Original Article

Comparison of Material Removal Rate of Aluminium Alloy AA6082 Using Novel AlTiN Coated Tool with Uncoated Carbide Tool while CNC Turning

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Abstract

Aim: This research study is about comparison of Material Removal Rate of aluminium alloy AA6082 while CNC turning using AlTiN (Aluminium Titanium Nitrate) novel tool coating and using Uncoated carbide tool.
Materials and Methods: Workpiece materials used in this study for Turning operation is Aluminium alloy AA6082. Tools used are AlTiN coated tool and uncoated Carbide tool. There are two groups i.e, control group and experimental group, each group contains 20 workpieces and total workpieces are 40. The pre-test power for testing was 80%, Alpha=0.05% and CL was 95%, G power test was used to fix the number of samples for each group.
Results: The level of cutting parameters and the resulting Material Removal Rate values are obtained for all machined workpieces with both Uncoated carbide tool and AlTiN coated tool and the results done by Turning operation. The mean Material Removal rate values using Uncoated Carbide tool is 0.16110g/s and AlTiN coated tool is 0.19745g/s and corresponding standard deviation values are 0.021472 and 0.039752 respectively. These values were obtained with a significance level of $p=0.047$ ($p<0.05$). Using AlTiN coated tool gives a higher Material Removal Rate than Uncoated carbide tool in CNC machining.
Conclusion: Within the limitations of this study, by the observation of results obtained it could be concluded that the material removal rate of Aluminium Alloy AA6082 using AlTiN coated tool is more than Uncoated carbide tool.
Keywords: Aluminium Alloy, CNC Turning, AlTiN coated tool, Novel tool coating, Uncoated carbide tool, AA6082, Material Removal Rate.

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INTRODUCTION

This review was conducted on Aluminium Alloy AA6082 by CNC turning using an Uncoated carbide tool and using AlTiN (Aluminium Titanium Nitrate) novel tool coating. The main objective of the research is to improve material removal rate using AlTiN (Aluminium Titanium Nitrate) coated tool when CNC turning of Aluminium Alloy AA6082 (Singh et al. 2020). Material Removal Rate of AA6082 by both tools are compared to determine the tool which is suitable for higher yield of Material Removal Rate. Higher Material removal rate increases the productivity rate and decreases production time and cost (A et al. 2021). As Aluminium Alloy AA6082 is used in different applications like in construction of bridges,production of milk churns, cranes, and beer barrels selected for this study. It is also used in transport applications (Babu, Naresh Babu, and Muthukrishnan 2020; Lakshmikanthan and Prabu 2017).

Research papers that are relevant to this study are 34 in google scholar and 29 in science direct. In previous study S.Ramakrishna had done experimentation while hard turning of Aluminium Alloy HE30 6082 material to determine the impact of process parameters like speed (N), feed (f) and cutting apparatus materials on material removal rate and surface roughness (Asiltürk and Akkuş 2011). He concludes that by increasing the speed and feed, material removal rate and surface roughness increases. In the study by Syed jilani, it was observed that it has optimized cutting parameters by using Taguchi-ANOVA method in CNC milling. The study conducted experiments on Al6082 and Al6063 material to determine process parameters and surface roughness (Carter et al. 2017). Tools used in this study are HSS drill, coated TIN drill and coated AlTiN drill. The study concluded that parameters recommended for AL6063 surface roughness are 1500rpm speed, 150mm/min feed rate, 0.6mm depth of cut and for material removal rate are 1500rpm speed, 150mm/min, 0.8mm depth of cut with HSS+AlTiN tool (Rakhmonov et al. 2020). Parameters that recommended for AL6082 surface roughness are 1500rpm speed, 150mm/min feed rate, 0.8mm depth of cut and for material removal rate are 1200rpm speed,150mm/min feed rate, 0.8mm depth of cut with HSS+AlTiN tool (Tan et al. 2019). In this paper, experiments were based on orthogonal array and turning experiments with parameters for aluminium alloy AA6082 using tungsten carbide tool. Parameters were spindle speed, feed rate, Depth of cut which are used to determine the surface roughness and material removal rate using Taguchi and ANOVA method and Temperature on chip was compared. (Sivasankaran 2017). This study concludes that speed is the vital parameter for material removal rate (MRR) and feed is the vital parameter for surface roughness (Ra) (Rowolt et al. 2020). For the parameters of speed 1600rpm, feed 0.15 mm/rev, and depth of cut 2mm values of material removal rate and surface roughness are 36102.79 mm^3/rev and 0.76 μm respectively (Palaniappan et al. 2020). Best relevant paper to this study investigates process parameters of aluminium alloy 6082 using Taguchi and ANOVA method (Sivasankaran 2017).Our team has extensive knowledge and research experience that has translate into high quality publications(Venkat Jayanth et al. 2020; Sathish et al. 2021; Chandramohan et al. 2021; Muthu et al. 2021; Vijayakumar et al. 2021; Logendran, Chandramohan, and Sathish 2020; Krishna Priya, Jayakumar, and Suresh Kumar 2020; Mary Treasa Shinu and Needhidasan 2020; Rajkumar and Ganapathy undefined 2020)Our team has extensive knowledge and research experience that has translate into high quality publications(Bhansali et al. 2021; Jayanth et al. 2021; Sudhakar, Ravel, and Perumal 2021; Sathiyamoorthi et al. 2021; Deepanraj et al. 2021; Raju et al. 2021; Arun Prakash et al. 2020; Kamath et al. 2020; Shanmugam et al. 2021; Rajasekaran et al. 2020; Adhinarayanan et al. 2020; Rajesh et al. 2020; Aurtherson et al. 2021)

In previous research papers, comparison of material removal rate using uncoated carbide tool and coated AlTiN tool with novel tool coating were not done. To compare the material removal rate of Aluminium Alloy AA6082 using coated AlTiN coated tool and using uncoated carbide tool while CNC turning.

MATERIALS AND METHODS

For this study Machining (turning), cutting was conducted in CNC turning machine in Saveetha Engineering Industries at Saveetha School of Engineering (SSE), Saveetha Institute of Medical and Technical Sciences,Chennai. Ethical approval is not required because of no human samples are used in this study. There are two groups for experimentation, namely control group and experimental group. The sample workpieces that are machined using an uncoated carbide tool are a control group and the sample workpieces that are machined using a coated AlTiN tool with novel tool coating are an experimental group. Each group contains twenty sample workpieces and total number of samples in study are forty. Sample size of groups are determined using clincalc online sample size calculator. G-power is 80% with mean value 0.411 and standard deviation 0.1 (Palaniappan et al. 2020).

Aluminium Alloy AA6082 is used as a material in this research study and it was bought in rod form with 25mm diameter and 2.5m length from Arihant aluminium agencies at new no.182, old no.230, Linghi chetty street, Chennai-600001. CNC turning inserts AlTiN coated tool as shown in Fig. 1 and uncoated carbide tool shown in Fig. 2 were bought from small tool centre at 203/105, Broadway, Chennai-600108. Sample workpieces are prepared cutting Aluminium Alloy AA6082 rod with dimensions 100mm length and 25mm diameter and twenty samples are prepared in the same way. Fig. 3 shows the sample before machining. Aluminium Alloy AA6082 has medium strength and high corrosion resistance.It is also known as structural alloy. As it has high corrosion resistance suitable for welding. The chemical composition of aluminium 6082 is: Si - 0.7 to 1.3% , Fe - 0 to 0.5%, Cu - 0 to 0.1%, Mn - 0.4 to 1.0%, Mg - 0.6 to 1.2%, Zn - 0 to 0.2%, Ti - 0 to 0.1%, Cr - 0 to 0.25%, Al - Remaining%. The mechanical properties of AA6082 are Tensile strength is 290 Mpa, Elongation is 6%, Hardness brinell is 95 hbn.

Aluminium titanium nitrate (AlTiN) CNC turning tool is in black colour. It is a harder and smoother tool. Properties are hardness 90Rc, Friction coefficient is 0.45, surface roughness is 0.15μ□, thickness is 2-4 microns. It is generally used in dry machining. Uncoated tungsten carbide tool CNC turning tool is in grey colour. Composition of the tool is 90.1% of tungsten carbide(WC), 9.5% of carbon monoxide (CO), 0.4% of vanadium carbide (VC). Properties of the tool are grain size is 0.8, hardness is 1500hv, thermal conductivity is 85 W/mK, thermal expansion is 5.5x10^{-6} /K, compression is 4 GPa, fracture toughness 15 MPa $m^{1/2}$, TRS 3.5 GPa

As the same material is used for the experimental group except the tool used for CNC turning. Tool used in the experimental group is AlTiN coated tool. By using a CNC machine (turning operation) as shown in Fig. 4, sample workpieces are machined using both AlTiN coated tool and uncoated carbide tool to find material removal rate and

CNC machine specifications shown in (Table1). By using digital weighing machine weight of the sample before and after the machining. Sample length is 100mm and 25mm diameter.

In this study experiments are carried out by machining each sample for 45mm length with one tool and measuring the weight of sample before and after machining.Time taken for machining sample for 45mm length was calculated using a stopwatch. Procedure repeated for all the samples with different parameters as shown in Table 2, like spindle speed, feed rate, depth of cut and consider the average value to avoid errors. Material removal rate is calculated by using formula with weight loss of sample after machining and time taken for machining. The input parameters and results obtained by each sample using the AlTiN coated tool shown in the Table 3 and using the Uncoated carbide tool shown in the Table 4.

$$MRR=\frac{\text{[illegible]} - \text{[illegible]}}{\text{[illegible]}}\frac{\text{[illegible]}}{\text{[illegible]}}$$

STATISTICAL ANALYSIS

Statistical analysis in this study was done by using SPSS statistical software. The independent variables were spindle speed (rpm), feed rate (mm/rev), depth of cut (mm). The dependent variable was material removal rate which was influenced by independent variables. The values of Material removal rate (dependent variable) that are obtained were analyzed and compared using SPSS software, ANOVA tables and graphs (Palaniappan et al. 2020).

RESULTS

The material removal rate of aluminium alloy AA6082 using AlTiN coated tool and uncoated carbide tool obtained values are 0.16110g/s and 0.19745g/s respectively in the Table 5. From the experiments, it was observed that high spindle speed, feed rate and depth of cut gives high material removal rate. It was observed that the AlTiN coated tool with novel tool coating has higher material removal rate than the uncoated carbide tool. The material removal rate of the experimental group was 22.56% increased compared to the control group. The results were subjected to an independent sample T-test using SPSS v.26 statistical software. The mean material removal rate value obtained for AlTiN coated tool and uncoated carbide tool shown in Table 5.The control group (Uncoated carbide tool) mean is found to be significantly lower than the mean of the experimental group (AlTiN coated tool). Obtained standard deviation value for AlTiN coated tool is 0.039752 and for Uncoated carbide tool is 0.021472 shown in Table 5. Significant value for this comparative study is found to be $p=0.047$ which is less than 0.05 shown in Table 6. This study was performed with a confidence level of 95% as shown in Fig. 5.By changing the process parameters (spindle speed, feed rate, depth of cut) material removal rate will vary.

DISCUSSION

The experiment resulted in more Material Removal Rate for the experimental group (AlTiN coated tool) than control group (Uncoated carbide tool). The results observed are recorded and analyzed in SPSS software.The mean value of material removal rate of aluminium alloy AA6082 using AlTiN coated tool and Uncoated carbide tool are 0.19745g/s and 0.16110g/s respectively and corresponding standard deviation values are 0.039752 and 0.021472 respectively.

Machining parameters are important in turning operation to achieve high performance.It clearly shows that the AlTiN coated tool improves the Material Removal Rate of AA6082 when compared to the Uncoated carbide tool.Aluminium Titanium Nitride coating is done to CNC turning inserts which is made of Tungsten carbide tool (Grzesik et al. 2018). Life of the AlTiN coated tool is more because of coating. It yields a higher material removal rate (Jadhav et al. 2017). The material removal rate is influenced by the cutting parameters like spindle speed, feed rate, depth of cut.Coated CNC turning tools has more wear resistance than uncoated CNC turning tools (Li et al. 2019). The tool life went through three stages, they are initial,normal and rapid wear stages.The wear flank value (VB) depends on two aspects, they are wear value changing from initial wear stage to normal wear stage and duration of normal wear stage (Lai et al. 2020).

Although Material removal rate is significantly improved, this research study has limitations.As this study was done in dry conditions, in future studies, machining can be done using coolant. The study was limited to using AlTiN coated tool and Uncoated carbide tool to increase Material removal rate. In future, studies can be done using different CNC turning tools other than these tools.

CONCLUSION

Within the limitations of this study, Material Removal Rate of aluminium alloy AA6082 using AlTiN coated tool and Uncoated carbide tool while CNC turning were statistically compared and analyzed using independent sample T- test in SPSS software. The results showed that the samples that are machined with AlTiN coated tool have 22.56% of higher material removal rate than the samples machined with Uncoated carbide tool.

DECLARATIONS

Conflict of Interest

The authors of this paper declare no conflict of interest.

Authors Contribution

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

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TABLES AND FIGURES

Table 1. CNC specifications

M/C TYPE	SUPER JOBBER
M/C NUMBER	2129
YEAR	2014
SUPPLY VOLT	380/415 AC, 3PEN, 50Hz
CONTROL VOLT	24 V D.C
BACKUP FUSE	63 A
RATED CURRENT	31/29 A
KVA RATING	21 KVA
SIZE OF WIRE	10 sq mm

Table 2. Machining parameters

Factors	Level 1	Level 2	Level 3
Spindle speed (rpm)	800	1200	1600
Feed Rate (mm/rev)	0.15	0.15	0.15
Depth of Cut (mm)	0.5	1	-

S.No	Speed (RPM)	Depth of Cut (mm)	Feed Rate (mm/rev)	Weight Before Machining (gm)	Weight After Machining (gm)	Weight loss (gm)	Time taken (s)	Material Removal Rate (g/s)
1	800	0.5	0.15	128	126	2	11	0.182
2	800	0.5	0.15	134	132	2	12	0.167
3	800	0.5	0.15	136	134	2	17	0.115
4	800	1	0.15	130	125	5	23	0.217
5	800	1	0.15	136	131	5	22	0.227
6	800	1	0.15	134	129	5	24	0.209
7	1200	0.5	0.15	133	131	2	12	0.167
8	1200	0.5	0.15	134	132	2	10	0.200
9	1200	0.5	0.15	134	132	2	11	0.182
10	1200	0.5	0.15	135	133	2	11	0.182
11	1200	1	0.15	134	129	5	21	0.238
12	1200	1	0.15	134	129	5	22	0.227
13	1200	1	0.15	132	127	5	21	0.238
14	1200	1	0.15	132	127	5	23	0.217
15	1600	0.5	0.15	138	136	2	11	0.182
16	1600	0.5	0.15	138	136	2	10	0.200
17	1600	0.5	0.15	135	133	2	12	0.167
18	1600	1	0.15	136	131	5	18	0.288
19	1600	1	0.15	132	127	5	39	0.127
20	1600	1	0.15	129	124	5	23	0.217

Table 3. Input parameters and results obtained for each sample using AlTiN coated tool

S.No	Speed (RPM)	Depth of Cut (mm)	Feed Rate (mm/rev)	Weight Before Machining (gm)	Weight After Machining (gm)	Weight loss (gm)	Time taken (s)	Material Removal Rate (g/s)
1	800	0.5	0.15	138	136	2	16	0.125
2	800	0.5	0.15	137	135	2	14	0.143
3	800	0.5	0.15	138	136	2	15	0.133
4	800	1	0.15	137	132	5	28	0.179
5	800	1	0.15	140	135	5	29	0.172
6	800	1	0.15	138	133	5	28	0.179
7	1200	0.5	0.15	138	136	2	11	0.183
8	1200	0.5	0.15	139	137	2	16	0.125
9	1200	0.5	0.15	140	138	2	14	0.143
10	1200	0.5	0.15	138	136	2	15	0.133
11	1200	1	0.15	138	133	5	31	0.159
12	1200	1	0.15	138	133	5	30	0.167
13	1200	1	0.15	139	134	5	29	0.172
14	1200	1	0.15	137	132	5	28	0.179
15	1600	0.5	0.15	138	136	2	14	0.143
16	1600	0.5	0.15	138	136	2	11	0.183
17	1600	0.5	0.15	138	136	2	13	0.161
18	1600	1	0.15	139	134	5	26	0.192
19	1600	1	0.15	138	133	5	29	0.172
20	1600	1	0.15	139	134	5	28	0.179

Table 4. Input Parameters and results obtained for each sample using uncoated carbide tool.

Table 5. Results of t-test for sample of Aluminium Alloy AA6082 which were machined by two methods. Group 1 samples are machined by Uncoated Carbide Tool and Group 2 samples are machined by AlTiN coated Tool. The sample means of the proposed method(Group 2) is significantly higher than the Uncoated Carbide tool used in the sample group 1 for Material removal Rate.

Group Statistics					
	Tool Used	**N**	**Mean**	**Std. Deviation**	**Std. Error Mean**
MRR	Uncoated Carbide Tool	20	.16110	.021472	.004801
	AlTiN Tool	20	.1974 5	.039752	.008889

Table 6. Results for Independent samples test for CNC turning of Aluminium Alloy AA6082 Material machined with Uncoated Carbide tool (Group 1) and proposed AlTiN coated tool (Group 2). It is observed that on performing One-Way ANOVA, there is a statistically significant difference for MRR (p= 0.047, p<0.05).

		F	**Sig.**	**t**	**df**	**Sig. (2-tailed)**	**Mean Difference**	**Std. Error Difference**	**95% Confidence Interval of the Difference**	
									Lower	**Upper**
MRR	Equal variances assumed	4.221	.047	-3.598	38	.001	-.036350	.010103	-.056802	-.015898

	Equal variances not assumed			-3.598	29.217	.001	-.036350	.010103	-.057006	-.015694

Fig. 1. AlTiN coated tool insert

Fig. 2. Uncoated carbide tool insert

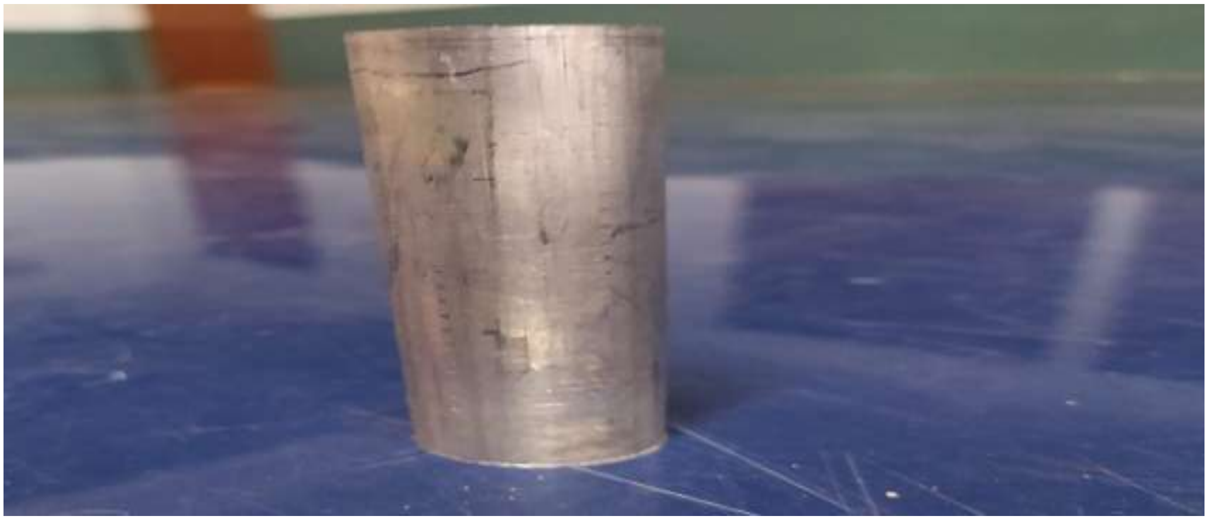

Fig. 3. AA6082 turning sample before machining

Fig. 4. CNC Turning machine

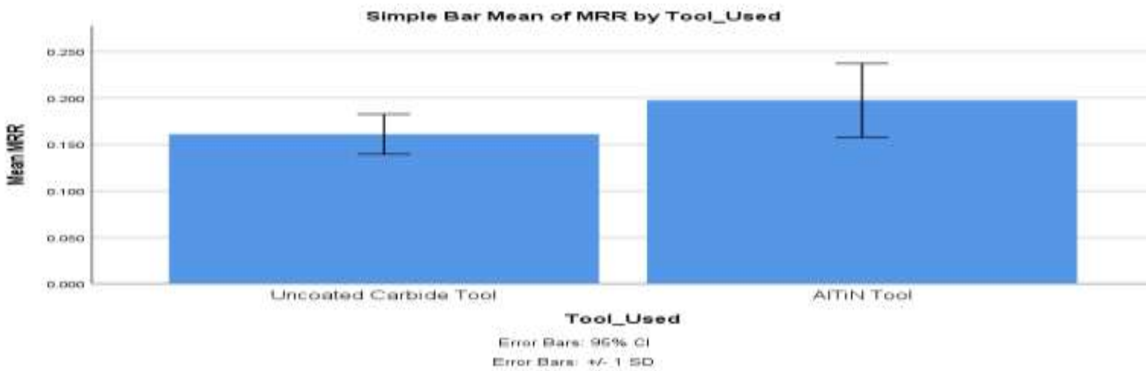

Fig. 5. Graph shows the Material Removal Rate of Aluminium Alloy AA6082 using Uncoated Carbide tool and AlTiN coated tool. From these tools the AlTiN coated tool produced high MRR even in variation of cutting speed, feed and depth of cut. X-axis: Uncoated Carbide tool and AlTiN tool, Y-axis: Mean MRR of detection ±1 SD.