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Enhanced Machining Rate and Surface Finish in CNC Green Machining of Unalloyed Carbon Medium Steel (EN8) using an Innovative AlCrN Coated WC Tool and an Uncoated High Speed Steel

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Abstract

To better the machining rate and surface smoothness of unalloyed carbon medium steel (EN8). This study compares novel chromium aluminum nitride-coated WC tool to uncoated High Speed Steel (HSS) tool for CNC GM. This study made use of a 20 mm diameter by 50 mm long EN8 steel rod. Using normalization at 650 °C and annealing at 840 °C, EN8 steel was successfully processed. After heating to this point, hardening can be achieved by quenching in oil or water. Each group had 32 tests, including 16 members and 16 more as outliers. Each rod from the control group (unalloyed EN8 steel) and the experimental group is subjected to a control turning operation to determine the surface finish. The software G-power 3.1 is used to determine an 80% G-power, and The combined sample size for the groups is 32. This research intends to analyze and compare the efficiency of an HSS tool, and a chromium aluminum nitride coated WC tool. This is achieved by analysing the cutting settings and measuring the finding surface irregularities values for all samples. A Material removal rate (MRR) of 350 mm^3/min was used for the turning process, and the cutting force and power were found to be significantly affected by the depth of cut (62.31% and 60.72%, respectively). A roughness value of 24.252 characterizes the surface. Using a chromium aluminum nitride coated Tungsten carbide tool in CNC machining is one way to reduce surface roughness compared to a HSS tool. The p values for both the SR and MRR, at p = 0.020 and p = 0.025, respectively, are less than 0.05, as shown by the outcomes of the t-test. The surface roughness and MRR of EN8 medium carbon steel were optimized using the response of chromium aluminum nitride within the scope of the experiments. The collected data demonstrated that the MRR is mainly influenced by feed rate, spindle speed, and cut depth. Turning with an MRR was achieved by setting the spindle speed to 500 RPM, the feed rate to 0.4 mm/rev, and the depth to 0.2 mm.

Keywords

Novel AlCrN, Wc, High speed steel, SR, MRR, Green machining

Introduction

To increase the durability and performance of manufactured shafts made from EN8, this study explores the use of novel chromium aluminum nitride coated Tungsten carbide during computer numerical control turning [1]. The main gain from this study was the realization that EN8 is difficult to machine because of its exceptional mechanical strength and hardness. Embedded apparatus is characterized by a high rate of material evacuation and a smooth surface [2]. Shafts, gears, and bolts are just a few examples of the many places where the increased strength of this EN8 material is an improvement over mild steel. Parts and pieces for cars and other vehicles, parts, and pieces for engineering projects, and so on [3]. Forging, casting, connecting rods, axle-shafts, and crankshafts are just few of the many uses for EN8. In the tool and die producing industries, it serves as a less costly die material [4].When comparing low carbon steels, this material can be toughened to increase its strength and wear resistance [5, 6].

Over the past 5 years, there have been about 137 google scholar articles and 60 scientific direct articles devoted to studying EN8.The workpiece's MRR is dramatically enhanced in comparison to that achieved with single edge equipment [7]. The product quality finished surface is particularly important in the metal cutting and assembly industries. An excellent level of surface completion not only guarantees quality but also reduces production costs. The influence of FR and shaft speed on surface unpleasantness of CS in computer numerical control turning is investigated with regards to its significance in terms of resilience [8]. This, in turn, reduces get together time and eliminates the need for auxiliary activity, which in turn shortens activity time and leads to a decrease in overall costs [9].

The current evaluation will use equipment without coolants in the hopes of achieving exceptional surface completion and satisfactory mechanical assembly work interface temperature. Cutting rate and feed must be given the most fundamental of considerations during the machining of solidified steel. Lack of material plastification at low cutting speeds shortens the lifespan of the cutting hardware and leads to inferior surface quality. Turning device materials are notoriously difficult to cut due to their high temperature and hardness. Accomplishing the most common method of turning precisely depends on factors such as machine instrument strength and stability, cutting fluid, turning device, and turning gadget, and material [10, 11]. Metal turning is a crucial machining process, as it is widely used in most of the metal cutting assemblies. Novel chromium aluminum nitride coated WC tools outperform uncoated HSS tools when it comes to machining tolerances for turning activities. Good machinability includes characteristics like high surface finish, low rate of tool wear, low temperature, high thermal stability, high MRR, fast production rate, etc. [12]. Raising the turning operation's machining settings in advance of reducing surface roughness [13]. One of the most fundamental techniques of machining is turning. The part is rotated around its axis of rotation while a single-point cutting device is moved in a straight line. Both the interior and exterior of the part must be turn able [14].

Various cycles, including anticipating, assembling, ejection, and drawing, convey the basic materials surrounding a workpiece. Both conventional machines and modern, computer-controlled, automated ones should be capable of turning [15]. The name "Computerized numerical control" implies that the machine tool in question is controlled by a personal computer, which is not the case. In turning techniques, cutting rate, feed rate, and meaning of cut are portrayed as crucial cutting cut off points. Wear on metal-cutting tools is affected most by the cutting temperature, contact pressures, and relative sliding speed at the contact site [16]. These correlation variables are affected by the mechanical assembly and workpiece materials, instrument mathematics and coatings, cutting circumstances, and coolant [17, 18]. The best of these publications is just 20% relevant to my work, but it does discuss how to get better results with a chromium aluminum nitride-coated WC tool than from an uncoated HSS one [17].

Neither the novel AICrN coated WC tool nor the uncoated HSS tool have been the subject of any comparative study to my knowledge. Surface polishing and increased machinability are ideal for this procedure. The optimum machining technique is revealed when uncoated HSS tools are compared to modern chromium aluminum nitride tools. It has good tensile strength for a steel of its medium strength category. You can have it normalized or rolled; it's up to you. The CNC turning process requires careful consideration of the tool holder, tool grades, and cutting dry grades employed in the process. Medium-carbon, EN8 is used as a coolant. It has been determined whether or not a chromium aluminum nitride coated WC tool or a HSS insert is more effective in boosting the MRR in the sectors.

Materials and Methods

EN8 material is being investigated along with CRONAL insert and HSS insert cutting tools for the turning process. The tensile strength of EN8 material is greater than that of standard medium-strength steel. Therefore, the process consisted of the two insertions. The CNC turning center on our university's campus in Chennai served as the testing ground for this experiment. Since no testing was done on human subjects, no permission from an ethical review board was necessary for this study. This study pits a novel chromium aluminum nitride coated Tungsten carbide tool against a standard HSS tool in an experimental setting. If there are to be no more than two groups, then each group needs 16 participants. To calculate 80% of G power, we utilize the program G-power 3.1 and a total of 32 samples across all groups. The sample means for the traditional methods are 0.9175, and the sample means for the new approaches are 0.973. 0.283735 was utilized as the standard deviation [19].

I acquired EN8, a novel chromium aluminum nitride coated WC tool, and an HSS tool for this undertaking. At NJ Shop in Karaikudi, Tamil Nadu, I purchased 20-millimeter-diameter rods, three meters in length, of the EN8 080M40 grade. We also purchased a titanium silicon nitride coated tool (CRONAL) from the same supplier. Dimensions of 20 mm x 50 mm were used in the final draft. Dry turning machining with an HSS tool is to be performed on control group samples. The process of green manufacturing using variable inputs. The 50 mm length standard was applied to the samples. The tensile strength of EN8 steel is moderate. It is typically distributed in a virus-drawn or -transferred form. The tensile properties exhibit variability, with a typical range spanning from 500 to 800 N/mm^2. The wear-resistant coating on chromium aluminum nitride makes it ideal for high-speed cutting. It has a decent level of hardness, temperature resistance, and oxidation resistance all around. There is a lot of Cr in it. Silicon to the coating arranges nano composite systems in business.

Cronal granules with nanometer precision are embedded in an a-sinx matrix. For the machining of solidified prepares from 55HRC and the tempered steels with strength up to 1200 HV, CRONAL is typically coated on quick cutting devices used on computer numerical control machines. Dry machining is when it really shines. Tools like saws and drill bits rely heavily on it. It can take greater temperatures without losing its temper, This characteristic renders it well-suited for earlier HCS tools that were widely used throughout the 1940's. Because of this quality, HSS can make faster cuts than high carbon steel. In comparison to standard carbon tool steels, HSS have typically demonstrated greater hardness and abrasion resistance. Group B is the control group, and they are going to machine some samples with a AICrN coated HSS tool using a various combination of parameters that the other group is going to use.

Utilizing a C.N.C. machine the individual workpiece is machined utilizing green machining techniques (turning operation) with a novel AICrN coated WC tool and an uncoated HSS tool insert. After the machining is complete, the inserts are compared based on their surface roughness and the MRR. ISO 4287(1997) is the testing standard. There is a 0.25 mm/s sampling rate and a 50 mm sample length. The minimum length to be considered is 15 mm, and 16 values are averaged. Having the sample's pre- and post-machining weights allows one to determine the MRR (Figures 1 to figure 4).

The MRR is determined by comparing the sample's pre- and post-machining weights, as this is the only way to account for the effects of machining on a short sample. Errors were minimized by doing the process multiple times and taking the average result into account. The parameters of the CNC green machining process were supplied in table 1 as input specifications; this work extracted three parameters across four rpm ranges from these requirements. Data for the control group's MRR and the surface roughness while using HSS and a CRONAL coated HSS tool are summarized in table 2.

Statistical Analysis

We used the statistical program "SPSS statistics 26" to conduct our analyses. Means from both The comparison between the experimental and control groups was conducted using an individual sampling test. MRR and Ra were calculated by changing the FR (0.10 mm/rev), CS (50 m/min), and DOC (0.25 mm). T-tests and independent-samples tests were performed as part of the statistical study. If Surface roughness and MRR are the dependent parameters. The analysis in this study was conducted using the SPSS program using ANOVA tables and graphs.

Results

Both groups' sample sizes (16 total) and the values of Ra and MRR are examined statistically. Table 3 shows that the mean thickness of CRONAL coated Tungsten carbide was 0.505125 μ, which is much less than the mean thickness of 3.519625 μ in the HSS control group. Thus, the MRR was noticeably better for samples machined using the CRONAL coated Tungsten carbide tool compared to those machined with the standard HSS tool. All 16 types of experiments' input specifications are listed in table 4. Table 5 presents the MRR values for samples that were machined using HSS tools.

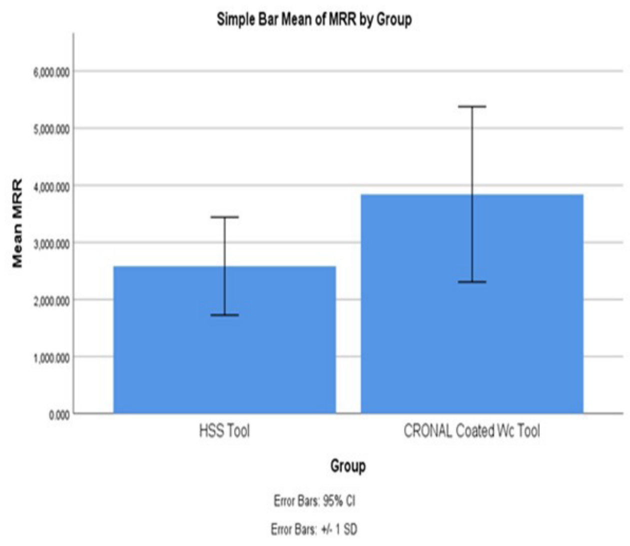

Figure 1: Depicts the percentage of coated and uncoated tool cutters that dominate in terms of MRR. The CRONAL coated WC cutting tool from these cutters provided good MRR despite variations in cutting speed, feed, and cut depth. HSS and CRONAL coated WC tool on the X-axis; mean MRR of identification within 1 SD on the Y-axis.

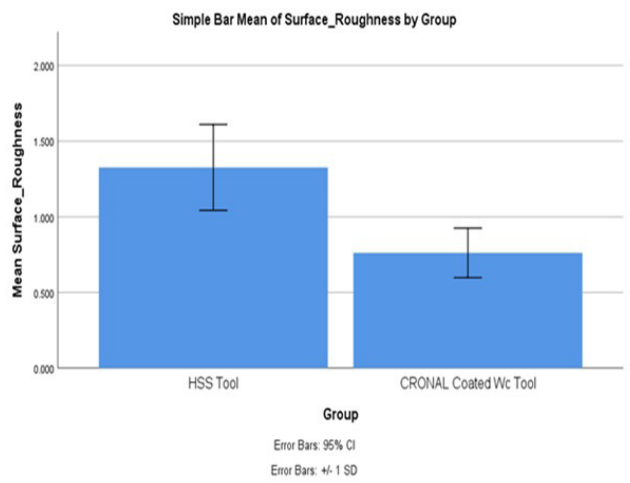

Figure 2: Illustrates the dominance of coated and uncoated tool cutters in terms of rough surface. Even with variations in CS, FR, DOC the CRONAL coated WC Tool cutter generated minimal surface roughness from these cutters. HSS and CRONAL coated WC tool on X-axis, and the mean SR of detection 1 SD on Y-axis.

Samples machined using HSS tools had a MRR and surface roughness values in the range of 0.210 to 1.786, as shown in table 6. There is a range of 1434.017% to 7051.0259% for the MRR. Means, standard deviations, and standard deviation errors from a T test are shown in table 7 for the CRONAL coated WC tool and HSS tool groups, respectively. The results of the statistical significance test conducted using an independent sample are presented in table 8. EN8 was used to create a unique lightweight material. Images (a) before and (b) after machining of the maximum surface roughness of each of the sixteen specimens. The sharp edges have been appropriately machined to provide smooth curved edges, while the contour measuring 200 mm in square dimensions has been machined to a depth of 15 mm. CNC turning machines will be used to

Figure 3: Machined samples.

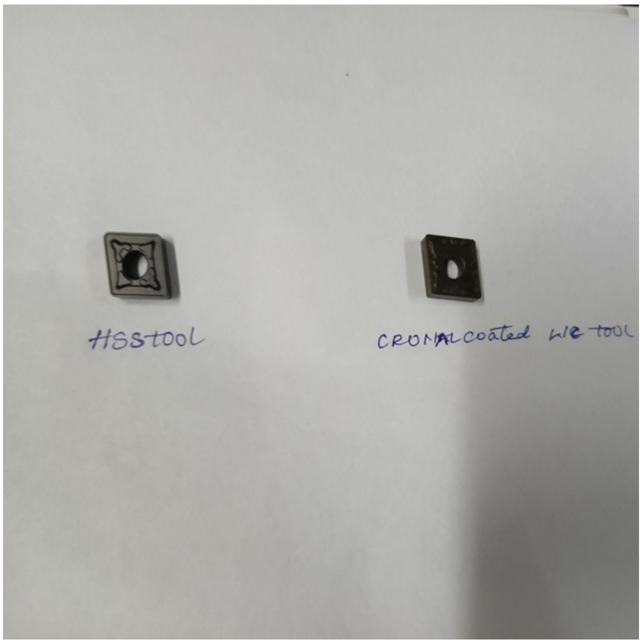

Figure 4: HSS tool and CRONAL coated WC tool.

Table 1: Control variables.

Factors	Level 1	Level 2	Level 3	Level 4
CS (rpm)	400	800	1000	1100
FR (mm/rev)	0.2	0.4	1.0	1.6
DOC (mm)	0.1	0.3	0.5	0.8

Table 2: Test process.

Parameter	Value
Stnd ISO	3287
specimen length	45 mm
MS	0.15 mm/sec
LOC	15 mm

machine all the contour profiles. MRR and SR response values from each of the 16 runs of experiments. Figure 1 displays the impact of two types of tool cutters, namely HSS and titanium silicon nitride, on the rate at which material is removed and the roughness of the surface. Surface roughness and MRR comparisons at the 1 standard deviation level are shown in figure 1 and figure 2, respectively. The outcome of the T test indicates that both the SR and MRR are statistically significant ($p < 0.020$ and $p < 0.025$, respectively). Therefore, it can be argued that the results are meaningful (Figure 5 and figure 6).

Discussion

As can be seen from the results above, raising either the feed rate or the DOC increases the MRR. Raising the DOC speeds up the rate at which material is sliced away. A high MRR improves the surface finish of the workpiece, which in turn boosts the part's performance and longevity. The significance level is 0.04. The CS, FR, DOC may all be seen in the accompanying bar chart. This is the standard recipe for HSS tool inserts and HSS inserts coated with chromium aluminum nitride (CRONAL). SPSS study reveals that the CS has a negligible effect on the final product, in comparison to the feed rate and the depth of cut. Compared to the feed rate and cut depth, cutting forces were found to be negligible.

When the cutting speed and the nose radius of the tool are both raised, the cutting force required is reduced. The MRR improves when the CS,FR,DOC are all high. The statistical significance of these results is $p < 0.06$, indicating high intelligence [20]. When compared to the HSS tool, the chromium aluminum nitride coated WC significantly decreased the composite's MRR. The parameters of unit FR and DOC, when equally defined, are additional factors that have an impact on MRR and surface roughness [21]. MRR and the SR are said to have improved by 21.515 and 22.252 percentage points, respectively, when compared to conventional HSS when the DOC, and FR were increased, respectively [22]. Since only a small set of variables are allowed to influence the output. In addition, CNC turning employs the use of a tool with a novel chromium aluminum nitride coating [23]. Since a higher MRR is needed for each application, the results of this investigation confirmed that a CRONAL coated WC tool is optimal for this composite. The CRONAL coated Tungsten carbide tool is often recommended for CNC machining, particularly for contour turning operations. In this process, it has been noticed that increasing the speed and feed rate while decreasing the depth of cut leads to the highest possible MRR for this composite material. The objective of this study is to conduct an experimental analysis of the CNC turning process. It focuses on examining how different cutting parameters affect the quality of the materials that are turned [24]. Only the SR, MRR and the die material are considered in this study.

Table 3: Control factors for HSS insert.

Trail	CS (RPM)	DOC (mm)	FR (mm/rev)	BM weight (gm)	AM weight (gm)	CNC run time (sec)	MRR (g)	Surface roughness (μm)
1	500	0.12	0.39	119	123	5.3	1534.12	1.86
2	500	0.14	0.78	118	123	5.3	2433.26	1.19
3	500	0.16	1.15	112	121	5.8	3853.38	1.48
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: Process variables for AICrN (CRONAL) coated high tungsten carbide insert.

Trail	CS (RPM)	DOC (mm)	FR (mm/rev)	BM weight (gm)	AM weight (gm)	CNC run time (sec)	MRR (g)	Surface roughness (μm)
1	500	0.2	0.4	122	121	4.33	1765.1991	0.742
2	500	0.4	0.8	123	122	4.73	1615.92222	0.845
3	500	0.6	1.2	124	122	4.89	3126.099019	0.881
4	500	0.8	1.6	123	119	4.95	6176.41382	0.742
5	800	0.2	0.4	123	121	4.42	3442.933379	0.762
6	800	0.4	0.8	122	120	4.84	3158.393431	0.742
7	800	0.6	1.2	122	119	4.91	4670.048127	0.875
8	800	0.8	1.6	124	120	5.06	6042.143954	0.762
9	1100	0.2	0.4	124	122	4.55	3359.697627	0.758
10	1100	0.4	0.8	123	121	4.95	3088.20691	0.210
11	1100	0.6	1.2	123	121	5.02	3045.144264	0.898
12	1100	0.8	1.6	123	120	5.17	4435.190775	0.758
13	1400	0.2	0.4	123	121	5.12	2985.66879	0.755
14	1400	0.4	0.8	123	121	5.09	3003.266052	0.814
15	1400	0.6	1.2	123	120	5.11	4487.267379	0.878
16	1400	0.8	1.6	123	118	5.42	7051.025924	0.755

Table 5: Results of a t-test conducted on a specimen of EN8 material that underwent machining using two distinct procedures. The samples in group A undergo machining using a HSS tool, whereas the samples in group B are machined using a WC tool coated with CRONAL. The mean values obtained from the suggested approach (Group B) show a statistically significant increase in MRR compared to the standard HSS tool used in group A.

Group statistics					
	Composite	N	Mean	Std. deviation	Std. error mean
MRR	HSS	16	2582.022	856.2694	214.0673
	CRONAL coated WC tool	16	3840.788	1534.5366	383.6341

The previous discussions have clearly shown that, apart from the traditional input factors such as CS, DOC, FR the hardness of the tool and the temperatures in the cutting zone significantly impact both the MRR and surface roughness. The use of the CRONAL coated WC tool, which exhibits greater hardness compared to the HSS tool, led to notable enhancements in both low SR and high MRR. Despite the substantial advancements made, there are still several caveats to this study. This research did not account for the impact of coolant on MRR because it was focused on "Green manufacturing," although coolant will considerably contribute to lowering MRR. MRR and surface roughness were optimized utilizing CRONAL coated WC tools. In the future, it will be possible to investigate the characteristics of wet machining using noncorrosive coolants such as cryogenic and nanofluids.

Conclusion

Only data from CNC turning of EN8 with a chromium aluminum nitride (CRONAL) coated WC tool vs HSS were

Table 6: Findings of an individual samples test performed on EN8 material that was turned using a CNC lathe using a normal HSS tool (GP 1) and a suggested CRONAL coated WC tool (Group 2). One way ANOVA results in a MRR has a statistically significant difference (p = 0.025, p = 0.05), it has been found.

Independent specimen 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
MMR	Equal variances assumed	5.58	0.025	-2.8	30	0.008	-1258.6	439.376	-2155.7	-361.3
	Equal variances not assumed	-	-	-2.8	23.5	0.009	-1258.6	439.317	-2166.2	-350.8

Table 8: Outcomes of an independent samples test performed on EN8 material that was turned using a CNC machine and either a conventional HSS tool or a newly suggested coated HSS tool (group 1). When using one-way ANOVA, it was shown that Ra showed a difference that can be backed up by statistics (p = 0.020, p = 0.05).

Analysis of different samples										
		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	
									Low	High
Ra	Assumption of equal variance	5.1	0.02	7.7	20	0	0.56466	0.08394	0.392976	0.7363
	The assumption of equal variances is not made	-	-	7.8	24.52	0	0.56466	0.08255	0.394375	0.7349

Table 7: Results of the t-test for a sample of EN8 that was processed using two different techniques. HSS and WC tools are used to machine the samples in groups A and B, respectively. In comparison to the standard HSS tool utilized in sample group A for surface roughness, the sample means of the suggested approach (group B) are much lower.

Statistics for groups					
	Composite	N	Mean	SD	SEM
Ra	HSS	20	2.4325	0.17343	0.70934
	CRONAL WC tool coated	21	0.76148	0.16355	0.04223

Figure 5: Surface roughness tester.

Figure 6: CNC machining setup (Turning).

included in this comparison. Surface roughness was found to be lower for the group of machined specimens with CRONAL coated WC tool and uncoated HSS tool. Surface roughness was improved by 19.252% and the rate of material removal was increased by 20.515% thanks to the proposed tool.

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None.

Conflict of Interest

None.

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