COMPARING MACHINABILITY PERFORMANCE OF NOVEL TITANIUM SILICON NITRIDE COATED HSSTOOL WITH UNCOATED HSS TOOL FOR COMPUTERIZED NUMERICAL CONTROL GREEN MACHINING OF UNALLOYED MEDIUM CARBON STEEL (EN8) FOR IMPROVING MACHINING RATE AND SURFACE FINISH

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Abstract

AIM: The main aim of the research is to compare Machinability performance of Novel Titanium Silicon Nitride coated High speed steel tool with Un-coated High speed steel tool for CNC green machining of unalloyed medium carbon steel (EN8) for improving machining rate and surface finish.
Materials and Methods: EN8 steel rod of diameter 20 mm and length 50 mm was used in this research work. EN8 steel was normalized at 650 degree Celsius and annealed at 840 degree Celsius with the help Quenching in oil or water after heating to this temperature will harden the steel. Test samples per group (N = 16+16=32) where CNC turning operation is used to find the surface finish taken from each rod of experimental group and control group (unalloyed EN8 steel)**.** Total sample size used for the Groups is 32 and 80% of G power is calculated using the software G Power 3.1.
Results: Within this limitations of study the confidence level of cutting parameters and the response Surface Roughness values are obtained for all machined specimens with both HSS tool and Novel Titanium Silicon Nitride coated High speed steel tool and the results done by Turning were conducted with speed, feed and depth cuts to turning process with an MRR is 350mm^3/min and depth of cut affects considerably cutting force and power (62.31% and 60.72%). And the Surface Roughness is 19.04%. Using TiSiN coated HSS tool gives lower surface roughness than HSS tool in Computerized Numerical Control machining.Then the observation shows that it is actually because the T test output significant value are: P= 0.027 for MRR and P=0.010 for SR and they are P< 0.05.
Conclusion: Within the limitations of the studies, the optimization of EN8 carbon steel Material removal rate, Surface finish and Surface Roughness using response of Novel Titanium Silicon Nitride. The results obtained revealed that spindle speed,feed rate and depth of cut have a significant influence on the MRR was also absorbed that optimum machining setting of spindle at 500 rpm, the feed rate of 0.4mm/rev and depth is 0.2mm resulted in a turning process with an MRR.

Keywords: Computerized Numerical Control, Novel Titanium Silicon Nitride coated High speed steel, Un-coated High speed steel, Surface Roughness, Material removal rate, Surface finish and Green Machining.

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1. Introduction

This research is about investigating the possibility of improving material removal rate and surface rough finish with use of Novel Titanium Silicon Nitride coated High speed steel tool for Computerized Numerical Control turning of Unalloyed Carbon medium steel (EN8) material for shaft manufacturing to improve life performance (Pujari, Srikiran, and Subramonian 2019). The biggest advantage of this research is that machining Unalloyed carbon medium steel alloy (EN8) was difficult because it has high mechanical strength and hardness . Tool inserts have more material removal rate and low surface roughness. (Aamir et al. 2021) This Unalloyed carbon medium steel (EN8) material is more suitable for the all general automotive applications required for strength than mild steel such as Shafts,Gears & Bolts. General Automotive and general engineering components and Other general engineering parts etc (Kini, Vijaya Kini, and Chincholkar 2010). The wide varieties of unalloyed carbon medium steel (EN8) material of application not only applicable for Forging, casting, Connecting bars, hub shafts and driving rods. It is utilized for minimal expense pass on material in devices and bite the dust making enterprises. This material can be solidified to give a more prominent strength and wear resistance in comparison in low carbon steels (Khan, Adam Khan, and Gupta et al.2021).

For the research last 5 years,research related to Unalloyed carbon medium steel (EN8) material resulted in around 187 research papers in google scholar and 72 research papers in science direct. The material removal rate of the workpiece is much better compared to the one which was before finished with single edge apparatuses. The surface harshness and material evacuation rate were distinguished as quality ascribe and thought to be straightforwardly connected with execution of mechanical pieces, effectiveness and creation cost for machinability. The current article manages the different info process boundaries like cutting power, Cutting pace and depth of cut (Das et al. 2017). Machinability of EN8 steel while turning with established carbide apparatuses. It is generally utilized for machinability, since it is broadly utilized in car industry for the development of pivot, roller orientation, metal balls, shear sharp edges, axle , shaping and trim passes on, rollers, blanking and framing instruments, knurling apparatuses and spline shafts, etc (Navarro-Devia et al. 2017). Turning is the important machining process for the production parts and Surface Roughness and Material Removal Rate during Turning of Unalloyed carbon medium steel (EN8) material (B. R. Kumar and Ram Kumar 2016; Abdallah 2014). The turning activity is an essential metal machining activity that is utilized generally in businesses managing metal cutting. The machining boundaries for a turning activity is a most significant errand to oversee superior execution for Novel Titanium Silicon Nitride covered High speed steel device contrasted with uncoated HSS instrument. By high creation, we mean great machinability, surface completion, high tempareature, lesser pace of hardware wear, hardness, lower temperature, higher material evacuation rate, lesser rate of tool wear,quicker pace of creation and so on Improvement machining boundaries in a turning activity gets ready to limit surface harshness (Dixit, Chatterjee, and Zhang 2021). The feed rate was the main function of the yield reaction of surface roughness constructed with different variables like turning speed. For machining boundaries of surface hardness demonstrates that cutting pace is contributing towards the machining execution for lower surface roughness.feed rate is the main variable for the surface roughness reaction when compared with other. (B. R. Kumar and Ram Kumar 2016; Abdallah 2014) Out of the above mentioned articles, the best article is mostly 20% related to my project that manages high performance for TiSiN coated HSS tool compared to Uncoated HSS tool.

Our institution is keen on working on latest research trends and has extensive knowledge and research experience which resulted in quality publications (Rinesh et al. 2022; Sundararaman et al. 2022; Mohanavel et al. 2022; Ram et al. 2022; Dinesh Kumar et al. 2022; Vijayalakshmi et al. 2022; Sudhan et al. 2022; J. A. Kumar et al. 2022; Sathish et al. 2022; Mahesh et al. 2022; Yaashikaa et al. 2022).To the best of my knowledge ,no research has been carried out to investigate for comparing with TiSiN coated High speed steel tool and Un-coated High speed steel tool in this process the best suitable is surface finishing and improved machinability. Comparing Uncoated HSS tools with moder Titanium silicon nitride tools it shows best machining process.The chemical composition of the Unalloyed carbon medium steel (EN8) material is C=0.35%-0.45%+Mn=0.60%-1.0%+Si=0.05%-0.35%+P=0.015%-0.06%+S=0.015%-0.6%+Cr%+Mo%+Ni%+N% by casting process. It is a medium strength steel with good tensile strength.It is variable as normalized or rolled. If the selection of turning tool grades,tool holder and cutting dry grades which are used in theComputerized Numerical Control turning operation. Unalloyed carbon medium steel (EN8)material with coolant. It is turned in the Computerized Numerical Control with Green

Machining to high surface roughness and to low material removal rate by the comparison of the performance of Novel Titanium Silicon Nitride coated High speed steel tool and Un-coated High speed steel insert for improving the Material Removal Rate in the manufacturing industries.

2. Materials and Methods

The material considered for the turning process is EN8 material and cutting tools are TiSiN insert and HSS insert. EN8 material is a medium strength steel with better tensile strength. Hence the two inserts were considered the process .This study was carried out in the CNC turning center which is available at Saveetha School of Engineering,Saveetha Institute of Medical and Technical Sciences,Chennai. For this research did not involve any human samples for testing, ethical approval was not required. This experimental research compares two groups namely Control group(HSS tool) and Experimental group(TISiN coated HSS tool). Number of groups should be 2,and therefore the sample size for every group is 16.The Total sample size used for the Groups is 32 and 80% of G power is calculated using the software GPower 3.1. The sample means used are 0.9675 for conventional methods and 0.9763 for proposed methods and standard deviation used was 0.23735 (Kane et al. 2021). If the pretest g power is 80%, Alpha 0.05.

For the project purpose I bought the unalloyed carbon steel (EN8) material , TiSiN coated HSS tool and HSS tool. I bought Unalloyed carbon steel (EN8) 080M40 material 20 mm diameter and 3 meter length rod at Sri sati metal shop,17A, Mugappair Road, Padi, Chennai, Tamil Nadu, 600050. And also I bought Titanium silicon nitride coated tool and Uncoated High speed steel tool (fig.1) at VINAYAGA ENTERPRISES Dealers in HSS CuttingTools,CarbideInserts,CNC Tools MAchines,#250,Kannappar Thidal,Chennai-600003. The specifications were prepared with dimensions 20*50mm and as shown in (fig.2). Control group samples are to be dry turning machining with the utilization of an HSS tool. The green machining with different combinations of input parameters. The sample length of 50 mm was prefixed. EN8 is a medium strength steel with sensible tensile strength. It is regularly provided in the virus drawn or moved condition. Tensile properties can shift yet are ordinarily between 500-800N/mm2. Titanium Silicon Nitride has wear opposition covering for fast cutting. It is covered with acceptable hardness,thermal and Oxidation resistance.In enterprise of silicon to the covering bring about the arrangement of nano composite system.Nano measured TiSiN grains are installed in formless a-sinx matrix. TiSiN is commonly covered on rapid cutting devices utilized on CNC machines for machining of solidified prepares from 50 to 60 HRC. It is generally utilized in dry machining. It is mostly used for cutting tools and drill bits. It is suitable for the older high carbon steel tools used extensively through the 1940s in that it can withstand higher temperatures without losing its temper. This property allows HSS to cut faster than high carbon steel,hence the name as high speed steel. HSS have generally displayed high hardness and abrasion resistance compared with common carbon tool steels.

Through the same work material for both groups, the Group B is an Control group in which samples are to be machined with Titanium Silicon Nitride coated HSS tool with different combination of parameters as followed for the group.

By the Computerized Numerical Control Green machining (turning operation)(fig 6) the machining for workpiece by using the Novel Titanium Silicon Nitride coated High speed steel tool and Uncoated HSS tool insert with an individual workpiece. By finishing the machining to get the material removal rate and surface roughness(fig 5) by comparing both inserts. For testing standard ISO is 4287(1997). Sample length is 50mm and measuring speed is 0.25mm/sec. Cut off length is 15mm and the average of each 16 values is taken into consideration The MRR is calculated by having the weight of the sample before and after machining.

Material removal rate =Weight Loss /Machining Time taken for machining *Density of the material

After machining the sample for limited sample length the MRR is calculated by having the weights of the sample before and after machining. The procedure repeated and average of them was considered for avoiding errors. The input specifications furnished in Table 1 presented the Computerized Numerical Control Green machining process parameters, this work took off three parameters with four levels of the rpm of Computerized Numerical Control Green Machining. TABLE 2 presented the Control group summary of the material removal rate and surface roughness with the utilization of two tools namely High speed steel and Novel Titanium Silicon Nitride coated High speed steel tool.

Statistical Analysis

Statistical analysis was administered with the utilization of 'SPSS statistics 26' software. The independent sample test performed for comparing means both the experimental group (Table 4) and control group(Table 5). The independent variables were cutting speed(50m/min), feed rate (0.10 mm/rev) and Depth off cut (0.25 mm) and therefore the variables were used for determining the MRR and Sa. The statistical analysis like T-test and independent samples test conducted. If the dependent variables are Material removal rate and Surface roughness. In this research analysis done by the SPSS software and ANOVA tables and graphs.

3. Results

The calculated Material Removal rate (MRR) and Surface roughness(Ra) value for samples of both groups (16 Samples per group) are statistically analyzed. The intervention group TiSiN Coated HSS mean 0.805125 microns is found significantly lower than the mean 1.519625 microns of the control group (HSS)(. Hence the MRR significantly improved with use of TiSiN Coated HSS tool than those samples machined with conventional HSS tools. Table 1 gives the specification of inputs utilized from the 16 experiment types. Table 2 shows the MRR of samples which were machined by HSS tools. Table 6 shows the Surface roughness values are between 0.715 and 1.786 and Material removal rate of samples which were machined by HSS tools. Table 3 shows the Material removal rate values are between 1434.01728 and 5640.820739. Table 7 reveals the results of T test like means, standard deviation, standard deviation errors of groups of TiSiN Coated HSS tool and Un-coated High speed steel tool. Table 8 shows the results of the Independent sample test to examine the test of significance. Fig 4 shows the synthesis of novel light weight material of Unalloyed cabron medium steel(EN8). Fig 3 Shows the sixteen specimens (a) before and (b) after machining images, the contour profile was machined on the highest surface roughness of each specimens. 200 mm square contour was machined with the 15mm depth; the sharp edges are machined well for smooth curve edges. All the contour profiles are to be machined with the assistance of Computerized Numerical Control turning machines. Represents the sixteen experimental runs with the response value of Material Removal Rate,Surface finish and Surface roughness. In this considered the Material removal rate and surface roughness with the influence of two tool cutters namely High Speed Steel and Titanium Silicon Nitride. Fig 1 and Fig 2 exhibits the comparison of group mean at ± 1 standard deviation level for Material Removal Rate and Surface Roughness. Then the observation shows that it is actually because the T test output significant value $P< 0.05$ and $P= 0.027$ fior MRR and $P=0.01$ for SR.

4. 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 0.027 for MRR and p=0.01 for SR. From the fig 1, it shows the parameters of speed, feed and depth of cut. This formula is used for both Titanium Silicon Nitride (TiSiN) coated High speed steel insert and HSS tool insert. The influence of cutting conditions is that the cutting speed has a small effect compared with that of the feed rate and the depth of cut and this can be noted in SPSS analysis.

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(Audy 1995). When high cutting speed, lower depth of cut, and high feed rate provide increased MRR (Aamir et al. 2021). They show smart significance statistically with a significance worth $p<0.05$. The MRR of the composite was considerably reduced with the usage of the TiSiN coated HSS tool once it is compared to the HSS tool (Arunnath and Haja Syeddu Masooth 2021; Abdallah 2014). Also, alternative parameters that were influencing MRR and surface roughness are unit depth of cut and feed rate that's equally declared (Arunnath and Haja Syeddu Masooth 2021) If feed rate and depth of cut increases then Material rate rate also will increase and Surface roughness reduced supported this it is often stated that MRR was improved by 25.069% and the surface roughness reduced by 19.010% with the utilization of TiSiN coated HSS tool than conventional HSS tool. Because of the usage of a minimal range of input parameters(Das et al. 2017). Also, usage of coated Titanium Silicon Nitride tool in Computerized Numerical Control machining in turning (K. Kumar, Ranjan, and Paulo Davim 2020). Further, this study showed that TiSiN coated HSS tool is suitable for this particular composite to urge maximized MRR as increased MRR is required for each application to urge improved MRR (Dixit, Chatterjee, and Zhang 2021). Since the TiSiN coated HSS tool is usually recommended tool for Computerized Numerical Control machining in specific operation namely contour turning with this maximal range of input parameters during which higher speed, higher feed rate, and lower depth of cut gives maximized MRR (Çiçek et al. 2021). For this composite this work reports experimental analysis of the Computerized Numerical Control turning process to measure the effect of cutting parameters to urge the highest quality of turning materials (Kane et al. 2021). During this research, only three factors namely Material removal rate , Surface roughness and die material are considered.

From the above discussions, it is understood that apart from standard input variables (feed, speed, and depth of cut) the tool hardness and cutting zone temperatures play an enormous role in Material Removal Rate and Surface Roughness. Because the TiSiN coated HSS tool is way harder than the HSS tool the results improved high Material removal rate and low surface roughness significantly.

Though the results improved significantly this research features a couple of limitations. As this study focused on Green manufacturing it doesn't consider coolant effects on MRR but coolant will significantly contribute to reducing the MRR. The study was limited to using TiSiN coated HSS tools to increase Material removal rate and reduced surface roughness. The future scope can investigate the wet machining properties with various non corrosive coolants including cryogenic, nanofluids etc.

5. Conclusion

Within this limitation of the study, the Computerized Numerical Control turning of the Unalloyed carbon medium steel (EN8) material with Titanium Silicon Nitride coated HSS tool and Un-coated High speed steel were compared for increasing Material Removal Rate and decreasing Surface Roughness. The result shows that the group of samples which machines with TiSiN coated HSS tool and Un-coated High speed steel tool resulted in less surface roughness than HSS tool.Hence the proposed tool reduced surface roughness by 19.010% and material removal rate by 25.069%.

Declarations

Conflict of internet

The author of this paper declares no conflict with the internet in this manuscript.

Authors Contribution

Author PL was involved in data collection, data analysis and manuscript writing. Author TS was involved in Conceptualization, data validation and critical review of the manuscript.

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Tables and Figures

Table 1. Machining parameters

Factors	Level 1	Level 2	Level 3	Level 4
Cutting speed (rpm)	500	700	900	1100
Feed (mm/rev)	0.4	0.8	1.2	1.6
Depth of Cut (mm)	0.2	0.4	0.6	0.8

Table 2. Testing Procedure

Parameter	Value
Standard ISO	4287 (1997)
Sampling Length	50mm
Measuring Speed	0.25 mm/sec
Cut Off Length	15 mm

Table 3. Input Parameters for High Speed Steel (HSS) Insert

Trail	Speed (RPM)	Depth of Cut (mm)	Feed (mm/rev)	Before Machining weight (gm)	After Machining Weight (gm)	CNC Run Time (sec)	Material Removal Rate (g)	Surface Roughness (µm
1	500	0.2	0.4	124	123	5.33	1434.01728	1.786
2	500	0.4	0.8	124	123	5.73	2333.911362	1.519
3	500	0.6	1.2	124	121	5.8	3953.437294	1.248

4	500	0.8	1.6	124	120	5.95	4138.361077	1.108
5	800	0.2	0.4	124	123	5.44	1405.020607	1.113
6	800	0.4	0.8	124	123	5.84	1808.786319	1.985
7	800	0.6	1.2	124	122	5.91	2586.569239	1.011
8	800	0.8	1.6	124	122	6.06	2522.545248	1.155
9	1100	0.2	0.4	124	123	5.55	1377.173352	1.264
10	1100	0.4	0.8	124	122	5.95	2569.180538	1.332
11	1100	0.6	1.2	124	122	6.02	2539.306346	1.197
12	1100	0.8	1.6	124	121	6.17	3716.359207	1.256
13	1400	0.2	0.4	124	122	6.12	2497.814412	1.743
14	1400	0.4	0.8	125	123	6.09	2510.118917	1.248
15	1400	0.6	1.2	124	122	6.1	2506.003968	1.204
16	1400	0.8	1.6	123	119	6.4	3777.070064	1.049

Table 4. Input Parameters for Titanium Silicon Nitride (TiSiN) coated High speed steel Insert

Trail	Speed (RPM)	Depth of Cut (mm)	Feed (mm/rev)	Before Machining weight (gm)	After Machining Weight (gm)	CNC Run Time (sec)	Material Removal Rate (g)	Surface Roughnes s (µm)
1	500	0.2	0.4	124	123	4.35	1757.083242	0.741
2	500	0.4	0.8	124	123	4.75	2609.118337	0.721
3	500	0.6	1.2	124	121	4.82	5757.248196	0.732
4	500	0.8	1.6	124	120	4.97	6151.559036	0.971
5	800	0.2	0.4	124	123	4.46	2113.211	0.734
6	800	0.4	0.8	124	123	4.86	2572.697963	0.715
7	800	0.6	1.2	124	122	4.93	3100.735133	0.742
8	800	0.8	1.6	124	122	5.08	4009.117993	0.968
9	1100	0.2	0.4	124	123	4.57	1672.497178	0.754

10	1100	0.4	0.8	124	122	4.97	3075.779518	0.739
11	1100	0.6	1.2	124	122	5.04	3533.060358	0.761
12	1100	0.8	1.6	124	121	5.19	4418.099481	0.952
13	1400	0.2	0.4	124	122	5.14	2974.054102	0.756
14	1400	0.4	0.8	125	123	5.11	2991.511586	0.738
15	1400	0.6	1.2	124	122	5.12	4985.245779	0.765
16	1400	0.8	1.6	123	119	5.42	5640.820739	0.932

Table 5. Results of t-test for sample of Unalloyed Carbon medium steel (EN8)Material which were machined by two methods. Group A samples are machined by HSS tool and Group B samples are machined by TiSiN coated HSS tool. The sample means of the proposed method (Group B) is significantly higher than the conventional HSS tool used in the sample group A for Material removal rate.

Group Statistics					
	Composite	N	Mean	Std. Deviation	Std.Error Mean
MRR	HSS	16	2604.72970	888.726762	222.181690
	TiSiN Coated HSS Tool	16	3585.11905	1431.344161	357.836040

Table 6. Results for Independent samples test for CNC turning of Unalloyed Carbon medium steel (EN8) Material machined with conventional HSS tool (Group 1) and proposed TiSiN coated HSS tool (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR (p= 0.027, p<0.05).

Independent Samples Test									
	Levene's test for Equality of variances		T test for equality of Means						
	F	Sig.	t	df	sig. (2 tailed)	Mean Difference	Std. Error Difference	95% confidence interval of the Difference	
								Lower	Upper

MRR	Equal variances assumed	5.0	0.027	-2.32	30	0.027	-980.38	421.20	-1840.59	-120.17
	Equal variances not assumed			-2.32	25.0	0.028	-980.38	421.20	-1847.75	-113.02

Table 7. Results of t-test for sample of Unalloyed Carbon medium steel (EN8)Material which were machined by two methods. Group A samples are machined by HSS tool and Group B samples are machined by TiSiN coated HSS tool. The sample means of the proposed method (Group B) is significantly lower than the conventional HSS tool used in the sample group A for Surface Roughness.

Group Statistics					
	Composite	N	Mean	Std. Deviation	Std.Error Mean
Ra	HSS	16	1.32612	0.283735	0.070934
	TiSiN Coated HSS Tool	16	0.81931	0.104692	0.026173

Table 8. Results for Independent samples test for CNC turning of Unalloyed Carbon medium steel (EN8) Material machined with conventional HSS tool (Group 1) and proposed TiSiN coated HSS tool (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for SR ($p= 0.010$, $p<0.05$).

Independent Samples Test										
		Levene's test for Equality of variances		T test for equality of Means						
		F	Sig.	t	df	sig. (2 tailed)	Mean Difference	Std. Error Difference	95% confidence interval of the Difference	
									Lower	Upper

Ra	Equal variances assumed	7.5	0.01	6.70	30	0.000	0.506812	0.07560	0.3254	0.661
	Equal variances not assumed			6.70	19.010	0.000	0.506812	0.07560	0.3456	0.665

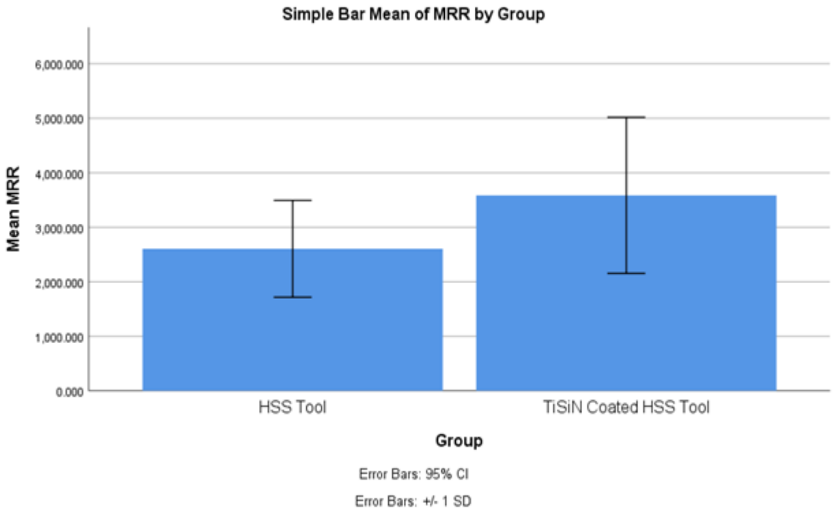

Fig. 1. Shows the figure for dominating both coated and uncoated tool cutters in Material Removal Rate. From these cutters the TiSiN coated HSS Tool cutter produced high MRR even in variation of cutting speed, feed and depth of cut. X-axis: HSS and TiCN Coated HSS Tool, Y-axis: Mean MRR of detection ± 1 SD.

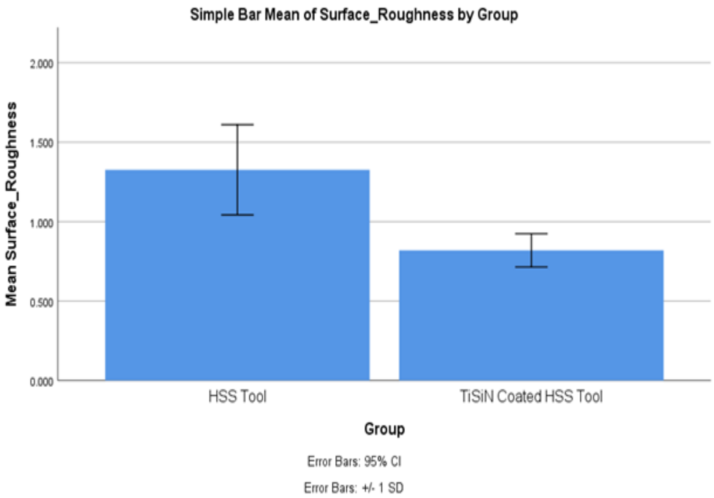

Fig. 2. Shows the figure for dominating both coated and uncoated tool cutters in Surface Roughness. From these cutters the TiSiN coated HSS Tool cutter produced low Surface Roughness even in variation of cutting speed, feed and depth of cut. X-axis: HSS and TiSiN Coated HSS Tool, Y-axis: Mean Sa of detection ± 1 SD.

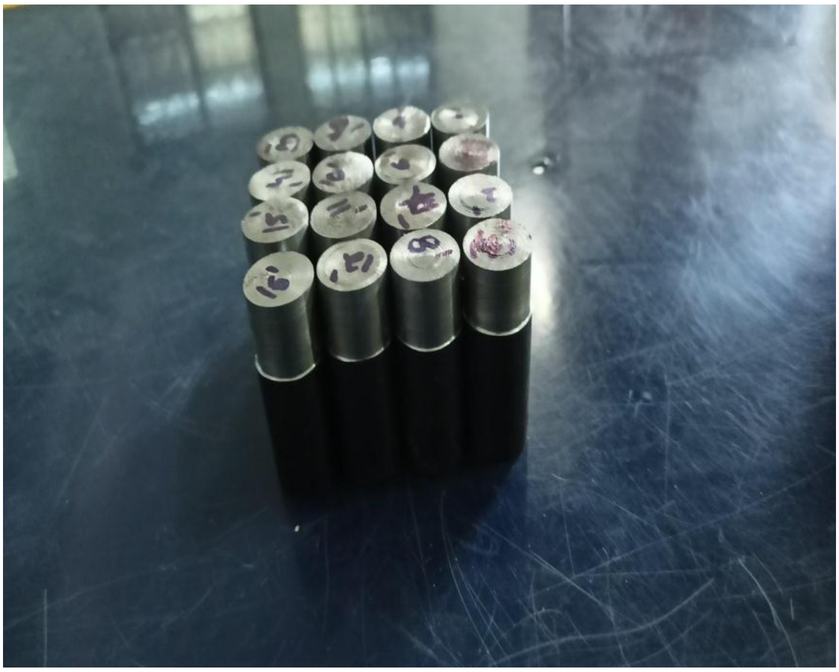

Fig. 3. Samples after machining

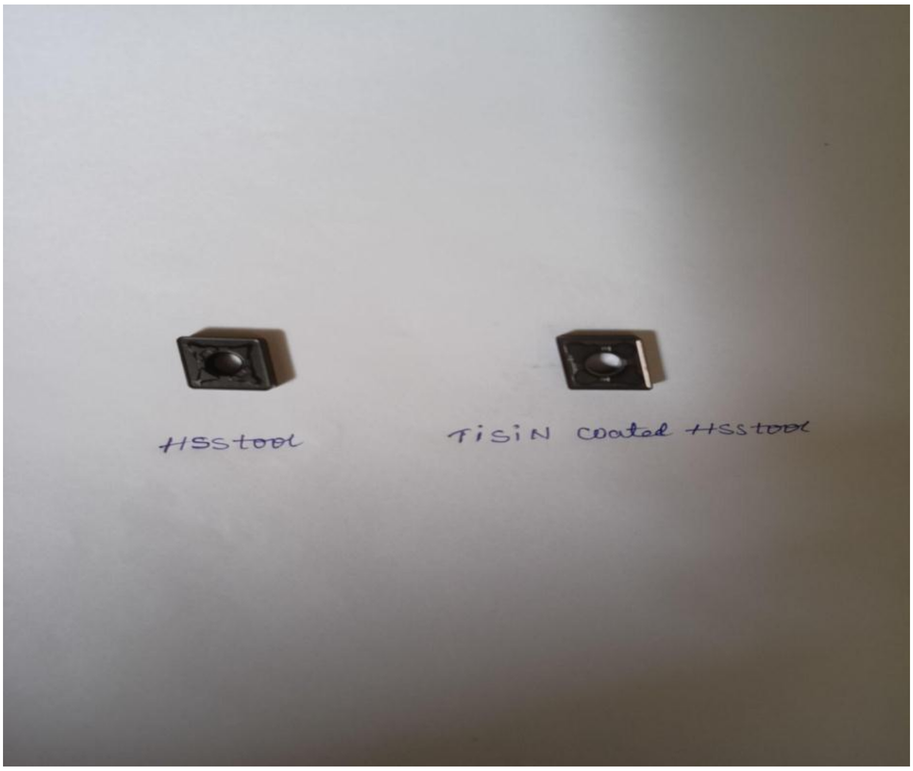

Fig. 4. HSS Tool and TiSiN coated HSS Tool

Fig. 5. Surface Roughness testing machine

Fig. 6. CNC machine (Turning)