (poly crystalline cubic boron nitride) inserts with vary cutting speed (100, 125 and 150 m/min) and a feed rate (0.10, 0.15 and 0.20 mm/rev) corresponding to a fixed depth of cut of 0.25 mm. It have been found that effect of above parameter on tool wear (tool life), surface roughness, and cutting forces which was analyzed using ANOVA techniques.

The performance of cBN–TiN coated carbides inserts and commercially available PCBN inserts was compared in terms of tool wear, surface roughness, and cutting forces at cutting conditions of V = 125 m/min, F = 0.15 mm/rev, and DoC = 0.25 mm. At these cutting conditions, the cBN–TiN coated carbide inserts tool life of approximately 18–20 min per cutting edge, whereas PCBN tools produced a tool life of 32 min. The surface roughness for the cBN–TiN coated inserts was below 1.3micro m and while the PCBN tool gave a constant surface roughness value. The cutting forces are slightly different between them. Based on cost analysis, shows that the cBN–TiN coated carbide tools are capable of reducing machining costs so it’s suitable for hard turning.

(4) *Cutting forces in turning of gray cast iron using silicon nitride based cutting tool*, J.V.C. Souza, M.C.A. Nano, M.V. Ribeiro, J.P.B. Machado and O.M.M. Silva, Materials and Design 30 (2009) 2715–2720

Researcher have reported to investigation about the effect of cutting forces on gray cast iron turning using silicon nitride (Si3N4) based ceramic tool. It have been carried out experiments with five different cutting speeds(180, 240, 300, 360 and 420 m/min) and feed rates(0.12, 0.23, 0.33, 0.40 and 0.50 mm/rev) while constant depth of cut 1.0 mm. Tool performance was evaluated cutting forces, tool wear, temperature and surface finish produced during turning.

It have been show that the cutting forces is reduced after cutting speed of 300 m/min and the low tool wear of the inserts suggests that Si3N4 is best for machining gray cast iron average temperature is reduced at same speed and higher the feed rates.

(5) Effect of Tool Edge Geometry on Work piece Subsurface Deformation and Through- Thickness Residual Stresses for Hard Turning of AISI 52100 Steel, Jeffrey Thiele and Shreyas Melkote, Journal of Manufacturing Processes Vol. 2/No. 4 2000

Researcher have reported that a detailed experimental investigation into the effects of cutting edge preparation and work piece hardness on the surface finish and cutting forces in the finish hard turning of AISI 52100 steel using cubic boron nitride (CBN). It have been carried experiment with various edge hone radius (22.86, 93.98, 121.92) tends to increase the average surface roughness because of increase in the ploughing component compared to the shearing component of deformation and also carried out experiment with various work piece hardness (41,47,57 HRC) and edge geometry interaction on the surface roughness was also found to be very significant. The effect of edge hone on the surface roughness decreased with increase in work piece hardness.

Finally, It have been found that the cutting edge geometry has a significant effect on the axial and radial cutting force components (or the equivalent thrust force), and that the effect of work piece hardness on the force components was found to be significant mainly for the 93.98 and 121.92 mm edge hones.

(6) Effect of cutting parameters on the degree of work hardening and tool life during high-speed machining of Inconel 718, Dinesh G. Thakur and B. Ramamoorthy, Int J Adv Manuf Technol DOI 10.1007/s00170-011-3529-6

In this paper researcher experiment on Inconel 718 with use of cryogenic treated tungsten carbide tool and to measured cutting forces, tool life, tool flank wear and residual stress with use of cryogenic treated tungsten carbide tool, with range of cutting speed (40 and 65 m/min), feed (0.08 and 0.2 mm/rev) and depth of cut (0.5 and 1 mm). On that experiment, it have been showed that the magnitude of cutting forces lower in case of use of cryogenic-treated tungsten carbide tool than the corresponding untreated tungsten carbide tool by about 10% to 15%.

The statistical analysis of tool life use of MINITAB, version 14, software was used with ANOVA and analysis of mean on the data and it indicates that cutting speed, feed, and type of tool were the most significant deciding parameters of tool life. It has been shown that cryogenic post treatment improved the tool life of tungsten carbide tool.

They show that the degree of work hardening can be minimized by properly selecting the cutting parameters and Tool flank wear was found to be more uniform in the case of cryogenic post treated tungsten carbide tool than untreated tungsten carbide tool and residual stresses were found to be 7% less in cryogenic post treated tool than untreated tool.

III. CONCLUSION

As per review of research papers, we can see that researcher worked on various material like Inconel 718, AISI1040 steel, AISI 52100 steel, C45 steel, gray cast iron, -Si Al alloy and AISI 4340 steel with various cutting tools. They were measured cutting force, surface roughness, chip morphology and tool wear with the help of various process parameters like speed, feed and depth of cut. The aim of the paper is to optimize the temperature & cutting force during hard turning of Inconel 625.

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