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The Effect of Automated Coolant System on Surface Roughness During Machining Aluminium Alloy

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Abstract*: *To promote sustainable manufacturing process, the use of coolant during machining should be controlled in order to reduce environmental pollution and health problems. Furthermore, the amount of coolant used in the conventional flooded technique is quite huge that caused an increment in production cost. It is believe that the amount of the coolant supply during machining process need to be reduced and controlled in order to solve the problems. The aim of this study is to investigate the effectiveness and the performance of a proposed automated coolant supply system with the use of PLC to control the amount of coolant supply through timing control in order to minimize the use of cutting fluid. The performance of the automated coolant system has been assessed based on surface roughness when machining Aluminium alloy and the results are compared to the one with conventional flooded coolant system. The experimental evidences show that surface roughness for 5 second on-off coolant supply is higher than conventional flooded cooling technique while the surface roughness for 10 second to 20 second on-off coolant supply is largely improved and much better than conventional flooded cooling technique. However, the roughness results for 25 second on-off coolant supply is slightly worse than 20 second on-off coolant supply but it still better than conventional flooded cooling technique. The results of this research work indicated that automated coolant supply system can replace the conventional flooded cooling technique in machining operation without any significant negative effect on the surface roughness result.

Index Terms*: *Automated Coolant Supply, Aluminium Machining, Surface Roughness, Sustainable Manufacturing

I. INTRODUCTION

Cutting fluids plays an ultimately important role in machining process with the intention of raising the productivity. When cutting fluid is applied, the quality of the machined surface is able to be enhanced and the tool wear is diminished [1]. More over cutting fluids is use to increase the machinability through lubricating the contact areas between rake face and chips, flank face and machine surface and reducing the friction induce heat and removing the generated heat from the cutting zone as a result of severe plastic deformation [2]. Approximately 85% of cutting fluids being use around the worlds are petroleum base oils. Even though the use of cutting fluid facilitate benefit to the machining performance, it has been reported that the uses of cutting fluid create many negative effects on environment, which drawbacks their usage. About 80% of all works related contagions of the workers because of close skin interaction of operator with cutting fluids [3]. Besides that, greatly use of poisonous and less biodegradability cutting fluids can cause severe health problems like respiratory infections, lung cancer, dermatological as well as inherent diseases and also numerous techno-environmental problems [4]. Types of occupational risk associated with cutting fluids which become airborne and formed aerosol during machining, show that these risk were numerous and widespread. In addition, the costs for cutting fluid supply and disposal are not negligible with respect to overall production cost [5]. Furthermore, it is believed that the only small amount of coolant play role in the cooling system application. Therefore, it is important to find a way to manufacture products using the sustainable methods and processes that minimize the use of cutting fluids in machining operation [6].

Dry machining is one of the alternatives for green cutting because cutting fluid is not applying during this process. Although there are some benefits of using dry machining such as it can be able to extend the tool life in the condition of low cutting speed, but this condition can lead to low production rate and also overheating of cutting tools. This will produce tool wear on the cutting tools [7]. Moreover, high friction occurs between the tool and workpiece can lead to the increasing of temperature and eventually results in higher standard of oxidation, abrasion and diffusion [8]. In addition, the excessive heat occurring in the workpiece will consequently impede the achievement of tight tolerances and metallurgical damage. It should be noted that even though the use of dry cutting promotes some advantages in terms of sustainable and cost, there are some workpiece materials that are difficult to machine dry.

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The use of titanium alloy, nickel alloy, hardened steels and aluminum alloy still requires assistance for cooling and lubricating to reduce tool wear, deteriorate surface finish and formation of built up edge.

Flood lubrication is the most common application method used to machine these steels because this method can deliver a stable flow of fluid. During machining, the coolant flow continuously controlled by the G-code embedded inside Computer Numerical Control (CNC) system, which provide continues coolant flow from starting of machining process until completed cycle.

In some extent, the coolant still continuously flows even though the machining is completed due to direct information from CNC controller. Excessive usage of the flooded coolant not only gave negative effect to the environmental pollution and health problems but also cost of production to manage the disposal. To promote sustainable manufacturing process, the use of coolant during machining should be reduced. The introduction of automated controlling volume of coolant may be resulting adequate cooling usage but also performed well in machining.

This paper presents the machining process with an automated coolant supply system with the help of Programmable Logic Controller (PLC). The main purpose of this paper is to introduce a new innovation to assist coolant control in addition of controller inside CNC system. For initial assessments, the surface roughness between automated coolant supply system and conventional flooded coolant system when machining aluminum alloy has been compared and the result for both conditions are explained in detail.

II. EXPERIMENTAL PROCEDURE

A. System Development

A series of experiments was conducted on a CNC Milling machine with spindle speed of 1500 rpm, 250 mm/s feed rate and 0.5 mm depth of cut. The workpiece used is Aluminium and it was prepared as a 150mm x 150mm x 50mm rectangular block. The slot of milling process using automated coolant supply and flooded system were separately conducted in order to compare the performance for both cooling techniques. In the automated coolant supply technique, the system was operated by using Keyence Programmable Logic Circuit (PLC). The applied cutting fluids for both techniques known as Al Soluble Extra and the cutting tool selected is High Speed Steel. The development of the automated coolant supply system is divided into two main parts which are software development and hardware development. In the software development, a ladder diagram is designed by using CX programmer software model CP1E and CPU type N40. Then the program is interfaced between PLC and CNC machine to control the amount of coolant by timing the flow during machining operation. Finally, the program is debugged by using CX-Simulator, which is a ladder simulation tool without the PLC, is used to test the functionality of the system. Fig. 1 shows the ladder diagram developed in the PLC.

Hardware development is basically divided into two parts which are electrical and mechanical part. In electrical part, basically four electrical components which are 220V power supply, relay, Omron PLC and ON/OFF switch button, are linked together. An alternating current iss supplied to the 220V power supply, the main purpose is to convert current from AC to DC. Fig. 2 shows electrical and wiring part of the system.

In the mechanical parts, a coupling is designed through SOLIDWORKS which consist of small inlet that is connected to the pneumatic fitting with diameter of 8mm while the bigger outlet was used to connect to the valve with diameter of 24.38mm. Swept cut with 1.5mm diameter is added to both inlet and outlet port to increase the grip force and prevent the piping from slipping out due to the high pressure of coolants from CNC machine. Fig. 3 shows the connection of the mechanical parts in the automated coolant supply system.

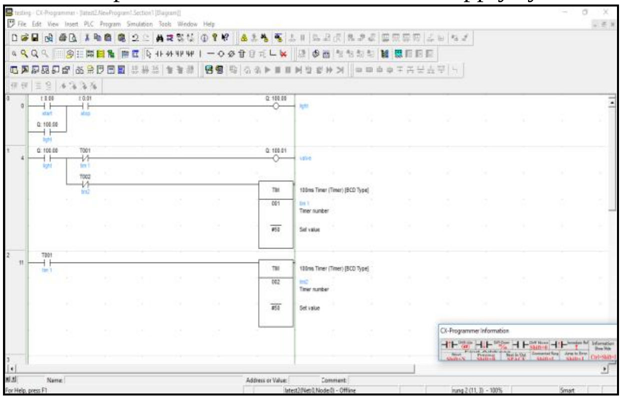

Fig. 1: Ladder Diagram Schematic In CX-Programmer Software

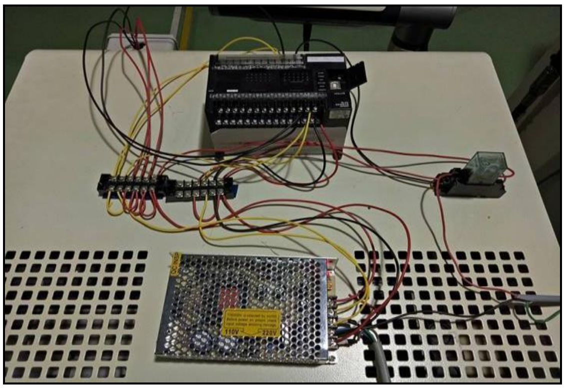

Fig. 2: Electrical And Wiring Part Of The System

Figure 3: Connection Of The Mechanical Parts Of The Hardware

B. Experimental Setup

Before starting the machining, coolant has been mixed with some ice cubes in order to increase the cooling capacity of the coolant.

Then performance of automated coolant supply system was examined by attaching the automated coolant supplying system to the CNC machine and the position of the nozzle is adjusted to the specific position which enables the coolant to reach the cutting zone and tool chip interface. Fig. 4 shows the position of the nozzle installed on the CNC Milling machine.

Fig. 4: Mechanical Part Installed On CNC Machine

Fig. 5 illustrates the machining process with automated coolant supply system attached on CNC milling machine. Experiments are conducted for 5s, 10s, 15s, 20s and 25s of interval time.

Fig. 5: Machining Process With Automated Coolant Supply System

Fig. 6 shows the result of milling process undergone on the Aluminium block. Each interval time period is running for three times and recorded with blue marker pen. Purpose of running three times for each interval time is to have a better average roughness result. After all the experiments are done, surface roughness tester is used to obtain the values of surface roughness of each cutting.

Fig. 6: Milling Process Is Undergone On The Aluminium Block

III. RESULT AND DISCUSSION

The result obtained for surface roughness is measured using Mitutoyo Surface Roughness Tester SJ-310 manual and tabulated in Table 1. The data from each set of the experiment is plotted and compared as shown in Fig. 7, 8, 9 and 10.

Table 1: Average surface roughness obtained from the experiments

Coolant Supply	Surface Roughness			
	Experiment 1	Experiment 2	Experiment 3	Average
Flooded	0.8110	0.8150	0.8020	0.8093
5s	0.8218	0.8360	0.8238	0.8272
10s	0.7713	0.7688	0.7663	0.7688
15s	0.7588	0.7488	0.7585	0.7554
20s	0.7175	0.7063	0.7145	0.7128
25s	0.7395	0.7453	0.7370	0.7406

According to the four graphs of Fig. 7 to Fig. 10, it is clearly seen that the results of the roughness tests for 5s to 20s is greatly in a reduced pattern but increased slightly in 25s. In fact, the roughness results of 10s to 25s are better than the result of flooded test, except for the 5s test.

From the observations stated above, roughness values for 5s test is higher than conventional flooded test which is also means that the surface texture for 5s test is coarser than the one under flooded test. Based on Carlos et al. [9], the roughness values obtained by the conventional flooded test were lower than the readings attained by the MQL technique. The result of 5s test perhaps fulfill the finding by Bianchi et al. This is mostly because of the conventional flooded method supply an abundant stream of cutting fluids on the cutting zone and chips from the internal diameter of the workpiece are able to be fully removed. However, in this research work's proposed technique with 5s on-off coolants supply, the small amount of the intense air flow did not have sufficient energy to remove cutting scratches and chips from the cutting zone. In addition, the small amount of the atomized cutting fluids mixed with the chips and slurry condition formed. Perhaps this worsens the quality of the workpiece and resulted in surface roughness values increased. This explained the degradation of the surface roughness values attained by the proposed technique with 5s on-off coolants supply than the conventional flooded system. However, this situation need to be further clarified in order to find the actual cause.

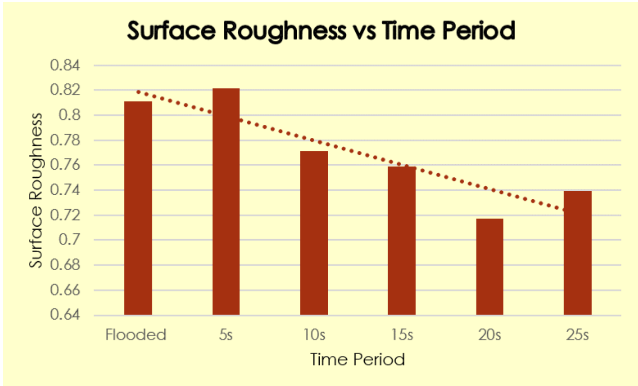

Fig. 7: Graph Plotted Based On The Data From Experiment 1

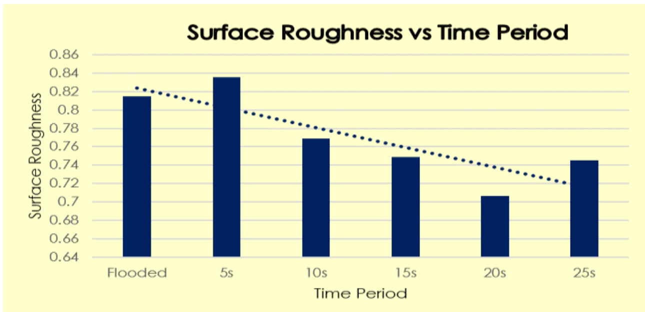

Fig. 8: Graph Plotted Based On The Data From Experiment 2

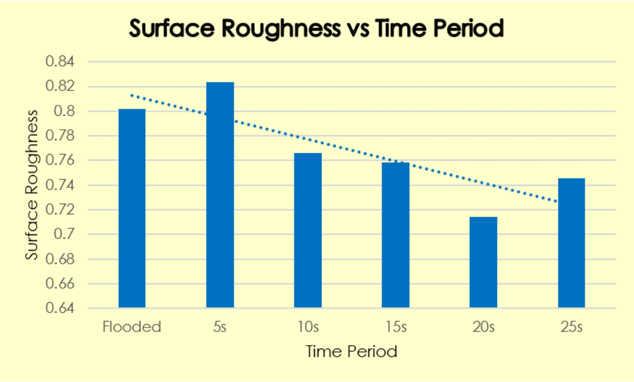

Fig. 9: Graph Plotted Based On The Data From Experiment 3

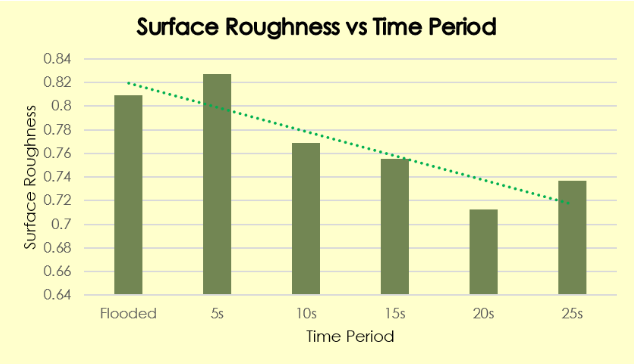

Fig. 10: Graph Plotted Based On The Average Data From The Overall Experiments

The roughness values were reduced significantly from 10s to 20s and the lowest roughness value belong to 20s. This verified the previous studies that MQL provided better surface roughness compared to conventional cooling method. Kedare et al. [10] claimed that the essential index of machinability that need to be controlled is the machining temperature at cutting zone. MQL was able to offer some favorable effects mainly through reduction in cutting temperature. Besides that, Lajis et al. [11] found that when the chips left the tool where the contact of chip-tool is in partially elastic, MQL was able to supply coolants in small quantity into the elastic contact zone by capillary effect. This is probably offered the more effective cooling to the machining zone. Hence, this explains that the surface roughness values by the proposed technique with the range of 10s to 20s on-off coolants supply is much better compared to the conventional coolant method.

IV. CONCLUSION

Based on the experiment, the results obtained is basically follows the theoretically predicted which is the longer the time intervals of the coolants supply, the better the surface roughness obtained. However, the performance for 5s on-off coolants supply is worse than the conventional cooling technique. This is perhaps due to the reason that in 5s on-off, the small amount of intense air did not have sufficient energy to remove cutting scratches and chips from the cutting zone. The surface roughness obtained from 10s to 20s on-off coolant supply provides the better surface roughness compared to the conventional flooded cooling technique. Besides that, 20s on-off coolants supply provides the best surface roughness performance in the overall experiment. Supposing that the surface roughness values attained from the proposed technique with 25s on-off coolants supply should be much better than 20s. However, the resulted roughness values are higher than the expected action. This situation might be due to the cutting tool is already wear or blunt after several trials and testing that caused the cutting process is not done properly. It can be concluded that the development of automated coolant supply is practical and can be an alternative for green machining in industry.

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REFERENCES

1. J.M. Viera, A.R. Machado, and E.O Ezugwu, "Performance of cutting fluids during face milling of steels ," Journal of Materials Processing Technology, vol. 116, no. 2-3, 2001, pp. 244-251.
2. A. Shokrani, V. Dhokia, and S.T. Newman, "Environmental conscious machining of difficult-to-machine materials with regard to cutting fluids," International Journal of Machine Tools & Manufacture, vol. 57, 2012, pp. 83-101.
3. Y.M.A. Shashidhara and S.R. Jayaram, "Vegetable oils as a potential cutting fluid - An evolution," Tribiology International, vol. 43, no. 5-6, 2010, pp. 1073-1081.
4. B. Ozcelik, E. Kuram, M. H. Cetin, and E. Demirnas, "Experimental investigations of vegetable based cutting fluids with extreme pressure during turning of AISI 304L," Tribology International, vol. 44, no. 12, 2011, pp. 1864-1871.
5. P.C. Priarone, M. Robiglio, L. Settineri, and V. Tebaldo, "Effectiveness of minimizing cutting fluid use when turning difficult-to-cut alloys," Procedia CIRP, vol. 29, 2015, pp. 341-346.
6. M.M.A. Khan, M.A.H. Mithu, and N.R. Dhar, "Effects of minimum quantity lubrication on turning AISI 9310 alloy steel using vegetable oil based cutting," Journal of Materials Processing Technology, vol. 209, no. 15-16, 2009, pp. 5573-5583.
7. M.P. Groover, Fundamentals of Modern Manufacturing: Materials, Processes and Systems. John Wiley &Sons, Inc., 2010.
8. A.E. Diniz and A.J. de Oliveira, "Optimizing the use of dry cutting in rough turning steel operations," International Journal of Machine Tools & Manufacture, vol. 44, 2004, pp. 1061-1067.
9. B.E. Carlos, R.S. Destro, M.H. Oikawa, and M.C. de Sampaio Alves, "The minimum quantity of lubricant (MQL) technique in the surface grinding of steel," WIT Transactions on Engineering Sciences, vol. 66, 2010, pp. 249–260.
10. S.B. Kedare, D.R. Borse, and P.T. Shahane, "Effect of minimum quantity lubrication (MQL) on surface roughness of mild steel of 15HRC on universal milling machine", Procedia Materials Science, vol. 6, 2014, pp.150–153.
11. M.A. Lajis, A.N. Mustafizul Karim, A.K.M. Nurul Amin, A.M.K. Hafiz, and L.G. Turnad, "Prediction of tool life in end milling of hardened steel AISI D2," European Journal of Scientific Research, vol. 21, no. 4, 2008, pp. 592–602.

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