# INFLUENCE OF CUTTING PARAMETERS ON TOOL WEAR AND SURFACE ROUGHNESS IN MACHINING SS304 USING CARBIDE AND CERAMIC INSERTS

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## ABSTRACT

Aeronautical metals, such as titanium alloys and nickel centred blends, display reduced cutting characteristics in the red to their outstanding physical possessions which include low thermal conductivity and high hardness at elevated temperatures. For these hard to turn metals, the demand for High Speed Machining (HSM) is swelling in edict to achieve great output and to save turning price. For uses it is vital to custom firm and devoted turning setups and mechanisms with exact plans and choices. The method to ensure constant stock for each operation and tool is a prerequisite for HSM and acts as a basic criterion for high productivity and process security. As machining speed is reliant on machining and insert parameters, this type of machining should be well defined as true machining overhead a certain level. So the rate at which feeding is done is inversely proportional to the tool dimension if the other parameters are unaltered. To recompense for a lesser span the rotating speed must be improved to keep the equal machining speed. The main area of concern insert hotness and insert attire depends on the machining speed and spindle speed. Thus, the studies investigates the relationship between insert hotness and inserts attire during turning of SS304 and examine the deviation of surface finish and cutting forces for two diverse kinds of machining inserts and also a model is developed for authentication.

**Keywords:** high speed machining, SS304, tool wear.

## 1. INTRODUCTION

Amongst the utmost active and effectual contemporary production tools, HSM is hired to rise output while instantaneously enlightening creation eminence and dropping production prices. Reliant on metal and insert along with insert span necessities, the machining speed used here is habitually 2 to 50 epochs greater than those engaged in outdated turning [1]. Owing to its great metal subtraction rate and small creation life span, this type of manufacturing has established progressively rising uses in new years in many engineering segments, such as security, aeronautical, airplane, motorized, and die and mold making [2]. Study on this production process includes an extensive diversity of jobs fluctuating from soft metals to hard metals. Amongst forward-thinking aeronautical metals, two have been widely premeditated: titanium alloy Ti6Al4V and nickel-based super alloy Inconel718 [3]. Owing to their strangely countless properties, exceptional mechanical assets and superior erosion confrontation, Ti6Al4V and Inconel 718 have established rising requests in creation of precarious portions, components, and constructions. For instance, titanium blend works make up most part of the final assemble. Though, since their great strength and small heat coefficient, this type of machining of the above said metals frequently origin many hitches in current production [4]. The printed works unquestionably progresses the vital accepting of various aspects of HSM processes.

Though, petite works is accessible to liken machining of two alloys while possession of all other constant. The massive mainstream of the printed works emphases on either Ti6Al4V, often is connecting dissimilar experiments. The study also analyzed the effect of these on the governing machining parameters. The investigation conclusions from this production of one material cannot be straight related to this machining of the extra metal [5]. Kitagawa *et al* [6] jagged out that the despicable insert heat on the rake side is relative to the heat coefficient, the density and the specific heat of the job and in overall, it is not the despicable heat but limited edge heats that rule insert attire. Too proposed that exact determination of the hotness is a main subject in the cutting learning. In footholds of the life of heat treated carbide inserts, heats at the metal insert is a dominant factor.

Abukhshim *et al* [7] established that the power consumption and the heat generation in metal cutting processes are dependent on a mixture of the mechanical stuffs of the material and tool material, turning settings and the insert geometry.

This paper mainly investigates the relation between insert hotness and insert attire during turning and analyze the variation of insert abrade with machining speed, deviation of insert temperature with machining speed, deviation of turning force with machining speed and deviation of surface finish or brogue elevation with machining speed. Temperature and wear of turning inserts are examined by way of machining trials. Determination of insert job boundary temperature in the course of turning, which is also modeled on turning, is very mandatory to expose the viability of great speed turning and that depends on a fleeting temperature increase and temperature drip. Performance of two types of tools, carbide and ceramic are evaluated and compared. Mathematical prototypical is also suggested to confirm the temperature determination.

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## 2. EXPERIMENT

The material selected is Stainless steel 304. The properties and composition SS304 are as follows in Table-1 and Table-2. It is evident that the material SS 304 is having fairly good hardness value and low thermal conductivity which makes it a little tougher to machine insisting the reason of usage of HSM to machine the material.

**Table-1.** Properties of SS304.

| Properties | Value |
|---|---|
| Tensile Strength (MPa) | 520-720 |
| Compression Strength (MPa) | 210 |
| Proof Stress 0.2% (MPa) | 210 |
| Elongation A5 (%) | 45 Min |
| Hardness Rockwell B | 92 |

**Table-2.** Composition of SS304.

| Element | Composition (%) |
|---|---|
| C | 0-0.07 |
| Mn | 0-2.0 |
| Si | 0-1 |
| P | 0-0.05 |
| S | 0-0.02 |
| Cr | 17.5-19.5 |
| Ni | 8-10.5 |
| Fe | Balance |

Two tools namely carbide and ceramic of different hardness values are selected to study and analyze the variation of output parameters like temperature, wear, cutting force and surface finish.

Hardness of carbide and ceramic tool are 600 and 550 BHN respectively. Performance of carbide tool is examined at different levels of experiments to measure different parameters like temperature, wear, surface finish by orthogonal turning.

A square type insert is clamped to get different tool angles, a round bar of 100mm length and 40mm radius is turned in CNC lathe and cutting speed is altered from over the range 250 m/min.

Design of experiment (DOE) is employed to perform diverse tests. Factorial strategy is normally employed to study interaction between input variables. A 3^3 factorial design will have three levels of input parameters named high, low and medium. Table-3 shows the different levels and corresponding values for 3 factorial DOE. Table-4 represents design of an orthogonal matrix of the nature L18.

**Table-3.** Different levels and corresponding values for 3 factorial DOE.

| Parameter | HIGH | MEDIUM | LOW |
|---|---|---|---|
| | **+1** | **0** | **-1** |
| Cutting speed (m/min) | 277 | 251 | 226 |
| Depth of cut(mm) | 1 | 0.5 | 0.25 |
| Feed rate, f (mm/rev) | 0.05 | 0.025 | 0.015 |

**Table-4.** Design of an orthogonal matrix L18.

| Expt. No | Cutting speed V (m/min) | Depth of cut d (mm) | Feed rate f (mm/rev) |
|---|---|---|---|
| 1 | +1 | 0 | -1 |
| 2 | +1 | -1 | 0 |
| 3 | -1 | 0 | +1 |
| 4 | -1 | +1 | 0 |
| 5 | 0 | -1 | +1 |
| 6 | 0 | +1 | -1 |
| 7 | +1 | -1 | +1 |
| 8 | +1 | 0 | +1 |
| 9 | -1 | 0 | -1 |
| 10 | -1 | +1 | -1 |
| 11 | 0 | +1 | 0 |
| 12 | 0 | -1 | 0 |
| 13 | -1 | +1 | +1 |
| 14 | 0 | -1 | -1 |
| 15 | +1 | 0 | 0 |
| 16 | +1 | +1 | 0 |
| 17 | -1 | -1 | +1 |
| 18 | 0 | 0 | -1 |

Infrared thermometer is used for measuring temperature, Tool Makers Microscope for examination insert wear and surface roughness tester TR200 for measuring surface finish.

## 3. RESULTS AND DISCUSSIONS

Table-5 displays the temperature detected by means of IR thermometer, insert wear dignified by means of tool makers microscope and surface finish of the job using surface roughness tester in orthogonal machining of SS304 using carbide tool.

**Table-5.** Output parameters temperature, surface roughness and wear of carbide tool.

| Expt. No | Temperature (˚C) | Surface roughness (µm) | Wear (mm) |
|---|---|---|---|
| 1 | 66.2 | 2.691 | 0.22 |
| 2 | 50.7 | 2.501 | 0.08 |
| 3 | 50.3 | 2.924 | 0.205 |
| 4 | 60.9 | 3.201 | 0.06 |
| 5 | 71.3 | 4.105 | 0.13 |
| 6 | 70.3 | 1.529 | 0.19 |
| 7 | 76.4 | 4.213 | 0.413 |
| 8 | 58.3 | 3.302 | 0.249 |
| 9 | 61.2 | 3.704 | 0.18 |
| 10 | 84.3 | 2.512 | 0.125 |
| 11 | 83.4 | 1.437 | 0.07 |
| 12 | 62 | 4.322 | 0.21 |
| 13 | 72.7 | 2.602 | 0.332 |
| 14 | 78.7 | 0.927 | 0.137 |
| 15 | 65.6 | 2.517 | 0.19 |
| 16 | 65.9 | 2.609 | 0.23 |
| 17 | 60.4 | .992 | 0.32 |
| 18 | 65.4 | 2.917 | 0.21 |

Table-6 represents the measured output parameters of temperature, surface roughness and wears when ceramic tool is used for machining. Experiments are conducted with the same set of input values that was employed in the situation of carbide tool. In general, on linking of carbide and ceramic insert, the determined temperature of ceramic insert is more than carbide insert and likewise the properties of surface finish and insert wear are more improved for carbide tool than ceramic tool.

### 3.1 Temperature

Temperature on the metal insert point is the significant constraint in the examination and switch of turning. Metal insert point is measured using non-contact IR temperature thermometer. In Figure-1 temperature is plotted against different machining speed for the test with depth of cut 0.5mm and feed rate 0.015mm/rev which represents the deviation drift. It is obvious that temperature at the insert job border increases steeply for ceramic tool when compared with carbide tool for which the rise is gradual.

**Table-6.** Output parameters temperature, surface roughness and wear of carbide tool.

| Expt. No | Temperatur e (˚C) | Surface roughness (µm) | Wear (mm) |
|---|---|---|---|
| 1 | 90.2 | 6.502 | 0.91 |
| 2 | 91.2 | 4.113 | 0.455 |
| 3 | 113.4 | 4.906 | 0.275 |
| 4 | 105.1 | 3.552 | 0.985 |
| 5 | 111.2 | 6.321 | 0.49 |
| 6 | 98.2 | 2.512 | 0.66 |
| 7 | 79.2 | 3.133 | 0.095 |
| 8 | 90 | 1.215 | 0.08 |
| 9 | 70.5 | 3.556 | 0.2 |
| 10 | 75.5 | 4.793 | 0.805 |
| 11 | 89.3 | 4.116 | 2.19 |
| 12 | 78.2 | 3.226 | 0.2695 |
| 13 | 59.2 | 3.431 | 2.61 |
| 14 | 60.2 | 1.24 | 0.605 |
| 15 | 92.3 | 2.491 | 0.375 |
| 16 | 103.7 | 5.321 | 0.475 |
| 17 | 60.5 | 2.186 | 0.05 |
| 18 | 85.4 | 3.253 | 0.327 |

Through the turning operation, a substantial quantity of the energy is moved to hotness through hot working of the metal exterior, the resistance of the cut metal on the insert side and the resistance between turning insert and the job, majority of the insisted energy is transformed into hotness. This consequence in a increase in the insert and material temperatures.

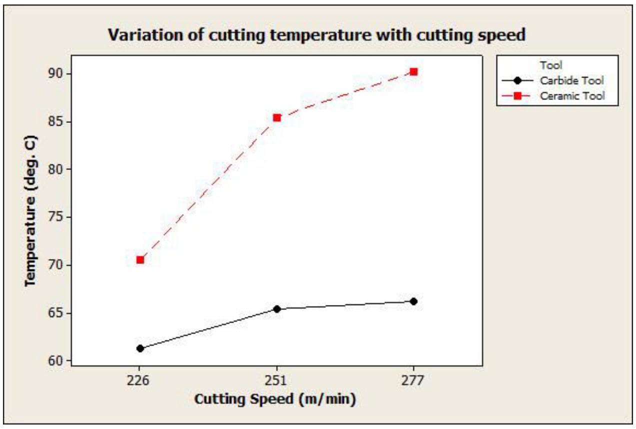


**Figure-1.** Deviation of temperature with cutting speed.

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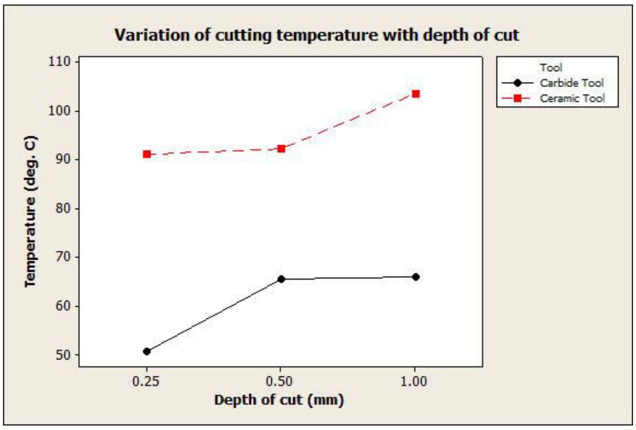


**Figure-2.** Deviation of machining temperature to depth of cut.

Figure-2 shows the deviation of machining temperature to the depth of cut for the experiment with cutting speed 277 m/min and feed rate 0.015mm/rev. In fact in machining with ceramic tool, the temperature experienced is vastly higher than that of carbide tool. While the machining step rises and cut material width is preserved the similar, the explicit interaction strains at the insert metal borders rises, which in go rises the normal interaction hotness. So, a rise in the machining step should rise the insert abrade proportion if the turning is conceded out at the optimal machining command.

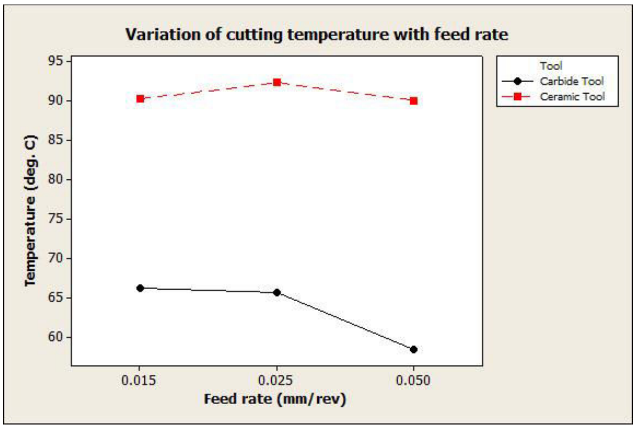


**Figure-3.** Deviation of machining temperature with feed.

Figure-3 shows the deviation of machining temperature with the feed rate for the experiment with cutting speed 277 m/min and depth of cut 0.5mm. In fact in machining with ceramic tool, the temperature experienced is vastly higher than that of carbide tool. This may because of the reason of thermal softening of material at higher feed rate and absence of the coolant, the temperature rises for rise in feed.

### 3.2 Surface roughness

It is a natural behaviour of a tool inserts that by the growth in machining speed the surface finish of material upsurges.

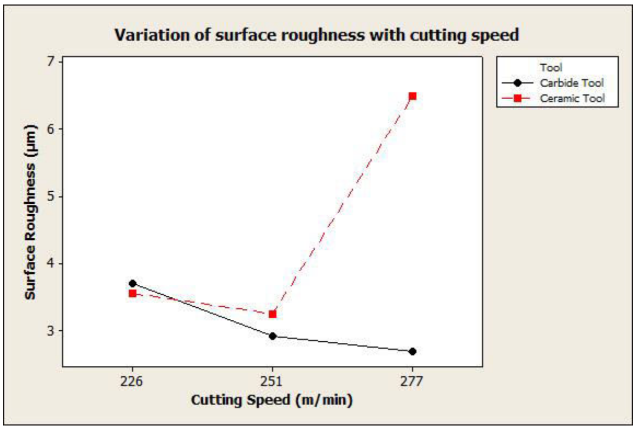


**Figure-4.** Deviation of surface finish with cutting speed.

Figure-4 shows the deviation of surface finish with cutting speed. It is evident from Figure-4 that for carbide tool surface roughness decreases with greater cutting speeds for depth of cut 0.5mm and feed rate 0.015mm/rev as compared to ceramic tool where there is an abrupt increase in roughness. A peak of the burr appears at a speed of around 150 m/min, which corresponds to huge lateral movement of cut metal. In event of ceramic cut hard burrs in combination with noticeable lateral movement of the uncut metal turn as abrasive at the insert border.

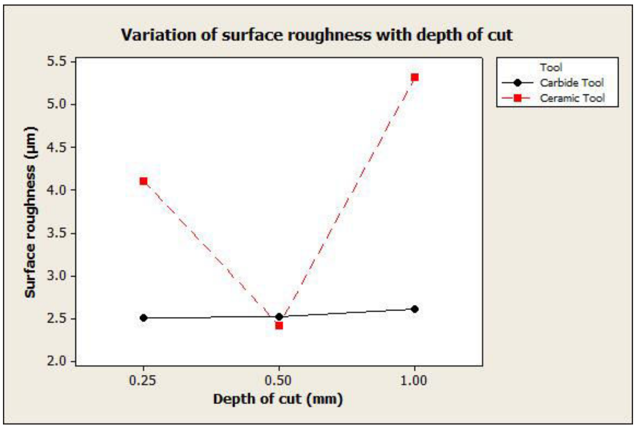


**Figure-5.** Deviation of surface finish with depth of cut.

Figure-5 shows the deviation of surface finish with depth of cut. From Figure-5, it is clear that there is an abrupt decrease and a steep increase in surface finish characteristics of ceramic tool at constant machining speed and feeding whereas carbide tool shows minute increase in surface roughness.

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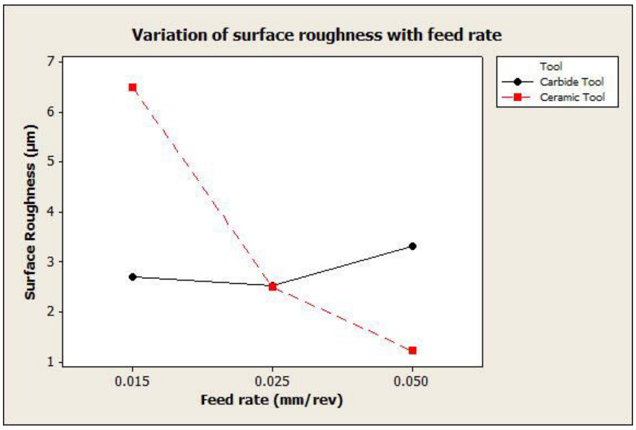


**Figure-6.** Deviation of surface finish with feed rate.

Figure-6 shows the deviation of surface finish with feed rate. It is shown that for ceramic tool the surface roughness decreases with increases in the feed rate whereas for carbide tool increase in surface finish is observed. It is because of the reason of increased cutting temperature and increase in the induced stress, surface finish is also decreased in quality.

### 3.3 Tool wear

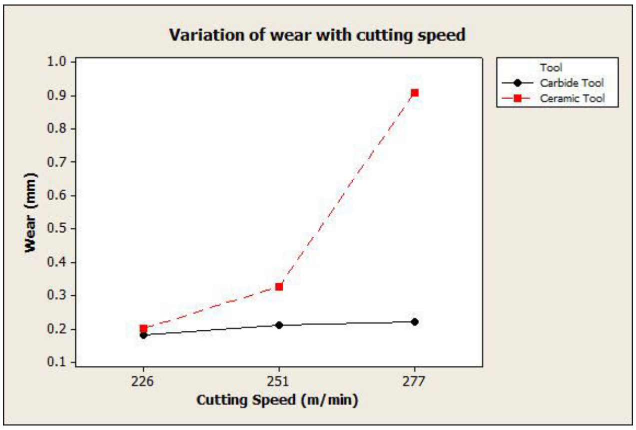


**Figure-7.** Deviation of insert wear with cutting speed.

Figure-7 shows the deviation of insert wear with cutting speed. From Figure-7 with depth of cut 0.5mm and feed rate 0.015 mm/rev the increase in surface finish in case of carbide tool with increase in cutting speed is greatly explained by wear behaviour. Wear in carbide tool slightly increases whereas ceramic tool shows steep increase in wear. Wear in ceramic tool is mostly produced by the scums inside the job material, in addition to the extra rubbles. This is a physical wear which is the chief source of the insert abrade at high machining speeds.

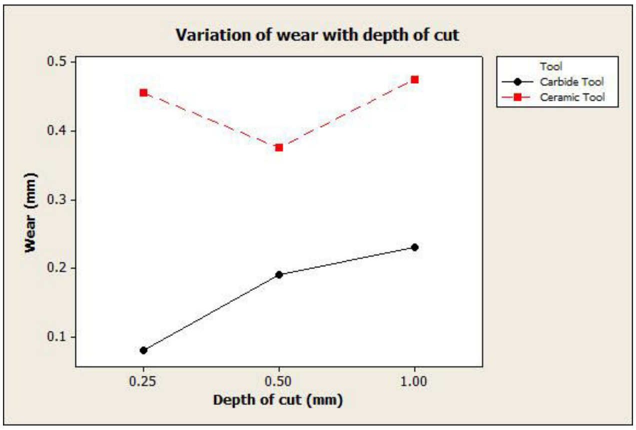


**Figure-8.** Deviation of insert wear with depth of cut.

Figure-8 shows the deviation of insert wear with depth of cut. In the wear characteristics in case of carbide tool shows steady increase whereas ceramic tool shows abrupt decrease and a steep increase in wear. This is done at constant machining speed and feed. The rise in dimension should upsurge the insert wear if the turning is passed in the best machining regime.

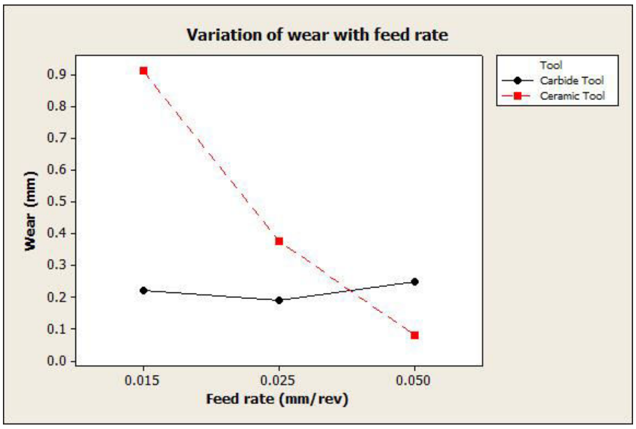


**Figure-9.** Deviation of wear with feed rate.

Figure-9 shows the deviation of tool wear with feed rate. It is clear from the graph that tool wear falls with rise in feed rate. The rise in machining temperature and rise in machining force rise the insert wear in both carbide and ceramic insert.

### 3.4 Mathematical modelling

A calculated prototypical is established for the justification of the experiments. For a given set of input parameters, different values for output parameters were generated using the developed mathematical model. Then these values are checked against experimentally obtained values for the same set of input parameters.

The following are different mathematical models developed for temperature, insert wear and surface finish using statistical software.

**A. Temperature model**

The despicable temperature on the insert- metal interface is
Carbide temp = 4.27+0.025v+0.0425d-0.0242f
Ceramic temp = 0.63+0.295v+0.125d+0.094f

**B. Tool wear model**

The tool wear is modelled as
Carbide tool wear = 2.61-0.008v+0.064d+0.180f
Ceramic tool wear = 1.96+0.08v+0.137d+0.296f

**C. Surface roughness model**

Surface roughness obtained when using a
Carbide tool Ra = 6.70+1.10v-0.036d+0.310f
Ceramic tool Ra = 4.7-0.93+0.799d-0.005f

Where v is cutting speed (m/min), d is depth of cut (mm) and f is feed rate (mm/rev).

Table-7 represents the values generated using the mathematical model developed for temperature, wear and surface finish in the event of both carbide tool and ceramic tool. Table-8 represents the values experimentally obtained for the same the set of input values for Temperature, Wear and Surface finish in the event of both carbide insert and ceramic insert.

By picking five diverse values of machining speed, depth of cut and feed rate, the output values are determined by experimental tests. And for the same series of input values, the mathematical model developed using statistical software was used to find the same output values. Then the comparisons of both the values are done for the purpose of validation.

**Table-7.** Output values generated by model.

| S. No | v(m/s) | doc(mm) | f(mm/rev) | CARBIDE | | | CERAMIC | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Temp(˚C) | Wear(mm) | Ra(μm) | Temp(˚C) | Wear(mm) | Ra(μm) |
| 1 | 263 | 0.3 | 0.08 | 55.6 | 0.197 | 1.821 | 100.23 | 0.268 | 4.2108 |
| 2 | 238 | 0.2 | 0.2 | 56.026 | 0.238 | 2.763 | 94.027 | 0.3559 | 5.4788 |
| 3 | 213 | 0.7 | 0.13 | 37.6 | 0.176 | 5.412 | 94.56 | 0.871 | 3.572 |
| 4 | 207 | 0.1 | 0.11 | 33.27 | 0.335 | 0.6636 | 70.91 | 0.179 | 4.128 |
| 5 | 219 | 0.8 | 0.03 | 38.92 | 0.115 | 1.5156 | 82.33 | 0.6377 | 3.75 |

**Table-8.** Output values generated using the experiment.

| S. No | v(m/s) | doc(mm) | f(mm/rev) | CARBIDE | | | CERAMIC | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Temp(˚C) | Wear(mm) | Ra(μm) | Temp(˚C) | Wear(mm) | Ra(μm) |
| 1 | 263 | 0.3 | 0.08 | 51.2 | 0.24 | 1.11 | 82.4 | 0.349 | 3.507 |
| 2 | 238 | 0.2 | 0.2 | 53.2 | 0.197 | 2.213 | 89.2 | 0.411 | 5.114 |
| 3 | 213 | 0.7 | 0.13 | 45.8 | 0.432 | 1.532 | 75.7 | 0.32 | 5.159 |
| 4 | 207 | 0.1 | 0.11 | 43.7 | 0.22 | 0.992 | 71.3 | 0.334 | 1.726 |
| 5 | 219 | 0.8 | 0.03 | 55.6 | 0.185 | 1.735 | 92.3 | 0.452 | 3.522 |

The deviation of trial and prototypical designed outputs are likened and authenticated. The dissimilarity of trial and prototypical outputs of cutting temperature for carbide and ceramic tools with respect to cutting speed are shown in Figure-10.

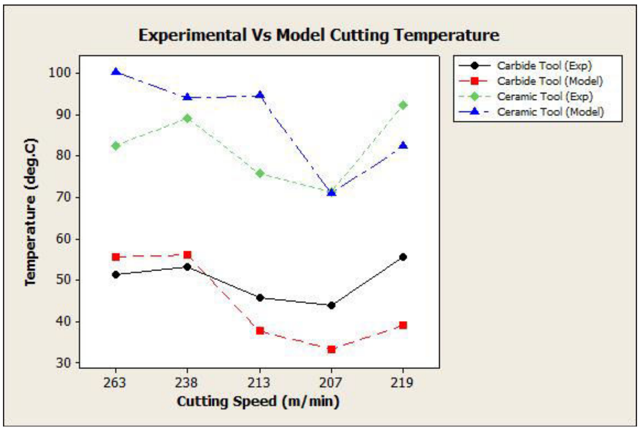


**Figure-10.** Experimental vs model cutting temperature.

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From Figure-10, it is clear that variation trend of model predicted values of cutting temperature is similar to the trend followed in experiment. The model predicted cutting temperature of ceramic tool is also greater than the carbide tool. On comparing, the close relationship is followed at 207 m/min for ceramic tool and 238 m/min for carbide tool. The maximum nonconformity error found in carbide tool is 13.12% and the maximum nonconformity error in ceramic tool is 6.66%.

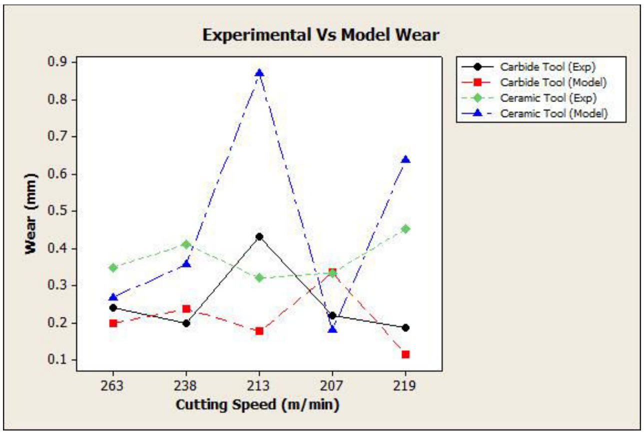


**Figure-11.** Experimental vs model tool wear.

The variation of experimental and model values of tool wear for carbide and ceramic tools with respect to cutting speed are shown in Figure-11. From Figure-11, it is clear that deviation drift of model foretold values of insert wear is alike to the drift followed in trial. The prototypical foretold insert wear of ceramic tool is also greater than the carbide tool. On comparing, the close relationship is followed at 238 m/min for both ceramic tool and carbide tool. The maximum nonconformity error found in carbide tool is 20% and the maximum nonconformity error in ceramic tool is 19.28%.

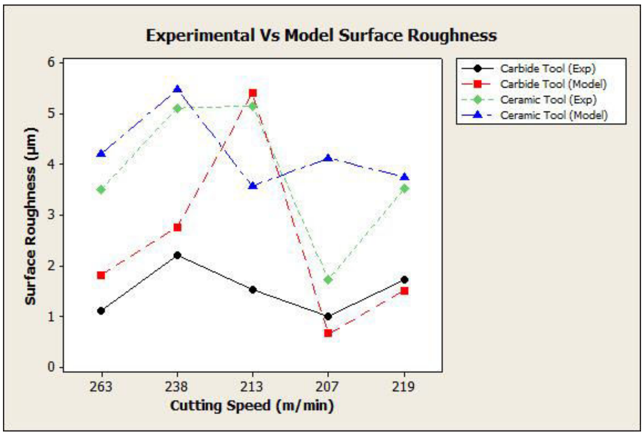


**Figure-12.** Experimental vs model surface finish.

The deviation of experimental and model values of surface roughness for carbide and ceramic tools with respect to cutting speed are shown in Figure-12. From Figure-12, it is clear that variation drift of model predicted values of surface roughness is alike to the drift followed in experiment. The model predicted surface roughness of ceramic tool is also greater than the carbide tool. On comparing, the close relationship is followed at 238 m/min for ceramic tool and at 207 m/min for carbide tool. The maximum nonconformity error found in carbide tool is 19.51% and the maximum nonconformity error in ceramic tool is 10%.

## 4. CONCLUSIONS

Grounded on the investigational information created from L18 array with three levels of machining speed, feed and penetration of machining, performance of two types of tools namely carbide tool and ceramic tool in High Speed Machining (HSM) is investigated and following conclusions are derived.

- The maximum temperature observed in case of carbide and ceramic tools are 78°C and 113.4°C respectively for which the wear experienced are respectively 0.125mm and 0.575mm.
- The superiority of carbide tool over ceramic tool has been demonstrated within a speed range from 226 to 277 m/min, where the tool temperature reaches around 113.4 °C.
- For both the inserts, with the rise in machining speed, temperature at the tool-chip interface also increase, however increase in the event of ceramic tool is steeper.
- However, carbide insert experiences low attire and surface finish as compared to ceramic insert, high insert attire and surface finish are observed with increase in cutting speed.
- Machining with ceramic tool is characterised by high temperature at tool-material interface, machine vibrations, low surface finish and eventually tool breakage.
- Finally, the results are validated by generating values using mathematical model. On average, the model created for temperature, wear and surface finish shows accuracy of 86%, 80% and 70% respectively for carbide tool whereas 93%, 80% and 90% respectively for ceramic tool.

## REFERENCES

[1] Haruki Tanaka, Tatsuya Sugihara, Toshiyuki Enomoto. 2016. High speed machining of Inconel 718 focusing on wear behaviors of PCBN cutting tool. Procedia CIRP. 46, 545-548.

[2] J.C. Hamann, F. Le Maitre, D. Guillot. 1994. Selective Transfer Built-up Layer Displacement in High-Speed Machining - Consequences on Tool Wear and Cutting Forces. CIRP Annals. 43, 69-72.

[3] D.M. D’Addona, Sunil J. Raykar, M.M. Narke. 2017. High Speed Machining of Inconel 718: Tool Wear

and Surface Roughness Analysis. Procedia CIRP. 62, 269-274.

[4] Derzija Begic-Hajdarevic, Ahmet Cekic, Malik Kulenovic. 2014. Experimental Study on the High Speed Machining of Hardened Steel. Procedia Engineering. 69, 291-295.

[5] V. Prasath, V. Krishnaraj, J. Kanchana, B. Geetha Priyadharshini, Ashish Tewari. 2017. Performance evaluation on high speed machining of custom 465 steel. Materials Today: Proceedings. 4, 10810-10815.

[6] T. Kitagawaa, Kuboa, K. Maekawa. 1997. Wear characteristics of various cutting tools in steel machining. Tribology Series. 32, 569-578.

[7] N.A. Abukhshim, P.T. Mativenga, M.A. Sheikh. 2006. Heat generation and temperature prediction in metal cutting: A review and implications for high speed machining. International Journal of Machine Tools and Manufacture. 6, 782-800.