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Comparing Performance of Novel Chrome Nitride Coated Tungsten Carbide Tool with Uncoated HSS Tool for Improving CNC Green Machining of EN3B Steel

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Abstract

Aim: This experimental investigation compares the performance of Chrome Nitride (CrN) coated WC tool with uncoated HSS tool for CNC green machining in turning the High Strength Steel EN3B for improving surface finish and material removal rate in green machining method. Materials and Methods: The experimental group high strength steel EN3B material work were machined with Chrome Nitride (CrN) coated tungsten carbide WC tool insert and the same kind of works were machined with uncoated High Speed Steel (HSS) insert tool for control group. Calculated Sample size at G power 80% setting was 16 per group and total 32. Results: The results revealed that the feed rate was the most important parameter affecting the surface roughness and depth of cut affects considerably cutting force and power. The significance Value of p was 0.0275 and which is lesser than 0.05 for surface roughness observations and for material removal rate $p = 0.0344 < 0.05$. Conclusion: The material gives a good material removal rate (Averagely improved 29.22%) and surface roughness (Averagely Reduced by 56.61%) with use of with Chrome Nitride (CrN) coated tungsten carbide WC tool insert than conventional HSS tool insert in machining the high strength steel EN3B material work.

Keywords

Novel chrome nitride coated tungsten carbide, EN3B steel, Surface roughness, Material removal rate, Green machining, High speed steel.

INTRODUCTION

This research is about investigating the possibilities of improving the machinability in CNC turning of EN3B alloy steel material with the novel coated CrN and comparing with the HSS tool insert to get more material removal rate and to get low surface roughness (Statharas et al. 2019). Optimization of process parameters for Green Machining of the EN3B is more difficult because of its high Mechanical strength and high hardness (Kazlauskas, Jankauskas, and Tučkutė 2020). This research results can be used for the best result with less number of rejections for the machining combination of EN3B and novel CrN coated tool for turning process for use in the automotive industry (Sathish, Saravanan, et al. 2022). EN3B is an alloy steel which has high strength to make it useful in the chemical industry, plumbing, heating, oil and gas industry, water supply systems, paper and pulp industry, power plant, fabrication industry, food processing industry, structural pipe and heat exchangers (Wang et al. 2021).

About 1545 articles published according to Google scholar database and 842 articles published according to sciencedirect related to this kind of research (Aghajani and Behrangi 2016). The selected cutting parameters are cutting speed, feed, depth of cut used in the turning process (Davis 2002) : (Balan et al. 2022). The surface roughness during the CNC machining of the performance of the novel CrN coated carbide cutting tools and uncoated carbide cutting tools on the turning inconel alloy using gray relational analysis (Aghajani and Behrangi 2016). Multiple objective optimal ligation of cutting parameters in CNC turning off the stainless steel in the CrN coated tools (Srivatsan, Sudarshan, and Manigandan 2018) (Sathish, Sabarirajan, et al. 2022; Dinesh Kumar et al. 2021). Among the above research articles, (Balan et al. 2022) is very close to this research investigation.

Previously our team has a rich experience in working on various research projects across multiple disciplines (Venu and Appavu 2021; Gudipaneni et al. 2020; Sivasamy, Venugopal, and Espinoza-González 2020; Sathish et al. 2020; Reddy et al. 2020; Sathish and Karthick 2020; Benin et al. 2020; Nalini, Selvaraj, and Kumar 2020).Comparative analysis of performance of the novel CrN coated carbide is the turning tools insert and uncoated HSS tool carbide cutting tools on the turning tool insert the steel using grey relational analysis (Sathish, Sabarirajan, et al. 2022). Multi objective optimization of cutting parameters in the CNC turning of stainless steel in the CrN nano coated tool insert. In the EN3B material HSS tool CNC turns at the EN3B material in the novel CrN coated tool and the uncoated HSS tool inserts the turning. Compare the uncoated HSS tool and the coated CrN tool and increase the surface finish and the material removal rate (MRR) analysis. (Fischer and Bobzin 2011)

MATERIALS AND METHODS

The material considered for this research study and turning process is EN3B . comparing the novel CrN coated tool insert and HSS uncoated tool insert of the cutting process. Hence the two inserts were considered in the process. This study was carried out in the CNC turning which is available at Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences (formerly known as Saveetha University), Chennai. Total number of groups involved in this project is 2. The novel coated CrN insert is used as an experimental group and the HSS insert is used as a control group. The total sample size calculated per group was 13 with use of standard deviation of 0.12999 to 0.10818, mean of 0.452 to 0.441 used, the pretest G-power 80% was set (Balan et al. 2022). The used sample size is 16 per group. As there are no human samples used in this investigation there is no ethical approval required.

The control group samples were EN3B steel. In the procurement of EN3B steel diameter of 12mm and the length of 6 meter for the green machining from the EN3B steel and the testing of the material properties. The cylindrical rods were obtained from SAAJ, chennai. Chemical composition of EN3B was checked at SIMATS MET Mech LAB chennai-602105 and ensured the material's originality. Chemical properties for EN3B is the lowest percentage of carbon is 0.35 (Table 1). Mechanical properties for EN3B which have high tensile strength of 551 mpa and yield strength 241 mpa (Table 3). The control group samples are machined with a conventional HSS tool of 0.4 mm nose radius.

For the control group the samples are prepared as above and same work material but this group samples are machined with use of novel coated CrN HSS insert as a cutting tool. The specification of the tool insert is TNMG16040 with 0.4mm nose radius . It has a triangular shape and has 6 corners to do machining. The specification of the tool insert is

TNMG 16040 with 0.4mm nose radius. It is best to make use of extremely sharp and uncoated cutting edges.(Statharas et al. 2019)(Smyrnova et al. 2018)

The control group will be prepared by machining with an HSS uncoated tool whereas the intervention group will be machined with CrN coated tool. Machine in the CNC turning at simalp to turning tools HSS and novel coated CrN tool and petting tool for cutting in the control of the group prepared by HSS tool turning with CNC turning machine. The surface roughness tester of the machining process it is testing the surface finish of the material removal rate is the process which has be there material removaling form the machining in the material is MRR and the physical weigh scale by the weight of the schip when material removal in the green machining process. In the place of the machine comparonts near the probe and the switch the scale as the Ra (or) Rz and ruanthe machare the reading will menstrual (Sivaiah 2019)(Bouzakis et al. 2017). In the process of measuring the energy meter in the machining process of the operation before machining and the after machining for the material removal rate (MRR). The measuring of the surface roughness in the finishing of the material which has been machining the surface finish. The chip which is calculateding of the chip to calculate the material removal rate (MRR) of the machining process at the before and after the machining process. The testing inthe process of the checking the finish of the material in lab report for the testing material.

Surface roughness was measured in Mityong - SJ 410. The length examined is 4 mm with a cut-off of 0.8 mm and the measured values of Ra are within the range 0.05-40 μm. At each experiment the specimen machining time for the sample length of 50mm was recorded and the weight loss by machining was obtained by weighing the specimen before and after machining.Each specimen was calculated using the following formula.

MRR (g/s) = weight of the sample before machining - weight of sample after machining × machining time taken for machining

Statistical Analysis

The SPSS software is to check the material value in the SPSS software. The process which needs to get the feed 0.10-0.25 mm/rev, speed 50-110 mm/min and depth of cutting 0.25-1.00mm in the green machining process. The process of material removal rate (MRR) in the operation and giving the surface finish in the material. The independent variable sample T-Test was used to analyze the output to identify significance value among the CrN and HSS inserts (Parthiban et al. 2021).

RESULT

The mean value of the CrN insert is 0.452 to 0.441 and standard deviation values are 0.12999 to 0.04111. The standard error mean for CrN insert is 0.04111and HSS insert is 0.04102. T-test on independent samples has been carried out and significance value P=0.0275 and for surface roughness. The mean value of the CrN insert is 475.5563 to 472.6543 and standard deviation values are 106.47784 to 106.47037. It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR ($p= 0.0344$, $p<0.05$) and for Surface roughness ($p=0.0275$, $p<0.05$).

Table 1 shows the Chemical composition of EN3B like Si is 0.35 max and percentage value C is 0.25% max. Table 2 furnishes the Physical properties for EN3B that have a high melting point at 1425℃. Table 3 exhibits the mechanical properties for EN3B which have high Tensile strength of 551 MPa and yield strength of 241 MPa. Table 4 shows the 16 different combinations of Input parameters for investigating the performance of novel CrN coated HSS tool insert and HSS tool. Calculated MRR values for novel CrN insert and HSS insert with the parameters speed, feed and depth of cut. The obtained observations of time, measured surface roughness and calculated material removal rate were consolidated and presented in Table 5 and Table 6 for proposed and conventional methods of machining respectively. Table 7 shows the group statistics of MRR performance resulting from the t test. Table 8 shows the independent samples test results of test of significance for the observations of surface roughness. Similarly, Table 9 shows the Results for t test and the independent samples test for the observation of MRR in Table 10.

Figure 1 shows the samples machined with High-Speed Steel (HSS) insert thickness 4.8 mm, corner radius 0.4 mm, fixing hole diameter 3.81 mm. Figure 2 shows the Titanium Nitride coated HSS insert of specification - grade of TNMG 16040 - insert angle 61° degree, insert thickness 4.8 mm, corner radius 0.4 mm, fixing hole diameter 3.81 mm. Figure 3 and Fig. 4 show the samples machined with conventional uncoated HSS tool and CrN Coated HSS tool respectively. Figure 5 exhibits the CNC turning process. Figure 6 shows the experimental facility of CNC turning center - specifications: swing carriage - 260 mm, maximum turning diameter - 290 mm, maximum turning length - 400/500 mm, swing bed - 500 mm, max spindle speed - 4000 rpm, no of station - 8, chuck size - 200/250. Figure 7 shows the mitutoyo SJ-410 surface finish analyzer allows high-accuracy measurement with a hand-held tester. It features confirmation of measurement results and an assessed profile without printout. Figure 8 and Figure 9 show the G -Graphs generated from the independent samples test results for surface roughness and MRR observations respectively.

DISCUSSION

The above result shows that the material removal rate increases when the feed and depth of cut is more. High depth of cut will increase material removal rate. High material removal rate results in a good surface finish and performance and durability of the parts are increased, significance of P value is 0.0275. From the bar graph , it shows the parameters of speed, feed, depth of cut. This formula is used for both DLC and HSS tool insert. The signal to noise ratio by main effect is plotted for data mean (Parthiban et al. 2021; Jayaprakash et al. 2021). It was observed that cutting forces were small compared with that of the feed rate and depth of cut. In general, a decrease in cutting force can be achieved as speed increases, tool nose radius is increased (Choy 2019). The progrease of tool wear was examined with increasing time at high cutting speed at different levels of feed and depth of cut.

The influence of cutting conditions on cutting force evolutions shows that the cutting speed has a small effect compared with that of the feed rate and this can be noted in SPSS analysis (Voznyuk 2017). The signal to noise ratio by main effect is plotted for data mean. It was observed that cutting forces were small compared with that of the feed rate and depth of cut.(Kazlauskas, Jankauskas, and Tučkutė 2020; Sathish, Mohanavel, et al. 2022). Our institution is passionate about high quality evidence based research and has excelled in various fields. We hope this study adds to this rich legacy. EN3B steel materials are hard to machine and the coolants are essential for the machining in CNC (Kazlauskas, Jankauskas, and Tučkutė 2020). It has a low mechanical strength and poor cutting performance (Mishra and Palani 2019): (Wilczek et al. 2020). This reduction was probably caused by an increase in the temperature at the cutting zone which leads to the workpiece software.

Findings of this study limited to green machining in CNC turning center, because machining with the conventional lathe may be economical. The wet machining helps to improve surface quality and material removal rate. Hence in the future scope the investigation may involve the wet machining environment. The effect of coolant may be investigated in the above said responses. In future the same machining inputs with use of conventional automatic or semi automatic lathe will reduce the machining cost considerably.

CONCLUSION

Within the limits of this study and based on the experimental results, parameters analysis, the material gives a good material removal rate (Averagely improved 29.22%) and surface roughness (Averagely Reduced by 56.61%) in machining of the EN3B with the novel coated CrN insert than conventional HSS. It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR ($p = 0.0344$, $p<0.05$) and for Surface roughness ($p=0.0275$, $p<0.05$).

DECLARATION

Conflict of interests

The authors of this paper declare no conflict of interest.

Author contribution

Author VV was involved in data collection, data analysis, manuscript preparation. Author RS was involved in the conceptualization, guidance and critical review of the manuscript.

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TABLE AND FIGURES

Table 1. EN3B Alloy Steel Round Bar Chemical Composition

	C	Mn	Si	S	P	Cr	Ni
EN3B	0.35 - 0.45	0.60 - 1.00	0.10 - 0.35	0.050 max	0.050 max	-	-

Table 2. EN3B Alloy Steel Round Bar Physical Properties

Property	Quantity
Density (g/cm ^{3})	8.08
Density (lb/in ^{3})	0.292
Melting Point (℃)	1425
Melting Point (℉)	2600

Table 3. EN3B Alloy Steel Round Bar Mechanical Properties. Tensile strength : unit - ksi (MPa), MinimumYield strength : 0.2 % offset, unit - ksi (MPa), MinimumElongation : in 2", unit : % Minimum values as per ASTMB160

Condition	Tensile Strength (MPa)	Yield Strength (MPa)	Elongation (%)
Annealed	80 (551)	35 (241)	30

Table 4. Input Parameters for Chrome Nitride and High Speed Steel (HSS) Insert

Trall	Speed (mm/min)	Feed (mm/rev)	Depth of cut (mm)
1	50	0.10	0.25
2	50	0.15	0.50
3	50	0.20	0.75

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4	50	0.25	1.00
5	70	0.10	0.50
6	70	0.15	0.25
7	70	0.20	1.0
8	70	0.25	0.75
9	90	0.10	0.75
10	90	0.15	1.00
11	90	0.20	0.25
12	90	0.25	0.50
13	110	0.10	1.0
14	110	0.15	0.75
15	110	0.20	0.50
16	110	0.25	0.25

Table 5. Outputs Parameters of Surface Roughness, Material Removal Rate, and CNC Run Time for High Speed Steel (HSS) Tool Insert

Trial no.	Time Taken	MRR	Surface Roughness
1	9.96	2170.144461	0.533
2	10.26	2628.236266	0.543
3	9.86	2181.00481	0.547
4	10.56	2191.8553	0.542
5	8.86	2315.601929	0.392
6	8.71	2287.748559	0.402
7	9.26	2306.326121	0.422
8	8.57	2343.37746	0.41

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9	8.04	2361.709663	0.332
10	8.16	2313.928524	0.327
11	8.15	2353.765101	0.304
12	7.84	2321.911008	0.302
13	7.45	2450.726141	0.205
14	7.53	2400.171042	0.202
15	7.46	2443.525111	0.203
16	7.17	2436.317039	0.226

Table 6. Outputs parameters of Surface Roughness, Material Removal Rate, and CNC RunTime for Chrome Nitride (CrN)

Trial no.	Time Taken	MRR	Surface Roughness
1	9.52	2203.368461	0.532
2	9.82	2661.460266	0.542
3	9.42	2214.22881	0.546
4	10.12	2225.0793	0.541
5	8.42	2348.825929	0.391
6	8.27	2320.972559	0.401
7	8.82	2339.550121	0.421
8	8.13	2376.60146	0.409

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9	7.6	2394.933663	0.331
10	7.72	2347.152524	0.326
11	7.71	2386.989101	0.303
12	7.4	2355.135008	0.301
13	7.01	2483.950141	0.204
14	7.09	2433.395042	0.201
15	7.02	2476.749111	0.202
16	6.73	2469.541039	0.225

Table 7. Result of T-test for sample EN3B High Strength Steel Alloy which were machined by two methods. Group A samples are machined by High Speed Steel (HSS) insert and Group B samples are machined by Chrome Nitride (CrN) coated tungsten carbide insert. The sample means of the proposed method (Group B) significantly gives lower surface finish than the conventional high speed (HSS) insert used in the sample group A

Group Statistics					
	Group	N	Mean	Std. Deviation	Std. Error Mean
Surface Roughness	A	20	0.7984	0.12999	0.02907
	B	20	0.3464	0.10818	0.02581

Table 8. Results for independent samples test for CNC Green Machining of EN3B High Strength Steel Alloy machined with conventional High Speed Steel (HSS) insert (Group 1) and proposed Chrome Nitride (CrN) Coated Tungsten Carbide insert (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for Surface roughness ($p = 0.0275$, $p < 0.05$).

Independent Samples Test
Levene's Test for Equality of Variances

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		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Surface roughness	Equal variances assumed	0	0.0275	10.996	38	0	0.452	0.04111	0.36878	0.53522
	Equal variances not assumed			10.996	38	0	0.441	0.04102	0.36878	0.53522

Table 9. Results of T-test for sample of EN3B High Strength Steel Alloy which were machined by two methods. Group A samples are machined by Chrome Nitride (CrN) coated tungsten carbide insert tool. Tool. the sample means of the proposed method (Group B) significantly gives Higher Material Removal Rate (MRR) than the conventional High Speed Steel (HSS) insert used in the sample group A

Group Statistics					
	Group	N	Mean	Std. Deviation	Std. Error Mean
MRR	A	16	1627.489	106.47784	23.8075
	B	16	2103.0453	106.47037	23.8075

Table 10. Results for independent samples test for CNC turning of EN3B High Strength Steel Alloy machined with conventional High Speed Steel (HSS) insert (Group 1) and proposed Chrome Nitride (CrN) coated tungsten carbide insert tool (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR ($p= 0.0344$, $p<0.05$).

Independent Samples Test									
Levene's Test for Equality of Variances									
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference

									Lower	Upper
MRR	Equal variances assumed	0.18	0.0344	14.1	38	0	475.5563	33.6688	-543.7154	407.397
	Equal variances not assumed			14.1	38	0	472.6543	33.6688	-543.7154	407.397

Fig. 1. CNC turning machine center - specifications: swing carriage - 260 mm, maximum turning diameter - 290 mm, maximum turning length - 400/500 mm, swing bed - 500 mm, max spindle speed - 4000 rpm, no of station - 8, chuck size - 200/250.

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Fig. 2. High Speed Steel (HSS)- specification - grade of TNMG 16040 -insert thickness 4.8 mm, corner radius 0.4 mm, fixing hole diameter 3.81 mm

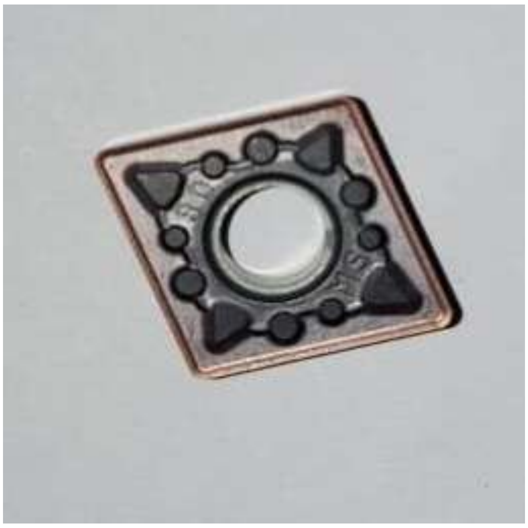

Fig. 3. Novel Chrome Nitride (CrN) - specification - grade of TNMG 16040 - insert thickness 4.8 mm, corner radius 0.4 mm, fixing hole diameter 3.81 mm

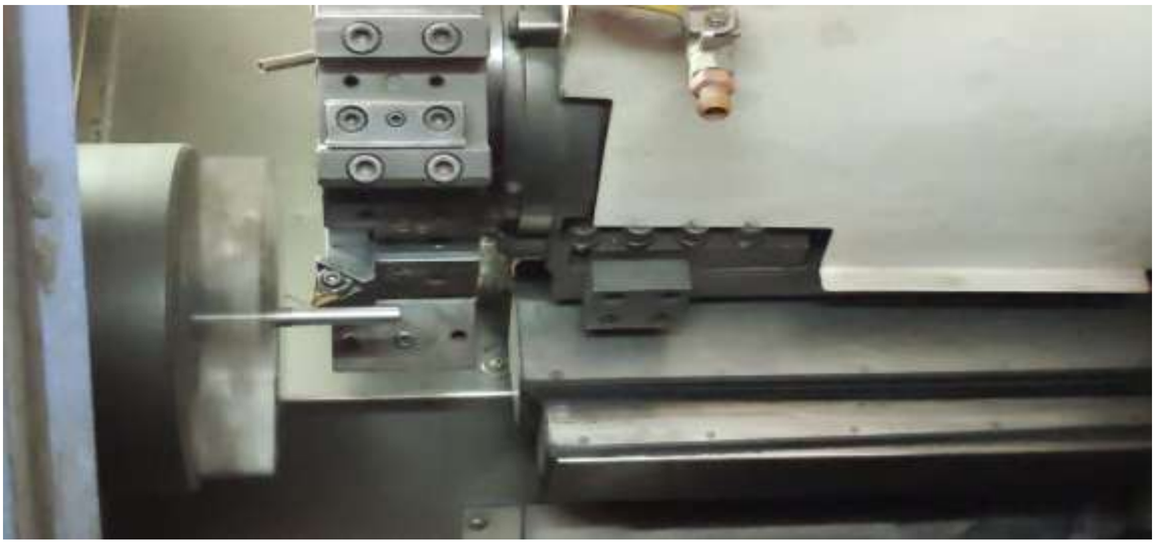

Fig. 4. CNC machining process

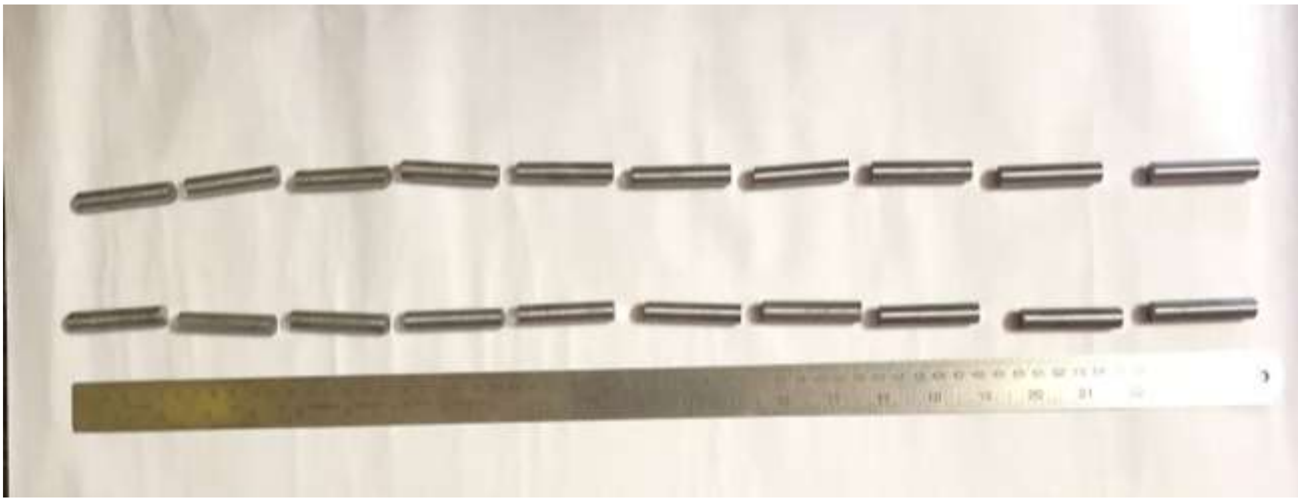

Fig. 5. High Speed Steel (HSS) uncoated tool finish material

Fig. 6. Novel Chrome Nitride (CrN) coated tool finish material

Fig. 7. The mitutoyo SJ-410 surface finish analyzer allows high-accuracy measurement with a hand-held tester. It features confirmation of a measurement results and an assessed profile without printout.

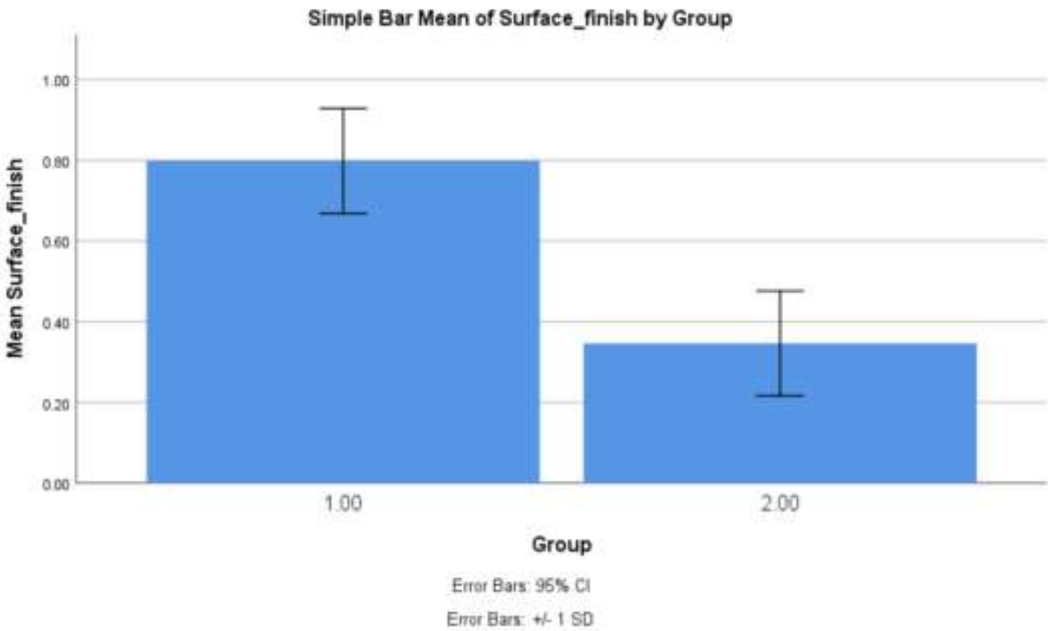

Fig. 8. Shows the sample bar between the Ra values for machined surfaces roughness using High Speed Steel (HSS) insert and Novel Chrome Nitride (CrN) coated Tungsten carbide insert tool. From the graph, the lower mean Ra values were obtained as 0.10818 micrometers using the Novel Chrome Nitride (CrN) coated Tungsten carbide insert tool compared to HSS tool which has 0.12999 micrometers. X-axis: HSS and Novel Chrome Nitride (CrN) coated Tungsten carbide insert, Y-axis: mean surface roughness ± 1 SD

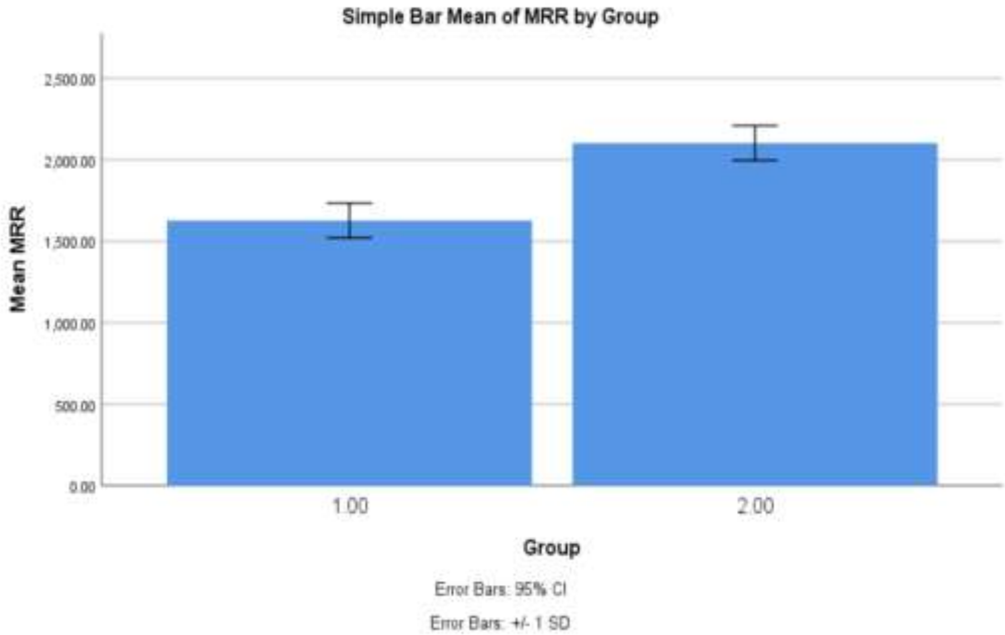

Fig. 9. Shows the graph for dominating both Novel Chrome Nitride (CrN) coated Tungsten carbide insert and uncoated High Speed Steel (HSS) insert cutters in material removal rate (MRR). From these cutters the Novel Chrome Nitride (CrN) coated Tungsten carbide insert cutter produced High material removal rate (MRR) even in variation of cutting speed, feed and depth of cut.X-axis: HSS and CrN coated HSS tool, Y-axis: mean MRR of detection± 1SD.