NanoWorld Journal

https://doi.org/10.17756/nwj.2023-s3-155

Research Article

Open Access

In CNC Turning with GM of Unalloyed Carbon Medium Steel (EN8), a Novel Chromium Nitride Coated WC Tool Improves Machining Rate and Surface Finish Compared to an Uncoated HSS Tool

Pandikunta Lokesh and T. Sathish*

Department of Mechanical Engineering, Saveetha School of Engineering, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India

***Correspondence to:**
T. Sathish
Department of Mechanical Engineering,
Saveetha School of Engineering,
Saveetha Institute of Medical and Technical Sciences,
Saveetha University,
Chennai, Tamil Nadu, India.
E-mail: sathish.sse@saveetha.com

Received: July 31, 2023
Accepted: November 01, 2023
Published: November 03, 2023

Citation: Lokesh P, Sathish T. 2023. In CNC Turning with GM of Unalloyed Carbon Medium Steel (EN8), a Novel Chromium Nitride Coated WC Tool Improves Machining Rate and Surface Finish Compared to an Uncoated HSS Tool. *NanoWorld J* 9(S3): S869-S875.

Published by United Scientific Group

Abstract

The study's primary aim is to determine whether using a CrN-coated WC tool for CNC green machining of unalloyed carbon Medium Steel (EN8) results in a better machining rate and surface finish than using an uncoated High-speed steel (HSS) tool. This study utilized a 20 mm in diameter by 50 mm in length EN8 steel rod. With the aid of a vacuum degassing furnace, the temperature ranges from normalizing to annealing for EN8 steel was 650 to 840 °C. Steel can be hardened by heating it to this temperature and then quenching it in oil or water. A CNC turning process was used to evaluate the surface finish of each bar in the trial group and the control group, which was made of unalloyed EN8 steel, and N = 16 + 16 = 32 test samples were taken from each group. The software G-power 3.1 is used to determine an 80% G-power, and the overall specimen size for the groups is 32. In this research, we determine the cutting parameters and response surface roughness values for all machined specimens using both the HSS tool and the novel chromium nitrate (CrN) coated HSS tool. In the experimental investigation, the turning process is utilized to vary the speed, feed, and depth of cut to attain a Material removal rate (MRR) of 350 mm^3/min. It is observed that the depth of cut significantly influences the cutting force and power, accounting for 62.31% and 60.72% of the respective variations. Also, the roughness is 19.04% on the surface. In computer numerical control machining, the surface roughness can be decreased by using a WC tool with a novel CrN coating rather than an HSS tool. Because these values are less than 0.05, they are considered significant by the T test, and the results are as follows: p = 0.001 MRR, and p = 0.020 for Ra. Within the scope of the investigations, the response of a novel CrN was used to optimize the surface roughness and MRR of EN8 carbon steel. The results that were gathered showed that the MRR is greatly influenced by the feed rate, spindle speed, and depth of cut. A MRR can be achieved by utilizing a feed rate of 0.4 mm per revolution and a depth of 0.2 mm during the turning operation.

Keywords

Material Removal Rate, Machining, New chromium nitride, High-speed steel

Introduction

To enhance the reliability and efficiency of EN8 shafts during manufacturing, this study explores the possibility of using novel CrN coated HSS during CNC turning [1]. EN8 has strong mechanical strength and hardness, making it challenging to machine. The surface roughness and MRR of a tool insert is both higher [2]. When it comes to strength, this EN8 material is preferable to mild steel for all general automotive applications including shafts, gears, and bolts [3]. Components used in the automotive industry, in general engineering, and in other applications [4]. In addition to its use in the production of forgings, castings, connecting rods, axle-shafts, and crank-shafts, EN8 is also widely applicable in several other mechanical engineering contexts [5]. For making inexpensive dies, it is used in the tool and die industry. With proper heat treatment, this material can outperform low carbon steels in terms of strength and wear resistance [6].

Over the past five years, there have been about 157 google scholar articles and 86 scientific direct articles about EN8. Cutting fluids are commonly used in metal cutting companies to enhance the longevity of cutting tools and improve the smoothness of finished components [7]. Oil-based lubricants are employed in metal forming processes to control friction, minimize die wear, and enhance the surface quality of components. In the metal cutting and shaping industries, lubricants and cutting fluids account for 16 - 20% of production costs and have numerous negative effects on human health and the environment. Green or dry machining is recommended because it is environmentally friendly, doesn't release harmful byproducts into the environment, and saves money without sacrificing quality [8]. This study reports the results of an examination of a polycrystalline cubic boron nitride cutting tool suitable for dry machining [9, 10]. When working with metal, internal grinding is a technique for getting a higher quality finish. Unfortunately, many fields of study rely heavily on external machining factors. The current investigation, then, centres on the machining parameters of the necessary coolant oil for internal grinding, as seen in our laboratory [11].

The literature suggests that EN8 steel is the most widely utilized engineering material in the automotive sector, so that's what we went with. For this experiment, we employed these two substances in an internal grinder. MRR, tool life, and surface roughness were some of the outcomes studied because of keeping an eye on several machining factors. In addition, coolant lubrication is crucial in improving surface quality and MRR. Surface roughness was assessed with a SE-1200 tester, and cutting force was recorded with a kistler dynamometer. In the presence of synthetic cutting oil, EN8 material produces the least degree of surface roughness while simultaneously increasing tool life [12, 13]. The objective of this study is to examine how the parameters of CNC machining, such as cutting speed, depth of cut, and feed rate, affect the surface roughness (Ra) when turning EN8 steel. Data analysis is conducted using the Taguchi technique and analysis of variance. Minitab 14 is used to assess the performance attributes of a cutting tool with coated carbide inserts on a CNC turning machine. This evaluation is conducted through a three-level, three-parameter design of experiment utilizing an orthogonal array. The performance of the tool is measured by computing the signal-to-noise ratio (S/N).

The research examines the impact of CS, FR, DOC on SR via the use of (S/N ratio) and ANOVA techniques. ANOVA was performed in conjunction with a Taguchi orthogonal test design to investigate the optimum ranges for the process parameters that influence SR. Validation tests are conducted to ensure the accuracy of the findings. The feed rate is identified as a significant factor in determining the surface roughness Ra for turning EN8. CNC multi-operations are becoming increasingly vital in the production of metal goods. Therefore, providing the highest quality at a competitive price is reliant on manufacturing companies picking the best machining parameters, tool shape, and cutting conditions for a wide variety of materials [14]. This research looks at how different MRR parameters affect MRR for multi-operations like turning, grooving, facing, and threading. The EN8 material underwent a battery of tests employing the central composite process with a wide range of input parameters. The output response is often referred to as the MRR. An empirical equation is developed by conducting experiments for multiple iterations of the investigation [14]. Using the empirical equation, we may estimate MRR's future value. The empirical equation is solved with the help of the genetic algorithm. The best settings can be found using a genetic algorithm, which manufacturers are encouraged to utilize [15]. The most relevant of these articles to my project is the one on the novel CrN coated WC tool's superior performance compared to the uncoated HSS tool; this article accounts for about 20% of the total [16].

So far as I am aware, no studies have been conducted to compare the novel CrN coated WC tool to the uncoated HSS tool. Surface polishing and increased machinability are ideal for this procedure. The optimal machining method is revealed by contrasting traditional uncoated high speed steel tools with cutting-edge CrN tools. percentage range, and these elements are cast into the metal. It's a steel with decent tensile strength despite being medium-strength. You can have it normalized or rolled; it's up to you. For CNC turning operations, the quality of the tools, holders, and cutting fluids utilized in the process all matter. Medium-carbon, unalloyed steel (EN8) used in this coolant-equipped product. By a comparative analysis of the outcomes achieved by using a novel CrN coated WC tool and an uncoated HSS insert, valuable insights may be gained about the enhancement of the MRR in the turning process of unprocessed material.

Materials and Methods

When it comes to the turning process, EN8 material is taken into consideration, and cutting tools are novel CrN coated WC tool insert. It is a high-tensile, MSS. This meant that the two inserts were the process. Institute Industry in Chennai is home to the CNC turning center where this research was conducted. Since no testing was done on human subjects, no permission from an ethical review board was necessary for this study. This experimental study evaluates two groups, a control group using a traditional HSS tool and an experimental group using a newly developed WC tool coated with CrN. There should be two groups, making the minimum sample size for each 16 people. Groups employ a total sample size of 32, and G Power 3.1 is used to compute 80% of G power. Conventional methods employ a sample mean of 0.9675, while proposed methods use a mean of 0.9773. 0.283735 was utilized as the standard deviation [17].

The novel CrN coated WC tool and the HSS tool were also purchased with the project in mind, as was the EN8 material. At KJ Shop in Vellore, Tamil Nadu, I purchased rod with a 20 mm diameter and a3 m length of EN8 080M40. In addition, we purchased carbide inserts, both coated and uncoated, from the same supplier (Figure 1). The dimensions of the specs were 20 mm x 50 mm, as indicated in figure 2. The samples in the control group will be machined using a dry turning technique with a HSS tool. The process of green manufacturing with a variety of input factors. The length of the sample was predetermined at 50 mm. The tensile strength of EN8 steel is moderate. The virus-drawn or -moved form is the most common delivery method. Tensile characteristics are variable but typically range from 500 to 800 N/mm^2. CrN wear-resistant coating allows for swift slicing. It has a decent level of hardness, temperature resistance, and oxidation resistance all around. It has a high CrN content. Silicon-based nanocomposites are developed by business enterprises and the application of silicon to the surface. CrN grains, measured at the nanometer scale, are implanted into amorphous a-sinx.

Commonly used on computer numerical control machines for the machining of solidified preparations from 55 HRC and the tempered steels with strength up to 1200 HV, novel CrN is coated on rapid cutting devices. 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, making it ideal for the old high CS tools that were widely used in the 1940s. HSS gets its name from the fact that it has a higher cutting speed than high carbon steel. In comparison to standard carbon tool steels, HSS have typically demonstrated greater hardness and abrasion resistance. Samples in group B, the control group, are machined using the same starting material but a novel CrN coated WC tool with a different set of settings than group A.

Using computer numerical control using a CrN-coated WC tool and an uncoated High-speed (Figure 3) ST insert, we performed GM (a turning operation) on a single workpiece (Figure 4). By completing the machining with both inserts, it is possible to compare their MRR and surface roughness (Figure 5). ISO 4287(1997) is the standard that should be used for testing. 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.

The MRR is determined after the sample has been machined to ensure a short sample length by comparing the sample's pre- and post-machining weights. To reduce the likelihood of mistakes, the process was repeated, and the average used. Computer numerical control green machining parameters were supplied in table 1 as input specifications; this study subtracted three parameters with four rpm levels of CNC green machining. Table 2 displays an overview of the SR and MRR achieved by the control group while employing HSS and a CrN coated WC tool.

Statistical analysis

The statistics were run with 'SPSS statistics 26'. The test

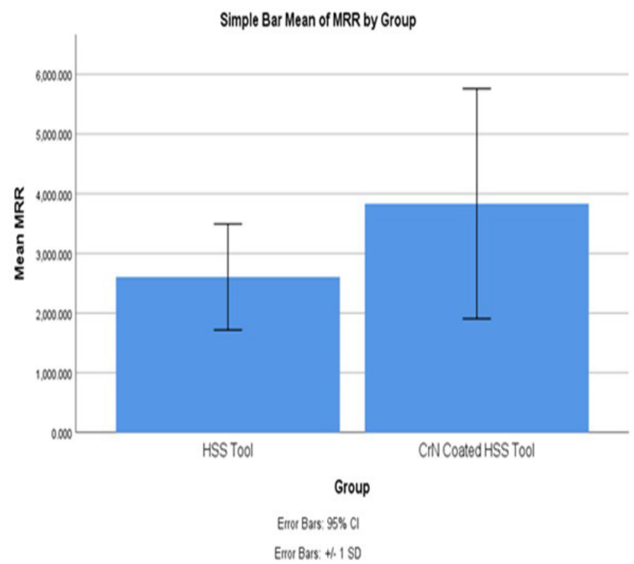

Figure 1: Depicts the percentage of coated and uncoated tool cutters that dominate in terms of MRR. The CRONAL coated WC cutting tool from these cutters provided good MRR despite variations in cutting speed, feed, and cut depth. HSS and CrN coated WC tool on the X-axis; mean MRR of identification within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

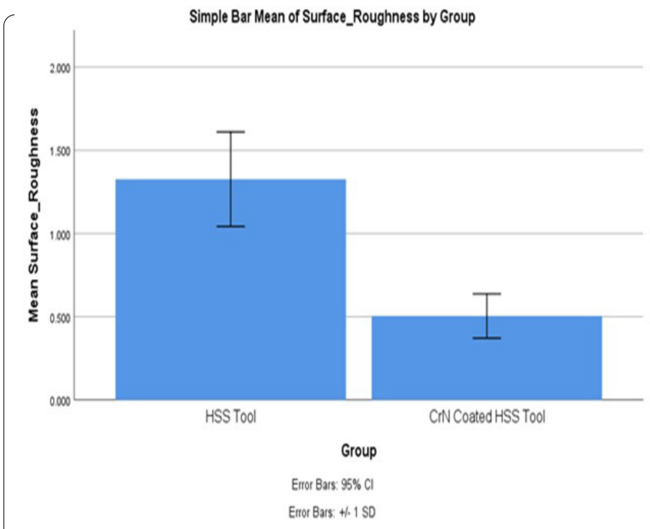

Figure 2: Illustrates the dominance of coated and uncoated tool cutters in terms of rough surface. Even with variations in CS, FR, DOC the CrN coated WC tool cutter generated minimal surface roughness from these cutters. HSS and CrN coated WC tool on X-axis, and the Mean SR of detection 1 SD on Y-axis.

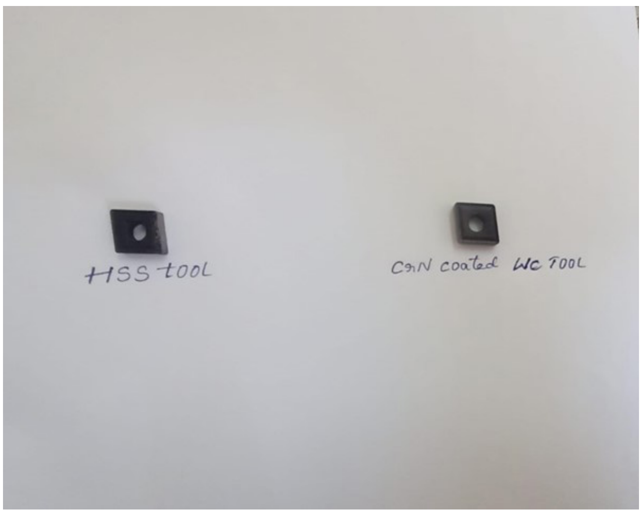

Figure 3: HSS tool and CrN coated WC tool.

Figure 4: Machined samples.

Figure 5: Surface roughness tester.

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

of independence between samples was used to compare the means of the experimental and control groups. CS (50 m/min), FR (0.10 mm/rev), and DOC (0.25 mm) were the independent variables utilized to calculate the MRR and Ra. The data was analyzed statistically, using techniques like the T-test and the Individual test samples. Rate of material removal and degree of surface roughness may be considered dependent variables. SPSS was used for data analysis in this study, along with ANOVA charts and tables.

Results

Ra and MRR (Figure 5) values are calculated and examined statistically for both groups (16 samples total). The average thickness of the novel CrN coated water closets (0.505125 μ) is substantially less than that of the standard stainless steel toilets (3.519625 μ). Consequently, as compared to MRR values obtained with samples machined using standard uncoated HSS tools, values obtained with the novel CrN coated WC tool showed a substantial improvement. Table 3 details the inputs used across all 16 experiment types. The values in table 4 for the MRR range from $1434.017 to $7051.0259. Samples machined using HSS tools are shown in table 5 MRR column. Samples machined with HSS tools have a surface roughness and MRR in the range of 0.210 - 1.786%. Table 6 displays the outcomes of the T test for the novel CrN coated WC tool and table 7 gives the same data for the uncoated HSS tool. The findings of the statistical significance test conducted using an independent sample are presented in table 8. New, lightweight EN8 is seen being synthesized in figure 2. Images (a) before and (b) after machining of the maximum surface roughness of each of the sixteen examples are shown in figure 3. The smooth curved edges are achieved through excellent machining of the sharp edges, and the 200 mm square contour was machined to a depth of 15 mm. All the contour profiles in figure 6 will be manufactured with the use of CNC lathes and mills. MRR and surface roughness response values from each of the 16 experimental runs are shown in figure 3. This figure 4 compares the effects of HSS and CrN tool cutters on response factors. MRR and SR are compared at the 1 standard deviation group mean level in figure 1. Since all these values are less than 0.05, the findings of the T test are statistically significant: p = 0.001 for MRR and p = 0.020 for Ra.

Discussion

The preceding findings demonstrate that a greater FR and DOC both lead to a greater rate of material removal. A high DOC will result in a faster rate of material removal. A high MRR improves surface finish, which in turn boost's part performance and longevity. The results of the T test are statistically significant at the p = 0.001 level for MRR and at the p = 0.020 level for Ra. Control variables such as DOC and FR can be shown in a bar chart. This method is employed for both HSS tool inserts and CrN coated HSS inserts. SPSS study reveals that the cutting speed has a negligible impact on the cutting conditions compared to the DOC and the feed rate [18]. Cutting forces were found to be negligible when put next to DOC and feed rate. Cutting force can be reduced by increasing either the speed or the radius of the tool's nose.

If the MRR improves with higher cutting speeds, shallower cuts, and faster feed rates, those conditions have been met. The statistical significance of these results is p0.06, indicating high intelligence [19]. While compared to the HSS tool, utilizing the novel CrN coated WC tool, the MRR of the composite was drastically decreased. Other parameters affecting SR and MRR were unit DOC and input rate, both of which were equally specified [20]. It is commonly analyzed that MRR was better by 23.515% and the SR was decreased by 24.252% when using a novel CrN coated WC tool rather

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 CrN. 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	2582.02	856.2694	214.0673
	CRONAL coated WC tool	16	3840.79	1534.5366	383.6341

than a conventional uncoated HSS tool, and there is evidence to support these claims. Because we only need to adjust a few settings up front. CNC turning also makes use of coated CrN tools [21]. As a higher MRR is essential for every application, this research confirmed that the CrN-coated WC tool is an excellent choice for this combination [22] this study presents an empirical investigation aiming to assess the impact of control factors on the optimal quality of turned materials. Specifically, the focus is on contour turning, a CNC machining operation where the use of a CrN coated WC tool is commonly advised [23]. The study explores the range of input parameters that yield the highest MRR for this composite, finding that increased CS and FR, along with reduced DOC, result in

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 CrN coated WC tool (GP 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	5.58	0.025	-2.8	30	0.008	-1258.6	439.376	-2155.7	-361.3
	-	-	-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 analysis for equal of variances		T test for equality of means						
	F	Sig	t	df	Sig. (2 tailed)	Mean difference	Std. error difference	Difference's 95% confidence interval	
								Low	High
MMR	5.1	0.02	7.7	20	0	0.56466	0.08394	0.392976	0.7363
	-	-	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

maximized MRR [24]. Only the MRR, the rough surface, and the die material are considered in this study.

SR and MRR are significantly affected by tool hardness and cutting zone temperatures, in addition to the more traditionally considered input factors [25]. The high MRR and low surface finish were greatly enhanced using the CrN coated WC tool, which is much harder than the HSS tool.

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. The scope of the research was restricted to investigating the influence of using CrN coated WC tools on the rates of MRR and the quality of SR. In future research, considering the use of non-corrosive coolants like cryogenic fluids and nanofluids, it could be beneficial to investigate the wet machining characteristics.

Figure 6: CNC machining setup (Turning).

Conclusion

Specifically, this analysis evaluated the SR and MRR achieved by CNC turning EN8 using a CrN coated WC tool to that achieved by turning the same material using HSS. SR was identified to be lower for the set of samples machined using CrN-coated WC tool and uncoated high SS tool. Consequently, the proposed tool decreased SR by 22.252% and the MRR by 21.515%.

Acknowledgements

None.

Conflict of Interest

None.

References

1. Pujari S, Srikiran S, Subramonian S. 2019. Recent Advances in Material Sciences: Select Proceedings of ICLIET 2018. Springer Singapore.
2. Verma M, Pradhan SK. 2020. Experimental and numerical investigations in CNC turning for different combinations of tool inserts and workpiece material. *Mater Today Proc* 27: 2736-2743. https://doi.org/10.1016/j.matpr.2019.12.193
3. Sathish T, Ağbulut Ü, George SM, Ramesh K, Saravanan R, et al. 2023. Waste to fuel: synergetic effect of hybrid nanoparticle usage for the improvement of CI engine characteristics fuelled with waste fish oils. *Energy* 275: 127397. https://doi.org/10.1016/j.energy.2023.127397
4. Ramadass R, Sambasivam S. 2018. Process variables optimization in lapping of EN8 material using Taguchi method. *Eng Math* 2(1): 50-55. https://doi.org/10.11648/j.engmath.20180201.15
5. Sathish T, Ağbulut Ü, Muthukumar K, Saravanan R, Alwetaishi M, et al. 2023. Pore size variation of nano-porous material fixer on the engine bowl and its combined effects on hybrid nano-fuelled CI engine characteristics. *Fuel* 345: 128149. https://doi.org/10.1016/j.fuel.2023.128149
6. Sachdeva A, Kumar P, Yadav OP, Garg RK, Gupta A. 2019. Operations Management and Systems Engineering: Select Proceedings of CPIE 2018.
7. Mehershilpa G, Muralidharan K, Kaliappan S, Patil PP, Sathish T, et al. 2023. Mechanically constrained single-loop 6-bar chain from double 6R chain. *AIP Conf Proc* 2747(1).
8. Srinivasan D, Meignanamoorthy M, Gacem A, Vinayagam M, Sathish T, et al. 2022. Tribological behavior of Al/nanomagnesium/aluminum-nitride composite synthesized through liquid metallurgy technique. *J Nanomater* 2022: 1-12. https://doi.org/10.1155/2022/7840939
9. Davim PJ. 2012. Green Manufacturing Processes and Systems. Springer Science & Business Media.
10. Sivarajan S, Padmanabhan R. 2014. Green machining and forming by the use of surface coated tools. *Procedia Eng* 97: 15-21. https://doi.org/10.1016/j.proeng.2014.12.219
11. Jamuna E, Duraisivam S, Balamurugan A, Sathish T, Deepalakshmi R, et al. 2023. Study on the process parameters and mechanical properties of FSWed AA7075 to AZ31B alloy. *Mater Today Proc* 2023. https://doi.org/10.1016/j.matpr.2023.05.555
12. Das MK, Barman TK, Kumar K, Sahoo P. 2017. Effect of process parameters on MRR and surface roughness in ECM of EN 31 tool steel using WPCA. *Int J Mater Form Mach Proc* 4(2): 45-63. https://doi.org/10.4018/IJMFMP.2017070104
13. Das MK, Kumar K, Barman TK, Sahoo P. 2014. Investigation on electrochemical machining of EN31 steel for optimization of MRR and surface roughness using artificial bee colony algorithm. *Procedia Eng* 97: 1587-1596. https://doi.org/10.1016/j.proeng.2014.12.309
14. Koshariya AK, Krishnan MS, Jaisankar S, Loganathan GB, Sathish T, et al. 2024. Waste to energy: an experimental study on hydrogen production from food waste gasification. *Int J Hydrogen Energy* 54: 1-2. https://doi.org/10.1016/j.ijhydene.2023.05.221
15. Jegan CD, Selvakumaran T, Karthe M, Hemachandu P, Gopinathan R, et al. 2023. Influences of various metal oxide-based nanosized particles-added algae biodiesel on engine characteristics. *Energy* 284: 128633. https://doi.org/10.1016/j.energy.2023.128633
16. Navarro-Devia JH, Amaya C, Caicedo JC, Aperador W. 2017. Performance evaluation of HSS cutting tool coated with hafnium and vanadium nitride multilayers, by temperature measurement and surface inspection, on machining AISI 1020 steel. *Surf Coat Technol* 332: 484-493. https://doi.org/10.1016/j.surfcoat.2017.08.074
17. Kane WJ, Hassinger TE, Xu TO, Kirkner AE, Maddox MJ, et al. 2022. Incidence and characterization of rectal complications from fecal management systems. *Dis Colon Rectum* 65(1): 108-116. https://doi.org/10.1097/dcr.0000000000002013
18. Gamst G, Meyers LS, Guarino AJ. 2008. Analysis of variance designs: a conceptual and computational approach with SPSS and SAS. Cambridge University Press.
19. Parthiban A, Sathish S, Suthan R, Sathish T, Rajasimman M, et al. 2023. Modelling and optimization of thermophilic anaerobic digestion using biowaste. *Environ Res* 220: 115075. https://doi.org/10.1016/j.envres.2022.115075
20. Arunnath A, Masooth PH. 2021. Optimization of process parameters in CNC turning process on machining SCM440 steel by uncoated carbide and TiCN/Al_2O_3/TiN coated carbide tool under dry conditions. *Mater Today Proc* 45: 6253-6269. https://doi.org/10.1016/j.matpr.2020.10.699
21. Kumar K, Ranjan C, Davim JP. 2020. CNC programming for machining. Springer.
22. Sathish T, Saravanan R, Vijayan V. 2022. Investigations on influences of MWCNT composite membranes in oil refineries waste water treatment with Taguchi route. *Chemosphere* 298: 134265. https://doi.org/10.1016/j.chemosphere.2022.134265
23. Deena S, Vedanayaki S, Sathish T, Dao MU, Rajasimman M, et al. 2023. Magnetic Co/CoOx@ NCNT catalysts for activation of potassium peroxymonosulfate to deteriorate phenol from wastewater. *Environ Res* 216: 114763. https://doi.org/10.1016/j.envres.2022.114763
24. Ghubade A, Gupta A, Abrol A, Singh S. 2015. Study of uncoated and coated carbide insert on tool life, surface roughness and material removal rate in machining of EN27 steel. *J Manuf Sci Produc* 15(2): 205-214. https://doi.org/10.1515/jmsp-2014-0024
25. Atar E, Alpaslan Ö, Çelik Ö, Çimenoĝlu H. 2014. Tribological properties of CrN coated H13 grade tool steel. *J Iron Steel Res Int* 21(2): 240-245. https://doi.org/10.1016/S1006-706X(14)60037-6