Australian Journal of Basic and Applied Sciences, 10(16) November 2016, Pages: 88-91

AUSTRALIAN JOURNAL OF BASIC AND APPLIED SCIENCES

ISSN:1991-8178 EISSN: 2309-8414
Journal home page: www.ajbasweb.com

Effects of Compressed Cold Air, Coolant and Dry Conditions On Surface Roughness and Cutting Forces on Milling of Al-6061 Alloy

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ARTICLE INFO

Article history:
Received 10 September 2016
Accepted 10 November 2016
Published 28 November 2016

Keywords:
Aluminium alloy
Milling
Surface roughness
Cold air
Cutting force

ABSTRACT

Milling of aluminium alloys are increasingly used in manufacturing of products in these days. An experimental investigation was carried out in this connection to choose the best possible milling parameters for the 6061-T6 grade aluminium alloy with different cooling methods. The ingredients in the coolant affect the surface integrity of the work material and also the environment. In this study compressed cold air as a coolant is compared with commercial coolant. The experimental study conducted with combinations of two milling parameters i.e., speed, feed and three cooling methods, i.e., compressed cold air, coolant, dry condition and the outcome analysed to conclude the best available combination of parameters. The experimental results that were obtained suggest that the higher the speed rate and feed rate with dry milling produced lower surface roughness values, which result in a better finish on the material. However, milling with compressed cold air showed a similar trend, but slightly higher values of surface roughness.

INTRODUCTION

A wide range of applications of aluminium in the industry has proven that it is an important material for fabrication. While fabricating, end milling operations play an important role for alignment and fitting requirements. Qualities of manufactured products are determined by their surface properties. In the past, several researchers have studied the influence of machining variables on surface roughness. Chockalingam *et al* (2013) concluded that surface roughness generally increases with increase in feed. To study the influence exerted by the tool nose radius, flank width and the cutting conditions on residual stress and surface roughness, built prediction models by Taguchi method and response surface methodology. Ozcelik and Bayramoglu (2006) developed surface roughness model and determined cutting conditions. In their study, the influence of end milling parameters on surface roughness of aluminium alloy was established. Ryu *et al*. (2006) investigated the plane surface generation mechanism in flat end milling. These studies indicate that surface texture in end milling process is determined by the combinations of tool geometry and cutting conditions including feed rate and spindle speed. Tool run-out and setting error play an important role in the surface profile generation and tool deflection induced by cutting forces affects the surface form error. Chockalingam and Lee (2012) had done an experimental study on surface roughness in the milling of stainless steel. In their research work milling of stainless steel was carried out with combinations of parameters like speed, depth of cut and compressed cold air coolant and commercial coolant.

To Cite This Article: Chockalingam Palanisamy and Katheeravan Amirthalingam., Effects of Compressed Cold Air, Coolant and Dry Conditions On Surface Roughness and Cutting Forces on Milling of Al-6061 Alloy. ***Aust. J. Basic & Appl. Sci.,*** *10(16): 88-91, 2016*

MATERIALS AND METHODS

Milling process involves many parameters such as cutting speed, feed rate, depth of cut, tool geometry, coolant etc. The factors considered in the current experiments were cutting speed, feed, and depth of cut and cooling methods. Gobikrishnan and Umanath (2015) conducted machining to find the optimum machining condition of micro electrochemical machining for Titanium Alloy. The CNC machining centre with a HSS tool is used to mill the 6061 Aluminium alloy at combinations of machining parameters with compressed cold air, commercial coolant and dry conditions. The surface integrity of the machined surface was measured using surface roughness measuring instrument and forces during milling measured with the help of the dynamometer.

Table 1: Chemical and physical properties of Al6061-T6 alloy

Aluminium	98.6 %
Chromium	0.04 - 0.35 %
Copper	0.15 - 0.4 %
Iron	0 - 0.7 %
Magnesium	0.8 - 1.2 5 %
Manganese	0.15 % max
Silicon	0.4 - 0.8 5
Titanium	0.15 % max
Zinc	0.25 % max
Others	0.15 % max
Density	0.098
Specific Gravity	2.7 Kg/m^3
Melting Point	1090 ˚ C

The experimental study was carried out in a CNC machining centre, equipped with a maximum spindle speed of 4000 rpm and feed rate of 0-500 mm/min. The work piece material used was Al T6061-T6 which was in the form of 90 mm x 90mm x 8mm. Tables 1 provides the chemical and physical properties of the work piece material. A 5 mm two fluttered tool bit was used in the machining process.

RESULTS AND DISCUSSION

The experimental design and measured values are shown in Table 2. These 27 points were run in random orders to avoid any systematic errors that could occur during the machining processes. All machining operations produce cutting marks known as surface finish or surface roughness.

Milling parameters influence on surface roughness of work piece material:

The surface roughness plots for process variable are shown in Fig. 1. It was found from the Fig. 1 that in the case of compressed cold air cooling, the surface roughness values increased when feed rates increased at a constant low speed. However, the surface roughness value decreased at higher spindle speeds. This could be due to increased cutting and easier chip formation. When milling with coolant, higher surface roughness values were observed at increasing spindle speed. However, for all higher feed combinations recorded low surface roughness. In the case of dry milling, low surface roughness values were produced for all conditions. In the case of milling with compressed cold air, the high speed/medium feed combination produced low surface roughness.

The surface roughness obtained under dry milling was the least, when compared to that of milling with compressed cold air and commercial coolant at all levels of considered parameters. This could be due to the increased flow ability of the work material at high temperatures under machining conditions, leading to easier chip formation and thus decreasing the surface roughness. This support the conclusion of Chcokalingam and Kok (2013) result that grinding in dry condition was the most efficient in material removal in most of the conditions tested.

It has been observed from the Fig. 1 that the surface roughness decreased with an increase in feed rate in all the cases under the study except milling with compressed cold air at low spindle speeds. This is because of the increase in chip thickness due to the increase in feed rate. This observation in line with the findings of Anandan and Suresh prabhu (2016) that surface roughness is significantly affected by feed rate and least affected by speed. Furthermore, it can be seen that the surface roughness increased with the increase in cutting speed. One possible explanation is that, as cutting speed increases, heat generated in the shear zone could not be conducted away. As a result, material was more predominantly ploughed than cut, leading to higher surface roughness.

Milling with compressed cold air exhibited decreasing trend in cutting forces when the feed was increased. However, at 5090 rpm, lower forces than the other two cooling methods tested were produced. Milling with coolant resulted in increased cutting forces for increasing feeds. However, at a high speed, cutting force decreased. A similar trend was observed with milling in dry conditions.

Table 2: Experimental matrix and responses

Speed, (rpm)	Feed, (mm/ min)	Cold air				Coolant				Dry			
		Fx (N)	Fy (N)	Fz (N)	Ra (μm)	Fx (N)	Fy (N)	Fz (N)	Ra (μm)	Fx (N)	Fy (N)	Fz (N)	Ra (μm)
3185	50	160.93	130.48	211.51	0.16	79.63	83.05	20.51	0.36	78.65	81.1	14.658	0.10
3185	100	64.98	52.27	83.51	0.19	92.57	94.78	12.70	0.29	100.15	106.25	12.7	0.10
3185	150	9.77	9.041	16.674	0.33	108.21	117.01	13.67	0.30	119.97	131.68	13.67	0.13
5090	50	16.61	12.7	19.54	0.24	61.06	59.35	10.25	0.40	68.88	66.68	19.05	0.10
5090	100	7.33	5.13	4.84	0.20	72.29	71.32	12.21	0.41	77.67	77.18	15.15	0.10
5090	150	1.47	0.74	2.45	0.20	83.04	82.31	12.21	0.33	86.46	85.97	13.68	0.09
6350	50	91.83	74.01	119.21	0.28	47.87	45.92	11.72	0.46	49.09	45.18	122.6	0.12
6350	100	127.78	103.58	167.51	0.20	64.48	64.23	9.77	0.42	64.24	61.06	10.26	0.09
6350	150	4.15	2.45	2.93	0.19	69.61	74.74	11.24	0.35	74.74	75.47	10.75	0.10

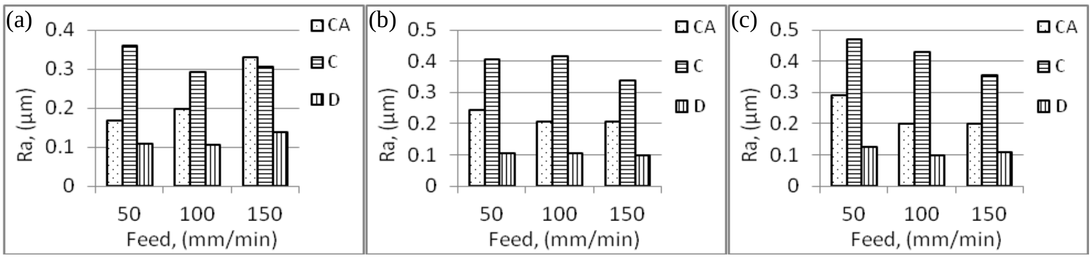

Fig. 1: Surface roughness chart for different feed a) at 3185 rpm b) at 5090 rpm c) at 6350 rpm

Effect of force:

It has been observed from the Fig. 2 that the cutting forces increased with an increase in feed rate in all the cases studied except milling with compressed cold air. This is because of the increased cutting due to the increase in feed rate. Furthermore, it can be seen that the forces decreased with the increase in cutting speed. This is because rapid cutting reduced friction at the contact zone.

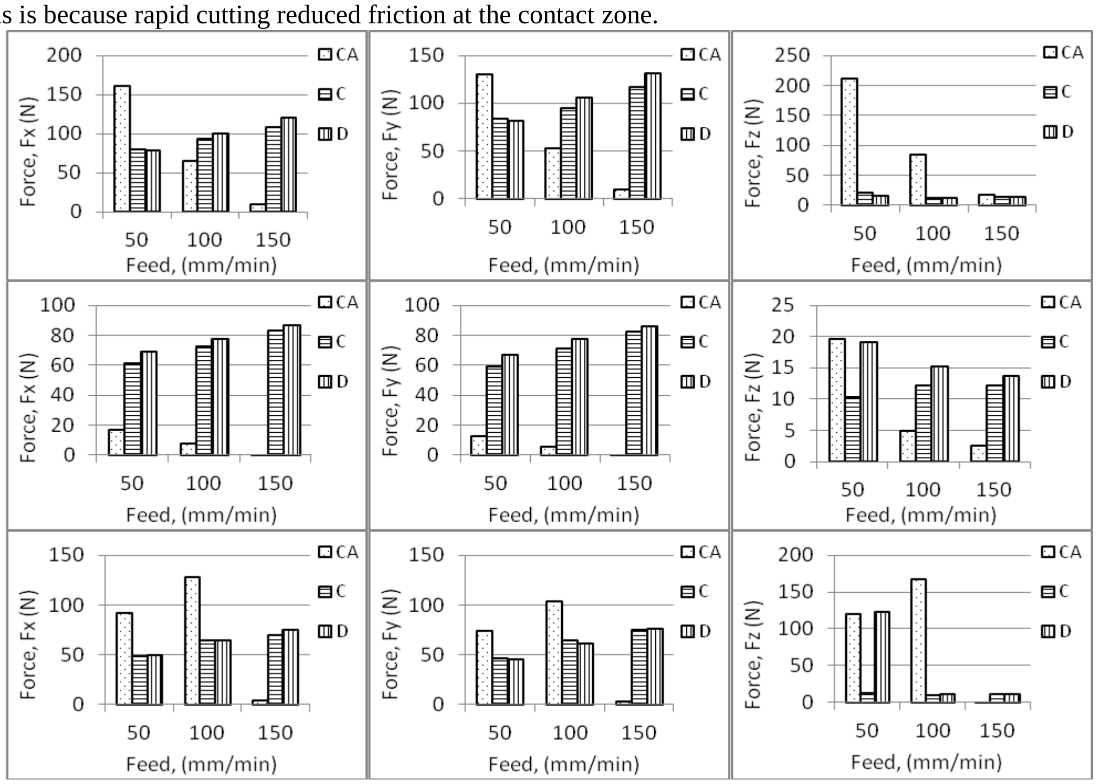

Fig. 2: Cutting force charts for different feed rates a-c) force value for 3185 rpm, d-f) force value for 5090 rpm, g-i) force value for 6350 rpm.

Conclusion:

This investigation attempted to optimize the surface roughness and cutting forces of aluminium alloy by determining the optimal machining level of cutting parameters in milling process using different cooling methods. In general, cutting parameters and cooling methods very much influence the surface roughness and cutting force in milling operations. Thus, cutting parameters feed, and speed varied to determine the optimal parameters. Then, the force and roughness analysis was carried out. Although it is not possible to avoid cutting forces by modifying the cutting parameters, the force can be reduced by selecting the appropriate parameters and cooling methods. The important experimental results of milling observed were given below:

Milling with dry cutting produces low surface roughness irrespective of feed and speeds. Milling with compressed cold air produced the lowest forces compared to other two milling methods. At low speeds, surface roughness increased with increasing feed rates. At high speeds, surface roughness decreased with increasing feed rates. For most of the conditions tested, cutting forces showed decreasing trend when feed increased.

In the case of milling with coolant, surface roughness was reduced with increasing feed rate for all spindle speeds. But, for all ranges of speed conditions, increasing feed rates resulted in higher cutting forces. In the case of milling in dry conditions, surface roughness was lowered with increasing the feed rate except for low speed conditions. In the case of cutting force, when feed rate increased, the force also increased for all conditions of speed.

The limitations of the techniques developed in this research study have indicated the following areas as recommendations for further work like, depth of cut parameters to be incorporated and extending the scope of the methodology by considering requirement for few more type of coolants. The study will points out relationship between the coolant, milling parameters and provide comparable information on milling of aluminium alloy.

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