Experimental Study and Finite Element Analysis of the Impact of Tool Edge Geometry in Orthogonal Machining of Super Alloy Inconel 718

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Abstract. The demand for super alloys of extraordinary hardness and confrontation for automobile and aeronautical applications. However, the metal cutting of super alloys like Inconel 718 are very tough because of various factors like the formation of built up edges, increased machining forces, increased machining temperature, high tool wear, etc. These reasons may lead to poor surface finish, reduced tool life and improper chip formation. The edge dimensions of tool inserts play a vital in the orthogonal machining of aerospace super alloys which are hard to machine alloys. This tool insert geometry also directly have an influence in chip formation mechanism which in turn panels the chip morphology. In this paper, orthogonal machining test on Inconel 718 have been conducted to examine the impression of the edge geometry in machining outputs like surface roughness, machining forces, temperature and cutting insert wear. The consequence of machining constraints are also studied on the above mentioned outputs. Cutting edges are modified using Wire EDM technique. Silicon Nitride and Cubic Born Nitride tool inserts were used for orthogonal machining. This paper is mainly focused to compare the machining outputs beforehand and later alteration of tool insert geometry. The tool cracks and built up edge formation by means of microscopic images were inferred and examined. The parameters which are to be varied in the experiment are defined by L9 orthogonal array. The metal cutting was developed in AdvantEDGE software to analyse conforming stress dissemination.

1. Introduction

Super alloys of nickel alloys like Inconel 718 is widely employed in aeronautical, automobile and electrical applications because of its alluring physical, chemical and mechanical properties. Inconel 718 alloy is extremely resilient to corrosion and rust so it is finest right for facilities in a very punitive atmosphere endangered to great pressure and great temperature [1]. Because of high percentage of super alloy in the metal, it may induce great resistance to plastic deformation while metal cutting and speed hardening also which may finally lead way great residual stress and dimension issues [2]. The main issues faced in metal cutting are reduced insert life because of above said hardening and properties of super alloy and degraded exterior workpiece finish because high machining load and stress because of work hardening [3]. Numerous investigators have examined the metal cutting

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physiognomies of Inconel 718 by bearing in mind the machining constraints and normal inserts which are as follows.

P Jeyapandiarajan et al. [4] studied the characteristics of metal cutting Inconel 718 by using various inserts like TiAlN and CBN coated on the basis surface, load and wear characteristics. He also the content of hardening and deformation observed at high loads and temperature. P. Pal Pandian et al. [5] established that by utilising the optimum constraints a better machining output responses like exterior finish and wear resistivity can be attained. Tatsuya Sugihara et al. [6] established a novel form CBN insert with special flank dace for improving the effect of coolant at machining region. He concluded that coolant is not effective in wear characteristics at high machining load and stress. Haruki Tanaka et al. [7] developed a guideline for PCBN insert in metal cutting of Inconel 718, by studying the wear characteristics at various machining constraints. He also studied the machining performances and dimensions of the inserts. F. Jafarian et al. [8] established a FE simulation to study the metal cutting of this super alloy in order to improve some of the limits and short comings in the improvement of forecast prototypical for machining. T. Karthik Reddy et al. [9] studied about the machinability and exterior quality of the workpiece after metal cutting the part under various constraint on both coated and uncoated inerts. Temperature and stress modulation during metal cutting process also studied. Rajkumar.G et al. [10] studied about the analysis of various turning constraints in metal cutting of this alloy by developing prediction models and regression model to find the implication and consequence of the same by using titanium and carbide tools. Jadam Thrinadh et al. [11] analysed the resistivity to corrosion provided by coated at different speeds and also examined chip characteristics with respect to various machining constraints. He also studied the mechanisms involved behind attire by employing EDS. So, there is motionless a possibility and test to analyse and appreciate the flora, grade, and real motives behind the difficulties of metal cutting.

Therefore, this paper is mainly attentive to parallel the machining responses beforehand and later alteration of tool insert geometry. The machining parameters are varied according to Taguchi array design of experiments. The machining turning operation is also simulated by using software and the values predicted are authenticated.

2. Methods
Material removal process of turning operation is done in the workpiece of super alloy using CNC machine. The raw material is of 120mm length and 25mm diameter. The process is done coolant free environment which is eco-friendly. The insert used for machining are of two types namely Silicon Nitride and Cubic Born Nitride. The experiment methodology is displayed in figure 1. The experiment were based L9 Taguchi array where three factors namely machining speed, feed and depth of cut are reserved and the identical are speckled in three level each as revealed in Table 1. The design of experiments revealed in Table 2 which is the standard format is employed for the tests. The experiment setup conditions are revealed in Table 3. Wire EDM machine is employed to adjust the nose of the insert. The alteration of the cutter yields to change of nose radius from 0.8mm to 0.4mm. From figure 1, it is clear that effort variations are the machining constraints. Similarly, the output responses are also displayed. These output responses are measured by using standardized techniques for measurement. The machining force is found by employing Kiztler Piezo electric Dynamometer which is calibrated and validated before use. The temperature is measured using IR non-contact temperature sensor. Surface quality and insert wear are determined using roughness tester and image analyser setup respectively. The average value of finish and insert wear measured only are taken for analysis and education. The chip morphology is also measured using machine vision setup and the mean values is analysed.
Figure 1. Experiment Methodology.

Table 1. Parameter Selection.

| Parameter              | Level 1 | Level 2 | Level 3 |
|------------------------|---------|---------|---------|
| Cutting Speed (m/min)  | 60      | 80      | 100     |
| Feed Rate (mm/rev)     | 0.1     | 0.15    | 0.2     |
| Depth of Cut (mm)      | 1       | 1.5     | 2       |

Table 2. Design of Experiments.

| Exp. No. | Cutting speed (m/min) | Feed (mm/rev) | Depth of Cut (mm) |
|----------|-----------------------|---------------|-------------------|
| 1        | 60                    | 0.1           | 0.5               |
| 2        | 60                    | 0.15          | 1                 |
| 3        | 60                    | 0.2           | 1.5               |
| 4        | 80                    | 0.1           | 1                 |
| 5        | 80                    | 0.15          | 1.5               |
| 6        | 80                    | 0.2           | 0.5               |
| 7        | 100                   | 0.1           | 1.5               |
| 8        | 100                   | 0.15          | 0.5               |
| 9        | 100                   | 0.2           | 1                 |

Finite element prediction model is developed by using AdvantEDGE software by employing the various conditions given in Table 4. The model is developed by means of a firm workpiece with material properties of the same super alloy and insert of both type with its corresponding properties and its same dimensions. The insert go in over the super alloy through simulation. The engaged software suggests well-known Johnson- Cook metallic ideal to describe work metal design. Friction between the job and insert is taken into account for calculations of various output responses. The piece was established of size 10mm to lodge the cutting size below the test restrictions. The raise of the part is taken as 4mm in contract to the metal removal length. The piece material is certain to Inconel 718.
The border situations are functional as the test constraints. The Silicon Nitride and CBN is nominated as insert material.

**Table 3.** Experiment Setup Conditions.

| Item                        | Parameter                        |
|-----------------------------|----------------------------------|
| Work Material               | INCONEL 718                      |
| Work (mm)                   | 120 x 25                         |
| Cutting Speed (m/min)       | 60, 80, 100                      |
| Feed (mm/rev)               | 0.1, 0.15, 0.2                   |
| Depth of Cut (mm)           | 0.5, 1, 1.5                      |
| Environment                 | Dry                              |
| Lathe                       | CNC Lathe                        |
| Tool Holder                 | PCLNR2020K12                     |
| Insert                      | Uncoated                         |
| Rake Angle (°)              | 5                                |
| Clearance Angle (°)         | 10                               |
| Tool Material               | Silicon Nitride and Cubic Boron Nitride (CBN) |
| Cutting edge radius (mm)    | 0.8 is modified to 0.4 using Wire EDM |
| Experimental Methodology    | L9 Array                         |
| Force Measurement           | Kistler Dynamometer              |
| Chip Thickness Measurement  | Machine Vision System            |
| Surface Roughness Measurement| Surface Roughness Tester        |
| Tool Wear Measurement       | Image Analyser                   |
| Temperature Measurement     | Non-Contact Type Infrared Temperature Sensor |

**Table 4.** Simulation Conditions.

| Item                              | Parameter |
|-----------------------------------|-----------|
| Avg. length of cut ratio          | 10        |
| Chip breakage                     | 0         |
| Max. no of nodes                  | 24000     |
| Max. Element Size                 | 0.1 mm    |
| Min. Element Size                 | 0.02 mm   |
| Fraction of Radius                | 0.6       |
| Fraction of Feed                  | 0.1       |
| Mesh Refine                       | 2         |
| Mesh Coarse                       | 6         |
| Output Frame                      | 30        |
| No. of threads                    | 1         |

### 3. Results and Discussion

#### 3.1. Cutting Forces

The machining force observed during metal cutting of the work part are recorded using dynamometer and the same machining force are predicted by the FE simulation model. The experimental results and FE model predicted values of machining forces are given in Table 5.
Table 5. Experimental and FE Model Results – Machining Force.

| Exp. No | Cutting speed (n/min) | Feed (mm/rev) | Depth of Cut (mm) | Experimental Results | Finite Element Model Results |
|---------|-----------------------|---------------|-------------------|----------------------|-----------------------------|
|         |                       |               |                   | SiN Insert R=0.8mm   | CBN Insert R=0.8mm |
|         |                       |               |                   | Machining Force (N)  | Machining Force (N)       |
|         |                       |               |                   | SiN Insert R=0.4mm   | CBN Insert R=0.4mm |
| 1       | 60                    | 0.1           | 0.5               | 254                  | 267             |
| 2       | 60                    | 0.15          | 1                 | 678                  | 765            |
| 3       | 60                    | 0.2           | 1.5               | 1392                 | 1311           |
| 4       | 80                    | 0.1           | 1                 | 601                  | 531            |
| 5       | 80                    | 0.15          | 1.5               | 1124                 | 1104           |
| 6       | 80                    | 0.2           | 0.5               | 513                  | 580            |
| 7       | 100                   | 0.1           | 1.5               | 805                  | 730            |
| 8       | 100                   | 0.15          | 0.5               | 412                  | 390            |
| 9       | 100                   | 0.2           | 1                 | 1011                 | 934            |

From Table 5, it is clear that minimum machining force is obtained at 60m/min, 0.1mm/rev and 0.5mm which are at low levels because in those low levels only the MRR is very low which induces low machining force. On the comparison of trial outcomes of SiN and CBN inserts, forces observed in
SiN insert are comparatively less than CBN insert because of the insert properties and characteristics. Similarly same trend is also followed FE predicted results as SiN gives less force than CBN insert. In the same fashion, on comparing beforehand and later alteration of the insert that is between 0.8mm and 0.4mm nose radius insert, in most of the cases the machining force observed in the tool with edge radius 0.8mm is more than that of 0.4mm because when the edge radius is sharp the load required for material removal will be low. The same trend is followed in both inserts experimentally and FE model prediction. Figure 2 and 3 displays the Mean effect of experimental forces with the various machining constraints of SiN insert beforehand and later alteration of the same. It is observed in the situation of SiN insert beforehand and later the alteration, the machining force is found to rise with rise in feed and depth because when the load in which the insert enters the job increases ultimately the force induced also rises. Figure 4 and 5 shows the Mean effect of the same for CBN insert. Because of the same above said reason, the same trend is followed in CBN insert also.

Figure 6. Mean Effect of Machining force (FE.) (SiN – R=0.8mm).

Figure 7. Mean Effect of Machining force (FE.) (SiN – R=0.4mm).

Figure 8. Mean Effect of Machining force (FE.) (CBN – R=0.8mm).

Figure 9. Mean Effect of Machining force (FE.) (CBN – R=0.4mm).

Figure 6 and 7 displays the Mean effect of FE simulation predicted forces with the various machining constraints of SiN insert beforehand and later alteration of the same. It is detected in the situation of SiN insert beforehand and later the alteration, the machining force is found to rise with rise in feed and depth because of the load constraints and the belongings of the metal and insert characteristics. Figure 8 and 9 displays the Mean effect of the same for CBN insert. Because of the same above said reason, the same drift is followed in CBN insert also. The validation of experimental results of machining force and FE predicted forces are exposed in Figure 10 and 11 for SiN insert and the same validation for CBN insert is exposed in Figure 12 and 13. In the event of SiN insert, it is clear that both beforehand and later the alteration of the insert, the minimum error of 1.4% and 3.39% are observed at the same machining constraints of 60m/min, 0.2mm/rev and 1.5mm and 100m/min,
0.1mm/rev and 1.5mm respectively because of the characteristics, properties and simulation conditions of both process and jobs.

In the event of CBN insert, it is clear that before alteration of the cutter, the minimum error of 0.6% is observed at the same machining constraints of 60m/min, 0.2mm/rev and 1.5mm and after the alteration of insert, the minimum error is observed at 2.31% at 100m/min, 0.2mm/rev and 1mm which may be because of prototypical which is used in imitation for prediction.

3.2. Temperature

The temperature observed during alloy removal of the job at the interface of the machining which are chronicled using IR temperature sensor and the same temperature are predicted by the FE simulation model are revealed in figure 14 and 15. From figure, it is vivid only at the contact interface region maximum temperature is recorded. The experimental results and FE model predicted values of machining temperature are given in Table 6.
From Table 6, it is clear that minimum temperature at interface is obtained at 60 m/min, 0.1 mm/rev and 0.5 mm which are at low levels because in those as said low levels only the MRR is very low which induces low machining force and so the temperature induced is also low as load is less. On the
comparison of trial outcomes of SiN and CBN inserts, temperature observed in SiN insert are comparatively more than CBN insert because of the insert properties and characteristics which is found to be the opposite to machining forces. Similarly same trend is also followed FE predicted results as SiN gives more temperature than CBN insert. In the same style, on comparing beforehand and later alteration of the insert that is between 0.8mm and 0.4mm nose radius insert, in most of the cases the temperature observed in the tool with edge radius 0.8mm is less than that of 0.4mm because when the edge radius is sharp the load required for material removal will be low and high load. The same trend is followed in both inserts experimentally and FE model prediction. Figure 16 and 17 displays the Mean effect of temperature with the various machining constraints of SiN insert beforehand and later alteration of the same. It is detected in the situation of SiN insert before the alteration, the temperature is found to escalate with surge in feed and speed because when the load in which the insert enters the job increases ultimately the force and the temperature induced also rises but after alteration it rises only with the feed. Figure 18 and 19 shows the Mean effect of the same for CBN insert. The trend followed in CBN insert is established to be vice versa of SiN insert because of its characteristics and properties.

Figure 20. Mean Effect of Temperature (FE.) (SiN – R=0.8mm).

Figure 21. Mean Effect of Temperature (FE.) (SiN – R=0.4mm).

Figure 22. Mean Effect of Temperature (FE.) (CBN – R=0.8mm).

Figure 23. Mean Effect of Temperature (FE.) (CBN – R=0.4mm).

Figure 20 and 21 displays the Mean effect of FE simulation predicted temperature with the various machining constraints of SiN insert beforehand and later alteration of the same. It is detected in the event of SiN insert beforehand and later the alteration, the temperature is found to upsurge in feed and speed because of the load constraints and the belongings of the metal and insert characteristics. Figure 22 and 23 displays the Mean effect of the same for CBN insert. Because of the same above said reason, the temperature is found to increase with speed only before alteration but after alteration the same rose with rise in speed and feed. The validation of trial test outcomes of
temperature and FE predicted temperature are exposed in Figure 24 and 25 for SiN insert and the same validation for CBN insert is exposed in Figure 26 and 27.

![Figure 24. Validation of Temperature (SiN – R=0.8mm).](image)

![Figure 25. Validation of Temperature (SiN – R=0.4mm).](image)

![Figure 26. Validation of Temperature (CBN – R=0.8mm)](image)

![Figure 27. Validation of Temperature (CBN– R=0.4mm).](image)

The validation of temperature is not as good as machining forces between the experimental and FE predicted temperature values. In the event of SiN insert, it is clear that both beforehand and later the alteration of the insert, the minimum error of 0.89% and 3.9% respectively are observed at the same machining constraints of 80m/min, 0.15mm/rev and 1.5mm which are medium levels of machining speed and feed because of the characteristics, properties and simulation conditions of both process and jobs. In the event of CBN insert, it is clear that before alteration of the insert, the minimum error of 0.6% is observed at the same machining constraints of 100m/min, 0.15mm/rev and 0.5mm and after the alteration of insert, the minimum error is observed at 1.5% at 80m/min, 0.1mm/rev and 1mm which may be because of model which is used in simulation for prediction.

### 3.3. Surface Roughness

The exterior finish of the workpiece after metal cutting is recorded using the roughness tester. The dimension is looked at different positions and the mean value is reserved for consideration. The experimental values of surface finish recorded are revealed in Table 7. From table, it is vivid that for SiN insert, the minimum surface finish is recorded at 100m/min, 0.1mm/rev and 1.5mm before alteration and at 100m/min, 0.15mm/rev and 0.5mm after medication. The best surface finish is obtained at only higher speeds in SiN inserts as the MRR is higher and machining time is less. Similarly in the situation of Cubic Boron Nitride cutter the minimum surface finish is detected 80m/min, 0.2mm/rev and 0.5mm before alteration and at 60m/min, 0.2mm/rev and 1.5mm after medication.
alteration which shows that at high feeds in CBN better results are achieved as the load in which the tool enters the job is high. On comparing SiN and CBN insert, CBN showed better surface finish in most of the cases and no comparing trend is followed while comparing beforehand and later alteration in general.

| Table 7. Experimental and FE Model Results – Surface Roughness |
|---------------------------------------------------------------|
| Exp. No | Cutting speed (m/min) | Feed (mm/rev) | Depth of Cut (mm) | Experimental Results – Surface Roughness (μm) |
|         |                       |               |                  | SiN Insert | CBN Insert |
|         |                       |               |                  | R= 0.8mm | R= 0.4mm | R= 0.8mm | R= 0.4mm |
| 1       | 60                     | 0.1           | 0.5              | 0.769     | 0.989     | 0.584     | 0.570     |
| 2       | 60                     | 0.15          | 1                 | 0.872     | 0.977     | 0.826     | 0.950     |
| 3       | 60                     | 0.2           | 1.5               | 0.515     | 0.665     | 0.551     | 0.005     |
| 4       | 80                     | 0.1           | 1                 | 0.480     | 0.587     | 0.086     | 0.922     |
| 5       | 80                     | 0.15          | 1.5               | 0.559     | 0.356     | 0.940     | 0.589     |
| 6       | 80                     | 0.2           | 0.5               | 0.897     | 0.461     | 0.001     | 0.085     |
| 7       | 100                    | 0.1           | 1.5               | 0.472     | 0.394     | 0.550     | 0.145     |
| 8       | 100                    | 0.15          | 0.5               | 0.971     | 0.280     | 0.698     | 0.847     |
| 9       | 100                    | 0.2           | 1                 | 0.295     | 0.923     | 0.856     | 0.707     |

Figure 28. Mean Effect of Surface Roughness (SiN – R=0.8mm).

Figure 29. Mean Effect of Surface Roughness (SiN – R=0.4mm).

Figure 30. Mean Effect of Surface Roughness (CBN – R=0.8mm).

Figure 31. Mean Effect of Surface Roughness (CBN – R=0.4mm).

Figure 28 and 29 shows the Mean effect of exterior finish observed with SiN insert beforehand and later the adjustment of the insert. It is found that the surface finish is found to fall with rise in machining speed because more the speed less the surface finish before the alteration but after
alteration there is no proper trend with respect to any parameter. Similarly Figure 30 and 31 shows the Mean effect of surface finish observed with CBN insert beforehand and later the alteration of the insert. The exterior finish is found to upsurge with upsurge in depth of cut before alteration as the more depth affects the exterior finish but after alteration the same is found to upsurge with upsurge in speed to contrary.

3.4. Tool Wear

The insert wear after metal cutting is determined using image analyser attached with optical microscope. The experimental values of insert wear recorded are revealed in Table 8.

| Exp. No | Cutting speed (m/min) | Feed (mm/rev) | Depth of Cut (mm) | Experimental Results – Insert Wear (µm) |
|---------|-----------------------|---------------|------------------|----------------------------------------|
|         |                       |               | R=0.8mm   | R=0.4mm   | R=0.8mm   | R=0.4mm   |
| 1       | 60                    | 0.1           | 0.5        | 11.58     | 11.15     | 12.99     | 9.40      |
| 2       | 60                    | 0.15          | 1          | 30.92     | 31.94     | 34.97     | 24.75     |
| 3       | 60                    | 0.2           | 1.5        | 63.47     | 54.74     | 67.23     | 51.51     |
| 4       | 80                    | 0.1           | 1          | 27.41     | 22.17     | 24.32     | 19.36     |
| 5       | 80                    | 0.15          | 1.5        | 51.25     | 46.10     | 45.66     | 38.93     |
| 6       | 80                    | 0.2           | 0.5        | 23.39     | 24.22     | 23.68     | 18.11     |
| 7       | 100                   | 0.1           | 1.5        | 36.71     | 30.48     | 36.26     | 28.45     |
| 8       | 100                   | 0.15          | 0.5        | 18.79     | 16.28     | 18.91     | 13.27     |
| 9       | 100                   | 0.2           | 1          | 46.10     | 39.00     | 47.96     | 33.01     |

**Figure 32.** Mean Effect of Insert Wear (SiN – R=0.8mm).

**Figure 33.** Mean Effect of Insert Wear (SiN – R=0.4mm).
Figure 34. Mean Effect of Insert Wear (CBN – R=0.8mm).

From table 8, it is vivid that for SiN insert, the minimum insert wear is recorded at 60m/min, 0.1mm/rev and 0.5mm beforehand and later alteration of the insert. The reduced insert wear is obtained at only lower speeds in SiN inserts as the MRR is low and machining time is high. Similarly in the situation of Cubic Boron Nitride insert the minimum insert wear is detected 60m/min, 0.1mm/rev and 0.5mm before alteration and alteration which shows that at low speed, low feed and low depth in CBN better results are achieved as the load in which the insert enters the job is low. On comparing SiN and CBN insert, CBN showed reduced insert wear in most of the cases and on comparing beforehand and later alteration, inserts after modification exhibited less wear because of induction of less load. Figure 32 and 33 shows the mean effect of insert wear observed with SiN insert beforehand and later the adjustment of the insert. It is found that the insert wear is found to upsurge with upsurge in feed and depth whereas the same found to fall with upsurge in speed because more the speed induces more load which induces more wear. Similarly Figure 34 and 35 shows the mean effect of insert wear observed with CBN insert beforehand and later the alteration of the insert. The same trend which is followed in SiN insert is followed in CBN also.

3.5. Chip Thickness

The chip thickness of metal removed during metal cutting is determined using machine vision. The experimental values of chip thickness recorded are revealed in Table 9.

### Table 9. Experimental and FE Model Results – Chip Thickness.

| Exp. No | Cutting speed (m/min) | Feed (mm/rev) | Depth of Cut (mm) | Experimental Results – Chip Thickness (mm) |
|---------|-----------------------|---------------|------------------|------------------------------------------|
|         |                       |               | R= 0.8mm         | R= 0.4mm                                 | R= 0.8mm | R= 0.4mm |
| 1       | 60                    | 0.1           | 0.5              | 0.81                                     | 0.85     | 0.91     | 0.87     |
| 2       | 60                    | 0.15          | 1                | 2.17                                     | 1.12     | 1.23     | 1.19     |
| 3       | 60                    | 0.2           | 1.5              | 2.13                                     | 1.92     | 1.93     | 1.73     |
| 4       | 80                    | 0.1           | 1                | 1.92                                     | 1.70     | 1.70     | 1.79     |
| 5       | 80                    | 0.15          | 1.5              | 1.72                                     | 1.95     | 1.72     | 1.93     |
| 6       | 80                    | 0.2           | 0.5              | 1.64                                     | 1.86     | 1.65     | 1.68     |
| 7       | 100                   | 0.1           | 1.5              | 2.58                                     | 1.23     | 1.64     | 1.84     |
| 8       | 100                   | 0.15          | 0.5              | 1.32                                     | 1.25     | 1.32     | 1.23     |
| 9       | 100                   | 0.2           | 1                | 1.21                                     | 1.10     | 1.97     | 1.76     |
3.6. Stress

The stress induced in metal cutting is predicted using finite element prediction model. The foretold values of stress are revealed in Table 10. Figure 40 and 41 shows the stress model for SiN and CBN which induces more stress at the interface region.
Table 10. Experimental and FE Model Results – FE Model Stress

| Exp. No | Cutting speed (m/min) | Feed (mm/rev) | Depth of Cut (mm) | Experimental Results – FE Model Stress (MPa) |
|---------|----------------------|--------------|------------------|---------------------------------------------|
|         |                      |              |                  | SiN Insert | CBN Insert |
|         |                      |              |                  | R= 0.8mm | R= 0.4mm | R= 0.8mm | R= 0.4mm |
| 1       | 60                   | 0.1          | 0.5              | 2615.85  | 3006.29  | 6606.78  | 4261.19  |
| 2       | 60                   | 0.15         | 1                | 2772.50  | 2679.07  | 3353.11  | 3236.06  |
| 3       | 60                   | 0.2          | 1.5              | 2626.76  | 4187.2   | 6902.1   | 5549.24  |
| 4       | 80                   | 0.1          | 1                | 3026.45  | 2781.98  | 6182.73  | 3426.87  |
| 5       | 80                   | 0.15         | 1.5              | 2357.20  | 2843.35  | 3377.38  | 3526.62  |
| 6       | 80                   | 0.2          | 0.5              | 2310.90  | 2670.11  | 3416.34  | 4581.44  |
| 7       | 100                  | 0.1          | 1.5              | 2570.34  | 2906.92  | 4756.4   | 4350.87  |
| 8       | 100                  | 0.15         | 0.5              | 2753.87  | 2812.01  | 3789.97  | 4454.16  |
| 9       | 100                  | 0.2          | 1                | 2979.68  | 2822.72  | 4721.95  | 2798     |

From table 10, it is vivid that for SiN insert, the minimum stress is foretold at 80m/min, 0.2mm/rev and 0.5mm beforehand and later alteration of the insert. The reduced stress is obtained at only high feeds in SiN inserts as the induced load upsurges when feed upsurge. Similarly in the situation of Cubic Boron Nitride insert the minimum stress is detected 1mm depth before alteration and alteration which shows that at medium depth in CBN better results are achieved as the load in which the insert enters the job is low.

Figure 40. Stress FE Model (SiN Insert).

Figure 41. Stress FE Model (CBN Insert).

Figure 42. Mean Effect of Stress (SiN – R=0.8mm).

Figure 43. Mean Effect of Stress (SiN – R=0.4mm).
Figure 44. Mean Effect of Stress (CBN – R=0.8mm).

Figure 45. Mean Effect of Stress (CBN – R=0.4mm).

Figure 42 and 43 shows the mean effect of stress observed with SiN insert beforehand and later the adjustment of the insert. It is found that the stress does not show a common trend either before or after modification. Similarly Figure 44 and 45 shows the mean effect of stress observed with CBN insert beforehand and later the alteration of the insert. The trend is stress is found to upsurge with upsurge in depth as more load will induce more stress.

4. Conclusion

This paper is mainly engrossed the experimental investigation on the impact of edge geometry and process constraints like cutting speed, feed rate and depth of cut on the various retorts like machining force, surface roughness, tool wear, temperature, chip morphology and stress based L9 Taguchi array.

- Cutting force is observed to be comparatively more for SiN inserts than CBN Inserts in most of the experimental cases. The machining force is also predicted using FE model which showed a better validation with a minimum error percentage of 2.6%

- Temperature at the machining contact point is observed to be comparatively more for SiN inserts than CBN inserts. In most of the cases, inserts with 0.4mm cutting edge radius showed a better outputs than 0.8mm with respect to temperature. The temperature is also predicted using FE Model which also showed a better validation characteristics.

- Surface roughness exhibited irregular proportional characteristics with cutting edge radius and insert tool material

- Tool Wear is comparatively observed to be more in SiN inserts than CBN inserts and inserts with 0.4mm radius exhibited less wear compared to 0.8mm

- Chip thickness is also established to exhibit similar characteristics like tool wear where it is more for SiN inserts than CBN inserts and inserts with 0.4mm radius is instituted to be better.

- Stress induced is determined to be more for CBN inserts than SiN inserts which is nearly two times that of SiN inserts. Stress induced is comparatively less for inserts with 0.4mm radius

5. References

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