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Performance of Novel Calico Aluminum Titanium Nitride Coated tungsten carbide Tool comparing with Conventional Uncoated High Speed Steel Tool in CNC Green Machining of EN3B Steel for Machinability Improvements

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Abstract

Aim: This research compares the effect of Aluminum Titanium Nitride (AlTiN) coated tungsten carbide (WC) insert tool and uncoated HSS insert tool in CNC green machining (turning process) of High Strength Steel EN3B for improving rate of material removal and surface finish. **Materials and Methods:** The high strength steel EN3B material jobs which are machined with AlTiN coated WC tool are an experimental group and those jobs are machined with uncoated High Speed Steel (HSS) insert tool in the same green machining process as the control group. The total sample size is 32 (16+16) and the G power 80% was used for prediction of group size. **Results:** The results revealed that the feed rate was the most important parameter affecting the surface roughness and depth of cut and also affects cutting force and power. The significance of p Value was found as 0.021for material removal rate and 0.001 for surface roughness observations which is lesser than 0.05. **Conclusion:** The material removal rate averagely improved 46% and the Surface roughness averagely reduced by 54% with use of novel AlTiN coated WC tool insert than conventional HSS tool insert.

Keywords

High speed steel,, EN3B steel, Material removal rate, Novel calico aluminum titanium nitride coatTungsten carbide, Green machining, Surface roughness..

INTRODUCTION

This research is about investigating the possibilities of improving the machinability in CNC turning of EN3B alloy steel material with the novel AlTiN and optimizing the process parameters, compared with the HSS tool insert to get more material removal rate and to get low surface roughness (Lee et al. 2019).optimization of process parameters for Machining of the EN3B is more difficult because of its high Mechanical strength and high hardness (Thanikodi Sathish et al. 2021). This research results can be used for the best result with less number of rejections for the machining combination of EN3B and novel AlTiN coated tool for turning process for use in the automotive industry (Jayaprakash et al. 2021). 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 (Abu-Mahfouz, Banerjee, and Rahman 2021).

About 1120 articles published according to Google scholar database and 710 articles published according to sciencedirect related to this kind of research (Marrocco et al. 2020).The selected cutting parameters are cutting speed, feed, depth of cut used in the turning process (Chen et al. 2021). The surface roughness during the CNC green machining of the performance of the AlTiN coated carbide cutting tools and uncoated carbide cutting tools on the turning inconel alloy using gray relational analysis. (Zhu et al. 2021). Multiple objective optimal ligation of cutting parameters in CNC turning off the stainless steel in the AlTiN coated tools. From the above the research article is very close to this research investigation (Ye et al. 2021). Aluminum Titanium Nitride (AlTiN) coated carbide of the cutting tools and uncoated carbide cutting tools on the turning machining of stainless steels in the novel coated ALTiN of the HSS of the HSS coated tool (Kavitha et al. 2021). The EN3B steel material is tested by machining with the HSS tool in the CNC turning operation (Mohanavel et al. 2022). Hence above mentioned research findings and procedures the contribution of (Mohanavel et al. 2022) is best and very close to this piece of 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; T. Sathish et al. 2020; Reddy et al. 2020; T. Sathish and Karthick 2020; Benin et al. 2020; Nalini, Selvaraj, and Kumar 2020).Though ongoing research is wide in investigating the machinability of materials and alloy this research is unique and no similar publications found. In the EN3B Steel material and HSS tools are used in the CNC turning and the EN3B steel material is using novel AlTiN coated HSS tools are used for turning material in CNC machining. The EN3B steel material is operated at the ALTiN coated HSS tool turning. To compare the HSS uncoated tool and novel AlTiN coated tool and increase the surface finish and the material removal rate of the analysis.

MATERIALS AND METHODS

The material considered for this research study and turning process is EN3B . comparing the AlTiN coated WC tool insert and HSS uncoated tool insert of the cutting process. Hence the two inserts were considered in the process. Group A samples are machined by High Speed Steel (HSS) insert and Group B samples are machined by Novel Calico Aluminum Titanium Nitride 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. The total sample size calculated per group was 13 with use of standard deviation of 114.53572 to 115.72842, mean of 750.1013 to 732.2012 used, the pretest G-power 80% was set (Mohanavel 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.

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 AlTiN insert is used as an experimental group and the HSS insert is used as a control group. The control group samples were EN3B steel. In the procurement of EN3B steel diameter of 12mm and the length of 6 meter for the machining from the EN3B steel and the testing of the material properties. The cylindrical rods were obtained from SAAJ,

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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 AlTiN WC tool 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 green 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.(Bülbül et al. 2016). Chemical composition for EN3B is Si is 0.35 max and percentage value C is 0.25% max. Mechanical properties for EN3B which have high Tensile strength of 551 Mpa and yield strength of 241 Mpa. Physical properties for EN3B have a high melting point at 1425 ℃. Group statistics-AlTiN insert provides higher MRR values.

Procurement of the EN3B steel at the diameter of 12 mm and the length is 6 m for the machining process and it is from the saas steel and testing material. In the machining process the CNC turning operation of the simalp are turning tools HSS uncoated and novel AlTiN coated WC tool insert and the petting tool for the cutting process . The control of the group was prepared by the HSS tool of turning process with the CNC turning machine.In the test process are surface roughness testers of the material which machined the process of material to test the surface finish (Sivaiah 2019).

The material removal rate and physical weight scale by weight of the schip in the green machining process. In the place michael compartment are the probe and switch the scale as Ra (or) Rz and ruanthe machare reading wil montreal.The process of measuring the energy meter which was used before and after the machining process. The measuring the weight of the material in machining to check the weight before and after the machining process. The measuring of the surface roughness of the material for the machining process gets over. The chip will be coluction for the material removal rate (MRR) for checking the weight of the MRR before and after machining process.lab report for testing the material of analysis and the comparison of the material. Input parameters for AlTiN and HSS tool insert with cutting speed from 50-110 mm/min and feed 0.10-0.25mm depth of cut from 0.25-1.00mm. The three levels and three factors show that the minimum surface roughness at the speed of 50 mm/min, feed 0.10mm/rev, depth of cut.0.25 mm at the optimum values. Calculates MRR values for novel AlTiN insert and HSS insert with the parameters speed, feed and depth of cut. 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 machining process. The process of material removal rate (MRR) in the operation and giving the surface finish in the material (T. Sathish et al. 2021). The independent variable sample T-Test was used to analyze the output to identify significance value among the AlTiN and HSS inserts.

RESULTS

The mean value of the CrN insert is 750.1013 to 732.2012 and standard deviation values are 114.53572 to 115.72842. The standard error mean for novel coated AlTiNWC tool insert is 39.96267 and HSS insert is 40.91617. T-test on independent samples has been carried out. It is observed that on performing One-Way ANOVA, there is a statistically significant difference for material removal rate (p= 0.021 ($p<0.05$) and for Surface roughness p=0.001, ($p<0.05$). The mean value of the AlTiN insert is 0.464 to 0.321 and standard deviation values are 0.12636 to 0.12584.

Table 1 shows the Chemical Composition of EN3B Alloy Steel Round Bar. Table 2 furnishes the Physical Properties of EN3B Alloy Steel Round Bar. Table 3 consolidates the Mechanical Properties of EN3B Alloy Steel Round Bar in which the Tensile strength was stated in MPa and that is Minimum value/ Similarly, the Minimum Yield strength with 0.2 % offset in MPa and Elongation represented in 2”, unit : %, as Minimum values as per ASTM B160. Table 4 explains the details of Input Parameters set for machining at each experiment which were machined with Aluminum Titanium Nitride (AlTiN) cated iHigh Speed Steel (HSS) Insert. Table 5 shows the experiment wise average observations of surface roughness on job, Material Removal Rate, and CNC Run Time by machining with conventional High Speed Steel (HSS) Tool Insert. The same for use of the proposed Aluminum Titanium Nitride (AlTiN) coated tool insert is shown in Table 6. Table 7 comparatively depicts the result of the T-test for the samples EN3B High Strength Steel Alloy which was machined by both methods. 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 Aluminum Titanium Nitride (AlTiN) Coated Tungsten Carbide insert (Group 2). The observed results are statistically significant. Table 9 shows results of T-test for samples of EN3B High Strength Steel Alloy which were machined by two methods. Group A samples are machined by Aluminum Titanium Nitride (AlTiN) 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. 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 Aluminum Titanium Nitride (AlTiN) coated tungsten carbide insert tool (Group 2). The observed results are statistically significant.

Figure 1 shows the 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. Figure 2 illustrates the 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. Figure 3 demonstrates the Novel Calico Aluminum Titanium Nitride Coated Tungsten Carbide - specification - grade of TNMG 16040 - insert thickness 4.8 mm, corner radius 0.4 mm, fixing hole diameter 3.81 mm. Figure 4 demonstrates the CNC machining process. Figure 5 exhibits the work pieces machined by High Speed Steel (HSS) uncoated tool and Fig. 6 exhibits the work pieces machined by CalicoAluminum Titanium Nitride (AlTiN) coated tool insert. Figure 7 shows the surface roughness tester namely mitutoyo SJ-410 surface finish analyzer which allows high-accuracy measurement with a hand-held tester. It features confirmation of a measurement results and an assessed profile without printout.

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 0.0021. From the bar graph , it shows the parameters of speed, feed, depth of cut. Figure 8 shows the sample bar between the Ra values for machined surfaces roughness using High Speed Steel (HSS) insert and CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert tool. From the graph, the lower mean Ra values were obtained as 115.7284261micrometers using the CalicoAluminum

Titanium Nitride (AlTiN) coated Tungsten carbide insert tool compared to HSS tool which has 114.5357247 micrometers. X-axis: HSS and CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert, Y-axis: mean surface roughness ± 1 SD. Similarly, Fig. 9 shows the graph for dominating both CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert and uncoated High Speed Steel (HSS) insert cutters in material removal rate (MRR). From these cutters theCalicoAluminum Titanium Nitride (AlTiN) 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 AlTiN coated WC tool insert, Y-axis: mean MRR of detection± 1SD.

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. Hence the observed results are statistically significant (Thanikodi Sathish et al. 2021). 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 (Srinivasa Pai and Krishnaraj 2021). In general, a decrease in cutting force can be achieved as speed increases, tool nose radius is increased (Sultan et al. 2020). The progrease of tool wear was examined with increasing time at high cutting speed at different levels of feed and depth of cut (Sultan et al. 2020; Gupta and Pramanik 2021):(T. Sathish et al. 2022). It is showing the comparison of the uncoated HSS tools and the novel AlTiN coated WC tool insert and we are showing an increase in the surface finish and the material removal rate (MRR) analysis (Srivatsan, Sudarshan, and Manigandan 2018).

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 (Tsai and Yu 2009). 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 (Parthiban et al. 2021).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 (Ponnusamy et al. 2021) .

This reduction was probably caused by an increase in the temperature at the cutting zone which leads to the workpiece software. Limitations involved in this study of EN3B steel material are hard to machine and the coolants are essential for the machining in CNC. It has a low mechanical strength and poor cutting performance. In future scope, different cryogenic parameters were compared in the machining test using carbide insert. We have not used any coolant and remembering that machining so it causes low surface contamination and low material ejection rate. In automated machining we will encourage in future by adding cooling and remembering that machining and making with different devices with more models

CONCLUSION

Within the limits of this study and based on the experimental results, parameters analysis, the material removal rate and surface roughness of the EN3B with the novel AlTiN coated WC tool insert is higher than conventional HSS tool insert. and surface roughness is lower with novel AlTiN coated WC tool insert than conventional HSS tool insert. The material removal rate averagely improved 46% and the Surface roughness averagely reduced by 54% with use of novel AlTiN coated WC tool insert than conventional HSS tool insert. It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR ($p= 0.021$ ($p<0.05$) and for Surface roughness $p=0.001$, ($p<0.05$).

DECLARATION

Conflict of interests

There are no conflict of interests for the authors

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

Properties	**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

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

Table 4. Input Parameters for Aluminum Titanium Nitride (AlTiN) and High Speed Steel (HSS) Insert

Trail	**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
4	50	0.25	1.00
5	70	0.10	0.50
6	70	0.15	0.25
7	70	0.20	1.00

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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	1.00
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	12.24	1453.267161	0.996
2	12.54	1911.358966	1.006
3	12.14	1464.12751	1.01
4	12.84	1474.978	1.005
5	11.14	1598.724629	0.855
6	10.99	1570.871259	0.865
7	11.54	1589.448821	0.885
8	10.85	1626.50016	0.873
9	10.32	1644.832363	0.795
10	10.44	1597.051224	0.79
11	10.43	1636.887801	0.767

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12	10.12	1605.033708	0.765
13	9.73	1733.848841	0.668
14	9.81	1683.293742	0.665
15	9.74	1726.647811	0.666
16	9.45	1719.439739	0.689

Table 6. Outputs parameters of Surface Roughness, Material Removal Rate, and CNC Run Time for Aluminum Titanium Nitride (AlTiN)

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
9	7.6	2394.933663	0.331
10	7.72	2347.152524	0.326
11	7.71	2386.989101	0.303

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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 Novel Calico Aluminum Titanium Nitride 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
MRR	A	16	1627.269483	114.5357247	28.9321065
	B	16	2377.370783	115.7284261	28.9321065

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 Aluminum Titanium Nitride (AlTiN) Coated Tungsten Carbide insert (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR ($p= 0.0021$, $p<0.05$).

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

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MRR	Equal variances assumed	0	0.0021	-18.3	30	0	750.1013	40.916177	-833.66	-666.5
	Equal variances not assumed			-18.2	30	0	732.2012	39.962677	-834.62	-667.5

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 Aluminum Titanium Nitride (AlTiN) 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
Surface Finish	A	16	0.7984	0.12999	0.02907
	B	16	0.36725	0.1258474	0.0302585

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 Aluminum Titanium Nitride (AlTiN) coated tungsten carbide insert tool (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for surface roughness ($p = 0.001$, $p < 0.05$).

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
Surface Finish	Equal variances assumed	0	0.001	10.386	30	0.000	0.464	0.0446767	0.3727	0.5552

	Equal variances not assumed			10.386	30	0.000	0.321	0.0446701	0.3727	0.5552

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.

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

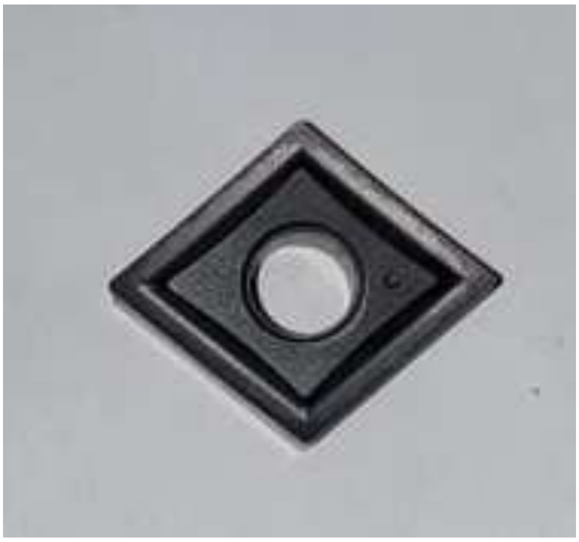

Fig .3. Calico Aluminum Titanium Nitride (AlTiN) - specification - grade of TNMG 16040 - insert thickness 4.8 mm, corner radius 0.4 mm, fixing hole diameter 3.81 mm

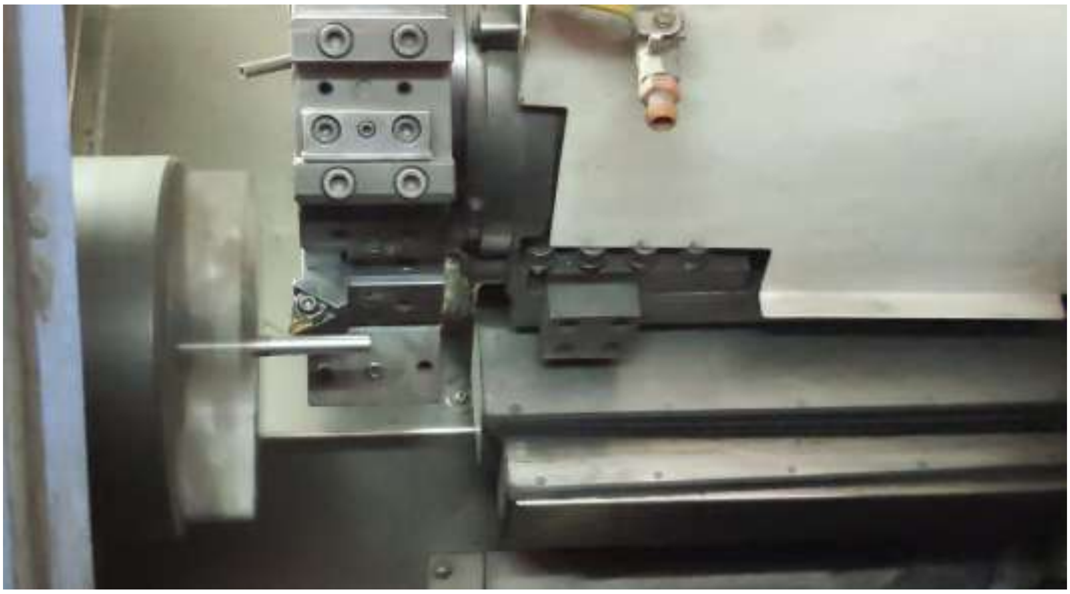

Fig .4. CNC machining process

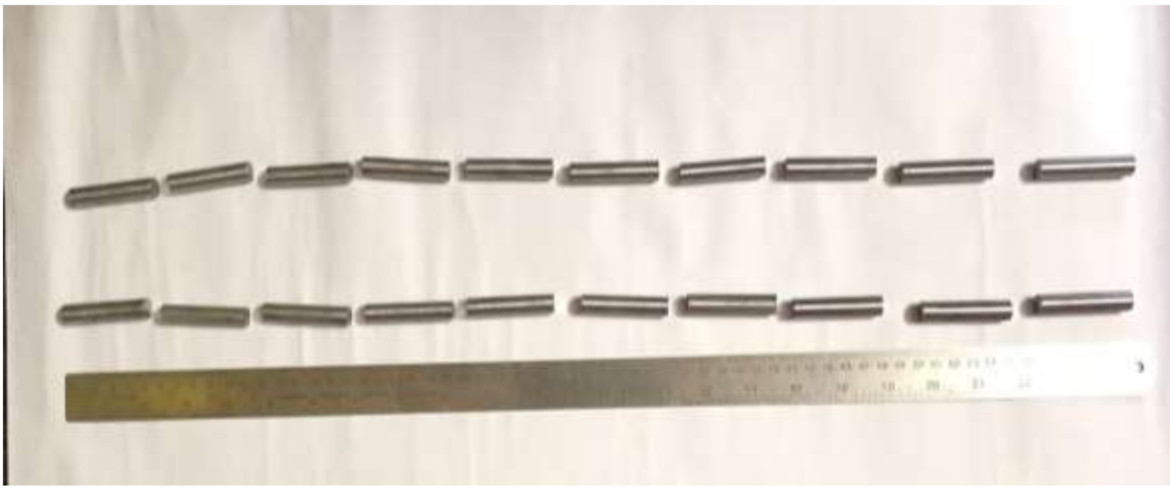

Fig.5. High Speed Steel (HSS) uncoated tool finish material

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Fig .6. CalicoAluminum Titanium Nitride (AlTiN) 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.

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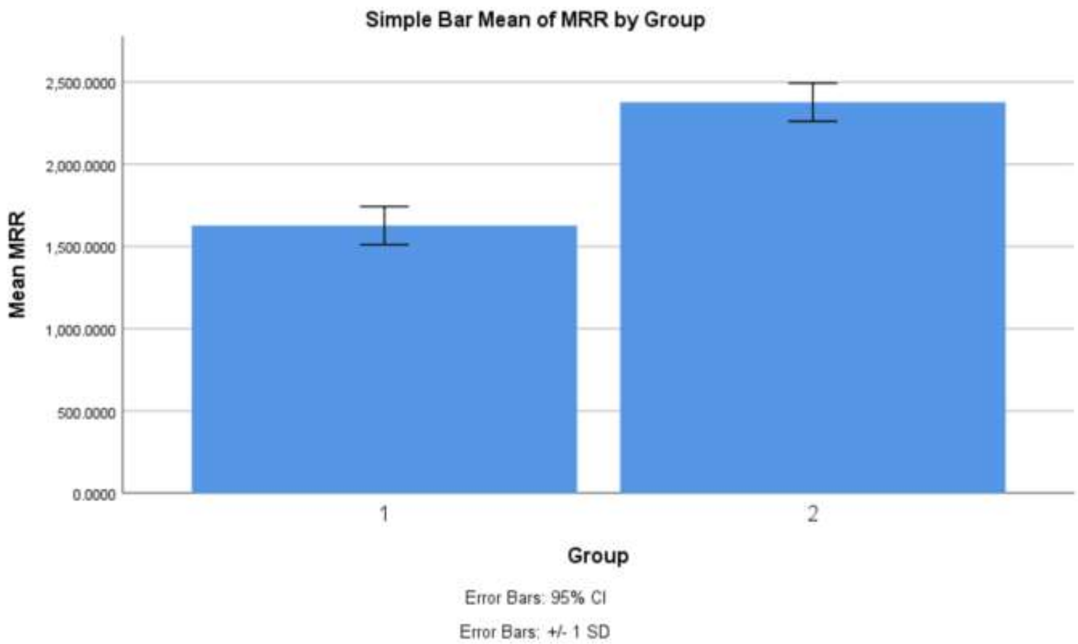

Fig. 8. Shows the sample bar between the Ra values for machined surfaces roughness using High Speed Steel (HSS) insert and CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert tool. From the graph, the lower mean Ra values were obtained as 115.7284261 micrometers using the CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert tool compared to HSS tool which has 114.5357247 micrometers. X-axis: HSS and CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert, Y-axis: mean surface roughness ± 1 SD

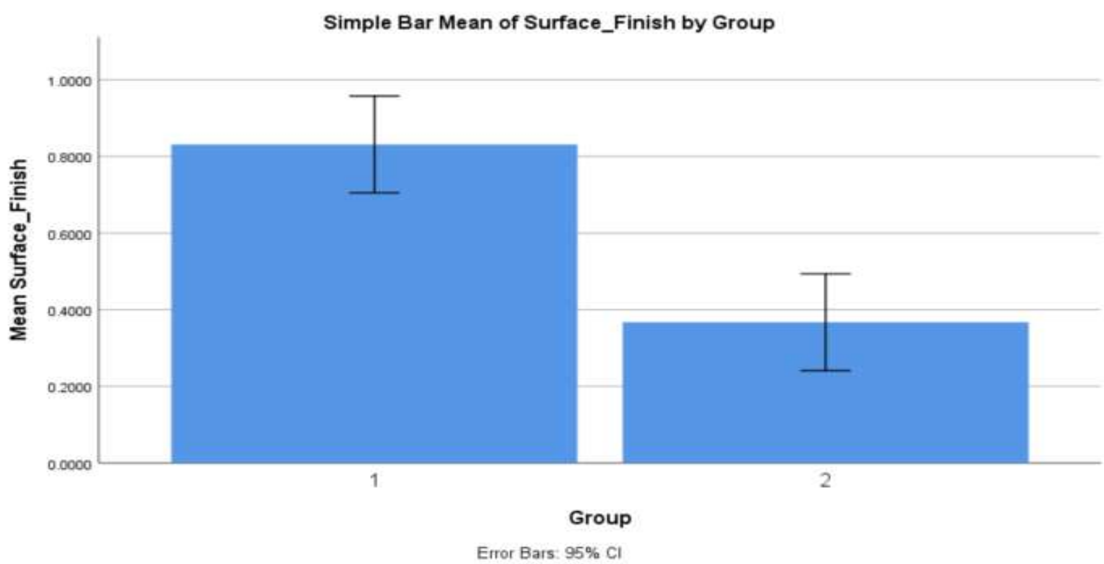

Fig .9. Shows the graph for dominating both CalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert and uncoated High Speed Steel (HSS) insert cutters in material removal rate (MRR). From these cutters theCalicoAluminum Titanium Nitride (AlTiN) coated Tungsten carbide insert cutter produced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