Comparing the Performance of TiC tool and uncoated tool in novel CNC green turning of martensitic and precipitation hardening steel grade 420 for minimizing surface roughness.

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ABSTRACT

Aim:This research is to compare performance between Titanium Carbide (TiC) tool and uncoated tool (cemented carbide) in CNC turning of martensitic and precipitation hardening steel grade 420 and a detailed analysis is made on the surface roughness (SR) obtained by these inserts. **Materials and Methods:** In this work, the experimental group was TiC insert and control group was uncoated insert. Martensitic and precipitation hardening steel grade 420 was used in this experiment. A number of 27 samples were machined in a CNC machining centre by utilizing the selected input factors such as speed of cut, rate of feed and cut depth. **Result:** While comparing TiC insert and uncoated insert, mean SR values of both inserts were 0.765004 µm and 0.939870 µm respectively. From the group of experiment and control group of control the significant value obtained was 0.001. **Conclusion:** Within the limits of this experiment, TiC insert provides greater surface finish than uncoated insert during machining process.

Keywords: Green machining, Surface Roughness, TiC insert, Uncoated insert, Martensitic and precipitation hardening steels grade 420, Novel machining.

INTRODUCTION

Turning is a conventional process of securing cylindrical specimens that are fixed in a rotating chuck and the tool is fed to the workpiece to remove material for creating desired shape. Before 1950's machining process was carried out using mostly by lathe machines only. During those days surface quality and productivity used to be very low and mass production was really hard to achieve. Later, CNC machines were invented and they helped in improving product quality and improved productivity (Jha and Upadhyay 2021). Machining in which if material is removed without using coolants, it is called green machining which is environmentally friendly. Due to anti corrosive properties and high hardness, martensitic and precipitation hardening steel grade 420 was used in this study (Lee 2019). It also contains increased carbon for improved mechanical properties. This material is used to manufacture dental and surgical instruments (Mohd et al. 2020); (Averyanova and Bertrand 2009).

There are many studies conducted to minimise surface roughness using CNCturning operation. Almost 7450 researchers published in google scholar and 850 in science direct. The ideal influence of rotating speed, rate of feed, cut depth, and radius of tool tip are examined and as a result it is proven that DE optimization technique minimises surface roughness (Nee et al. 2018). In a research it is clearly indicated that surface roughness and MRR will be improved when cutting tool used is coated insert. Taguchi's L9 orthogonal array method to vary input parameters was used by (Moganapriya et al. 2018). In another study, an experimental and statistical analysis were made on AlSl 1045 using different types of coated carbide insert to improve surface roughness. In that study, the authors (Paese et al. 2020) concluded that TiC insert has provided better surface quality than other inserts used in the experiment. The Taguchi approach was shown to be particularly effective in refining machining settings for minimum surface roughness in a study made by (Kıvak 2014). In a study, various process parameters were optimized during turning process of EN19 steel and it resulted in less vibration and better surface finish (Shankar et al. 2020). Best research that is found similar to this study is carried out by (Paese et al. 2020). Formerly, our team has vast expertise working on a variety of research projects in a variety of fields (Samuel et al. 2019; Johnson et al. 2020; Venu et. al., 2019; Keerthana et. al., 2016; Thejeswar and Thenmozhi 2015; Krishna and Babu 2016; Subashri et.al 2016; Sriram, Thenmozhi, and Yuvaraj 2015; Jain, Kumar, and Manjula 2014; Menon and Thenmozhi 2016)

From all the findings of these researches it is clear that maximum surface roughness is obtained when better surface finish is required during machining. In this work, evaluation of TiC insert during dry CNC machining of martensitic and precipitation hardening steel grade 420 is a novel thing. So, this experimental investigation focuses on comparing the TiC insert and uncoated insert during the CNC turning of martensitic and precipitation hardening steel grade 420 to achieve good surface quality.

MATERIALS AND METHOD

Martensitic and precipitation hardening steel grade 420 was the workpiece material used in this study. There were 2 groups namely experimental group and control group in this experiment. Cutting tools that were used in this experiment were TiC and uncoated inserts. Novel machining involved in this experimental work was carried out by using CNC machining center, Saveetha Industries at Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai. 27 samples of each for TiC insert and uncoated insert were used during novel machining (Prasath et al. 2018). A scientific web - based statistical calculator was used to calculate a sample group with an 80 percent g power. While the machining, the mean value and standard deviation were 0.77 and 0.076, respectively.

Martensitic and precipitation hardening steel grade 420 was the workpiece used in this experimental investigation. This material was selected for this experiment due to its charecteristics such as high carbon content and excellent ductility. Workpiece material which was available in the shape of cylindrical rod (160 mm length and 20 mm diameter) was cut into required pieces to the dimension of 50mm length and 20mm dia for conducting experiment. This material was procured from Metha metals, Chennai. Chemical composition of martensitic and precipitation hardening steel grade 420 is given in Table 1.

Titanium carbide (TiC) insert was used as an experimental group and it is shown in Fig. 1. TiC insert is a hard refracting material related to tungsten carbide. This insert was known for its enhanced tool life and productivity. It is mainly used to machine materials like space crafts, abrasive steel bearings, piston heads. Ceratizit India Pvt. Ltd, Chennai, was the seller. TiC tool specification : TNMG 160408. Titanium carbide insert - Specification - TNMG 160408 EN - M50 - Corner radius 0.8 mm; dia. of hole 9.52 mm; Condition of cutting edge code E - Rounded; N-Neutral Hand of neutral ; Cut depth - 0.5-5.0 mm; Range of feed - 0.15-0.4 mm/rev; Included angle of insert 60 degrees, Length of cutting edge 16.5 mm;.

Tool of uncoated grade was utilised as a group of control and it is shown in Fig. 2. This insert is mainly used to machine non-ferrous materials, bearing balls and nozzles. Ceratizit India Pvt. Ltd. in Chennai was also the provider. Specification is TNMG 160408. Fixing hole diameter -3.81 mm, Insert included angle 60 degrees, Cutting edge condition code E - Rounded; Length of cutting edge 16.5 mm; Thickness of insert 4.76 mm; Radius of corner 0.8 mm; Insert hand N-Neutral.

CNC machine used for this experiment was ACE Super Jobber which is shown in Fig. 3. Workpiece of 50 mm length and 20 mm dia. was clamped in a chuck. TiC insert and uncoated inserts were used to machine specimens. 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. Input factors speed of cut, rate of feed and cut depth were set as 110 m/min, 0.04 mm/rev, and 0.3 mm respectively. Saveetha Industries, Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences (SIMATS), Chennai was utilised to conduct CNC machining process and measuring of surface finish. Turned specimens were mounted on a tester to measure the surface finish. Surface roughness tester used in this experimental investigation was Mitutoyo- SJ-410 which is shown in Fig. 4. Specification of this Surface roughness tester are : Measuring range X-axis - 25mm (1inch); parameters - Ra, Rz, Rt, Rp, Rv; Measured profiles - roughness; graph analysis - BAC and ADC curves; cutoff length - 0.25 mm. Measured speed - 0.05 µm/sec; Measuring force - 0.75 mN.

Statistical analysis

The mean, standard error, and standard deviation were assessed utilising SPSS v.26 statistical software. Significance level is considered when the probability value $p < 0.05$. In this investigation, surface roughness was involved as a dependent output variable and speed of cut, rate of feed and cut depth were involved as independent input factors. The efficacy of TiC and uncoated inserts was evaluated using an independent sample T-test.

RESULTS

After turning, surface roughness of the specimens obtained with TiC (0.765004 µm) and uncoated inserts (0.939870 µm) have been measured and tabulated. Measured SR values are shown in Table 2. To obtain SR values, standard input factors such as speed of cutting, rate of feed and cut depth were followed for both experimental group and control group. It is observed from statistical analysis which is shown in Table 3, standard deviation is 0.0759428 and mean value is 0.765004 for TiC insert.

Table 4 shows the Independent sample T-test output values. From the table it is observed that the relevance value $p = 0.001$ ($p < 0.050$). Bar graph (Fig. 5) shows the SR value difference between experimental group and control group. TiC tools have a greater mean accuracy and standard deviation than uncoated tools, as per the graph.

DISCUSSION

Based on this investigation, it is clear that TiC insert provides marginally better SR than uncoated insert while machining Martensitic and precipitation hardening steel grade 420 by using a CNC machine. The Fischer value is 13.362, having a relevance value of 0.001 that is $P < 0.05$ which demonstrates that there is a considerable difference between two tools. Simple bar graph indicates that the TiC insert has a comparatively better surface quality than uncoated insert. Result of this experiment is in line with the experimental work done by (Dogra et al. 2011) using turning of hardened steel.

The findings of this research work is similar to the findings made by (Prabha et al. 2018). The authors stated that better surface finish is attained when EN36 steel is machined with coated insert because it has better cutting tool geometry than uncoated insert. Selection of independent input parameters of this experiment accords to the results of (Dinesh et al. 2016). These researchers used three important cutting factors namely, speed of cutting, rate of feed and cut depth, which are considered during the process of duplex stainless steel using Taguchi method to improve surface finish and rate of material removal.

Results of investigative activity that was done by (Kuppusamy and Ramalingam 2018) and (Kumar et al. 2018) are not in line with this experiment work because they concluded that the uncoated insert has better machining capabilities than coated insert in their study. This may be due to their experimental work might have been conducted with different input parameters and working conditions. Input cutting parameters like speed of cutting, rate of feed and cut depth are main variables to obtain surface roughness of workpiece while machining.

Main limitation of this experiment is the cost and availability of TiC insert, which is really high compared to any other coated insert. The temperature caused due to dry machining of the workpiece is really high, which may lead to deformation of the workpiece. The formation of built-up chips is also a factor that sets limitations to this study. In future, existing study can be carried out with different types of inserts and workpiece materials to reduce overall process cost.

CONCLUSION

The machining process of workpiece martensitic and precipitation hardening steel grade 420 was carried out using a CNC turning machine with different input parameters. It is concluded that the TiC insert provides a lower surface roughness value (0.765004 µm) than uncoated cemented carbide insert (0.939870 µm) which has a higher surface roughness value during machining of martensitic and precipitation hardening steel grade 420.

DECLARATIONS

Conflict of interest

The authors of this paper declare no conflict of interest.

Authors Contribution

Author GDP was involved in data collection, data analysis, 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 Martensitic and precipitation hardening steel grade 420 . It contains several elements like chromium,carbon, sulphur, silicon, phosphorus, manganese and iron.

Elements	**Cr**	**C**	**Mn**	**S**	**P**	**Si**	**Fe**
Weight (%)	12.00 - 14.00	0.16 - 0.25	1.50 max	0.03 max	0.04 max	1.0	Remaining

Table 2. Tabulated SR values for TiC insert and uncoated insert, which was measured with Mitoyo SR-140 surface roughness tester.

Specimen no	SR for TiC tool (µm)	SR for uncoated tool (µm)
1	0.7010	0.8097
2	0.7015	0.8004
3	0.7021	0.8013
4	0.7024	0.8016
5	0.7029	0.8025
6	0.7032	0.8027
7	0.7003	0.8015
8	0.7016	0.8045
9	0.7095	0.8067
10	0.7120	0.8095
11	0.7152	0.9012
12	0.7115	0.9015
13	0.7123	0.9019
14	0.7165	0.9023
15	0.7110	0.9035
16	0.7209	0.9035
17	0.7226	0.9056
18	0.8510	0.9099
19	0.8640	0.9017
20	0.8910	1.1000
21	0.8840	1.1200
22	0.8750	1.1300
23	0.8670	1.1400
24	0.8542	1.1735
25	0.8447	1.1852
26	0.8321	1.1600
27	0.8456	1.1963

Table 3. Statistics for group - Titanium carbide tool gives lower SR than uncoated tool.

Group	N	Mean	Std. Deviation	Std. Error Mean
TiC	27	0.765004	0.0759428	0.0146152
UC	27	0.939870	0.1467433	0.0282408

Table 4. Tabulation for independent sample t-test. The independent sample t test findings reveal a strong difference between the experimental and control groups. Relevance value $p = 0.001$ ($p < 0.05$).

<table>
<tr><th></th><th>F</th><th>Significance</th><th>t</th><th>df</th></tr>
<tr><td>SR- Equal variances assumed</td><td rowspan="2">13.362</td><td rowspan="2">0.001</td><td>-5.499</td><td>52</td></tr>
<tr><td>SR - Equal variances not assumed</td><td>-5.499</td><td>38.995</td></tr>
</table>

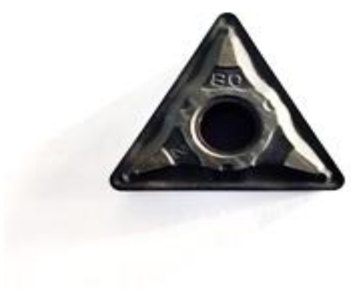

Fig. 1. TiC coated tool (TNMG160408 EN-M50)

Fig. 2. Uncoated cemented carbide tool (TNMG160408 EN-CF)

Fig. 3. CNC Turning Machine-ACE Super Jobber

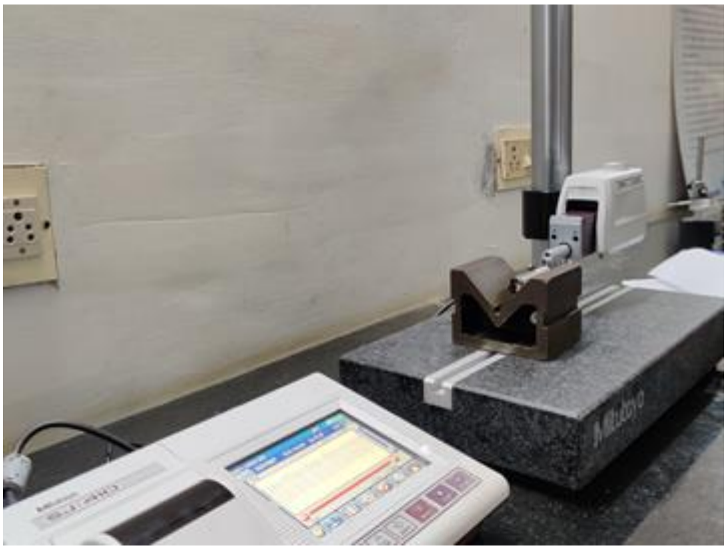

Fig. 4. Mitutoyo SJ-410 Surface roughness testing machine.

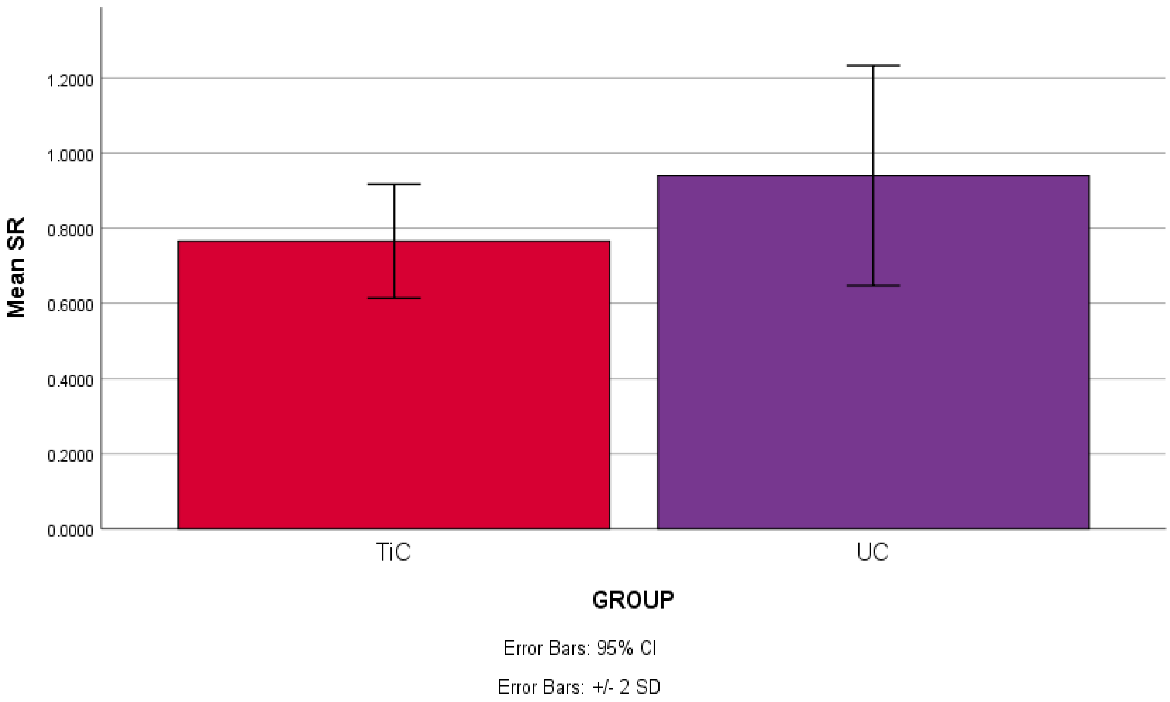

Fig. 5. Simple bar graph representing the mean difference in surface roughness values between groups. in terms of mean accuracy, TiC and uncoated inserts are compared. The standard deviation of TiC inserts is smaller than that of uncoated inserts, and the mean accuracy of TiC inserts is greater than that of uncoated inserts. X Axis: TiC insert vs uncoated insert. Y axis: Mean accuracy of detection ± 2 SD.