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A Novel Influence of Coated and Uncoated Carbon Boron Nitride on Material Removal Rate for Al-Si12Cu Alloy Using CNC Turning

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Abstract

The prime aim of this experimental study is to find the material removal rate (MRR) of CBN (Carbon boron nitride) coated and uncoated insert on Al-Si12Cu alloy via a novel computer numeric controlled (CNC) turning center. Al-Si12Cu alloy of 50 mm diameter and 200 mm length was utilized for this study. The samples (N = 20) are turned by CBN coated insert (experimental group) and the uncoated insert is considered as the control group to machining another 20 samples (N = 20). The weight of Al-Si12Cu alloy on both group samples was measured before and after the turning process via a digital weighing machine followed by MRR was calculated as per ASTM standard with 80% G-power calculation. Based on the experimental test results of MRR for the turned Al-Si12Cu alloy by CBN coated insert showed 2.762 mm^3/min and 1.781 mm^3/min were found gives a significant value of 0.001 ($p < 0.05$). There is a significant difference between the two groups considered. The two-tailed significance value obtained is 0.001 ($p < 0.05$) which is statistically significant compared to the uncoated insert showing the adequacy of the design matrix and there is a significant difference have been between the two groups. Within the limitations of this experimental study, the Al-Si12Cu alloys were turned via CBN coated insert has played a prominent role in the enhancement of MRR rather than the samples turned by the uncoated insert.

Keywords

Novel CNC turning, Al-Si12Cu, Cubic boron nitride coated insert, Uncoated insert, Quality of life, Material removal rate, Independent t-test

Introduction

Among the various machining operations, the turning operation is broadly utilized for the application of metal removal from round bars with reduced lead time [1]. The required qualities for turning are higher MRR, surface roughness, and dimensional accuracy obtained via conventional CNC lathe machines improving quality of life. The Al-Si-Cu alloys are attracted in automobile parts, and electronic, and aviation applications due to their superior mechanical and thermal characteristics compared to conventional aluminum alloys [2]. The aluminum alloy was turned by CNC with PVD-TiB_2 coated and uncoated tool insert. The PVD-TiB_2 coated insert performed superior surface quality and increased MRR as compared to the uncoated insert [2]. During the machining operation of Al-Si alloy, the built-up edges due to their enhanced frictional contact led to low surface quality and MRR. To overcome the problem tool inserts are used [3].

A total no of papers published about 1000 related research literature was available in Google Scholar for turning of aluminum alloy (Al-Si) by different tool inserts and more than 500 papers identified by the Science Direct platform over the past five years. The machinability performance of aluminum alloy was evaluated by carbide insert and its value was optimized via ANOVA (Analysis of Variance) response surface methodology [4]. The experimental study on the influences of various tool inserts in the choice of input machining parameters to meet the surface integrity and MRR [4]. The experimental analysis of machinability on Al-Si-TiB_2 composite machined by CNC turning operation improves quality of life with varied input process parameters via the uncoated and carbide-coated tool. The higher feed with an optimum spindle speed performs good surface quality with increased MRR [5]. However, the selection of the best suitable experimental and control group of input machining parameters to meet the better quality of machining operation. Which offers a high MRR, better surface quality and cost of machining to be reduced [6]. Different researchers and industries have to carry out experimental analysis of CNC turning operations of the aluminum alloy under minimum lubrication and dry conditions via ANOVA Taguchi approaches [7]. The best investigation is found from the different research literature on this experiment [8].

The main issue in past research is found on the machining of aluminum alloy with different coating tools quality of life addressed but there are no specific studies available on CBN coated insert which is compared to the machining characteristics of the uncoated insert. Based on the above research literature, the Al-Si12Cu alloy samples are machined by using CBN coated insert compared with an uncoated insert tool for finding the larger MRR [9]. The experimental study concentrates on the CBN coated insert tool on the machinability of the intermediate group and the novel CNC turning operation of Al-Si12Cu compared with the uncoated tool.

Materials and Method

The current experiment on the CNC turning performance of Al-Si12Cu was done by M/S. Saveetha Industries, Saveetha School of Engineering, Saveetha University, Saveetha Institute of Medical and Technical Science, Chennai (Tamil Nadu, India), using the required facilities in the Department of Mechanical. The constitutions of Al-Si12Cu alloy have good machinability, ductility, and a high strength-to-lightweight ratio. The turning operation of the selected Al-Si12Cu alloy was performed via CBN-coated and uncoated tool inserts. The sample size is 25 mm thick and 50 mm diameter. The CNC machining center is shown in figure 1.

80% of confidence with G-power fix with 0.05 and 0.27 of standard deviation and mean value [10]. 20 experiments were conducted on both groups. In the experimental group, a CBN coated insert is used to perform the CNC turning operation on Al-Si12Cu alloy with varied input parameters of cutting speed, feed, and depth of cut as mentioned in table 1. In this group, 20 samples are utilized to find the optimum machining parameters for quality of life MRR. The coated CBN inserts, and the machined specimen are represented in figure 2 and figure 3. The size of Al-Si12Cu is 200 mm in length and 50 mm in diameter.

Figure 1: CNC turning center.

Table 1: Input process parameters for CNC turning.

S. No.	Input process parameters	Units	Levels
1	Cutting speed	mm/min	700, 1000, 1200, 1500
2	Feed rate	mm/rev	0.18, 0.23, 0.28, 0.33, 0.38
3	Depth of cut	mm	1.2, 1.7, 2.2, 2.7, 3.2

In the control group, an uncoated coated insert is adopted in CNC turning operation executed with different input processes parameters like 750, 1050, 1250, and 1550 mm/min cutting speed, 0.18, 0.23, 0.28, 0.33, and 0.38 mm/rev of feed, and depth of cut of 1.2, 1.7, 2.2, 2.7, and 3.2 mm respectively. The uncoated insert is shown in figure 4. Similarly, 20 samples are turned via CNC and determine the optimum process parameter on MRR. The turned samples are illustrated in figure 5. The turned specimen from both groups is measured in

Figure 2: CBN uncoated insert.

Figure 3: Samples machined using CBN coated.

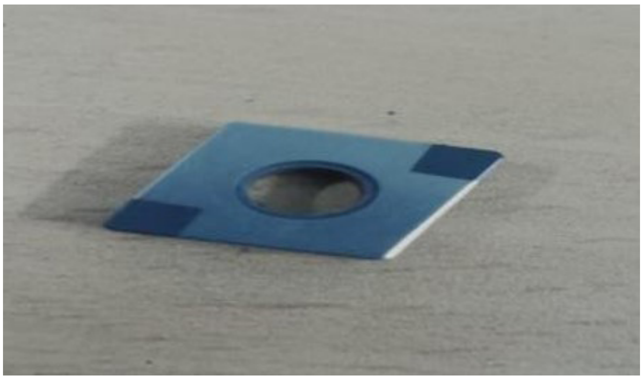

Figure 4: Uncoated insert.

Figure 5: Samples machined using uncoated.

its MRR via a digital weighing machine with an accuracy of ±0.001 g is represented in figure 6.

The 80% G-power calculation is adopted. Before the machining operation, the Al-Si12Cu alloy is weighted as W1 and W2 weighted after the machining operation. The stopwatch is adapted to measure the time during the turning operation as 't' in sec. The relations of W1, W2, and t of MRR were calculated by using equation 1. A similar process was repeated for all 40 samples. According to the evaluation report accessed by the t- test, the statistical significance range of 0.005 has to be $p < 0.050$.

$$MRR = W2/(t * W1)$$

Where, W2 - Weight of the Al-Si12Cu alloy after machining, W1 - Weight of the Al-Si12Cu before machining, and t - Time was taken during the machining operation from start to end.

Figure 6: Digital weighing machine.

The MRR of 40 turned samples from each group are measured by ASTM standard and the test results are optimized via ANOVA and its experimental group compared with the control group.

Statistical analysis

IBM Statistical Package for the Social Sciences version 26 tool was implemented for statistical studies. The independent variables on both the experimental and control group of the t-test are considered as cutting speed in mm/min, feed in mm/rev, and quality of life depth of cut in mm. The output response of MRR in mm^3/min is treated as the dependent variable. Significant MRR values for t-test and statics values on both groups are found [11]. The output for the statistical report bar was generated. Finally, the dominating input parameters on the MRR of Al-Si12Cu are analyzed by ANOVA.

Results

The measured test results of MRR with varied input parameters of uncoated and coated inserts are mentioned in table 2 and table 3. The mean MRR value for Al-Si12Cu alloy machined via CBN coated insert is found 1.2799 mm^3/min and 2.54100 mm^3/min observed on uncoated insert turned Al-Si12Cu alloy. The statistical measurements of mean, standard deviation, and standard mean error on both experimental and control groups are updated by 40 samples (Each group having 20 samples) and their value is mentioned in table 4. According to the evaluation report accessed by the t-test, the statistical significance range of 0.005 has to be $p < 0.050$ in table 5. Figure 7 illustrates the standard bar chart for the variance of mean value on MRR values between the CBN coated and uncoated insert performance with a standard deviation of ±1.

Table 2: Evaluated test results for MRR on Al-Si12Cu during the CNC turning operation with uncoated coated.

Specimens	Cutting speed (mm/min)	Feed rate (mm/rev)	Depth of cut (mm)	MRR (mm^3/min)
1	750	0.18	1.2	1.003
2	750	0.23	1.7	1.181
3	750	0.28	2.2	1.239
4	750	0.33	2.7	1.296
5	750	0.38	3.2	1.314
6	1050	0.18	1.2	1.397
7	1050	0.23	1.7	1.466
8	1050	0.28	2.2	1.352
9	1050	0.33	2.7	1.378
10	1050	0.38	3.2	1.299
11	1250	0.18	1.2	1.366
12	1250	0.23	1.7	1.409
13	1250	0.28	2.2	1.399
14	1250	0.33	2.7	1.472
15	1250	0.38	3.2	1.434
16	1550	0.18	1.2	1.607
17	1550	0.23	1.7	1.642
18	1550	0.28	2.2	1.631
19	1550	0.33	2.7	1.781
20	1550	0.38	3.2	1.743

Table 3: Evaluated test results for MRR on Al-Si12Cu during the CNC turning operation with CBN coated.

Specimens	Cutting speed (mm/min)	Feed rate (mm/rev)	Depth of cut (mm)	MRR (mm^3/min)
1	750	0.18	1.2	2.652
2	750	0.23	1.7	2.701
3	750	0.28	2.2	2.696
4	750	0.33	2.7	2.774
5	750	0.38	3.2	2.796
6	1050	0.18	1.2	2.684
7	1050	0.23	1.7	2.559
8	1050	0.28	2.2	2.964
9	1050	0.33	2.7	2.926
10	1050	0.38	3.2	2.946
11	1250	0.18	1.2	2.125
12	1250	0.23	1.7	2.164
13	1250	0.28	2.2	2.555
14	1250	0.33	2.7	2.645
15	1250	0.38	3.2	2.336
16	1550	0.18	1.2	2.556
17	1550	0.23	1.7	2.578
18	1550	0.28	2.2	2.664
19	1550	0.33	2.7	2.762
20	1550	0.38	3.2	2.898

Table 4: The values of mean and standard deviation in group statistics for the coated CBN insert were higher than the uncoated insert.

	Group	N	Mean	Std. deviation	Std. error mean
MRR	Uncoated	20	1.2799	0.247645	0.055375
	CBN Coated	20	2.54110	0.292590	0.065425

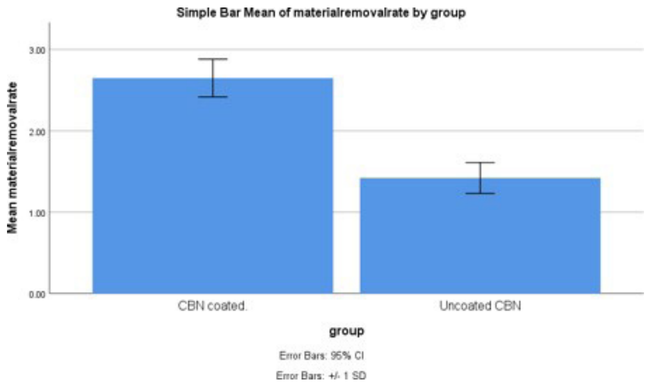

Figure 7: MRR group means value for CBN coated and uncoated inserts performed CNC turning operation on Al-Si12CU alloy. X-axis: MRR of the group (mean) of turned Al-Si12Cu alloy with CBN-coated inserts and uncoated inserts. Y-axis: Mean MRR of experimental and control group ±0.25 standard deviation with an error of 95%.

Discussion

The value of MRR was obtained by turning off Al-Si12Cu with different inserts like CBN coated and uncoated inserts. The test results revealed that the mean value of the CBN-coated insert achieved higher MRR compared to the mean value of the uncoated insert. So, the CBN tool performed a good MRR during the turning operation of the Al-Si12Cu alloy [12]. The CBN inserts are recommended for high-hardness material machining operations due to high thermal conductivity, good machinability, low thermal expansion and withstanding high friction force [13]. The novel CNC turning operation plays an important role in several manufacturing industries due to its enhanced surface quality, and increased productivity [14]. The machinability results on aluminum alloy turned by PVD-TiB_2 coated and uncoated with varied input parameters showed that the feed rate and cutting force were the most dominating parameter for affecting the machinability at 64.28% and 54.9%, respectively [14].

The results of the present investigation are obtained on the turning operation of Al-Si12Cu performed by CNC with CBN coated and uncoated insert. The higher MRR of 2.762 mm^3/min is achieved by CBN-coated inserts with input parameters of 1500 m/min at 0.25 mm/rev feed rate on 2 mm depth. Its MRR has increased by 11% as compared to the uncoated insert.

Conclusion

Within the limitations of this experimental study, the investigation of MRR for Al-Si12Cu alloy involved in a novel CNC turning operation done by CBN coated insert found 2.762 mm^3/min and 1.781 mm^3/min was noted by an uncoated insert. Based on the t-test independent and dependent variables on the mean value of test samples were significant with CBN coated insert rather than uncoated insert is fixed by the limit of $p = 0.05$ ($p < 0.050$). The CBN-coated insert obtained a maximum MRR when compared to the uncoated insert.

Acknowledgements

None.

Table 5: Independent t-test statistical test values for coated CBN and uncoated inserts in novel CNC turning. It is observed that on performing one-way ANOVA, there is a statistically significant difference for MRR.

		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% CI of the difference	
									Lower	Upper
Surface roughness	Equal variance assumed	4.198	0.035	-3.51	48	0.001	-0.4152	0.109108	-0.621	-0.113
	Equal variance not assumed	4.198	0.035	-3.563	27.39	0.001	-0.4264	0.109108	-0.631	-0.113

Conflict of Interest

None.

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