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Investigation on Surface Roughness during Milling of AL-61 Machining under Minimum Quantity Lubrication (MQL)

Er. Sher Singh[1], Er. Gora Ram Sharma[2]
[1, 2] Bhai Maha Singh College of Engineering, Sri Muktsar Sahib

***Abstract:** In modern production industries, main focus is on high productivity with best surface finish. For this purpose use of cutting fluid in machining of component plays major role in controlling the surface finish of components. The cutting fluids are generally applied continually during machining i.e. wet or flooded machining. The dry machining yields poor surface finish and less tool life whereas wet machining results in better surface finish as well as longer tool life. But continuous lubrication involves very large amount of consumption of cutting fluids which cause health hazards of machining operator and ill effects on environment. Moreover, continuous lubrication contributes to increase in total production cost of product. Hence, the Minimum Quantity Lubrication(MQL) is needed nowadays which works with less amount of cutting fluid (100-1000ml/hr) with pressurized air (as mist form) as compare wet machining (amount of cutting fluid 400-500L/hr approx.). The study focus on comparison of surface roughness behavior of AL-6061 under different lubrication conditions i.e. Dry, Wet and MQL. The experimental work performed on CNC milling machine involving cutting parameters feed rate, spindle speed and depth of cut as input parameters, where surface roughness and microstructure of specimens were observed as output parameters in the experiment. The machined components under different conditions i.e. DCM (dry cutting machining), MQL (minimum quantity lubrication), WCM (wet cutting machining) were examined for surface roughness using R-10 surface roughness tester whereas microstructure analysis was done using optical microscope. For given cutting parameters at 2000RPM spindle speed, 200mm/min. feed rate and it is found that better result of MQL from the dry machining and nearest of wet machining.*

***Keywords:** CNC face Milling, Minimum quantity lubrication (MQL), Surface roughness*

***Abbreviation used:** DCM: Dry cutting machining, WCM: Wet cutting machining, MQL(S): Minimum Quantity lubrications (setup), NOC: Number of cycle, NOS: Number of sides, M: Microstructure, SR: Surface roughness*

I. INTRODUCTION

In the machining era, metal cutting and metal removal in the machining are main process that are performed to impart desired shapes , size and surface finish by removing unwanted material from a solid . Metal cutting industries faced great challenges because of precise quality requirements and increase in the productivity. Global environment concerns, compelled industries to enforce environmental protection law for occupational safety and health regulations. Moreover for reducing production costs, has directed the industry to give careful thought to the role of the conventional metal working fluids used in manufacturing processes. In the previous researches, the total typical end-user cost of manufacturing a product is as 30% in machining, 25% in tool change, 16% in coolants, 3% in tool, 7% downtime and 19% other. The cost of using metal-working fluids may range 7% to 17 % of the total cost of the manufactured products. At high cutting speed and continuous use of cutting fluid, it is harmful impact on the environment and human health issue [11]. A cutting fluid refers to any liquid that is applied directly to the tool and work piece interface to cool and lubricate interface. It also acts to reduce tool wear and increases the tool life. Cutting fluid are applied in machining operation by various techniques such as wet machining, dry machining, minimum quantity lubrication etc. Currently environmentally suitable tool cooling technique is sought because cutting fluid contributes to workers health hazards. Moreover environmental pollution and soil contamination caused during disposal of waste cutting fluid are major concerns. The alternative Technique MQL (minimum quantity lubrication) is to be implemented in manufacturing industries or units as MQL system is a approach to reduce the temperature during machining as well as improving surface finish. The cooling technique require small amounts of high quality mist which is applied directly to the cutting tool/work piece interface instead of using flood coolant. MQL is also known as micro lubrication or near drive machining. It was concluded after going through previous literature that the application of MQL is cost affective, where the flow rate of cutting fluid is about 50 to 500 ml/h[6] as compared to the 1000 to 12000 ml/hr in conventional wet lubrication.

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II. EXPERIMENTAL SETUP AND DESIGN

To perform experimentation work under study for MQL sytem, a special type of setup is required to make the mist by mixing air and liquid in appropriate proportions. The required setups with all the components fitted in set up are shown in fig.1.

1) *MQL Setup Setting:* For carrying out the experimentation work using MQL process, the coolant was filed in reservoir. The used coolant under different cutting conditions is MOTUL Company series S0405005. The on/off valve is provided at bottom of reservoir. The pressurized air at 5 bars is passed through valve PRV1 and PRV2. When on/off valve is opened and air passes through reservoir, droplets of fluid are formed. A bypass pipe is provided to pass the air from compressor to PRV2. Both the air and cutting fluid are mixed in Y- connector and form a mist. A mist containing the air and cutting fluid in appropriate proportions are passed through nozzle. This mist is directed to the cutting zone while performing the machining operations.

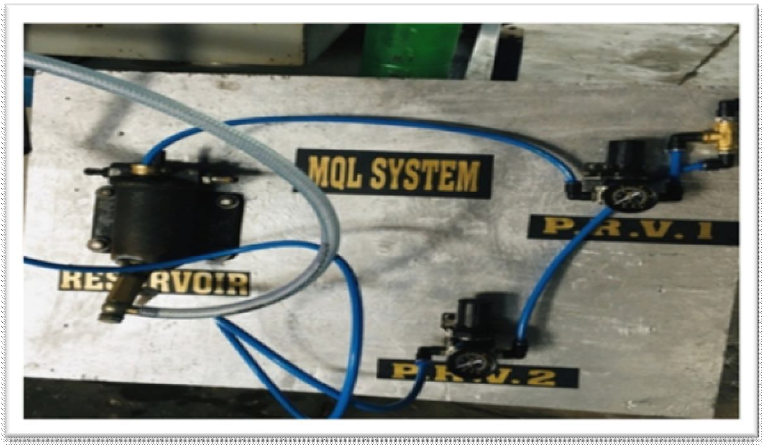


Fig.1 setup for MQL (mist)

2) *Work-piece material (Aluminum 6061):* The aluminum is a chemical element with symbol Al and atomic no. 13. It is silvery-white color and soft material. An alloy is metal made by combining two or more metallic elements to achieve improved material properties. The alloying process involves adding alloying elements in appropriate proportions into a base metal to give it distinct properties such as increased corrosion resistance, conductivity, strength and toughness etc. As well as aluminum metal and its alloys are implemented is most in the uses. Al61 is one of the aluminum alloys which is compatible for heat treatable, easily formed, weld-able and good for corrosion resistant. Because of these properties the vast use air-crafts, truck frames, welded assemblies, marine frames, fasteners, heat exchangers and heat sinks etc. The chemical composition of Al6061 is shown in table1.

Table: 1.1 Chemical composition of Al6061

Elements	Al	Mn	Si	Fe	Cu	Cr	Zn	Ti	Mg	Other
Amount (wt%)	96.80	0.9	0.7	0.6	0.30	0.25	0.20	0.10	0.05	0.05

Table: 1.2 Factors with values of different level

Factors	Spindle speed (rpm)	Feed rate (mm/min)	Depth of cut (mm)
Level 1	1500	150	1.5
Level 2	2000	200	1.0
Level 3	2500	250	2.0

III. EXPERIMENTAL DEIGN

The experimental work was performed on CNC milling machine considering feed rate, spindle speed and depth of cut as input parameters. Total nine experiments were performed for present work of study. Carbide tip multipoint milling cutter (Force milling cutter, diameter:D-40, Inserts:4) for machining of Al-61 was used. The machining operation was performed on vertical milling machine.

Table: 1.3 Experimental Designs

Sr. No.	Spindle speed (RPM)	Feed rate (mm/min)	DOC (mm)	NOC For cutting	Machining type	NOS of machined sides	For test
1	1500	150	1.5	3	DCM	6	M
2	1500	150	1.5	2	WCM	1	SR
3	1500	150	1.5	2	MQL	1	SR
4	2000	200	1.0	3	DCM	6	M
5	2000	200	1.0	2	WCM	1	SR
6	2000	200	1.0	2	MQL	1	SR
7	2500	250	2.0	3	DCM	6	M
8	2500	250	2.0	2	WCM	1	SR
9	2500	250	2.0	2	MQL	1	SR

IV. RESULT AND DISCUSSION

Surface roughness and microstructure of machined components were observed as output parameters for study. The surface roughness was measured by using R-10 surface roughness tester and microstructure was observed using optical microscope. The results obtained for roughness are shown in table 1.4

Table 1.4 Result of surface roughness from experiment work

Sr. no.	Machining type	INPUT PARAMETERS			OUTPUT PARAMETERS
		Spindle speed (RPM)	Feed rate (mm/min)	Depth of cut(mm)	Surface roughness (um)
1	DCM	1500	150	1.5	1.97
2	WCM	1500	150	1.5	0.64
3	MQL	1500	150	1.5	0.89
4	DCM	2000	200	1.0	0.98
5	WCM	2000	200	1.0	0.30
6	MQL	2000	200	1.0	0.64
7	DCM	2500	250	2.0	1.54
8	WCM	2500	250	2.0	0.70
9	MQL	2500	250	2.0	1.02

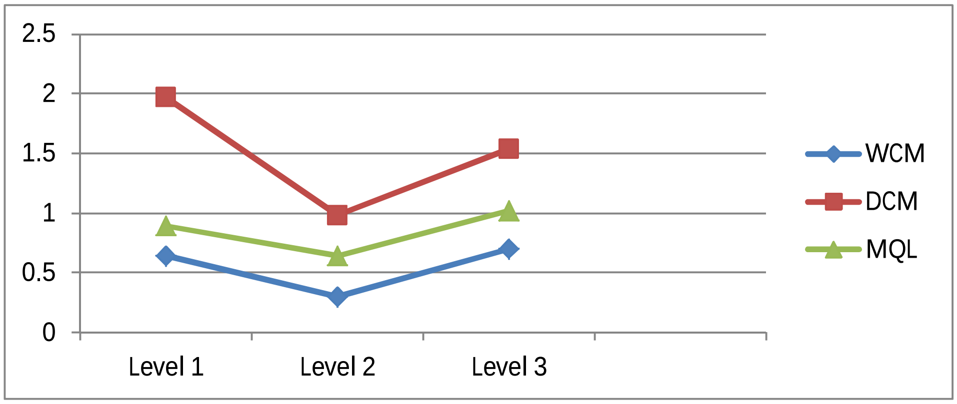
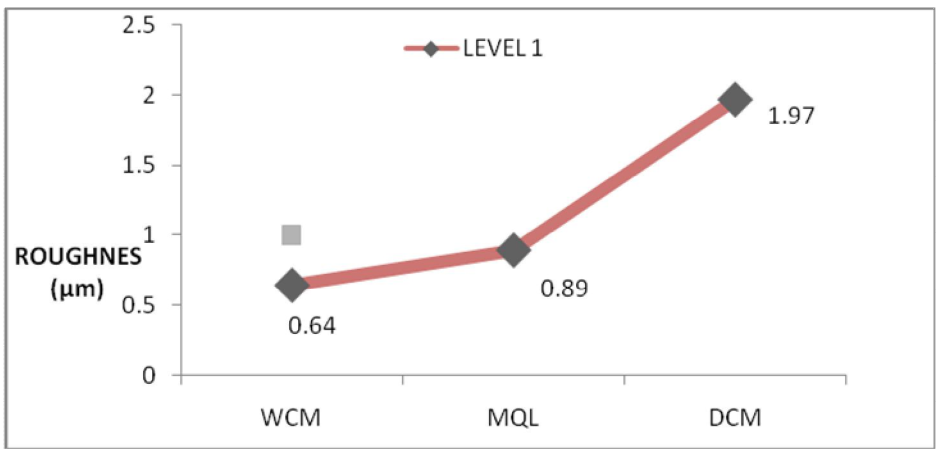
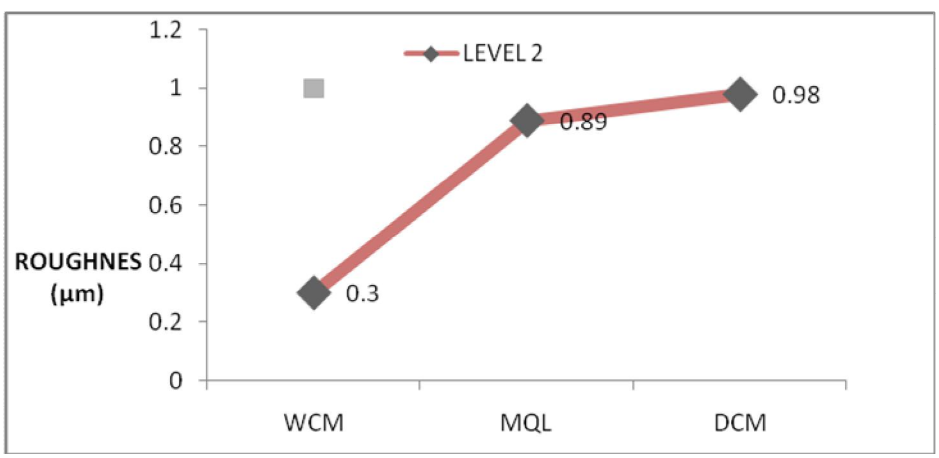


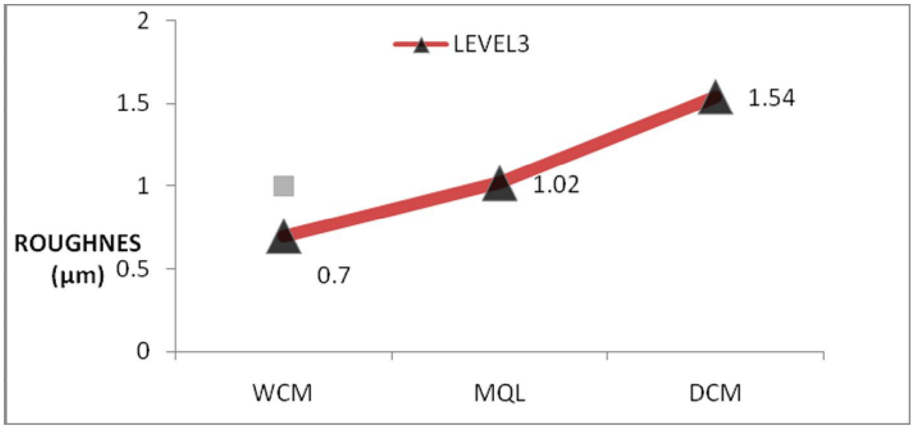
Fig. 2 The surface roughness variation for all three levels



The surface roughness variation of level 1



The surface roughness variation of level 2



The surface roughness variation of level 3

Fig 3 The variation of surface roughness (µm)

The trend of surface roughness of component while machining under wet cutting machining (WCM), dry cutting machining (DCM) and the minimum quantity lubrication (MQL) was observed for three different levels. Each level consists different cutting speed, depth of cut and feed rate respectively. It shows that the least surface roughness is obtained in case of WCM on the level 2 where spindle speed 2000 rpm, feed rate 200 mm/min and depth of cut 1.0 mm respectively and the while surface roughness under MQL is 0.64 µm and 0.98 µm under DCM conditions for level 2 respectively. The microstructure of various machined components was observed using optical microscope at 50x and 100x respectively. The microstructure of components under dry and wet lubrication shows uniform grain structure of Al matrix having uniform distribution of alloy particles. In the case of MQL the result of microstructure shows mixed grained structure having uniform distribution of alloy particles (observed at 50x & x100x) . According to result of microstructure, no any noticeable change in microstructure due to process of machining and cutting parameters of machining.

Fig 4 (a) Machining under MQL 50x

Fig 4 (b) Machining under MQL 100x

V. CONCLUSION

A. *Surface Roughness*

It is observed that MQL machining can be a best alternative to wet machining and can be observed as environmental friendly machining. From the study it is observed that:

1) It shows that lowest value of surface roughness is obtained in case of WCM at level 2 having spindle speed 2000 rpm, feed rate 200 mm/min and depth of cut 1.0 mm. Wet cutting machining have best quality of surface finish in all the three levels of machining parameters.
2) The surface roughness values in case of MQL and wet machining are close to each other at spindle speed 2000 rpm, feed rate 200 mm/min and depth of cut 1.0 mm. The quality of surface finish is nearly same in case of MQL and Wet machining in all the three levels. It indicates the good alternative is MQL of WET machining.
3) It is clear that, relatively the surface roughness is directly proportional to work piece of material and depth of cut and surface roughness is indirectly proportional to spindle speed.
4) Due to increase in spindle speed, the cutting force is increased. It produces a smooth surface with lower surface roughness values.
5) As the depth of cut increases surface roughness increases ie with increase in depth of cut produces higher surface roughness.

B. Microstructure

In the machining process the forces mainly arises from due to the friction between the tool and work-piece. Following conclusion are drawn for Microstructure from present study:

1) The all three cutting methods create a homogenous microstructure of a processed alloy and the whole process of grain refinement can be finely controlled. The microstructure of components under dry and wet lubrication shows uniform grain structure of Al matrix having uniform distribution of alloy particles.

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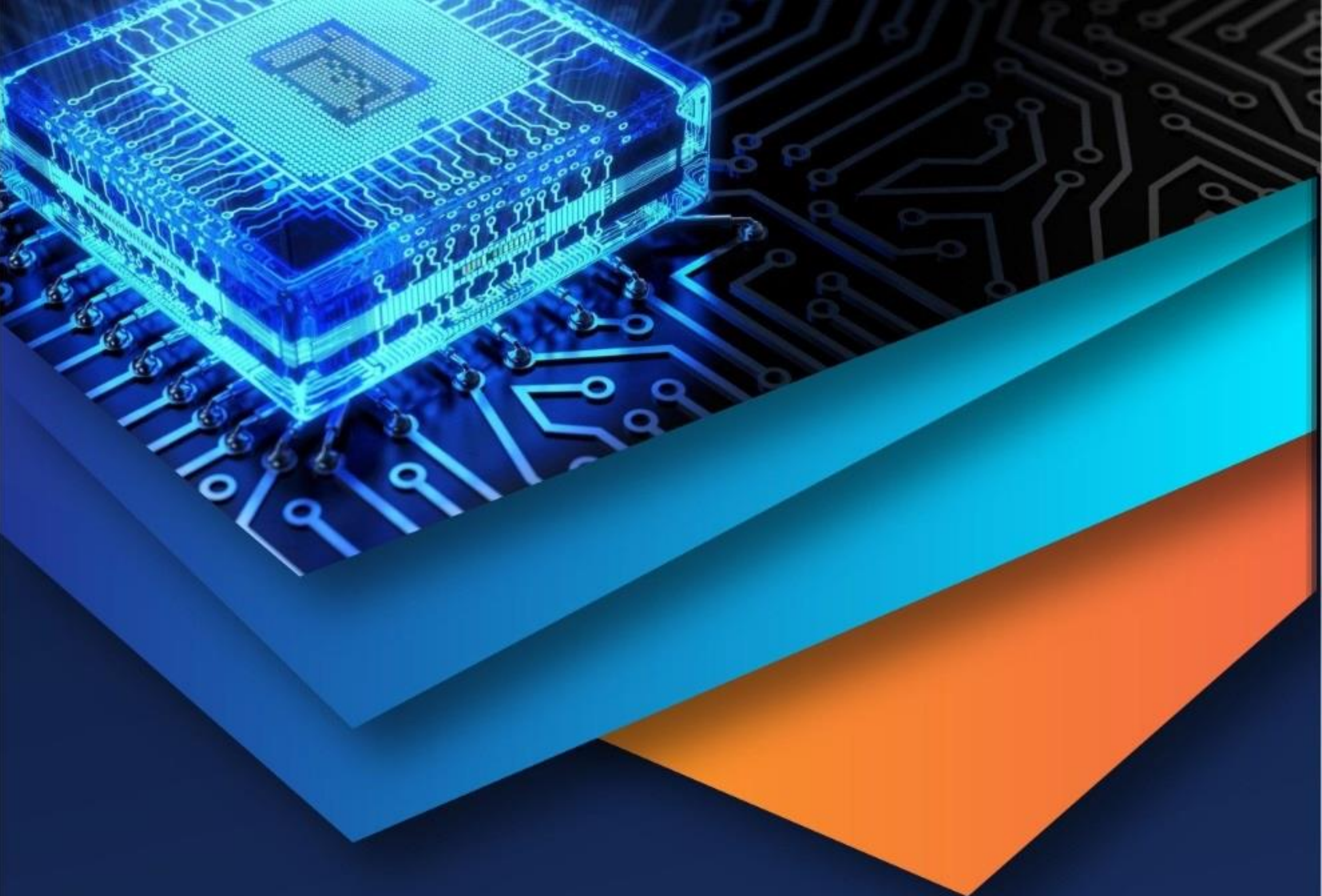

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