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A Novel Evaluation of Material Removal Rate for Al-Si7Mg Alloy Using TiCN Coated and Uncoated CBN Using CNC Turning

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Abstract

The scope of this study is to evaluate the material removal rate (MRR) of Al-Si7Mg alloy via CNC (Computer numerical controller) turning used with TiCN (Titanium carbon nitride) coated and uncoated CBN (Carbon boron nitride) insert. Al-Si7Mg alloy of 150 mm length and 50 mm diameter was used for this investigation. 20 samples (N = 20) are machined by TiCN coated insert (experimental group) and 20 samples (N = 20) are machined through an uncoated CBN insert (control group). The digital weighing machine is used to find the weight of Al-Si7Mg alloy samples before and after the machining process. The quality of life of MRR of machined samples is measured by ASTM test standard. The experimental study results of MRR on machined Al-Si7Mg alloy samples by TiCN coated insert is 1.801 mm^3/min and MRR of uncoated CBN insert found 1.624 mm^3/min. G-power 80% calculations with the investigation report generated by the SPSS (Statistical Package for the Social Sciences) statistical tool, TiCN coated insert 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. Within the limitations of this experimental study, the Al-Si7Mg alloy is machined with TiCN coated and uncoated CBN inserts via a CNC turning center. The quality-of-life performed higher MRR as compared to the uncoated CBN insert.

Keywords

Al-Si7Mg alloy, Novel CNC turning, TiCN coated insert, Uncoated CBN inserts, Material removal rate

Introduction

Turning is the most common and necessary operation to obtain the high-quality precision cylindrical bar applied in various engineering applications due to their enhanced MRR with minimized operation time. The MRR, surface quality, and surface roughness are the prominent factors for authorizing the dimensional accuracy of the sample. The attention of the Al-Si-Mg alloy combination is amplified in different engineering fields like automotive parts, aviation, and high-temperature applications due to its enhanced mechanical strength, good machinability, and high thermal stability as compared to the traditional quality-of-life materials [1]. Aluminum alloy was machined by PVD-TiB_2 coated and uncoated insert through the CNC machining center. The PVD-TiB_2 coated insert offers a high MRR and good surface quality compared to uncoated inserts [2]. High frictional contact between the tool quality of life and work material leads to the formation of built-up edges. It results in a low surface finish and tool wear. To avoid the above issues, coated tool inserts are introduced, and they are able to withstand the high frictional temperature during high-speed machining [3].

The total number of papers published over 1100 closely related research literature published over the past five years in Google Scholar was 800 papers and the remaining was collected by Science Direct. The machinability characteristic of aluminum alloy was measured by TiCN coated and uncoated CBN tool. The evaluated MRR affecting input parameters was optimized through ANOVA (Analysis of Variance) [4]. Similarly, the Al-Si-TiB_2 alloy composite was turned by CNC turning center with the use of carbide and uncoated inserts on quality-of-life different input parameters like spindle speed, and feed rate. The optimum input turning parameters for MRR are found at maximum speed with the least feed rate via ANOVA [5]. The surface integrity of Al-Si10Mg alloy machined by laser source was found higher MRR [5]. However, the choice of base material, machine, and input parameters like cutting speed, feed, and coolant have to fix the quality of the machined surface. The insert covered with Ti coat found enhanced MRR with reduced tool wear [5]. The temperature and nature of machining have one important parameter for deciding the surface quality of life and MRR during dry machining operations of alloy materials [6]. To achieve the best MRR, the researchers utilized the ANOVA optimization technique, which is considered various aspects like cutting speed range, feed rate, lubricant status, time, and position of tool related to their output response like surface roughness, and MRR [7].

The main scope of this present investigation is observed by the MRR of turning of Al-Si7Mg alloy with TiCN coated and uncoated CBN inserts through the relations of material weight loss and time. To the best of our knowledge, no similar research has been found in past literature. The research and development unit from Saveetha University starts with the modern and advanced material quality of life development with research investigation of their machinability behavior study [8]. The main objectives of this research are about the MRR behavior of Al-Si7Mg alloy by CNC turning operation made with TiAN coated insert (trial bunch) and compared to uncoated CBN inserts (control bunch).

Materials and Method

The present evaluation on MRR of Al-Si7Mg alloy turning setting, tool mode, operation nature, and comparisons of test results were made with the full support of Saveetha Institute of Medical and Technical Science, Chennai (Tamil Nadu, India), using the required facilities in the department of mechanical. The test mode considered the two groups such as TiCN coated inserts (experimental group) obtained 20 samples (N = 20) and uncoated CBN inserts offered another 20 samples (N = 20) from Al-Si7Mg alloy. In TiCN insert performed test results on 20 samples mean and the standard deviation is 2.54110 and 0.292590 found with G-power 80%. The total 40 machined samples were measured by (ASTM) the MRR equation as mentioned in Tolouei-Rad [9].

The TiCN-coated insert is considered an experimental group, and it was utilized as the primary tool for machining the Al-Si7Mg alloy through CNC turning (Figure 1) under the conditions of different speeds, depth of cut, and feed rates as mentioned in table 1. A sample size of 150 mm in length and 50 mm in diameter. Based on the above machining condition, the 20 samples are machined and their MRR is studied. TiCN coated and its turned Al-Si7Mg alloy is shown in figure 2 and figure 3.

In The same way, the uncoated CBN insert is fixed as a control group and was performed on 20 samples with different

Figure 1: CNC turning center (Super Jobber makes).

Table 1: Input machining parameters for Al-Si7Mg alloy via CNC turn.

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

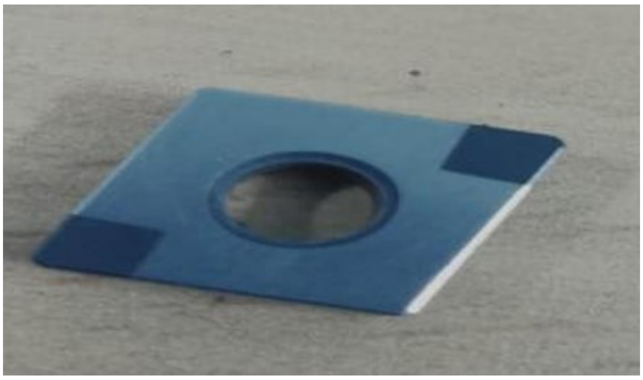

Figure 2: TiCN coated insert.

Figure 3: TiCN coated insert performed Al-Si7Mg alloy.

input process parameters of 700 mm/min to 1500 mm/min, 1.2 to 3.2 mm depth of cut and 0.18 mm/rev to 0.38 mm/rev feed rate. The uncoated CBN insert is illustrated in figure 4. The optimum process parameter for higher MRR is measured as per ASTM standards. The machined sample for the uncoated CBN insert is shown in figure 5.

In both the experimental and control groups of the sample MRR is measured through digital weighing apparatus with ±0.001 g accuracy. The digital weighing machine is used to weigh the sample and the Al-Si7Mg alloy samples are weighed before and after the turning process and it was named W1 and W2, respectively [10]. The digital stopwatch is used to calculate the actual time taken (t in a sec) for this machining operation in both groups. The above procedure was repeated on all other samples (N = 40). Equation 1 is denoted as the formula used for MRR calculation during the turning process of aluminum alloy.

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

Where, W2 - Weight of the Al-Si7Mg alloy after turning, W1 - Weight of the Al-Si7Mg alloy before turning, and t - Time is taken between the machining operation start to end.

MRR of 40 turned samples from each group follows the ASTM standard and its measure MRR values are optimized via ANOVA tool and its enhanced results were found via SPSS (Statistical Package for the Social Sciences) tool IBM software. According to the evaluation report accessed by the t-test, the statistical significance range of 0.05 has to be $p < 0.050$. Finally, the generated test result of the experimental group is compared with the control group. is measured by ASTM standard and the test results are optimized via ANOVA and its experimental group compared with the control group.

Figure 4: Uncoated inserts.

Figure 5: Uncoated CBN insert performed Al-Si7Mg.

Statistical analysis

The familiar SPSS tool from IBM is attached for statistical investigation. The experimental and control group chose cutting speed, depth of cut, and feed rate as independent variables. The machined response of the MRR is treated as the dependent variable. The significance value of MRR is predicted by t-test and its statistical trend bar chart for both groups is studied. The same trend for statistical analysis was done for aluminum alloy machining [11]. The final analysis was carried out to find the optimum turning parameters for obtaining higher MRR via the ANOVA technique.

Results

The calculated actual test values on MRR of Al-Si7Mg alloy with different machining parameters on both control and experimental groups are mentioned in table 2 and table 3. The Al-Si7Mg alloy machined by TiCN coated insert found a higher MRR with the mean of 20 samples is 2.54110 mm^3/min, a standard deviation of 0.292590, and a standard mean error is 0.065425. The mean value MRR of 1.2799 mm^3/min is noted by the uncoated CBN tool. It is lower than the experimental group (TiCN coated insert). A total of 40 samples from each group (20 + 20) found the average mean, standard deviation, and standard mean error via the statistical group SPSS test, and its values are mentioned in table 4. Based on evaluation results obtained by t-test, table 5, the statistical significance range is found to a limit of 0.005 to be $p < 0.050$. Finally, the evaluated results are plotted as a bar chart considering both TiCN coated and uncoated CBN inserts performance with ±1 standard deviations are shown in figure 6.

Table 2: Evaluated test results for MRR on Al-Si7Mg during the CNC turning operation with uncoated coated CBN.

Specimens	Cutting speed (mm/min)	Feed rate (mm/rev)	Depth of cut (mm)	MRR (mm^3/min)
1	700	0.18	1.2	1.003
2	700	0.23	1.7	1.181
3	700	0.28	2.2	1.239
4	700	0.33	2.7	1.296
5	700	0.38	3.2	1.314
6	1000	0.18	1.2	1.397
7	1000	0.23	1.7	1.466
8	1000	0.28	2.2	1.352
9	1000	0.33	2.7	1.378
10	1000	0.38	3.2	1.299
11	1200	0.18	1.2	1.366
12	1200	0.23	1.7	1.409
13	1200	0.28	2.2	1.399
14	1200	0.33	2.7	1.472
15	1200	0.38	3.2	1.434
16	1500	0.18	1.2	1.607
17	1500	0.23	1.7	1.642
18	1500	0.28	2.2	1.631
19	1500	0.33	2.7	1.781
20	1500	0.38	3.2	1.743

Table 3: Evaluated test results for MRR on Al-Si7Mg during the CNC turning operation with TiCN coated.

Specimens	Cutting speed (mm/min)	Feed rate (mm/rev)	Depth of cut (mm)	MRR (mm^3/min)
1	700	0.18	1.2	2.652
2	700	0.23	1.7	2.701
3	700	0.28	2.2	2.696
4	700	0.33	2.7	2.774
5	700	0.38	3.2	2.796
6	1000	0.18	1.2	2.684
7	1000	0.23	1.7	2.559
8	1000	0.28	2.2	2.964
9	1000	0.33	2.7	2.926
10	1000	0.38	3.2	2.946
11	1200	0.18	1.2	2.125
12	1200	0.23	1.7	2.164
13	1200	0.28	2.2	2.555
14	1200	0.33	2.7	2.645
15	1200	0.38	3.2	2.336
16	1500	0.18	1.2	2.556
17	1500	0.23	1.7	2.578
18	1500	0.28	2.2	2.664
19	1500	0.33	2.7	2.762
20	1500	0.38	3.2	2.898

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

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

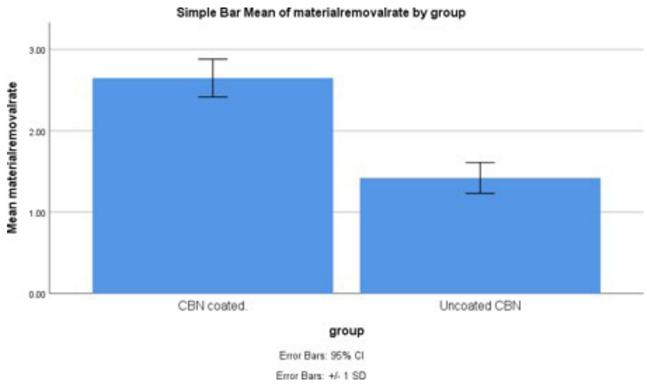

Figure 6: Mean value for MRR on TiCN coated and uncoated CBN inserts used CNC turning operation on Al-Si7Mg alloy. X-axis: MRR of group mean of turned Al-Si7Mg alloy with TiCN coated and uncoated CBN insert. Y-axis: Mean MRR of both experimental and control group with ±0.25 standard deviation with the error of 95%.

Discussion

The measured MRR values on Al-Si7Mg alloy by CNC turning operated with various inserts as TiCN coated and uncoated CBN are compared with the SPSS tool and analyzed by ANOVA technique. It was found that the mean values of Al-Si7Mg alloy satisfied with the TiCN inserts found an optimum MRR. The uncoated CBN machined Al-Si7Mg alloy was found to decrease MRR due to its uncoated insert may lead to reduced performance at a higher temperature. So, the TiCN-coated inserts performed well and their MRR value is high as compared to uncoated CBN inserts [12].

The TiCN-coated inserts can machine both hard and soft materials due to their enhanced thermal and mechanical behavior compared to conventional uncoated inserts [13]. The selection of the work machine and its configuration was the most important for the increase in machined product quality as well as MRR [14]. The machinability characteristics of aluminum alloy machined by PVD-TiB_2 coated and uncoated insert under different machining parameters are optimized by ANOVA. Its results showed that the machinability quality of life of aluminum alloy was affected by 54.9% and 64.28% due to the cutting force and feed rate [15]. A similar trend of MRR was affected by the input parameters of feed rate and cutting force was ranked as 1 and 2 [16]. The CNC truing of aluminum alloy with TiN coated was found to have a higher MRR as compared to uncoated tool inserts [17]. The MRR comparison of TiN coated insert and uncoated insert for aluminum alloy turning operation found higher MRR on TiN coated insert [17].

The obtained results from this current study are performed by turning operation on Al-Si7Mg alloy through a CNC turning center with TiCN-coated and uncoated CBN inserts. The maximum MRR is found 1.801 mm^3/min on TiCN coated insert under the conditions of machining parameters are 1500 mm/min at 2 mm depth of cut on 0.25 mm/rev feed rate. Its result compared to uncoated CBN insert was improved by 11%.

Conclusion

Within the limitations of this investigational study, the

Table 5: Independent t-test statistical test values for coated TiCN 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	95% CI of the difference: Upper
Surface roughness	Equal variance assumed	4.198	0.035	-3.51	48	0.0011	-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

evaluation of MRR for Al-Si7Mg alloy machined by CNC turning center using TiCN coated and uncoated CBN inserts. The MRR of both TiCN coated and uncoated CBN inserts are measured as 2.5411 mm^3/min and 1.2799 mm^3/min observed on uncoated insert. According to the evaluation for the t-test dependent and the independent variable on the mean value of A-Si7Mg alloy samples were significant by TiCN coated insert over uncoated CBN insert as fixed within the limit of $p = 0.05$ ($p < 0.050$). The TiCN-coated insert has obtained higher MRR when compared to the uncoated CBN insert.

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Conflict of Interest

No conflict of Interest in this manuscript

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