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Experimental Investigation of Aluminum 7075 using Dry, Wet and MQL Condition

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Abstract - *There have been continuous efforts in developing technology in metal cutting and cutting fluids due to increasing demands for high productivity so increasing cutting speed and feed rate. Due to increasing speed and feed rate temperature near the cutting zone will increases and tool life will be decreases. Conventional cutting and lubrication process is general practices in manufacturing industry for reducing temperature and friction in between tool and work piece. The use of vegetable cutting fluid in machining process has economic benefit and minimizes environmental impact and safety to employees. It play very important role in enhancing the machining performance, handling and disposed in proper way. These paper reports on the effect of different lubricant method apply when AL7075 alloy is machined. The effect of dry, flooded and minimum quantity lubricant (MQL) machining was analyzed with respect to the surface roughness and temperature near the cutting zone. The three types of coolant environment are compared. It is found that MQL Condition will be very good alternative compared to dry and flooded method.*

Key Words: Dry, Wet, MQL, Micro-machining, Surface roughness, Temperature, GRA etc.

1. INTRODUCTION

Now a day, due to the increasing productivity and quality of product at minimum cost, the use of cutting fluid is common strategy to improve tool life, product surface finish and size accuracy in metal cutting processes. The basic function of metal working fluid as a coolant is to decrease the temperature of chip tool interface, as well as provide lubrication simultaneously. An alternative to Dry or Flooding cutting fluid application, minimum quantity lubrication (MQL) process is introduced as an environmentally friendly and economically beneficial method. The advantages of MQL machining include: non-pollution of the atmosphere, reduced disposal and cleaning costs, no danger to health and safety as well as cost reduction in machining but this cooling technique required coated tool and which is costly. MQL cooling technique is sometimes referred to as near dry lubrication or micro-lubrication. The major benefits of MQL are reduction of consumption of cutting fluid, cost saving, reduction of impact to the environment and improved overall performances in cutting operation, surface quality and material removal rate which helps to increase tool life due to decrease in friction and heat generation at the machining zone. MQL machining has been recognized as one of the practical ways to the cleaner manufacturing in the context of the sustainable production. The principal of MQL is that it applies a fine mist of air and very small amount lubricant flow (ml/h instead of l/min) is used [1].

2. EXPERIMENTAL WORK

The performance of vegetable cutting oil by using MQL and conventional cutting fluid on Micro-machining AL7075 is carried out on CNC Engraving machine, three work pieces of rectangular size 210*150*16 mm is used for different type of machining operation. The operation is carried out firstly dry method, second flooded method and lastly MQL Method. Measuring surface roughness and temperature with the help of a portable stylus type instrument and infrared thermometer.

2.1 ENGRAVING MACHINE (SE4454S)

It is micro-machining make by Shilpin, Aurangabad. It is 3-axes CNC Engraving machine enabling engraving milling and drilling operation. Table movement is achieved by three AC servo motors, controlled by an interface. It is 3 Axes Double Column Machine The cutting process is performed by an serial engraver with the rotational speed range up to 24000 rpm and power consumption up to 5 HP. Available in JNEC, centre of excellence, Aurangabad.

2.2 WORKPIECE MATERIAL

AL7075 is a commonly zinc is high alloying metal. It is a silvery-white, soft, nonmagnetic and ductile metal in the boron group. 7075 aluminium is an aluminium alloy, with zinc as the primary alloying element. It is strong, with strength comparable to many steels, and has good fatigue strength and average machinability. 7075 aluminium alloy's composition roughly includes 5.8% zinc, 2.4% magnesium, 1.5% copper, and less than a half percent of silicon, iron, manganese, titanium, chromium, and other metals.

2.3 MQL SETUP

Minimum quantity lubrication (MQL), also known as near dry machining (NDM), refers to the use of cutting fluids of very small amount typically of a flow rate of 50 to 500 ml/hour. The MQL technique consists of a mixture of drops of cutting fluids (neat oils or emulsions) in a flow of compressed air, generating a "spray" called as aerosols (mists). In MQL process, oil is mixed with high-pressure air and the resulting aerosol is supplied near to the cutting edge. This aerosol impinges at high speed on the cutting zone through the nozzle. Air in the aerosol provides the cooling function and chip removal, whereas oil provides lubrication and cooling by droplet evaporation. The air pressure in MQL process varies from 4 to 6.5 Kg/cm2

2.4 CUTTING TOOL

In this experiment Carbide tool is used. Such tool has 6 mm diameter. For different machining like dry, flooded and MQL machining separate tool is used. In this experiment three endmill carbide tool used for roughing machining and three ballmill carbide tool used for final finishing operation.

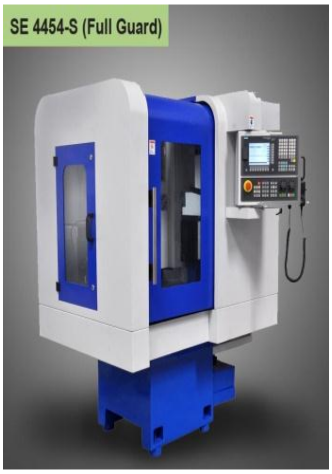


Fig -1: Machine

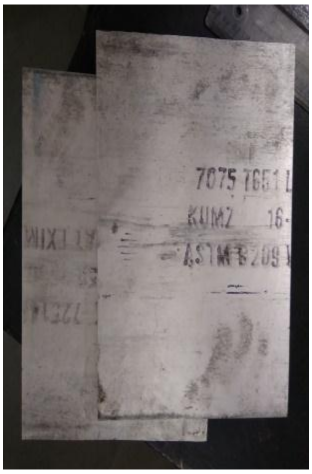


Fig -2 Work piece

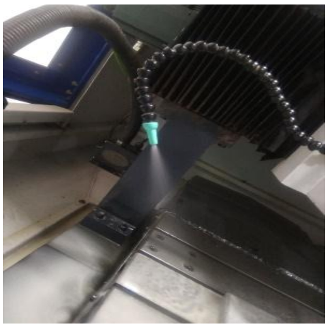


Fig -1: MQL Setup

Fig -2 Tool

2.5 CUTTING FLUID/LUBRICANT

The experiment conducted under Dry, Wet and MQL Machining as shown in photographic view. Machining of work piece without coolant in Dry process and machining of work piece with coolant in Wet process used. In wet machining Non-soluble vegetable grade cutting oil is used. But in MQL Process small amount of oil mix with compressed air to make mist form spray and impinges near the cutting zone.

2.6 PROCESS PARAMETER AND THEIR LEVEL

In this experiment study spindle speed, feed rate and depth of cut have been considered as process variable.

Process Parameter	Coded Level		
	-1	0	+1
Cutting speed S (rpm)	8000	10000	12000
Feed F (mm/min)	400	600	800
Depth of cut Doc (mm)	0.05	0.15	0.25

3. DESIGN OF EXPERIMENT

In engineering analysis and optimization Taguchi method is widely used. It is Statistical approach to optimize the process parameter and improve the quality of component that is manufacture. It is specially used in the development of design for studying variation.

Run	S	F	D	Dry Machining		Wet Machining		MQL Machining	
	rpm	mm/min	mm	Ra	θ_i	Ra	θ_i	Ra	θ_i
1	-1	-1	-1	0.325	40	0.242	36	0.217	36
2	-1	0	0	0.354	39	0.300	37	0.260	37
3	-1	1	1	0.360	39	0.346	38	0.294	37
4	0	-1	0	0.310	38	0.253	38	0.249	37
5	0	0	1	0.322	38	0.250	38	0.260	36
6	0	1	-1	0.258	40	0.230	38	0.190	37
7	1	-1	1	0.290	41	0.238	38	0.195	34
8	1	0	-1	0.220	42	0.195	38	0.140	35
9	1	1	0	0.239	41	0.245	38	0.192	37

During experiment surface roughness and temperature measured in each run by changing speed, feed and depth of cut. Temperature near the cutting zone is high. When speed increases the surface roughness decreases but when feed rate increases surface roughness increase because cheap load on cutting tool. In Wet machining temperature near the cutting zone is low and cutting resistance minimum as compare to dry machining. In flooded machining speed increases the surface roughness decreases. In MQL Machining it is observed that surface roughness is decreases as well tool of life will be increases. In MQL machining temperature near the cutting zone is low and cutting resistance minimum as compare to dry and flooded machining.

3.2 MEASUREMENT OF SURFACE ROUGHNESS

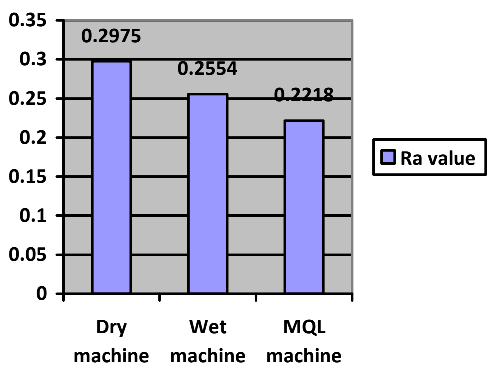
Surface roughness is measured in the metrology lab with the "SJ-410" surface roughness tester manufactured by "Mitutoyo" shown in figure It measures average roughness as irregularities exist on the surface by comparing all the peaks and valleys to the mean line and then averaging them all over the entire cut-off length. In this work the Ra (μm) was measured by Mitutoyo SJ410 Series Surface tester with cut of length 8mm has been taken.

3.3 MEASUREMENT OF CUTTING TEMPERATURE

To achieve our aim of measuring and analyzing the cutting temperature, the infrared thermometer is used. The temperature of cutting zone is to be measured during the machining time of every set of parameter at different machining environment (Dry, Near Dry and Flooded). We can select the temperature units ^{0}C and ^{0}F.

3.4 AVERAGE COMPARISION OF DRY, WET & MQL OF SURFACE ROUGHNESS

In this experiment surface roughness is main influence parameter which is measured by Mitutoyo SJ410 Ra value tester. It is observed Surface roughness in near dry machining or MQL Machining is less as compare to dry and wet machining as shown in figure. Figure show when feed rate increases surface roughness also somewhat increases. But when speed increases surface roughness decreases.



4. GRAY RELATIONAL ANALYSES

The optimization of multiple performances characteristics using GRA includes the following steps:
1. Normalization of the experimental results
2. Determination of deviation sequences.
3. Determination of grey relational coefficient (GRC).
4. Determination of grey relational grade (GRG).
5. Determination of optimal parameters.

Table 4.1: All GRA Values of experimental data (Dry)

RUN	S	F	Doc	Normalized values		Grey Relational Coefficient	
				Ra	θi	Ra	θi
1	-1	-1	-1	0.25	0.52	0.75	0.476
2	-1	0	0	0.042	0.71	0.957	0.285
3	-1	1	1	0	0.57	1	0.428
4	0	-1	0	0.357	0.90	0.642	0.095
5	0	0	1	0.271	1	0.728	0
6	0	1	-1	0.728	0.5	0.271	0.5
7	1	-1	1	0.5	0.28	0.5	0.714
8	1	0	-1	1	0	0	1
9	1	1	0	0.864	0.14	0.135	0.857

RUN	S	F	Doc	Grey Relational Grade		Avg. Grade	Rank
				Ra	θi		
1	-1	-1	-1	0.4	0.51	0.4560	7
2	-1	0	0	0.343	0.63	0.4897	6
3	-1	1	1	0.333	0.53	0.4358	9
4	0	-1	0	0.437	0.84	0.6387	3
5	0	0	1	0.406	1	0.7034	**1**
6	0	1	-1	0.648	0.5	0.5740	5
7	1	-1	1	0.5	0.41	0.4558	8
8	1	0	-1	1	0.3	0.6666	2
9	1	1	0	0.786	0.36	0.5774	4

Graph 1: GRA vs. Experimental Runs for Dry

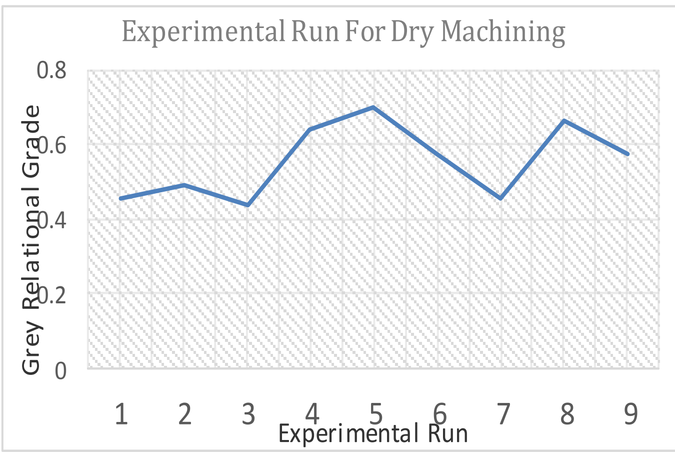


Table 4.2: Main effects of the factors on GRA (Dry)

Parameters	Level 1 (-1)	Level 2 (0)	Level3 (+1)	Max-Min	Rank
Cutting speed	0.460	0.638	0.566	0.178	1
Feed	0.516	0.619	0.529	0.103	2
Depth of cut	0.565	0.568	0.531	0.036	3

Table 4.1 shows highest grey relational grade, indicating the optimal process parameter set of S(10000), F(600) and Doc(0.25) for the best multiple performance characteristics among the 9 experiments. Here the Experiment 5 has the highest rank so it is the Optimal Experiment value that gives minimum amount of Ra and Temp.

Table 4.3: All GRA Values of experimental data (Wet)

RUN	S	F	Doc	Normalized values		Grey Relational Coefficient	
				Ra	Θi	Ra	Θi
1	-1	-1	-1	0.688	1	0.3112	0
2	-1	0	0	0.304	0.70	0.6953	0.2916
3	-1	1	1	0	0.08	1	0.9166
4	0	-1	0	0.615	0.37	0.3841	0.625
5	0	0	1	0.635	0.04	0.3642	0.9583
6	0	1	-1	0.768	0	0.2317	1
7	1	-1	1	0.715	0.25	0.2847	0.75
8	1	0	-1	1	0.16	0	0.8333
9	1	1	0	0.668	0.08	0.3311	0.9166

RUN	S	F	Doc	Grey Relational Grade		Avg. Grade	Rank
				Ra	Θi		
1	-1	-1	-1	0.6163	1	0.8081	**1**
2	-1	0	0	0.4182	0.631	0.5249	3
3	-1	1	1	0.3333	0.352	0.3431	9
4	0	-1	0	0.5655	0.444	0.5049	6
5	**0**	**0**	**1**	0.5785	0.342	0.4607	8
6	0	1	-1	0.6832	0.333	0.5082	5
7	1	-1	1	0.6371	0.4	0.5185	4
8	1	0	-1	1	0.375	0.6875	2
9	1	1	0	0.6015	0.3529	0.4772	7

Graph 2: GRA vs. Experimental Runs for Wet

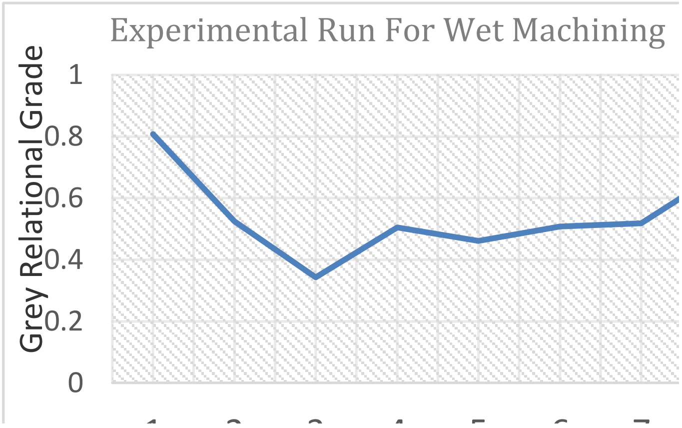


Table 4.4: Main effects of the factors on GRA (Wet)

Parameters	Level 1 (-1)	Level 2 (0)	Level3 (+1)	Max-Min	Rank
Cutting speed	0.5587	0.491	0.5611	0.069	3
Feed	0.6105	0.557	0.4429	0.167	2
Depth of cut	0.6679	0.502	0.4408	0.227	1

Table 4.3 shows highest grey relational grade, indicating the optimal process parameter set of S(8000), F(400) and Doc(0.05) for the best multiple performance characteristics among the 9 experiments. Here the Experiment 1 has the highest rank so it is the Optimal Experiment value that gives minimum amount of Ra and Temp.

Table 4.5: All GRA Values of experimental data (MQL)

RUN	S	F	Doc	Normalized values		Grey Relational Coefficient	
				Ra	Θi	Ra	Θi
1	-1	-1	-1	0.5	0.5384	0.5	0.5
2	-1	0	0	0.220	0.153	0.22077	0.779220
3	-1	1	1	0	0	0	1
4	0	-1	0	0.292	0.115	0.29220	0.707792
5	0	0	1	0.220	0.192	0.22077	0.779220
6	0	1	-1	0.675	0	0.67532	0.324675
7	1	-1	1	0.642	1	0.64285	0.357142
8	1	0	-1	1	0.846	1	0
9	1	1	0	0.662	0.153	0.66233	0.337662

RUN	S	F	Doc	Grey Relational Grade		Avg. Grade	Rank
				Ra	Θi		
1	-1	-1	-1	0.4615	0.5	0.51	3
2	-1	0	0	0.8461	0.3908	0.3811	8
3	-1	1	1	1	0.3333	0.3333	9
4	0	-1	0	0.8846	0.4139	0.3875	6
5	0	0	1	0.8076	0.3908	0.3866	7

6	0	1	-1	1	0.6062	0.4698	5
7	1	-1	1	0	0.5833	0.7916	2
8	1	0	-1	0.1538	1	0.8823	**1**
9	1	1	0	0.8461	0.5968	0.4841	4

Graph 3: GRA vs. Experimental Runs for MQL

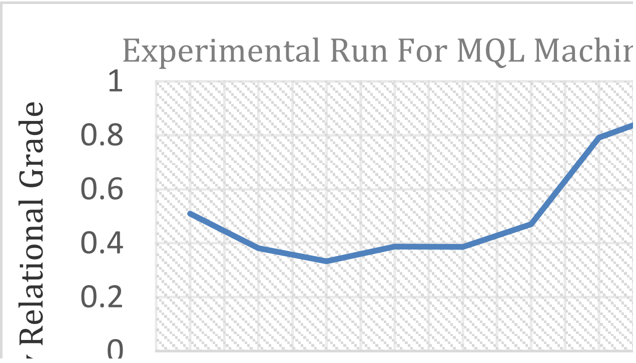


Table 4.6: Main effects of the factors on GRA (Wet)

Parameter	Level 1 (-1)	Level 2 (0)	Level 3 (+1)	Max-Min	Rank
Cutting speed	0.5587	0.491	0.5611	0.069	3
Feed	0.6105	0.557	0.4429	0.167	2
Depth of cut	0.6679	0.502	0.4408	0.227	1

Table 4.5 shows highest grey relational grade, indicating the optimal process parameter set of S(12000), F(600) and Doc(0.05) for the best multiple performance characteristics among the 9 experiments. Here the Experiment 8 has the highest rank so it is the Optimal Experiment value that gives minimum amount of Ra and Temp.

From this experiment we finalise optimal solution for each method but there is again chance to get precise optimum solution by small changing rank 1 value for each method, here speed is the most influence factor validated, likewise we conclude that the optimal solution for process parameter set under Dry, Wet and MQL conditions obtained by GRA method

5. CONCLUSION

Experimental results are obtained from the best combination of input and output process parameters. The present work helps in optimizing the use of vegetable cutting oil under the application of dry, flooded and MQL conditions. The amount of cutting oil is to optimize the appropriate cooling and lubricating effects are produced to achieve better machining results at lowest cost and environmental safety. The present work suggests that MQL is the best machining method because it improves surface finishing as well as easy to chip flushing. The developed experimental investigation of the cooling process makes it possible to study the effects of process parameters such as the speed, feed, and depth of cut. The results of the presented investigations show the benefits of using MQL cooling the Aluminum 7075 in comparison with dry machining, Result 26% and 10% reduction in Ra and Temperature respectively and in comparison with Wet machining, Result 14% and 5% reduction in Ra and Temperature respectively. Performance is almost same but by using MQL system to achieve both environmental and ecological benefits. In this experiment Speed, Feed and Depth of cut are the independent factors. Effect of these parameters was seen on the surface roughness & temperature near the cutting zone. The results from experimental tests are summarized here. It can thus be concluded that the use of vegetable grade cutting fluid in the machining no any hazardous, Safety to worker and environment friendly working condition

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