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Comparing Performance of HSS and TiAlN Coated WC Tool in CNC Machining of AA7475 + ZrN + Fly Ash Reinforcement Composite to Improve Surface Finish

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Abstract

Aim: By comparing two different kinds of tools on the reinforcement composite made of lightweight material like AA7475 + ZrN + fly ash, the This project's main goal is to produce good surface roughness.

Materials and Methods: Stir casting is used to create the novel, lightweight composite material AA7475 + ZrN + fly ash. The cast composite is prepared as workpieces for CNC machining and pre-processed to remove surface imperfections. Group 1 HSS tool and group 2 coated Tungsten carbide (WC) tool, each group needed the same number of participants, which was determined to be sixteen. The speed, feed, and depth of cut at four levels in sixteen possible combinations for dry machining or green production. When compared to the assistance provided by using surface roughness on machined surfaces, the overall performance of HSS and TiAlN covered WC tools is superior.

Results: Sample surface roughness was statistically examined group by group using SPSS. With a p value of 0.000 ($p < 0.05$), these findings demonstrated a statistically significant difference between the two groups. demonstrating the statistical independence of the observations and the validity of the statistical assumption that was discovered. The mean surface roughness of samples created with the TiAlN coated WC tool is less than that of samples created with the HSS tool.

Conclusion: Within the restrictions of this study, TiAlN coated WC tool offers lesser surface roughness than HSS tool.

Keywords

High-speed steel, Tungsten carbide tools with a titanium aluminum nitride coating, Light weight material, AA7475, Novel zirconium nitride, Fly ash, Computer numerical control, Machining, Surface finish, Stacking sequence

Introduction

The HSS tool and TiALN coated WC tool will be used in this study to compare the surface roughness of milled AA7475 surfaces [1]. The primary benefits of this work include lowering the price of the product, improving the surface finish's quality, and speeding up production. The lightweight material AA7475 and the novel ZrN+ fly ash can be used in aerospace and the production of ribs for aeroplane wings [2].

Over the past five years, the AA7475 + ZrN + fly ash reinforcement composite has been the focus of about 240 studies in Google Scholar and 71 papers in Science Direct. Cutting speed, feed rate, and cut depth are machining characteristics that are greatly influenced by material removal rate. while it comes to reducing surface roughness while machining alloys, the choice of great process parameters is far more crucial than surface roughness.

In the test, the samples' high-quality surface finish was achieved by using the insert's specified leading edge [3]. Additionally, the best surface finish was achieved with the least amount of energy used. The maximum value was found in the optimum test, and the value of discharge energy is less than because of surface damage [4]. To produce a good surface finish, a source is needed to regulate the contributing factors, such as the dielectric medium, material, and electrical characteristics.

The process parameters had the most impact on the AA6061 surface roughness analysis with SiC reinforcement. The Taguchi tool's strong design approach to sorting the parameters that should affect the surface roughness has been discovered. Cutting speed parameters are most affected by the surface roughness analysis, then feed rate, and then cut depth [5]. The feed rate was the most important characteristic of the output response (Surface roughness) in comparison to other variables like cutting speed and depth of cut. This study also suggested utilizing tougher tools to make hard material machining more practicable [6]. Our group has extensive prior experience working on a variety of multidisciplinary research projects. Now, we decided to go ahead with this project because of the growing trend in this area [7]. The most significant research into a new material's machinability is necessary. As a material that has been modified, aluminum alloys like AA7475 with 4% ZrN and 3% fly ash are widely applicable. The upcoming machinability studies. The conservative also as useful machining should be possible at CNC machining. There was no research on CNC milling and the machinability of AA7475 + 4% novel ZrN + 3% fly ash material. The machinability of AA7475, 4% ZrN, and 3% fly ash in CNC milling is the subject of this study.

Materials and Methods

The Saveetha School of Engineering at the Saveetha Institute of Medical and Technical Sciences in Chennai was where this study was conducted. Ethics clearance was not necessary for this investigation because no human samples were used. The intervention group (TiAlN coated WC tool) and the control group (HSS tool) are contrasted in this experimental investigation. There should be 16 groups, with a 16-person sample size for each category. The necessary sample size was calculated using an open-source sample size calculator. Examples of the techniques employed are g-power 80%, alpha 0.05, and 0.9773 for the proposed method and 0.9675 for the standard method [8].

Bdiboridehandari metals and alloys in Chennai, Tamil Nadu, India, supplied the reinforcement materials and aluminum. Stir casting was done with the AA7475 aluminum metal matrix composite.

Figure 1 at the Metmech casting industry in Chennai, Tamil Nadu, India, with 4% novel ZrN and 3% fly ash. The used matrix is: AA7475 (3.2 kg, 93%), titanium ZrN (0.4 kg, 4%), and boron carbide fly ash (0.096 kg, 3%). Using electric discharge from cut wire to create the specimens, the casting was sliced using machining. The samples were made with dimensions of 50 mm x 50 mm x 10 mm, as shown in figure 2.

Figure 1: Stir casting process.

Figure 2: Raw specimen without machining.

The samples from the control group will be dry milled using an HSS cutter. The sixteen unique input parameter combinations of green machining. The 25 mm sample length was prefixed. Even though the work material is the same for both groups, the intervention group, group B, will machine samples using a TiAlN coated WC tool and 16 different input parameter combinations, just like the control group.

For machining trials, the spindle nose taper BT40, spindle motor (Standard), and Vertical Milling Centre (YCM) EV 1020A 5.5/7.5 kW were employed for 15 more minutes. The HSS and TiAlN coated WC tool groups' machined examples are shown in figure 3 and figure 4, respectively. Using a Mitutoyo surface profilometer with a stylus that has a 2 µ tip radius,

Figure 3: Machined specimen (HSS tool).

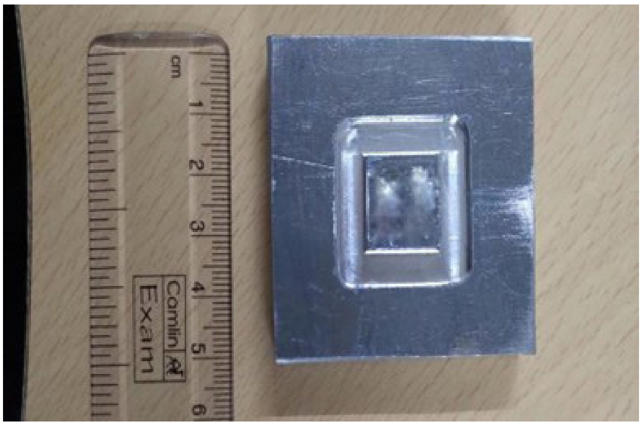

Figure 4: Machined specimen (TiAlN coated WC tool).

the surface roughness was measured [9-12]. The testing standard that came after was ISO - 4287 (1997).

After the sample was machined to a specific length, surface roughness was assessed using sampling length 5 at a measurement speed of 0.25 mm/sec. 2.5 mm was the cut-off length. The process was carried out three times at various points on the machined surface to eliminate errors, and the average of those repetitions was used. The input specifications shown in table 1, table 2 and table 3 present the surface roughness measurements for samples from the HSS group and TiAlN coated WC tool groups, respectively.

Table 1: Machining parameters.

Parameter	Value
Standard ISO	4287 (1997)
Sampling length	5
Measuring speed	0.25 mm/sec
Cut off length	2.5 mm

Table 2: Surface roughness obtained by using HSS tool (16 samples).

S.no	Cutting speed (rpm)	Feed (mm/min)	Depth of cut (mm)	Surface roughness (μm)
1	500	2	0.2	1.876
2	710	4	0.4	1.32
3	1000	6	0.6	1.43
4	1400	8	0.8	1.312
5	500	4	0.4	1.231
6	710	2	0.2	1.421
7	1000	8	0.8	1.67
8	1400	6	0.6	1.421
9	500	6	0.6	1.231
10	710	8	0.8	1.543
11	1000	2	0.2	1.456
12	1400	4	0.4	1.479
13	1100	2	0.8	0.999
14	1100	4	0.6	1.001
15	1100	6	0.4	1.095
16	1100	8	0.2	1.076

Statistical analysis

The statistical analysis was performed using IBM SPSS statistics 26. The means of the intervention and control groups were contrasted using the independent sample test. Surface roughness was the dependent variable, and the independent variables were cutting speed, feed rate, and depth of cut. It was done using the independent samples test and statistical analysis like the t-test. Results from the independent samples test have a significance level of 0.023. The results were acquired and represented as a bar chart with means.

Results

The deliberate surface roughness testing (Ra) esteem with utilization of profilometer for tests of the two gatherings (16 examples for every gathering) are measurably investigated. The intervention group's (TiAlN coated WC) mean is significantly lower than the control group's (HSS) mean, which is 1.547906 μ Therefore, compared to samples machined using standard HSS tools, the surface finish significantly improved when the TiAlN coated WC tool was utilized.

Table 1 lists the 16 various categories of experiment inputs. Table 2 displays the degree of roughness of the samples that were machined with HSS tools. Roughness measurements vary from 1.073 to 2.388. Table 3 displays the degree of roughness of the samples that were machined with HSS tools. Roughness measurements range from 0.194 to 1.5214. Table 4 displays the findings of the T test, including the means, standard deviations, and standard deviation errors for the TiAlN coated WC tool and HSS groups. The results of the Autonomous example test to look at the trial of importance are shown in table 5.

The synthesis of a novel, light material using AA7475, 4% ZrN, and 3% fly ash is depicted in figure 1. A sample of the prepared workpiece for CNC milling is depicted in figure 2. Figure 4 depicts the sample that was machined using the proposed TiAlN coated WC tool (sample of intervention group), while figure 3 depicts the sample that was machined using the

Table 3: Surface roughness obtained by using TiAlN coated WC tool (16 samples).

S.no	Cutting speed (rpm)	Feed (mm/min)	Depth of cut (mm)	Surface roughness (µm)
1	500	2	0.2	0.932
2	710	4	0.4	1.1
3	1000	6	0.6	0.899
4	1400	8	0.8	1.012
5	500	4	0.4	0.989
6	710	2	0.2	1.023
7	1000	8	0.8	1.198
8	1400	6	0.6	1.078
9	500	6	0.6	1.087
10	710	8	0.8	1.21
11	1000	2	0.2	0.98
12	1400	4	0.4	0.897
13	1100	2	0.8	0.879
14	1100	4	0.6	0.976
15	1100	6	0.4	0.988
16	1100	8	0.2	0.834

Table 4: Results of a t-test for a sample of the composite material AA7475 + ZrN + fly ash that was machined using two different techniques. HSS and TiAIN coated WC tools are used to machine group A samples and group B samples, respectively. The proposed method's sample means (Group B) are much lower than those obtained using the traditional HSS tool in sample group A.

Group statistics					
	Composite	N	Mean	Std. deviation	Std. error mean
Ra	HSS	16	1.3475625	0.2417102	1.327436
	TiAlN coated WC	16	1.005125	0.108345	0.999754

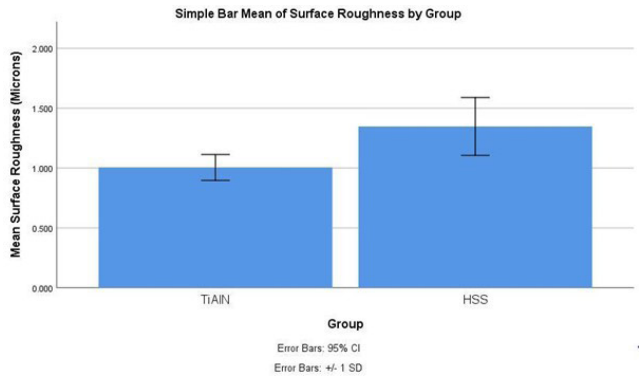

Figure 5: Displays a sample bar comparing the Ra values of surfaces that were machined using HSS and TiAlN coated WC tools. According to the graph, TiAlN WC tool yielded lower mean Ra values than HSS tool (1.547906 µm), 1.229031 µm to be exact. HSS and TiAlN coated WC tool on the X-axis, and mean surface roughness 1 SD on the Y-axis.

conventional HSS tool (sample of control group). At a level of 1 standard deviation, the comparison of the group mean is shown in figure 5.

Discussion

RBy employing a High speed steel (HSS) tool at a speed of 1400 m/min, 0.2 mm of cut depth, and 2 mm/rev of feed, the lowest surface roughness was discovered to be 1.073 µm. The largest surface roughness that could be measured was 2.0459 µm. A titanium aluminum Nitride coated WC cutter produced a minimal surface roughness of 1.08 µm at 1400 m/min speed, 0.4 mm cut depth, and 4 mm/rev feed. The maximum surface roughness that could be measured was 1.872 µm. According to the test results, the TiAlN coated WC tool's surface roughness is less than that of the HSS tool. With a p value of 0.000 ($p < 0.05$), these findings demonstrated a statistically significant difference between the two groups.

When surface roughness is reduced by a short cut depth, a high feed rate, and a high cutting speed. They show statistically intelligent significance at a significance level of 0.05. The usage of the TiAlN coated WC tool dramatically reduced the surface roughness of the composite when compared to the HSS tool. In addition, the feed rate and unit depth of cut, all of which are equally specified were additional parameters that were influencing surface roughness. If feed rate and profundity of cut increments, surface harshness additionally will build [13] upheld this it is much of the time expressed that surface unpleasantness was worked on by 21.82% with the usage of TiAlN covered WC device than customary HSS apparatus. Because only a small number of input parameters are used [14]. In addition, the newly prepared reinforced composites (Light weight material AA7475 + novel ZrN + fly ash) were machined using a coated carbide tool in CNC machining. Additionally, this study demonstrated that a TiAlN coated WC tool is appropriate for this composite to promote minimal surface roughness, as minimal surface roughness is necessary

Table 5: Results of independent samples tests for CNC milling of the reinforced composite material made of AA7475, ZrN, and fly ash using traditional HSS tools (Group 1) and a suggested TiAIN coated WC tool (Group 2). Because the significance value of 0.023 is less than 0.05, the obtained results are statistically significant.

Independent samples test										
		Levene's test for equality of variances		T test for equality of means					95% confidence interval of the difference	
		F	Sig.	T	df	Sig. (2 tailed)	Mean difference	Std. error difference	Lower	Upper
Ra	Equal variances assumed	5.77	0.023	2.11	30	0.043	0.318875	0.1508576	0.010782	0.62697
	Equal variances not assumed			2.11	26.66	0.044	0.318875	0.1508576	0.009158	0.62859

for each application to promote improved surface finish. In the current study, the CNC (VMC) drilling process is experimentally analysed to determine how cutting factors affect the production of high-quality drilled holes in composite materials. This is because, with this limited set of input parameters, the TiAlN coated WC tool is normally advised for CNC machining in the contour milling operation. greater speed, greater feed rate, and a shallower cut depth during this operation result in the composite's surface being as smooth as possible. It is possible to assess the influence of the process parameters on the output variables using Taguchi L9. These results could be used to produce squeeze cast components with better surface finishes. In this investigation, only the squeezing pressure, preheating temperature, and die material have been considered [15]. The previous discussions make it clear that tool hardness and cutting zone temperatures have a considerable impact on surface roughness in addition to the usual input factors (feed, speed, and depth of cut). The TiAlN coated WC tool's surface roughness dramatically lowered, producing better results.

Our institution is dedicated to performing high-quality, evidence-based research and excels in several areas [16]. We hope that this study will add to this extensive legacy. Even though the outcomes were considerably better, this study contains a few small flaws. Although coolant will significantly contribute to reducing surface roughness, this study does not consider its effects on surface roughness because it focused on green manufacturing. The study only looked at using a TiAlN coated WC tool to smooth out the surface. As a result, to further reduce surface roughness values, this study will be extended by incorporating cooling effects such as wet machining, minimum liquid quantity cooling, cryogenic cooling, and so on for tools that are specifically coated and harder than those that were previously considered.

Conclusion

The CNC milling of light weight material AA7475 + ZrN + fly ash reinforcement composite with HSS and TiAlN coated WC tools for reducing surface roughness was compared within the confines of this study. The outcome demonstrates that the group means of samples that were processed using a TiAlN coated WC tool had a surface roughness that was lower than that of an HSS tool. Thus, surface unpleasantness moderately decreased by 17.86%.

Acknowledgements

None.

Conflict of Interest

None.

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