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Empirical Study Regarding the Effects of Minimum Quantity Lubricant Utilization on Performance Characteristics in the Drilling of Al 7075

Cutting fluids are difficult and expensive to recycle. These drawbacks mentioned can be reduced or eliminated by performing the cutting operations with minimum quantity lubrication or without using any cutting fluid. In this study, the effects of different cutting parameters on performance characteristics are studied empirically during the drilling of Al7075. The work piece surface roughness and the temperature changes due to the incurred heat at the cutting process are taken as performance outputs. In the experiments, HSS tools with a diameter of 8 mm and an angle of 118o were used. Minimum quantity lubrication (MQL), compressed air and dry processing (without the usage of any cooling liquid) techniques are used as the applied cooling technique. In the processing technique with MQL, the cooling liquid is sent pulverized on the interface between the work piece and the tool. Boron oil-water emulsion is used as the cutting liquid. As a result of the experiments, it is determined that better results are achieved with the MQL technique than with other cooling techniques. The best surface roughness is achieved at 20 m/min cutting speed and 0.1 mm/rev feed rate.
Keywords: *MQL, aluminium composite, drilling, surface roughness*

Introduction

The usage of conventional cutting fluids at the manufacturing is a serious problem for the manufacturers. Cutting fluids still hold an important position due to their positive effects like cooling, lubricating and cleaning. However, on the other side, they create a great potential of danger regarding the environment, and the human and the disposal causes continuously increasing costs (Rahman et al., 2001; Obikawa et al., 2006). There is a great effort to decrease the usage of cutting fluids at the manufacturing despite their important functions. MQL is considered as a solution for reducing cutting fluid. Lubricants, which are used at aluminium cutting processes by conventional methods, are more expensive than at other materials. The reason is that the oil in the mixture needs a higher concentration. Thus, MQL will provide great benefits at aluminium processing (Heinemann et al., 2005). The MQL technique constitutes a real alternative to the conventional methods with emulsions and full quantity cutting fluid flow. MQL is the situation at which cutting fluid is given efficiently to the location of chips only at that amount as necessary by the process. By this process, the environment of the working machines remains clean and possible costs for cleaning residuary are prevented.

There are several studies completed and still going on regarding the usage of MQL at manufactures. In drilling processes, performed with the usage of the MQL technique, a better surface quality is achieved compared to the conventional cooling technique and it is determined that the usage of MQL increases the tool life (Heinemann, et al., 2005; Braga, et al., 2002). The incurred temperature during dry drilling process at small sized drilling processes performed with the usage of coated cutting tools is examined numerically (Ozcelik and Bagci, 2006). Zeilmann and Weingaertner (2006) examined the incurred temperature during the drilling of Ti6A14V alloy by MQL and the dry processing techniques. They determined that the MQL technique significantly influenced the incurred temperature during the drilling of Ti6Al4V and increased the cutting performance positively (Zeilman and Weingaertner, 2006). In a conducted study regarding the machining of the A356 aluminium alloy, the effect of high cutting speed and the usage of different cooling techniques on surface quality, chip structure and the tool performance are compared (Kishawy et al., 2005). The usage of the MQL technique at the machining of AISI4340 steel has a positive effect on performance characteristics such as surface quality and tool wear (Dhar et al., 2006). The effects of conventional and MQL techniques on surface quality at the processing of Ti-6Al-4V alloy on a CNC lathe by the utilization of PCD tools is examined. During the experiments, performed at different cutting fluid pressures, flow rates and cutting speeds, the surface roughness values remained below the limit value for the final processing of 1.6 μm. The surface after the processing with PCD tools is determined to be clean and at acceptable level regarding physical damages like cracks, tears, etc. (Ezugwu et al., 2007). It is observed that, if well pulverized, the usage of water added MQL provides a very good lubrication, and that the usage of MQL with synthetic ester without water addition harms the cutting tool and has a negative effect on the surface roughness of the workpiece (Lacalle et al., 2006). It is observed that the cutting performance at the machining of AISI 1040 is better in the MQL technique compared to the dry processing (Dhar et al., 2007). Beside this, the effect of the cooling methods used at manufacturing and the cutting parameters on the performance characteristics constitutes the subject of several studies (Huseyinoglu, 2008; Lianq Chern, 2006; Davidson et al., 2008; Pawade et al., 2007; Dhar et al., 2007; Diniz and Micaroni, 2007; Huseyinoglu and Tosun, 2009; Attanasio et al., 2006; Bruni et al., 2006; Da Silva et al., 2007; Bhowmick and Alpas, 2008; Bono and Ni, 2001; Kelly and Cotterell, 2002).

In this study, the variation of the temperature and workpiece and the surface roughness of the performance characteristics incurred in different cutting speeds and feed rates by the usage of the MQL techniques, compressed air, and dry cooling and the drilling of AA 7075 is examined empirically.

Experimental Procedure

Al 7075 alloy is used in the experiments as the workpiece material. The experiment samples are prepared at the size of 120 x 30 x 10 mm^3. The chemical composition of Al 7075 is given in Table 1 and the values of the variable parameters used in the drilling process are given in Table 2.

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Table 1. Al 7075 Chemical composition.

Element	Cu	Mg	Mn	Fe	Si	Cr	Zn	Al
Weight (%)	1.2-2.0	2.1-2.9	0.3	0.5	0.4	0.18-0.28	5.1-6.1	Remaining

Table 2. Drilling parameters and values.

Experimental Units	Values
Cutting speed, V_c (m/min)	5, 10, 15, 20
Feed rate, f (mm/rev)	0.1, 0.2, 0.3
Cooling technique	MQL, Compressed Air, Dry

Three different methods as the MQL, compressed air and dry method are used as the cooling techniques during the drilling of Al 7075. In the MQL methods, a boron oil-water mixture is used as the cooling fluid. The boron oil-water ratio is adjusted as 1/10 at the performed experiments. The MQL is given to the work-piece – tool interface in pulverized form. The pulverization and flow rate adjustment is provided by the utilization of an air compressor with piston and a flow rate adjustment valve. The pressure of this compressor is selected at 10 bar. In order to determine the flow rate at the MQL technique, drilling processes are performed at three different flow-rates as 20, 40 and 60 ml/h and the flow rate of 40 ml/h, in which the best performance characteristics were obtained, is selected as the working flow rate. This flow rate and the compressor pressure are maintained fixed at all experiments. The experiment setup, prepared in order to provide the MQL technique and to determine the temperature during the experiments, can be seen in Fig. 1. In drilling processes performed by the usage of compressed air as the cooling agent, only the compressor circuit of this system is used. The values obtained from the thermocouples, in order to determine the temperature at 1 mm below the cutting area, are sent to the five channel thermocouple data collector of the ORDEL® brand UDL100 model and from here to a computer via an OM04 cable.

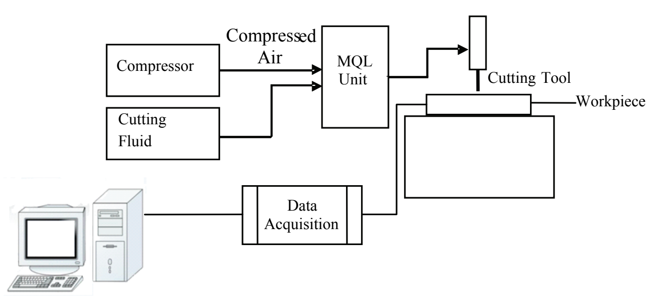

Figure 1. Setup of experiment.

Holes are drilled on the samples at an interval of 14 mm (Fig. 2(a)). In order to determine the incurred temperature in the drilling process, three holes of a diameter of 2 mm are drilled on the adjacent surface rectangular to the hole axis. Thermocouple is placed into these opened holes (Fig. 2(b)).

The surface roughness measurements are performed with the Taylor-Hobson's Surtonic 3+ surface roughness Measurement device. The sampling cut-off is selected as 8 mm and the sampling count as 3 at the measurements. The measuring process is performed parallel to the hole axis and the average of 4 measured surface values (Ra) is taken.

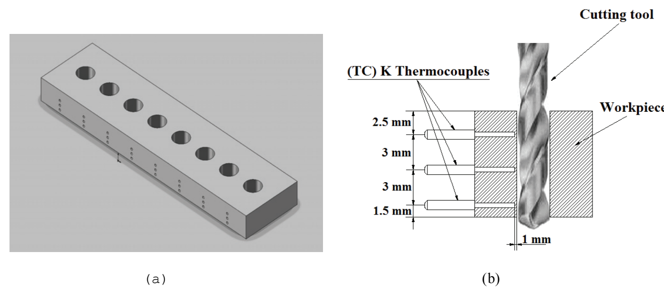

Figure 2. a) Holes on workpiece; b) Position of thermocouples.

Results and Discussion

Effect of Drilling Parameters on Temperature

The effects of cutting speed on the maximum temperature due to drilling are shown in Fig. 3.

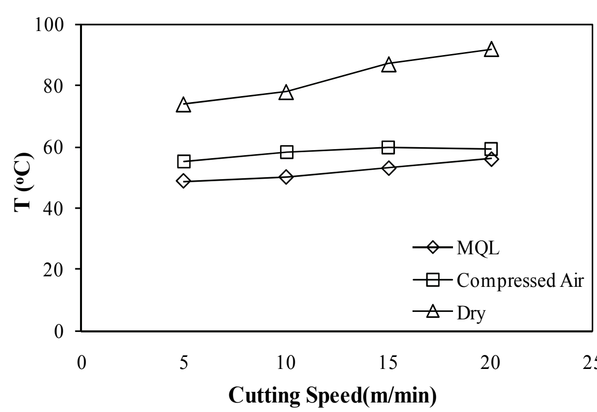

Figure 3. Maximum temperatures for different cooling methods.

From Fig. 3, it is possible to say that an efficient cooling is obtained with the MQL technique. The maximum temperature is obtained in the drilling process, performed with the dry drilling. This temperature value has shown a variation of 32-66% compared with other cooling techniques. When the dry drilling was compared with the compressed air, there was a decrease of these values by 30% at the processing with compressed air. Similarly, when compared with the MQL technique, there was a decrease by 40% of the maximum temperature incurred during the drilling process.

Regarding drilling processes performed by the MQL and compressed air, the maximum temperature exceeded 45°C at cutting speeds of 5 m/min and 10 m/min, and it is seen that this value exceeded 50°C at cutting speeds of 15 m/min and 20 m/min. The maximum temperature with the dry drilling at cutting speeds of 5-10 m/min is above 70°C. This value exceeded 85°C at cutting speeds of 15-20 m/min.

The effect of the cooling technique on the thermal distribution can be seen in Fig. 4(a, b and c). In these graphics, it can be seen that the temperatures show a stable behavior. The more the drilling depth increased, the more the incurred temperature at the cutting process increased and the maximum temperature incurred at the 3rd thermocouple.

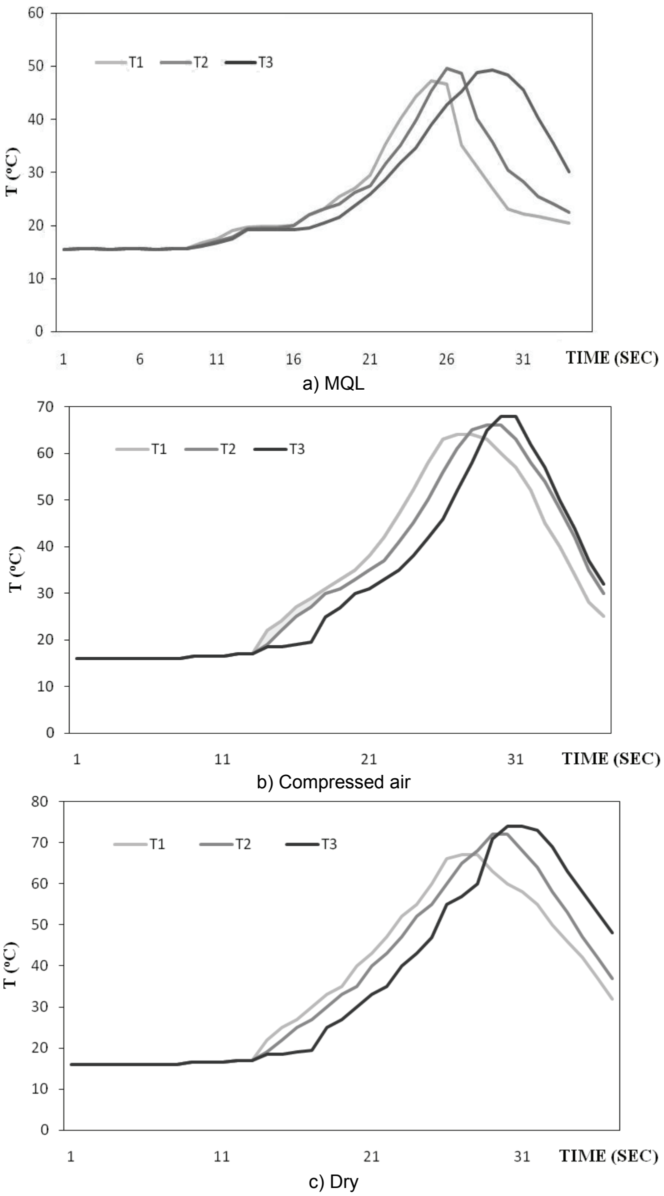

Figure 4. Change of temperature along drilling (Vc = 10 m/min, f = 0.1 mm/rev).

The temperature, incurred at 1 mm below the cutting area at the drilling process under these conditions, was close to 50°C in the MQL technique, close to 70°C in the drilling process with compressed air and 80°C in the dry drilling. There is the relation T1 < T2 < T3 among the temperature values obtained from 3 thermocouples.

The maximum temperatures at the hole processed with the MQL technique at 5 m/min cutting speed and three different feed rates are given in Fig. 5. As the graphic is examined, it can be seen that the temperature, incurred during the cutting process, increases also along with the increase of the feed rate and the cutting depth. The maximum temperature is determined at a feed rate of 0.3 mm/rev and 3rd thermocouple.

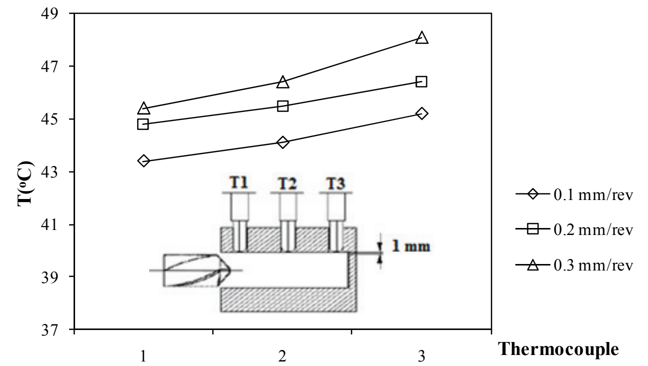

Figure 5. Maximum temperatures for MQL methods (Vc = 5 m/min).

Effect of Drilling Parameters on Surface Roughness

The surface roughness is the surface quality, incurring after the manufacturing process applied on the work-piece. There is a direct relation between the surface quality and parameters like cutting speed, feed rate and whether a cutting fluid is used or not. In order to determine this relation, a series of experiments are performed and the effect of the drilling parameters on the surface roughness is determined. Figs. 6-9 show the effect of feed rate on the surface roughness.

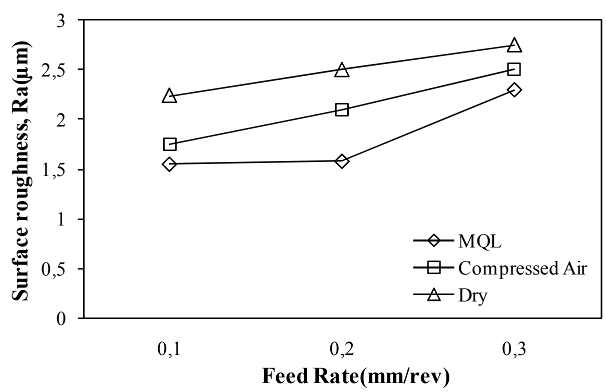

Figure 6. Effect of feed rate on surface roughness (Vc = 5 m/min).

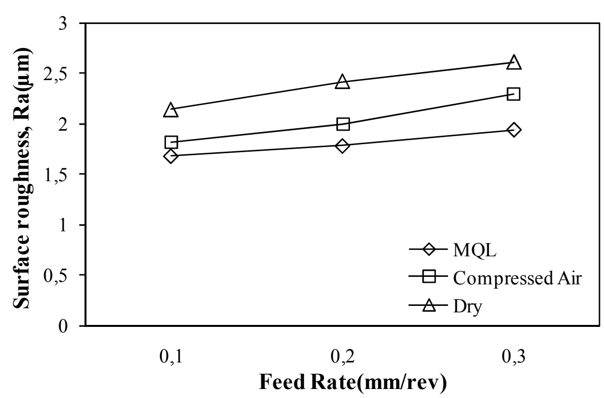

Figure 7. Effect of feed rate on surface roughness (Vc = 10 m/min).

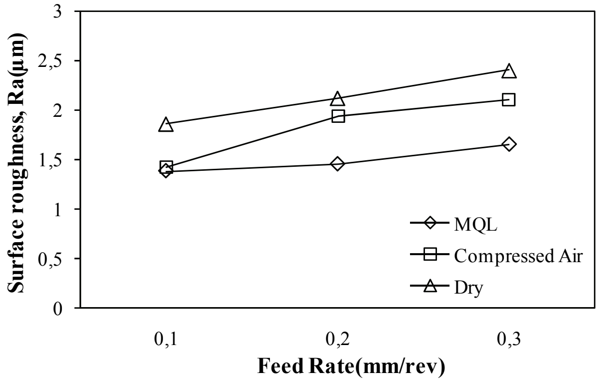

Figure 8. Effect of feed rate on surface roughness (Vc = 15 m/min).

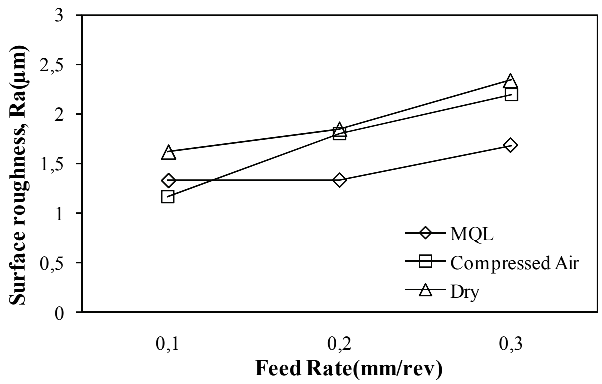

Figure 9. Effect of feed rate on surface roughness (Vc = 20 m/min).

In Figs. 6-9, it can be seen that the surface roughness increased by the increase of the feed rate for all cooling methods. The lowest surface roughness is measured at 0.1 mm/rev feed rate.

In order to increase the efficiency in manufacturing, it is necessary to remove high quantities of chips. The increasing demands for high productivity at establishments resulted in the need for high feed rates. As the cutting temperatures are to increase at machining with high feed rates, tool life decrease and along with the surface quality worsens (Dhar et al., 2006). The effects of cutting speed on surface roughness are shown in Figs. 10-12.

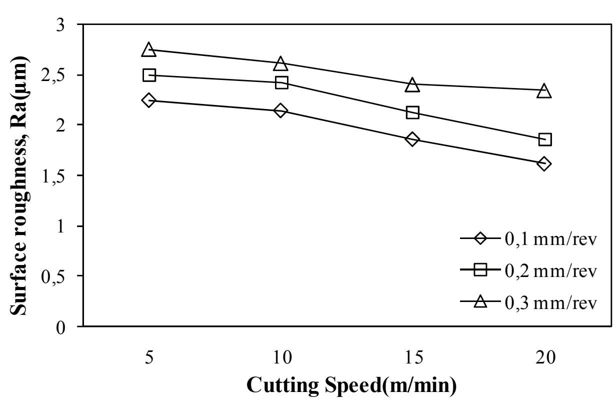

Figure 10. Effect of cutting speed on surface roughness (Dry).

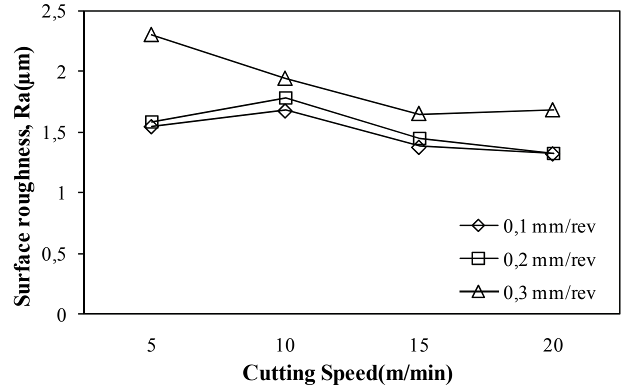

Figure 11. Effect of cutting speed on surface roughness (MQL).

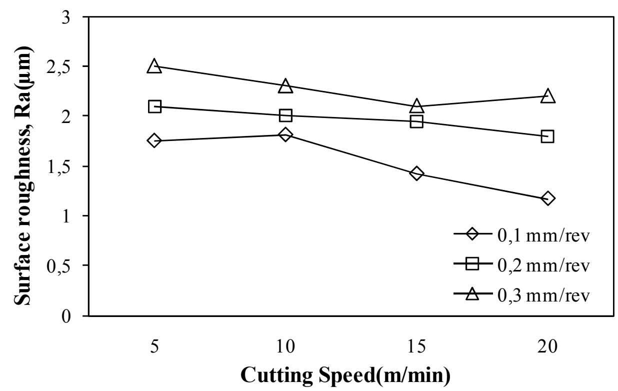

Figure 12. Effect of cutting speed on surface roughness (Compressed air).

From Figs. 10-12, it is determined that there is an improvement of the surface roughness by the increase of the cutting speed. The increase of the cutting speed results in the decrease of the cutting forces. In relation to the decrease of the cutting forces, an improvement of the surface quality of the drills incurs. Most of the Al alloys are processed at high cutting speeds in order to achieve good surface quality. The effect of the cooling method on the surface roughness is shown in Figs. 13-16.

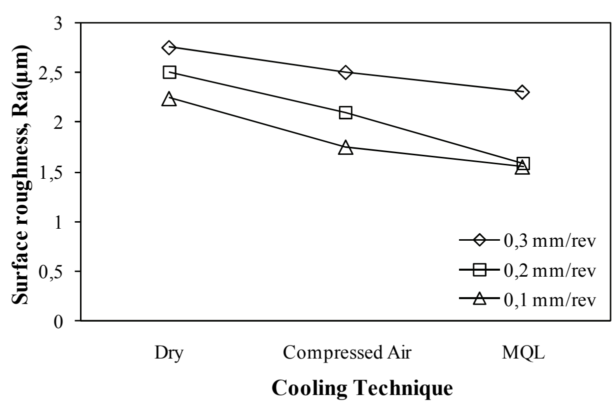

Figure 13. Effect of cooling technique on surface roughness (Vc = 5 m/min).

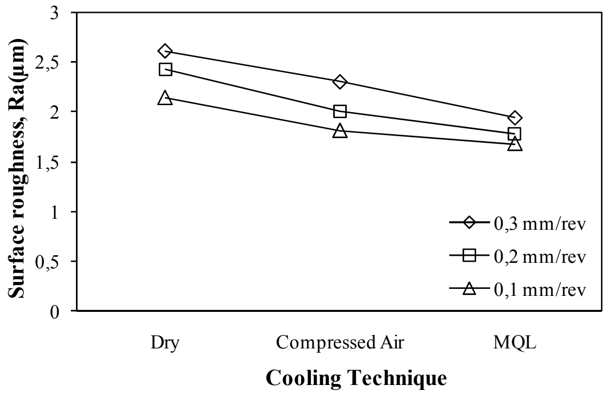

Figure 14. Effect of cooling technique on surface roughness (Vc = 10 m/min).

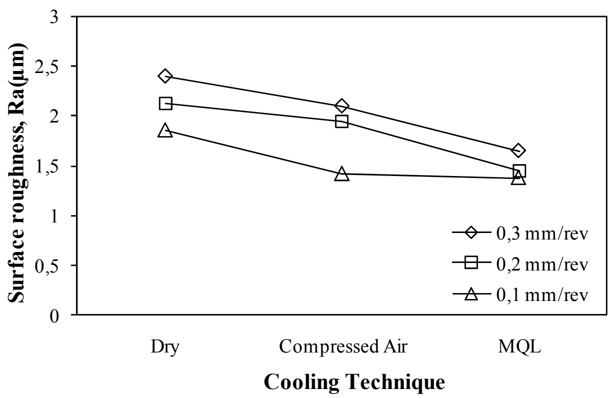

Figure 15. Effect of cooling technique on surface roughness (Vc = 15 m/min).

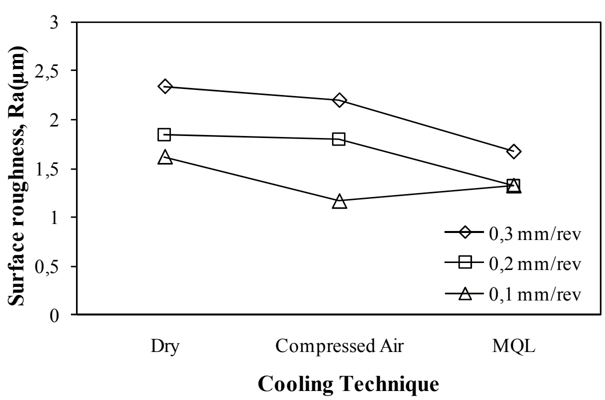

Figure 16. Effect of cooling technique on surface roughness (Vc = 20 m/min).

When the effect of the cooling method, used at the drilling process, on the surface roughness is examined (Figs. 13-16); it is seen that the least roughness is incurred at drilling processes performed by the usage of the MQL technique. Compressed air and the MQL technique have shown attributes, close to each other, when it was about high cutting speeds and low processing speed. And a worse surface quality was achieved at dry drilling processes compared to other cooling methods.

Conclusions

In this study, the effects of cutting speed, feed rate and the cooling technique on the temperature and the surface roughness of the drilled surface in the drilling of Al7075 is studied empirically.

It is observed that the MQL technique has shown a better performance than compressed air and dry processing by 8% and 66% respectively. It is also observed that the surface roughness in the MQL technique is lower than the surface roughness incurred in the other cooling technique. And again, it is determined that as the processing speed increased, the roughness value increased also. Except when the surface roughness in relation to the cutting speed is regarded; in the performed experiments regarding all cooling methods, it is observed that the surface roughness decreased the more the cutting speed increased.

When all results obtained by the performed drilling experiments are regarded; respecting the cooling method, the MQL cooling method can be preferred due to the advantages it has compared to compressed air and dry processing techniques. Along with the selection of a cooling method with such attributes, less deformation on processed surfaces and lower surface roughness values will be achieved by drilling processes at low processing speed and high cutting speed conditions.

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