Comparing the performance of TiC tool and Uncoated tool in Novel CNC Green turning of SS316L Stainless Steel to Minimize Surface Roughness

K. Bhanuprakash[1], C. Thiagarajan[2*]

[1]Research Scholar, Department of Automobile Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India. Pincode: 602105.

[2]Project Guide, Department of Automobile Engineering ,Saveetha School of Engineering,

Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India. Pincode: 602105.

*Corresponding Author: C. Thiagarajan

ABSTRACT

Aim: This research analyzes the performance of Titanium carbide (TiC) insert and uncoated cemented carbide insert in CNC turning of SS316L Stainless steel for improving surface roughness (SR). **Materials and Methods:** SS316L stainless steel was included in this investigation, with TiC tool serving as the experimental group and uncoated tool functioning as the control group. Cutting factors utilized in this process were speed of cutting, rate of feed and cut depth. A total of 27 samples were machined with the above-mentioned input variables. **Results:** Mean SR values achieved for TiC tool and uncoated tool were 0.746148 µm and 1.098970 µm respectively with a relevance value of 0.001 ($p<0.05$) which indicates a considerable difference among two tools. **Conclusion**: The results of the study indicate that when the specimen is processed with a TiC tool, the SR value is lower than when the specimen is produced with an uncoated tool.

Keywords: Green machining, Surface roughness, TiC tool, Uncoated tool, SS316L Stainless steel, Novel machining.

INTRODUCTION

Turning is a basic machining procedure in which a cutting tool is used to remove a certain quantity of material from a workpiece. A few years ago, poor surface quality and accuracy were the key issues that needed to be addressed in order to establish mass manufacturing. CNC machines are used to carry out machining with more surface finish and dimensional accuracy (Das, Panda, and Dhupal 2017). In green machining, material is removed without using coolants, which is environmental friendly. In order to improve surface smoothness and boost accuracy, the performance of coated and uncoated tools were tested. (Vasu and Shivananda Nayaka 2018). The material examined in this research was SS316L stainless steel. It's used in a range of areas, including vehicle bodywork, aeroplanes, train carriages, and airport roofs. (Paengchit and Saikaew 2018); (Cunat 2002).

From all the above mentioned research works, it is understood that TiC insert is a capable cutting tool. But by using this insert not many research works have been conducted in the field of improving surface roughness for machining SS316L stainless steel. In this work, evaluation of TiC coated insert during dry CNC machining of SS316L stainless steel is a novel thing. So, this experimental investigation focuses on comparing TiC insert and uncoated insert during CNC turning of SS316L stainless steel to achieve superior surface quality. Furthermore, our team has deep knowledge working on a variety of research projects in a range of areas.

(Samuel et al. 2019; Johnson et al. 2020; Venu et. al 2019; Keerthana and Thenmozhi 2016; Thejeswar and Thenmozhi 2015; Krishna and Babu 2016; Subashri and Thenmozhi 2016; Sriram, Thenmozhi, and Yuvaraj 2015; Jain, Kumar, and Manjula 2014; Menon and Thenmozhi 2016).

MATERIALS AND METHODS

SS316L stainless steel was the workpiece material used in this work. Cutting tool inserts used were TiC and uncoated tools. Specimens are hard to turn. As a response, these two tools were proposed in the paper. All processing was done using a CNC turning center, Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. The total number of groups engaged in this analysis was two (experimental group and control group). The TiC tool served as the experimental group, whereas the uncoated tool served as the control group. Size calculated for both TiC insert and uncoated insert was 27. With an 80 percent G power, for computing the sample size of the specimen, an online sample size calculator was used. Mean value and standard deviation considered for this experiment were 0.74 and 0.11 which was used to determine sample size (Özdemir 2019).

Workpiece material used in this work was SS316L stainless steel. SS316L Stainless steel is a more unique material since it has properties such as higher hardness, thermal conductivity, modulus of elasticity, density, elongation, and toughness. SS316L stainless steel is the low carbon version of SS316. For doing experiments, SS316L stainless steel cylindrical bar was cut into essential measurements of 20 mm diameter and 55mm length. Mehta Metals in Chennai supplied cylindrical rods. Table 1 presents the chemical composition of SS316L stainless steel.

Titanium carbide, regular additives of carbide properties, is mainly applicable at cratering when machining super alloy. TiC coating is to enhance tool life and productivity. TiC is utilized in preparation of cermets which are commonly used to machine steel materials at higher cutting speed. TiC is a hard refracting material related to tungsten carbide. TiC coated insert which is shown in Fig. 1 has applications in a variety of ways such as tool bits, watch mechanisms, space crafts, wear resistant tools, abrasive steel bearings, optics, electronics. Ceratizit India Pvt. Ltd, Chennai, was the vendor.

Figure 2 illustrates an uncoated tool. The best application of uncoated carbide inserts are machining aluminum, copper, titanium. Tool specification: TNMG 160408. Ceratizit India Pvt. Ltd., Chennai, delivered the uncoated insert.

The machining in this study was achieved on a CNC turning centre, as indicated in Fig. 3. The MTJNR 2525 M16 cutting tool holder was used to handle TiC and uncoated tools. Specimens (Dia. 20 mm and length 55 mm) were placed in the headstock of lathe. Selected specimens were machined by using TiC insert and uncoated insert. Both tools were placed in the work station's tool holder. Selected cutting variables were speed of cut (m/min), rate of feed (mm/rev) and cut depth (mm) (Debnath, Reddy, and Yi 2016). Selected cutting variables were followed in turning centres (Asiltürk and Akkuş 2011). A surface roughness tester (shown in Fig. 4) was used to quantify the same. Mitutoyo tester was used to measure surface roughness after machining (Sahoo and Sahoo 2013).

Statistical analysis

The mean, standard error, and standard deviation were determined using SPSS v.26 statistical software. Significance level is considered when the probability value $p<0.05$. In this research, independent variables used were speed of cut, rate of feed, cut depth and dependent variable was surface roughness (SR). Independent sample T-test was carried out to identify significance between TiC insert and uncoated cemented carbide insert during novel machining.

RESULTS

After machining, surface roughness of the specimens obtained with TiC and uncoated inserts are measured and tabulated. Measured SR values are given in Table 2. To obtain SR values, standard input variables such as speed of cutting, rate of feed and cut depth were followed for both experimental group and control group.

From statistical analysis which is shown in Table 3, it is observed that standard deviation is 0.1113434 and mean value is 0.746148 for TiC insert.

Table 4 presents the results of the independent sample T test. From this table it is clearly observed that the significance value among both groups is p=0.001 (p< 0.05).The evaluation of TiC and uncoated tools is depicted in Fig. 5 as a bar graph with mean accuracy and standard deviation.The bar chart illustrates that TiC tools have a greater mean accuracy and a lesser standard deviation than uncoated tools.

DISCUSSION

According to the data, TiC tools appear to perform much better than uncoated tools when it comes to surface roughness while processing SS316L stainless steel. The Fischer value for this study is 13.506, with a relevance value of 0.000 that is $p < 0.05$, confirming that there is a considerable difference between the two tools.

The bar graph clearly shows that when the specimen is machined with a TiC tool, the SR is lower, and when the same is machined with an uncoated tool, the SR is greater. In the turning process, most important factors affecting surface roughness are rate of feed, cut depth and speed of cut. The finding of this research is in accordance with works carried out by (Sampath Kumar et al. 2018); (Özdemir 2019). Input parameters and procedure followed in this experiment coincides with the experimental study conducted by (Bhattacharya et al. 2009).

Conclusions drawn during research work carried out by (Prabha et al. 2018) and (Sahoo et al. 2018) are not in line with this experiment work because they concluded that uncoated insert has better machining capabilities than coated insert in their study. This may be because their experiment might have been conducted with different input parameters and working conditions as well as different workpiece materials.

Limitation involved in this experimental work is vibration occured due to higher cutting speed which leads to poor surface finish. In future, existing study can be carried out with optimum cutting speed and different types of inserts to reduce overall vibration.

CONCLUSION

The machining process of workpiece SS316L stainless steel was carried out using a CNC turning machine with different independent input parameters. It is concluded that TiC insert provides a lower surface roughness value (0.746148 µm) than uncoated cemented carbide insert (1.098970 µm) which has a higher surface roughness value during machining of SS316L stainless steel.

DECLARATION

Conflict of interests

The authors declare that there is no conflict of interest.

Authors Contribution

Author BP was involved in data collection, data analysis and manuscript writing. Author CT was involved in conceptualization, data validation, and critical review of manuscript.

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Tables and Figures

Table 1. Chemical composition of SS316L stainless steel.

Elements	**Cr**	**Ni**	**Mo**	**Mn**	**Fe**
Wt %	16.00 - 18.00	10.00 - 14.00	2.00 - 3.00	2.0	68.319

Table 2. Experimental details with Measured SR for Titanium carbide and uncoated tool with set turning variables.

Trial no.	**SR for TiC tool (μm)**	**SR for uncoated tool (μm)**
1	0.6350	0.8510
2	0.6380	0.8550
3	0.5840	0.8590
4	0.6470	0.8620
5	0.6520	0.6742
6	0.5940	0.8690
7	0.6880	0.8740
8	0.5794	1.0000
9	0.6860	1.2500
10	0.7400	0.9880
11	0.7420	0.9520
12	0.8540	0.9310
13	0.8545	0.9490
14	0.5620	1.1860
15	0.8620	0.9620

16	0.7590	0.9780
17	0.7650	0.9860
18	00.7690	1.0000
19	0.8360	1.0100
20	0.6350	1.1140
21	0.8550	1.1280
22	0.8530	1.2540
23	0.8590	1.4250
24	0.8620	1.5340
25	0.8598	1.6270
26	0.8650	1.7280
27	0.9100	1.8260

Table 3. Statistics for Group - Titanium carbide tool results lower SR as compared with uncoated tool.

Group	**N**	**Mean**	**Std. Deviation**	**Std.Error Mean**
TiC	27	0.746148	0.1113434	0.0214280
Un-coated	27	1.098970	0.2929335	0.0563751

Table 4. Independent sample T test has been carried out and has a relevant difference among groups (control and experimental) - Relevance value $p = 0.001$($p < 0.05$).

	F	**Significance**	**t**	**df**
MRR - Equal variances assumed	13.506	0.001	-5.850	52
MRR - Equal variances not assumed			-5.850	33.359

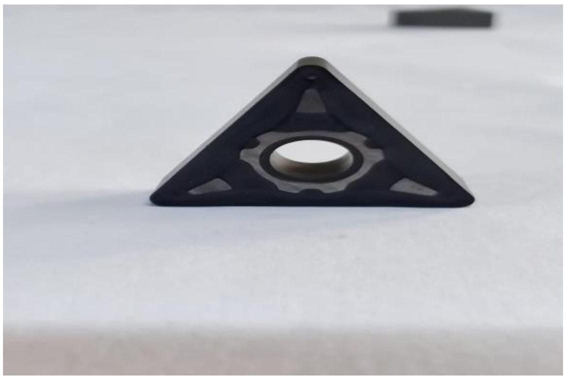

Fig. 1. Titanium carbide insert - Specification - TNMG 160408 EN - M50 - Included angle of tool 60 degrees, Length of cutting edge 16.5 mm; Thickness 4.76 mm; Radius of corner 0.8 mm; hole dia 9.52 mm; Code of cutting edge E - Rounded; Cut depth - 0.5 - 5.0 mm; Range of feed 0.15-0.4 mm/rev.

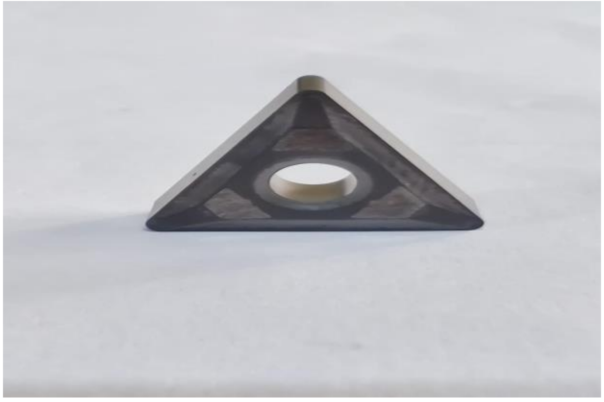

Fig. 2. Uncoated insert - Specification- TNMG 160408 EN - CF; CF - Angle of relief (Negative); Included angle of tool 60 degrees, Length of cutting edge 16.5 mm; Thickness 4.76 mm; Radius of corner 0.8 mm; Insert hand N-Neutral; Dia of hole -3.81 mm

Fig. 3. CNC Turning Machine-ACE. The specifications of CNC turning machine are: Dia of turning (Max) - 320 mm, Length of turning (Max) - 400 mm, Centre distance - 425 mm, Speed of spindle (Max) - 3500 rpm, Stations - 8, Bed swing -500 mm, Carriage swing - 260 mm. The input variables speed of cut, rate of feed and depth cut were set as 175 m/min, 0.150 mm/min and 0.6 mm respectively.

Fig. 4. Surface roughness tester - Surftest SJ - 410 - Range of measuring X-axis - 25 mm (1inch); Z1-axis - 800 µm, 80 µm, 8 µm; Measured speed - 0.05 µm/sec; Measuring force - 0.75 mN; parameters - Ra, Rz, Rt, Rp, Rv; Measured profiles - roughness; graph analysis - BAC and ADC curves; cutoff length - 0.25 mm.

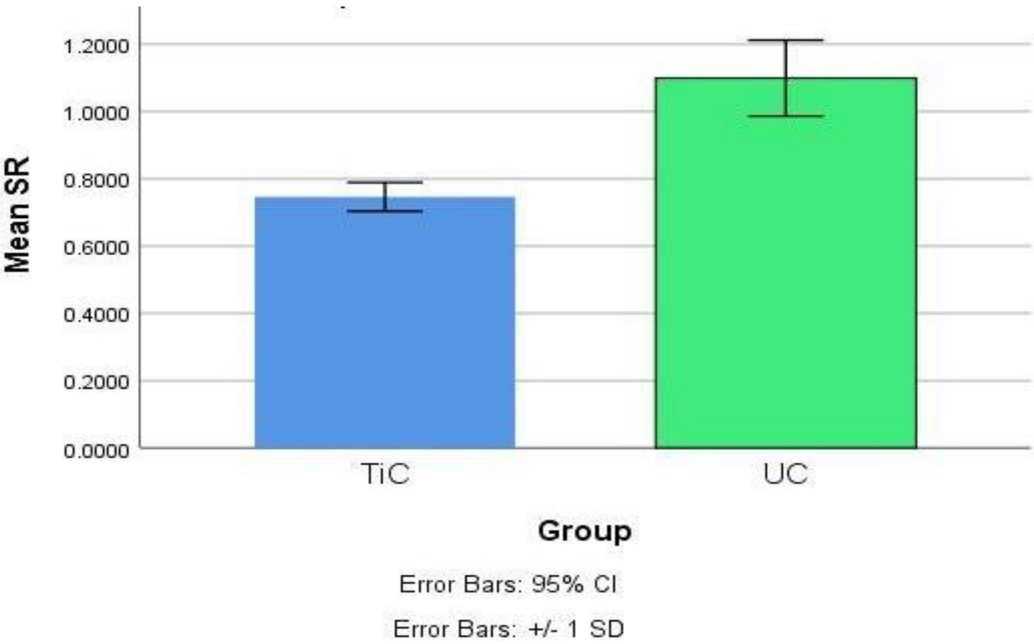

Fig. 5. With reference to mean accuracy, a comparison of TiC and uncoated tools. The mean accuracy of TiC tools is greater than that of uncoated tools, while the standard deviation of TiC tools is somewhat lower. X Axis: Type of cutting inserts (TiC and uncoated). Y Axis: Mean values of SR. Error bar with $\pm$ 1 SD.