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Evaluation of Material Removal Rate of Novel Al-Zn5Mg Alloy Using TiN Covered and Uncovered Ceramic Insert by CNC Turning

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Abstract

The main scope of the research about comparing the material removal rate (MRR) on Al- Zn5Mg alloy using TiN covered and uncovered tools through a CNC (Computer numerical controller) machining center. Al-Zn5Mg alloy of 200 mm length and 50 mm diameter was used for this study. The 20 Al-Zn-5Mg alloy samples are considered for novel CNC turning operation with TiN covered tool (experimental group). Another 20 Al-Zn5Mg alloy samples are machined the same way but the tool is changed to an uncovered ceramic tool (control group). The weight of each sample before and after the turning process is calculated via a digital weighing machine with ±0.001 gram accuracy. The system of MRR measuring follows the standard of ASTM with 80% G-power calculations. The evaluated results for this experimental study of MRR on Al-Zn5Mg alloy machined by TiN covered tool and uncovered ceramic tool found 1.598 mm^3/min and 1.254 mm^3/min respectively. The test results were statistically analyzed via the SPSS (Statistical Package for the Social Sciences) tool and gave a two-tailed significant value of 0.003 ($p < 0.05$). There is a significant difference between the two groups considered. The two-tailed significance value obtained is 0.003 ($p < 0.05$) which is statistically significant. Within the limitations of this present study, the Al-Zn5Mg alloy was turned by TiN covered and uncovered ceramic tools through a CNC (Computed numeric control) machining center. The higher MRR is found in the machining operation with TiN covered tool. The value of MRR is greater than the MRR of uncovered ceramic tools.

Keywords

Novel Al-Zn5Mg alloy, CNC turning, TiN covered tool, Uncovered ceramic tool, Quality of life, Material removal rate, Independent t-test

Introduction

The machining aspect, the turning, is the basic and essential primary operation to fulfill the required quality of cylindrical samples during the fabrication of various industry applications. The surface quality, surface roughness, MRR, and time to the machine are the important output responses for deciding the accuracy of components [1]. The utilization of Al-Zn5Mg alloys is increased in multi-disciplinary engineering applications due to their enhanced mechanical characteristics and lightweight as compared to traditional materials [2]. The peak-aged Al-Zn5Mg alloy has great potential in the high-temperature application. Recent research on aluminum alloy material is machined [3] by CNC turning and comparing the MRR on the PVD-TiB_2 coated and uncoated insert. The PVD-TiB_2 coated insert found an increased MRR value as compared to the uncoated tool insert. The aluminum alloy was turned by carbide-coated and uncoated insert to analyze the machinability characteristics via analysis of variance (ANOVA). The results found that the carbide-coated tool was high MRR with a good surface quality of life [4]. The high cutting force has led to damage to the tool and reduced the MRR during high-speed machining [5]. To avoid the above drawback coated tool inserts are implemented to get higher MRR with a good surface quality of life on high-speed machining [6]. A similar tendency was reported by Yu et al. [7] during the machining of aluminum alloy.

The recent literature over the past 5 years publications the total number of papers published related to the present research on 800 papers from Google Scholar and 200 papers from Science Direct. The surface quality of life of the turning operation [5] was increased by topographic inspection of the turned surface. The MRR comparison of aluminum alloy by TiN coated insert and the uncoated insert was evaluated by ANOVA and TiN coated insert found increased MRR. Moreover, the coated tool inserts performed a high volume MRR during CNC machining over the uncoated inserts [3]. The aluminum alloy was turned by the HSS tool with varied input parameters like cutting speed, feed, and depth of cut [8]. However, the selection of material, machine, and input parameters such as feed, coolant, and cutting speed has been fixing the quality of life of the machined surface. The insert covered with Ti coat was enhanced MRR with reduced tool wear. To obtain a high MRR with good surface integrity, the ANOVA optimization tool technique is used. The output MRR value dominating input parameters were analyzed and optimized through ANOVA [9]. Among the various investigations, the best study of the aluminum alloy turning process with high MRR is found in Gevorkyan [5].

The main aim of this current study is the evaluation of MRR on Al-Zn5Mg alloy via a novel CNC turning machine equipped with TiN coated and uncoated tool inserts. Both insert performance on MRR of Al-Zn5Mg alloy measured by ASTM. To the best of our knowledge, there is no similar research or report that was found in the past research literature. The R and D cell from Saveetha University initiates the advanced material development in the recent industrial applications based on research investigation of aluminum alloy machinability behavior evaluation. The theme of this evaluation is about comparing the MRR on machining of Al- Zn5Mg alloy with TiN coated (trial bunch) and uncoated ceramic insert (control bunch) [10].

Materials and Method

The current study on the MRR of Al-Zn5Mg alloy is machined by a novel CNC machine- setting, tool, program module, nature of the operation and its evaluation was done with the extreme support of Saveetha Institute of Medical and Technical Science, Chennai (Tamil Nadu, India), using the required facilities in the department of mechanical. The experimental group set with [11] TiN-covered tool inset (experimental group) will machine the 20 number of Al-Zn5Mg alloy samples (N = 20) [12]. The uncovered ceramic tool insert (control group) will machine the 20 number of Al-Zn5Mg alloy samples (N = 20) [13]. However, the TiN covered insert is obtained as an overall mean and the standard deviation is found by 1.598 and 0.208745 with an 80% G-power value. The 40 samples of 20 from each group follow the MRR equation and are satisfied with ASTM [14].

In the experimental group, TiN covered insert is used as the main tool for turning Al-Zn5Mg alloy by CNC. The experimental full setup of CNC is illustrated in figure 1 and its TiN covered insert is shown in figure 2. The turning input parameters like cutting speed, feed rate, and depth of cut values are detailed in table 1.

According to the input parameters, the N = 20 samples are turned and their MRR is calculated by equation 1. The successfully turned Al-Zn5Mg alloy samples are shown in figure 3. The sample size of the base material was 200 mm in length and 50 mm in diameter.

The uncovered ceramic tool insert with good quality of life is utilized to control group investigation and 20 test samples were machined via the CNC machining center with varied input machining parameters like the similar value of the experimental group. The uncovered ceramic tool insert is shown in

Figure 1: CNC turning center.

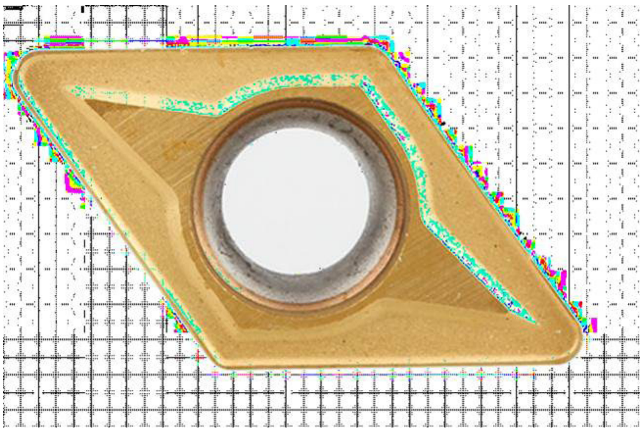
Figure 2: TiN covered tool.

Table 1: Al-Zn5Mg alloy turning parameters.

S. No.	Parameters	Units	Levels
1	Cutting speed	mm/min	700, 1000, 1200, 1500
2	Depth of cut	mm	1, 1.5, 2, 2.5, 3
3	Feed rate	mm/rev	0.15, 0.2, 0.25, 0.3, 0.35

Figure 3: Al-Zn5Mg alloy turned by TiN covered tool.

figure 4 and figure 5 illustrates the turned samples of Al-Zn-5Mg alloy.

The digital weighing machine, configured with a sensor system with an accuracy of ±0.001 g is adopted for measuring the weight loss of the Al-Zn5Mg alloy sample before and after the turning process. In the both experimental and control groups obtained 40 (20 + 20) Al-Zn5Mg alloy samples are weighted by "Wb" before the start of the turning process and "Wa" is weighted again after the turning process [15]. The time to machining operation is evaluated by a stopwatch. The

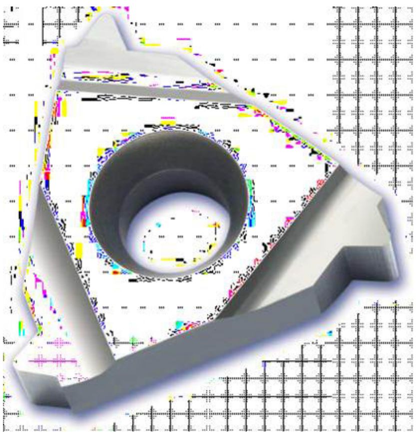

Figure 4: Uncovered ceramic tool.

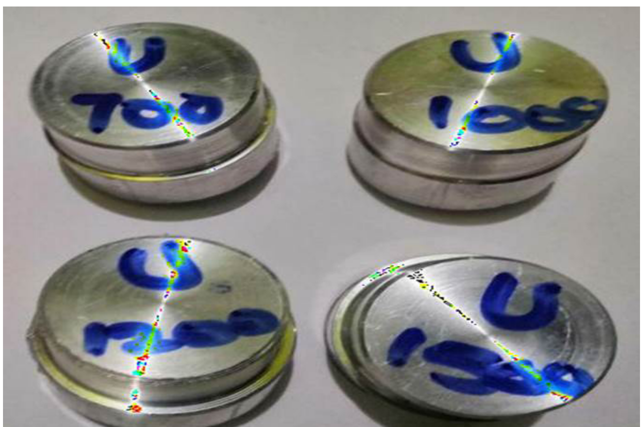

Figure 5: Al-Zn5Mg alloy turned by uncovered ceramic tool.

MRR is calculated based on the weight loss and time taken for turning operation on each sample is described in equation 1.

$$MRR = Wa/t * Wb \qquad (1)$$

Where, Wa - Weight of the Al-Zn5Mg alloy after turning, Wb - Weight of the Al-Zn5Mg alloy before turning, and t - Time is taken between the turning operation on each samples work to start - end.

Moreover, MRR for the Al-Zn5Mg alloy of 40 samples is calculated by ASTM and its values are analyzed by statistical significance tool SPSS software and the factor for domination of input parameters over the output response is controlled by ANOVA. According to the evaluation report accessed by the t-test, the statistical significance range of 0.003 has to be $p < 0.050$. Finally, the experimental and control group of MRR on Al-Zn5Mg alloy is compared. The optimum results of Al-Zn-5Mg alloy turning are summarized.

Statistical analysis

The IBM-known SPSS statistical analysis tool is utilized for the statistical study of turned Al-Zn5Mg alloy. The cutting speed, feed, and depth of cut on the turning process are treated as independent variables, and MRR is fixed as the dependent variable. The analysis from the SPSS tool predicted the significant MRR value continued t-test results on both group mean is studied. In the same way, the ANOVA Taguchi technique was utilized to find the optimum machining input variants in the aluminum alloy machining process [16].

Results

The calculated MRR values of the present experimental group of Al-Zn5Mg alloy turned with TiN covered and uncovered tool inserts (control group) are discussed in table 2.

The 20 Al-Zn5Mg alloy samples were machined by CNC turning center using TiN covered tool and attained higher MRR and mean, standard deviation, and standard error mean is 1.598 mm^3/min, 0.208745, and 0.041970, respectively. The next operations of Al-Zn5Mg alloy with 20 samples are machined by an uncovered ceramic tool to find the least MRR over the TiN covered insert tool results. The mean, standard deviation, and standard error mean value of the uncovered ceramic tool are noted as 1.254 mm^3/min, 0.292581, and 0.069402, respectively via the SPSS tool. Both experimental and control group statistical report is mentioned in table 3 and its ANOVA t-test one-way analysis is detailed in table 4.

Based on the SPSS analyzed results on MRR significance observed the limits of 0.003 are $p < 0.050$. The examined results of the statistical analysis bar chart on both the experimental (TiN covered) and control group (uncovered ceramic tool) with ±1 standard deviations are represented in figure 6.

Discussion

With the help of statistical analysis SPSS tool and ANOVA, the obtained test MRR results of machined Al-Zn5Mg alloy by TiN covered and uncovered tool are compared successfully [5]. The MRR results revealed that the Al-Zn5Mg

Table 2: Calculated MRR value of Al-Zn5Mg alloy via TiN covered and uncovered ceramic tool.

S. No.	Cutting speed (mm/min)	Depth of cut (mm)	Feed rate (mm/rev)	MRR (mm^3/min)	
				TiN covered tool	Uncovered ceramic tool
1	700	1	0.15	1.156	0.893
2	700	1.5	0.2	1.234	0.918
3	700	2	0.25	1.357	0.943
4	700	2.5	0.3	1.336	0.936
5	700	3	0.35	1.428	0.983
6	1000	1	0.15	1.362	0.976
7	1000	1.5	0.2	1.293	1.052
8	1000	2	0.25	1.378	1.103
9	1000	2.5	0.3	1.458	1.169
10	1000	3	0.35	1.636	1.214
11	1200	1	0.15	1.653	1.294
12	1200	1.5	0.2	1.567	1.366
13	1200	2	0.25	1.629	1.467
14	1200	2.5	0.3	1.715	1.525
15	1200	3	0.35	1.731	1.578
16	1500	1	0.15	1.703	1.592
17	1500	1.5	0.2	1.746	1.606
18	1500	2	0.25	1.801	1.624
19	1500	2.5	0.3	1.782	1.661
20	1500	3	0.35	1.823	1.698

Table 3: Statistical report for mean, standard deviation and standard error mean values of MRR on Al-Zn5Mg alloy via TiN covered and uncovered ceramic tool.

	Group	N	Mean	Std. deviation	Std. error mean
MRR	Covered tool	20	1.598	0.208745	0.041970
	Uncovered ceramic tool	20	1.254	0.292581	0.069402

alloy turned by TiN covered tool attained higher MRR compared to the control group. The uncovered ceramic (control group) noted decreased MRR over the experimental group. It was due to their poor thermal stability on higher frictional contact [17]. However, the TiN-covered tool inserts are found to have higher MRR rather than uncovered ceramic tools.

Moreover, the TiN-covered tool performs better machining in both steel and alloy materials due to its Titanium and nitrides coatings has led to increase thermal stability, resist the high indentation, and good wear resistance as compared to

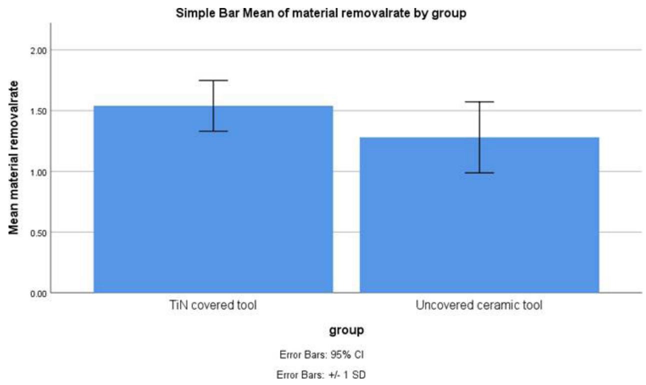

Figure 6: MRR mean values of TiN covered and uncovered tool utilized on Al-Zn5Mg alloy machining operation. X-axis: MRR of group mean of turned Al-Zn5Mg alloy with TiN covered and uncovered ceramic tool. Y-axis: MRR mean of both experimental and control group with ±0.25 standard deviation with error of 95%.

other inserts or conventional uncoated tools [18]. The effective ANOVA tool was utilized to find the optimum input parameters for affecting output response during the hard machining process. Similarly, the ANOVA implemented and found the input dominating parameters of aluminum alloy machining were 54.9% and 64.28% due to the cutting force and feed rate [19]. The cutting force and feed rate was the important factor in deciding the MRR. The carbide-coated insert was found to have a higher MRR with good surface quality [4]. Among the various concerns, the TiN coated insert was good surface roughness as well as a good MMR rating as compared to uncoated inserts [20].

The calculated test results of this current investigation on the turning process for Al-Zn5Mg alloy through a novel CNC turning center using TiN covered tool and uncovered ceramic tool. The Al-Zn5Mg alloy turned with TiN covered tool was identified as having higher MRR as compared to the uncovered ceramic tool. The MRR of the TiN covered tool is 1.801 mm^3/min. The high MRR performs the best input parameters (1500 m/min at 2 mm depth of cut on 0.25 mm/rev feed rate) observed via ANOVA.

Conclusion

Within the limitations of this present evaluation, the comparison of MRR for Al-Zn5Mg alloy turned by CNC turning center by using the TiN covered and uncovered ceramic tool. The MRR of both TiN-covered tools is 1.801 mm^3/min and 1.608 mm^3/min observed by the uncovered ceramic tool are

Table 4: Analysis of variance – one-way t-test approaches on the significant results of MRR ($p = 0.003$, $p < 0.05$) for TiN covered tool and uncovered ceramic tool used for turning of Al-Zn5Mg alloy.

		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
MRR	Equal variance assumed	5.430	0.005	3.229	38	0.003	1.598	0.208745	0.085702	0.321910
	Equal variance not assumed			3.229	34.362	0.003	1.254	.292581	0.085702	0.321910

measured via ASTM standard. Based on the evaluation results, the ANOVA t-test dependent and independent variable on the mean value of Al-Zn5Mg alloy (20 + 20) samples were significant through TiN covered tool rather than uncovered ceramic tool has been attached within the limit of $p = 0.003$ ($p < 0.050$). The TiN covered tool was noted as having maximum MRR as compared to the uncovered ceramic tool.

Acknowledgements

None.

Conflict of Interest

None.

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