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Experimental Study of Cryogenic Milling of AZ91D Mg Alloy-eco Friendly Machining

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Abstract

The purpose of this research is to evaluate the surface roughness (SR) received under dry, flood, and the novel cryogenic methods in machining of the magnesium (Mg) alloy. Two groups, the experimental group (cryogenic) and the control group (dry) were picked for the study. The quantity of samples is calculated using the sample calculator. There were 9 samples taken for each group. The Mg alloy is cut in the control group without any lubricant. In the experimental group, the cryogenic technique is applied to the machining which is contrasted against the dry and flood method. Each group's SR is measured using a SR tester. We examine the impact of the distinctive dry, flood, and cryogenic methods on SR. In comparison to samples acquired from machining, T-independent tests were done using the SPSS statistical tool. According to the experimental data, cryogenic technique has lower SR, with an average of ($p < 0.05$). Surface finish significantly increases whenever the cryogenic method is used as compared to dry and flood methods, which paves the way for sustainable manufacturing.

Keywords

Dry, Flood, Cryogenic, Magnesium alloy, Nanoparticles, Sustainable cooling

Introduction

The industry's lightest structural metal is Mg alloy. It has several interesting features [1]. It's as hard as metal while being as lightweight as plastic [2]. Its alloy is generally recyclable and has a low density, a high specific strength, and a high specific elasticity. Alloys of Mg in the automobile sector were extensively used. The automotive and aerospace sectors have recently tended to favor vehicle weight reduction to increase fuel economy [3]. The potential to make a vehicle lighter by using lightweight materials for its structural components has prompted researchers to investigate elements that are lighter than aluminum (Al). In this regard, because of its excellent characteristics, for example, strong toughness, high stiffness and low density, researchers have been investigating the potential of Mg alloys [4].

Mg is regarded as the metal that requires the least amount of power for the machine [5]. Despite possessing good qualities, there are a few problems that must be resolved before Mg and its alloys may be used to their full potential [6]. In recent decades, their use in the aviation sector has drastically diminished. Although they meet the aviation industry's standards, there is still concern regarding their flammability [7]. The use of water-based coolants might be harmful for the same reasons. Moreover, utilizing lubricants and coolants during the cutting process can have a negative impact on the economy and the environment [8]. As a result, dry conditions are preferred for the economic, environmental, and security advantages of milling Mg [9]. Turning typically produces a rough surface and removes stock from the material. As a result, SR is another important metric for assessing cutting performance. This study took into account the average SR, which is commonly used in industries [10]. When materials are machined, what kinds of cutting tools are used both have an impact on the surface characteristics produced [11]. During milling operations, surface finish is affected by cutting speed, feed rate, depth of cut, and tool nose radius, cutting tool lubrication, machine vibrations, tool wear and the mechanical and other properties of the material being machined [12].

The roughness of the Mg alloy's surface is machined using dry, flood, and cryogenic milling stages [13]. The list uses flood cooling applications as a solution for lightweight metals. As a result, this cutting area could become heated, and the geometry and shape of the machined parts could lack quality [14]. Cutting the Mg metal proved risky due to the collected tiny particles, powder-like pieces could catch fire [15]. Therefore, it is crucial to research how machining Mg is affected by speed. Read about finish face milling to comprehend how tool temperature and ignition conditions vary [16]. Cryogenic machining's effect on surface quality features is discussed and compared with dry, cryogenic, and flood-cooled manufacturing techniques. In addition to being an environmentally friendly method, our study reveals that cryogenic machining significantly improves the functional performance of machined components through its better and more desirable surface quality features [17]. Most of these four papers are related to this work.

According to the findings of the research, only a few studies have been conducted on the effects of novel cryogenic on SR of the AZ91D alloy [18]. The experimental and depth theoretical knowledge about various machining operations, Novelty of cryogenic technique motivated to carry out this research work [19]. This study is related to the machining of Z91D alloy under dry, flood and cryogenic techniques [20].

Materials and Methods

Saveetha Engineering Industries and the Saveetha Institute of Medical and Technical Sciences in Chennai performed the SR tests and machining operations required for this study. Since the focus of this research is on SR testing and CNC vertical milling machine YCM EV1020A (Figure 1) milling operations, human samples are not included in it. The two main groups in this study are the experimental group and the control group. A machining technique called a "control group" makes absolutely no use of lubricant. The machining process that uses AZ91D's cryogenic milling, in which pressurized lubricant is applied to a cutting zone, is considered experimental. A sample calculator is used to determine the sample count. The total number of samples taken was 27 (N = 3), with 27 samples being taken for each of the groups (N = 9). The industry's productivity of Mg alloy products high cutting speeds, however, would result in chip ignition or greater cutting temperatures. Investigating the effect of cutting temperature on the machining of Mg alloy is crucial as a result. In our experiments, the standard Mg alloy AZ91D was employed.

Figure 1: Vertical CNC milling machine YCM XV1020A.

The chemical makeup (in weight percent) was as follows: 4.5 - 5.3 Al, 0.0000 - 0.20 zinc, 0.2 - 0.5 manganese, 0.005 - 0.05 silicon, 0.008 - 0.01 copper, 0.001 - 0.01 Ni, and 0.001 - 0.01 iron, with the remaining Mg. This optical microscope is also used to describe the AZ91D Mg alloy's surface structure.

Cutting speed, feed rate, flank wear, temperature, and depth of cut, are independent variables, but SR is a dependent variable. The SPSS software is used to calculate the significance of each of the 27 samples from the experimental group and control group. SR versus trial number graphs and overall SR were used in the analysis for two groups of work items.

Statistical analysis

The SPSS software V.26 is used to determine the significant value for both the experimental group and the control group. For each of the 27 Mg alloy SR samples that were created using the method and the 27 samples of a cryogenic, flood, and dry SR. Using SPSS software the significant value, mean, and standard deviation for dry machining and cryogenic machining processes were examined with a 95% standard error. Simple dry machining versus cryogenic machining on the X-axis roughness of a surface is shown on the Y-axis. The independent variables are depth of cut, temperature, flood, cutting speed, feed rate, nanoparticles, and castor oil. The investigation was carried out using graphs comparing SR vs trail number for two groups of workpieces. The dependent variable is SR [21].

Results and Discussion

The SR of samples from the control group and experimental group was measured using a SR measurement device. Compared to the two groups in table 1, SR has an N value of 9, based on feed rate and SR. SR is 1.57333 um on average, and the feed rate is 1.0000 um. The results show that cryogenic machining produces surfaces with a better finish than dry machining. Cryogenic machining has a significantly improved SR, as shown by figure 2. A review table 2 showing both mean and standard deviation of SR for dry machining, flood, and cryogenic machining. They calculated the SR shown in table 2. Figure 3 presented the cryogenic, flood,

Table 1. Comparing SR with distinct coolants.

Group statistics					
Group		N	Mean	SD	SE mean
SR	1.00	9	2.293333	0.095	0.05621
	2.00	9	2.003333	0.108628	0.03621
	3.00	9	1.573333	0.108628	0.0214

Figure 2: Machined surface of Mg alloy.

Table 2: The experimental values of SR for dry machining, flood, and cryogenic machining.

S. No.	Coolant condition	speed	Feed rate	SR
1	Dry	45	0.8	2.3
2	Dry	45	1	2.35
3	Dry	45	1.2	2.47
4	Dry	60	0.8	2.21
5	Dry	60	1	2.26
6	Dry	60	1.2	2.38
7	Dry	75	0.8	2.21
8	Dry	75	1	2.17
9	Dry	75	1.2	2.29
10	Flood	45	0.8	2.02
11	Flood	45	1	2.07
12	Flood	45	1.2	2.19
13	Flood	60	0.8	1.93
14	Flood	60	1	1.98
15	Flood	60	1.2	2.1
16	Flood	75	0.8	1.84
17	Flood	75	1	1.89
18	Flood	75	1.2	2.01
19	Cryogenic	45	0.8	1.59
20	Cryogenic	45	1	1.64
21	Cryogenic	45	1.2	1.76
22	Cryogenic	60	0.8	1.5
23	Cryogenic	60	1	1.55
24	Cryogenic	60	1.2	1.67
25	Cryogenic	75	0.8	1.41
26	Cryogenic	75	1	1.46
27	Cryogenic	75	1.2	1.58

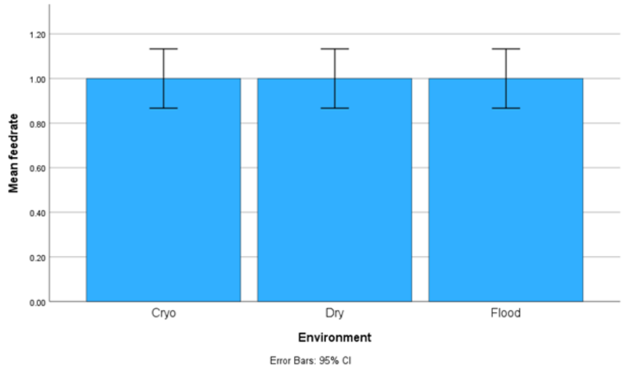

Figure 3: Mean of dry, flood and cryogenic environments - 95% CI, ± 1 SD.

and dry machining of a rectangle Mg alloy. Table 3 displays the SR independent group test, 95% confidence interval of a difference.

The response variable was SR, whereas the control variables include cutting speed, feed rate, temperature, depth of cut, nanoparticles, and castor oil [22]. To use the SPSS program, the value for each of the 27 values from the experimental group and control group is calculated. This analysis also included SR is 2.2933 um on average. The cryogenic graphs compare SR versus trial numbers for two groups of workpieces. Cutting speed, environment, and feed were the input variables used in this research. These responses include chip morphology, tool wear, and SR. Dry, cryogenic, and flood conditions each resulted in a 95% decrease in SR (Ra). Cryogenic machining presents improvements over dry and conventional machining, which are outweighed by the availability of cryogenic fluid.

The variables that affect the research study are the percentage weight ratio of nanoparticles, the viscosity of castor oil, compressor pressure, and nozzle diameter. The research has its limits due to the random nature of the workpieces manufactured by the hand lay-up process and the difficulty of achieving uniform distribution in manual manufacture. Research into the effects of different nanoparticles, castor oils, and mineral oils was conceivable. Nanoparticles with different sizes and volume fractions can be used for the same research.

Conclusion

The outcomes of an investigation's restrictions and the importance of an actual dry, flood and cryogenic. While machining Mg alloy, its effect on lubrication strategy for SR has been studied. The initial cryogenic SR of a machining process is compared with that of the dry machining technique. Cryogenic condition outperforms the other 2 conditions. Significant differences were observed between the material groups according to the T-test statistical analysis of the mean/ average Ra ($t = 5.468$, $p = 0.001$).

Acknowledgements

None.

Conflict of Interest

None.

Table 3: T-test for equality of means of the SR and feed rate.

Independent samples test										
SR	Levene's test		T-test							
	F	Sig.	t	df	Significance		Mean difference	SE difference	95% CI of the difference	
					One-sided p	Two-sided p			Lower	Higher
Equal variances	0.000	0.001	5.468	16	< 0.001	< 0.001	0.28000	0.05121	0.1714	0.3885
Non equal variances	-	-	5.468	16.000	< 0.001	< 0.001	0.28000	0.05121	0.1714	0.3885

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