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A Comparative Study of CNC Milling of Aluminium using Flood Coolant and Air Cooled Machining

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Abstract : The present work compares the performance of CNC milling operations using flood coolant and air-cooled machining of aluminium. At high speed and feed, the burr formation in air-cooled machining is significantly lower than that in flood coolant machining at the cost of surface roughness. SEM studies reveal higher oxidation of the workpiece in air-cooled machining. No significant difference in the hardness of the workpiece is observed.
Keywords: Air-cooled machining, Flood coolant machining, Surface roughness, Burr formation

I. Introduction

For many metal cutting applications high-pressure high-volume pumping is done to force a stream of liquid (usually an oil- water emulsion) directly into the tool chip interface, for the following purposes:- to cool the tool-chip interface, to reduce the friction between the tool and the work piece, to wash away the chips from the work piece, etc. This is the most common cooling system in manufacturing.

However, it has certain disadvantages like the cutting fluid is harmful to the environment and the workers' health etc. Moreover, it has been estimated that the cost of cutting fluids is approximately 7 to 17% of the total cost in machining process [i, ii]. So a lot of research has been recently directed towards minimizing the use of cutting fluids or to totally avoid them.

Compressed air, supplied through pipes and hoses from an air compressor and discharged from a nozzle directed at the tool chip interface can be used as a cutting fluid [iii-v]. The force of the decompressing air stream blows the chips away. Also the decompression has a slight degree of cooling action. Using a regulator filter between the nozzle and the compressor, water vapour can be removed from the air and dry air is obtained. Using dry air as cutting fluid, the health hazards associated with it can be avoided. Dry machining of AISI D2 steel, 6061 aluminium, EN-8 steel and PH 13-8 Mo stainless steel were studied [vi-ix]. Experimental investigations were carried out in machining characteristics of different grades of aluminium in near dry machining [vi] and with minimum quantitative coolant (MQC) [vii, x].

The action of a cutting tool in machining never results in absolutely smooth and even surface of the parts, the later invariably bear some traces of unevenness, roughness etc both in the direction in which cutting is performed and in the direction of feed. Primary texture (roughness) refers to finely spaced surface irregularities which result from the inherent action of the production process. Secondary texture (Waviness), caused by vibrations, machine or work deflection, chatter etc, consists of those surface irregularities which are of greater spacing than roughness [xi].

Burrs are commonly created by machining processes like milling. A burr is a raised edge or small piece of material remaining attached to a work piece after a modification process. It is usually an unwanted piece of material and is removed with a deburring tool in a process called deburring, which accounts for a significant portion of the manufacturing cost [x].

The present work studies the machining characteristics of CNC milling process on commercial grade aluminium workpiece in air-cooled and flood coolant machining conditions.

II. Material and Methodology

Machine

A series of face milling operations are performed on commercial grade aluminium workpiece of dimension 70 mm × 50 mm × 5mm with CNC milling machine (Make-MTAB, model-Compact Mill). A FANUC Oi Mate-MC motor drives the axes and a 3 phase, 415 V motor drives the spindle of the machine. The maximum spindle speed is 4000 rpm. A square tungsten carbide insert cutting tool having nose angle 90º is used in a suitable tool holder diameter of 24 mm.

Cutting Fluid

The cutting operation is performed first by using cutting fluid and then using dry compressed air. The cutting fluid used is commercially available Veedol solucut super.

Machining Conditions

The experiments are performed using the following process parameters:

- spindle speeds – 2000, 2500 and 3000 rpm
- feed rate – 50, 70, 100 mm/min
- Depth of cut – 0.7 mm (constant)

In air-cooled machining, a nozzle of diameter 5 mm is used to discharge of dry air which in the machining zone. An air filter regulator (make-Techno-pneumatic, model-AW4000-04) is used to regulate the air pressure and to remove the moisture content from the air **supply**. The air pressure used for air-cooled machining is 1.96 bar.

A single stage reciprocating air compressor (make-Toyo, model-TY2H) having a capacity of 3.92 bar is used to deliver the compressed air to the cutting zone.

A profile projector (make-Banbros, model-JT series) is employed to inspect the burr height developed in all the work pieces.

To measure surface roughness values (Ra), a Pocket Surf (make-Mitutoyo, model-SJ-210) is used. Ra values are obtained

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at three positions in each work piece with characteristic length in of 0.8mm and traversal speed of stylus 0.5 mm/s. Its measuring range is (–)200 µm to (+)160 µm. The average value of these three readings is used in the final result.

Scanning Electron Microscope (SEM) with Energy Dispersive Spectroscopy (EDS) is used to study the surface morphology and for determination of chemical composition of the workpieces.

Rockwell Hardness Tester (Make-Saroj, Model-RAS) is used to determine the hardness. A 100 kg load and a steel ball of diameter 1.58 mm is used for indentation.

III. Results and Tables

Study on Surface Roughness

The R_a-values obtained for different machining conditions are listed in Table 1.

Table 1: R_a-value for different feed rates and rpm

Expt. No	Spindle rpm	Feed (mm/min)	Surface Roughness- Ra (µm)	
			Flood coolant	Air-cooled
1	2000	50	0.096	0.781
		70	0.104	0.806
		100	0.121	1.032
2	2500	50	0.117	1.115
		70	0.137	1.186
		100	0.139	1.482
3	3000	50	0.291	1.041
		70	0.321	1.072
		100	0.491	1.594

Graphs are plotted for the results obtained in Table-1, which are shown in figures 1, 2 and 3 for experiment numbers 1, 2 and 3, respectively.

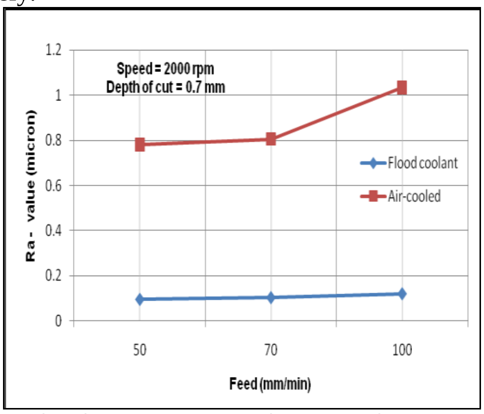

Fig.1: Variation of surface roughness with feed rate in flood coolant and air-cooled machining for expt. 1

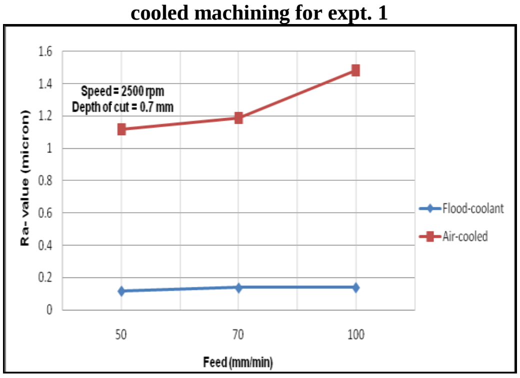

Fig.2: Variation of surface roughness with feed rate in flood coolant and air-cooled machining for expt. 2

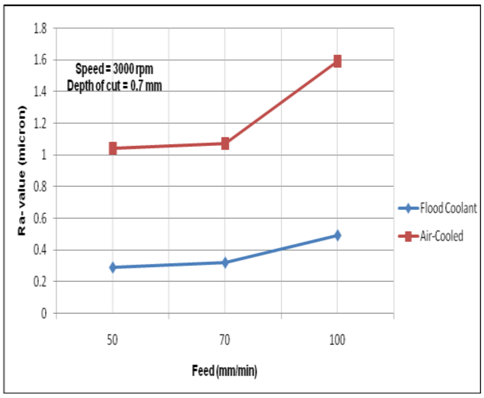

Fig.3: Variation of surface roughness with feed rate in flood coolant and air-cooled machining for expt. 3

It is observed from the above figures that surface roughness of the machined surface obtained by air-cooled machining is higher than that obtained by flood coolant machining. It is also observed that for both flood coolant and air-cooled machining, surface roughness increases with increase in feed rate at a given rpm. In air-cooled machining, cooling as well as lubrication is not effective as in flood coolant machining resulting in the higher surface roughness values.

The variations of surface roughness with speed at different feed rates for both the flood coolant and air-cooled machining are also studied. The results are plotted in figures 4 and 5.

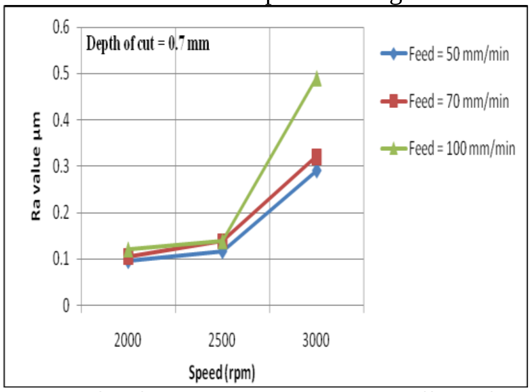

Fig.4: Variation of surface roughness with speed at different feed rates in flood coolant machining

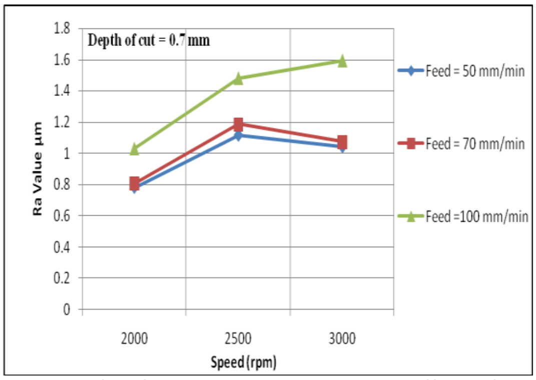

Fig.5: Variation of surface roughness with speed at different feed rates in air cooled machining

From figure 4, it is observed that at a given feed rate in flood coolant machining, the surface roughness increases with the increase in the spindle rpm. However, in case of air-cooled machining, a different pattern of variation of surface roughness with spindle rpm is observed. As shown in figure 5, at moderate feed rates (50-70 mm/min), the surface roughness first increases in between 2000 and 2500 rpm and then a slight decrease in the surface roughness values are observed when the rpm is increased to 3000 rpm. However, at higher feed rate (100 mm/min), the surface roughness increases with the increase of spindle speed.

Study of Burr Height

The burr heights of the workpiece obtained for both flood coolant and air-cooled machining are also measured. The bar height is observed to be maximum at the exit end [xii]. In the present work, burr heights are measured at the exit end of machining. The results are shown in Table–2.

Table 2: Maximum Burr heights for different feed rate at a given speed

Expt No.	Speed (rpm)	Feed (mm/min)	Burr Height (mm)	
			Flood coolant	Air-cooled
1	2000	50	0.848	0.093
		70	1.009	0.896
		100	1.642	0.860
2	2500	50	1.325	0.658
		70	1.683	1.036
		100	2.345	0.837
3	3000	50	1.415	0.578
		70	1.974	0.969
		100	2.786	0.399

Graphs are plotted for the results obtained in Table-2 which are shown in figures 6, 7 and 8 for experiment numbers 1, 2 and 3, respectively.

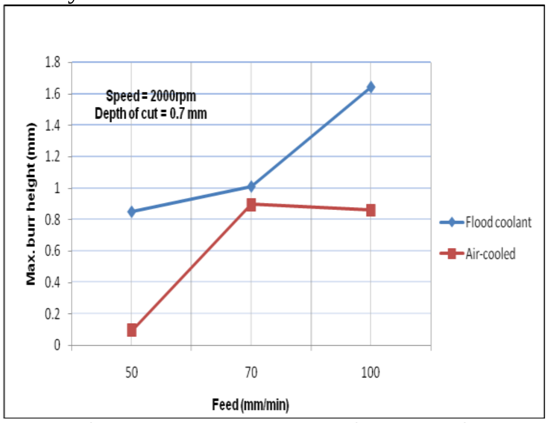

Fig.6 Variation of maximum burr height with feed rate in flood coolant and air-cooled machining for expt. 1

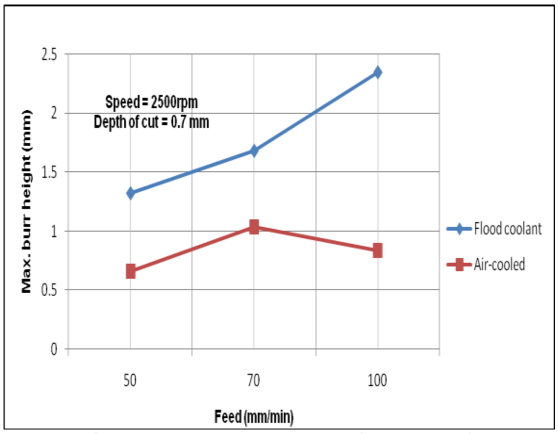

Fig.7 Variation of maximum burr height with feed rate in flood coolant and air-cooled machining for expt. 2

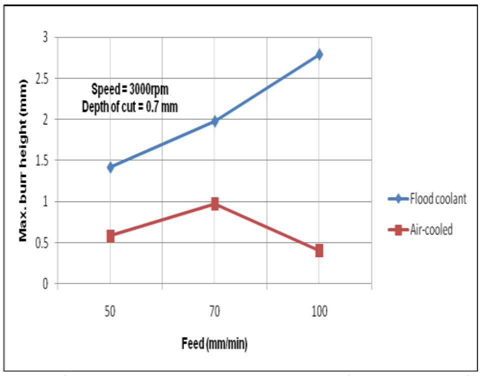

Fig.8 Variation of maximum burr height with feed rate in flood coolant and air-cooled machining for expt. 3

It has been observed from the figures (6-8) that at a given spindle rpm and feed rate condition, comparatively higher burr height is obtained in flood coolant machining than that in air-cooled machining. This is because of more ductile nature of fracture in flood coolant machining than that in air-cooled machining. For flood coolant machining, the burr height increases with increase in feed rate at a given rpm. But in air-cooled machining, within moderate feed rates (50-70 mm/min), burr height initially increases with feed rate. However, a reduction in the burr height is observed when the feed rate is increased to 100 mm/min at the studied rpm. This trend is similar to that observed in surface roughness values in air-cooled machining.

The variations of surface roughness with rpm at different feed rates for both the flood coolant and air-cooled machining are also studied. The results are plotted in figures 9 and 10.

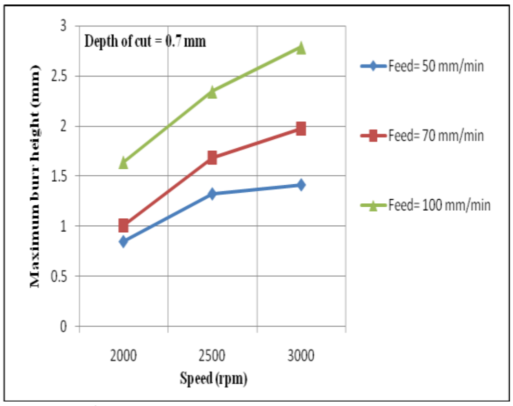

Fig.9: Variation of maximum burr height with spindle speed at different feed rates in flood coolant machining

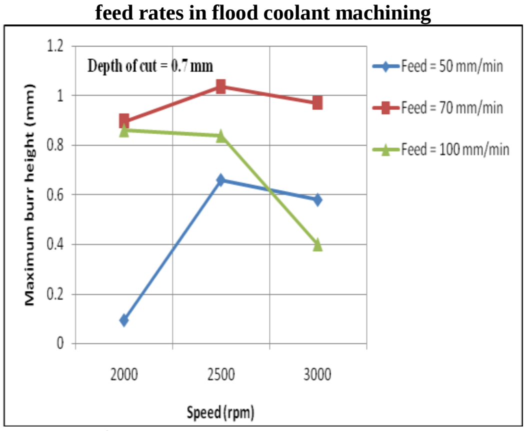

Fig.10: Variation of maximum burr height with spindle speed at different feed rates in air cooled machining

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From figure 9, it is seen that for flood coolant machining, the maximum burr height increases with increase of spindle speeds for all feed rates. As shown in figure 10, a different variation in burr height with increase in spindle rpm at all feed rate is observed in air-cooled machining. This variation is similar to that observed in surface roughness values (*cf.* figure–5). This may be because of more brittle fracturing occurring at maximum feed rate (100 mm/min).

To study the surface morphology and variation in the surface oxidation level after machining, SEM study is carried out. SEM micrographs in secondary electron (SE) mode of the workpiece surface corresponding to the machining condition of 3000 rpm and feed rate 100 mm/min are shown in figures 11 and 13 and the corresponding EDS patterns are shown in figures 12 and 14, respectively. EDS studies reveal that there is a considerable increase in the oxidation level from 043% to 2.07% after air-cooled machining. This may be one good reason which results in the reduction in surface roughness values and burr height formation at maximum feed rate. Hardness testing of the workpiece reveals only a marginal increase in the hardness values in air-cooled machining as compared to that in flood coolant machining.

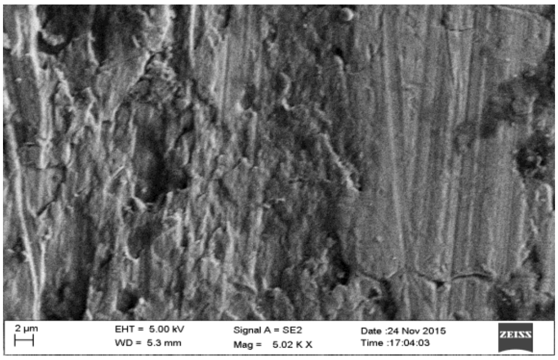

Fig 11: SEM micrograph (SE mode) for flood coolant machining

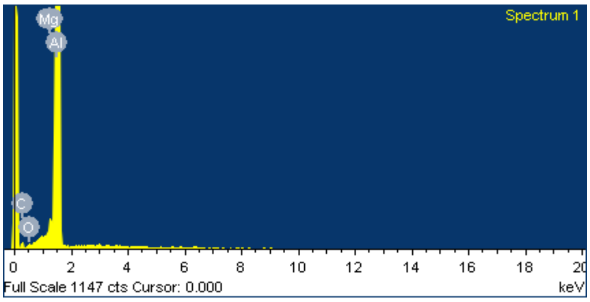

Fig 12: EDS pattern for the surface after flood coolant machining

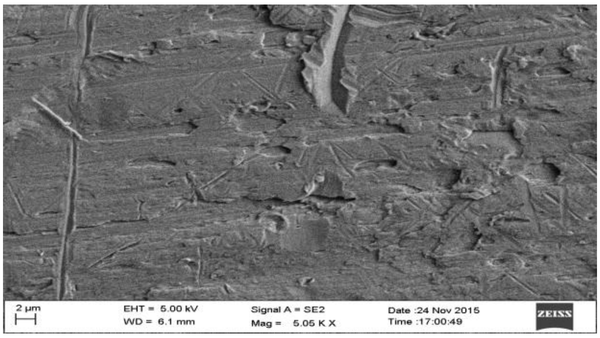

Fig 13: SEM micrograph (SE mode) for air-cooled machining

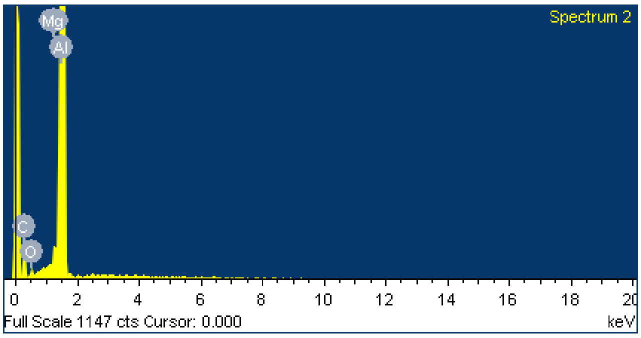

Fig 14: EDS pattern for the surface after air-cooled machining

IV. Conclusions

The surface roughness in air-cooled machining is significantly higher than that in flood coolant machining. With increase in the feed rate, burr height increases in flood coolant machining. However, in air-cooled machining, the burr height first increases to a maximum value and thereafter it decrease. At high speed and feed rate, the burr formation in air-cooled machining is significantly lower than that in flood coolant machining.

V. References

i. *Lawal, S.A., Choudhury, I.A., Nukman, Y., 2013, "A critical assessment of lubrication techniques in machining processes: a case for minimum quantity lubrication using vegetable oil-based lubricant", Journal of Cleaner Production, 41, 210-221.*

ii. *Shokoohi, Y., Khosrojerdi E., Shiadhi, B.H.R., 2015, "Machining and ecological effects of a new developed cutting fluid in combination with different cooling techniques on turning operation", Journal of Cleaner Production, 94, 330-339.*

iii. *Sarma, D.K., Dixit, U.S., 2009, "Environment-friendly strategies for efficient utilization of cutting tools in finish turning", Journal of Manufacturing Science and Engineering, 131,1-5.*

iv. *Sarma, D.K., Dixit, U.S., 2007, "A comparison of dry and air-cooled turning of grey cast iron with mixed oxide ceramic tool", Journal of Materials Processing Technology, 190, 160-172.*

v. *Sankar, M. R., Choudhury, S.K., 2015, "Experimental Study and Modelling of Machining with Dry Compressed Air, Flood and Minimum Quantity Cutting Fluid Cooling Techniques", Proceedings of the 15th CIRP Conference on Modelling of Machining Operations, 31, 228-233*

vi. *Sharma, J., Sidhu, B.S., 2014, "Investigation of effects of dry and near dry machining on AISI D2 steel using vegetable oil", Journal of Cleaner Production, 66, 619-623.*

vii. *Sreejith, P.S., 2008, "Machining of 6061 aluminium alloy with MQL, dry and flooded lubricant conditions", Materials Letters, 62, 276-278.*

viii. *Raykar, S.J., D'Addona D.M., Kramer D., 2014, "Analysis of Surface Topology in Dry Machining of EN-8 Steel", Proceedings of the 3rd International Conference on Materials Processing and Characterisation (ICMPC 2014), 6, 931-938.*

ix. *Silva, L.C., Mota, P.R., Silva, M.B., Ezugwu, E.O., Machado, A.R, 2015, "Study of burr behaviour in face milling of PH 13-8 Mo Stainless Steel" CIRP Journal of Manufacturing Science and Technology, 8, 34-42.*

x. *Hadi Y.,2010, "Study of Minimum Quantity Coolant (MQC) on Surface Roughness during Turning Operation on Aluminum", IEEE Journal, 370-374.*

xi. *Sarma,B., Dhar, A., Saikia, B., Borah, K., 2015, "An Experimental Study on Burr Formation in Drilling", Proceedings of the MEGRES'15, IIT-Bombay.*

xii. *Jozic,S., Bajic,D., Celent,L.,2015, "Application of compressed cold air cooling achieving multiple performance characteristics in end milling process" Journal of Cleaner Production,100,325-332.*

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