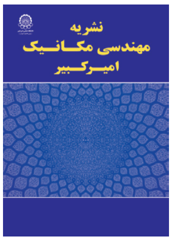

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Experimental Study of Abrasive Flow Rotary Machining and Effect of Abrasive Paste Temperature on Material Removal Rate of the Process

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ABSTRACT: Abrasive flow rotary machining is a new form of abrasive flow machining process which has been recently introduced by the authors as one of the non-conventional finishing and polishing methods. Since in abrasive flow machining process, the negative impact of temperature increase of the abrasive paste has been reported on the material removal rate, in this study the role of this parameter has been evaluated on the abrasive flow rotary machining. For this purpose, a new tool equipped with pressure and temperature measuring instruments as well as temperature control device has been designed and fabricated and the temperature changes of the abrasive paste during the process are measured. The process variables, in this case, have been selected based on the optimum machining conditions corresponding with the maximum material removal rate from the previous study of the authors. The experimental results with the new tool show that material removal rate and surface finish of abrasive flow machining are obtainable by abrasive flow rotary machining process. Also, no significant increase in paste temperature occurs in the abrasive flow rotary machining process during effective machining time intervals which is one of the advantages of abrasive flow rotary machining. In case of continuing the process, the material removal rate decreases by increasing the temperature of the paste, which shows similar behavior to the abrasive flow machining process.

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1- Introduction

The Abrasive Flow Machining (AFM) process is one of the advanced machining processes that can be used to polish metallic parts with complex or very fine features using an abrasive paste. New methods have been introduced to overcome some AFM disadvantages such as low Material Removal Rate (MRR) and the inability to machine the parts with blind cavities. Centrifugal force assisted AFM [1], drill bit-guided abrasive flow finishing [2], magnetic assisted AFM [3], ultrasonic AFM [4], electrochemical aided AFM [5] and orbital AFM [6] and are among these improved methods.

In all of the aforementioned methods, there is a reciprocating movement of abrasive material. This movement involves the engagement of the abrasive material with surfaces other than the surface of the piece which will depreciate the abrasive grains and material removal of unwanted surfaces. In order to optimize the use of abrasive material while improving process efficiency, the authors have proposed a method called Abrasive Flow Rotary Machining ((AFRM) [7].

Considering the important role of temperature changes of the abrasive paste in AFM material removal and the need for similar evaluation for the AFRM process, this paper addresses this problem. However, given that the tool introduced in Ref. [7] was not applicable for this purpose, a new tool equipped with pressure and temperature adjustment and measuring instruments was designed and fabricated and the performance of this tool under different conditions of pressure, rotational speed and time were evaluated. Then the surface roughness of the samples was studied under optimum conditions. Also, tests were carried out in 16 and 22 minutes to study the MRR and abrasive paste temperature changes over longer periods. Finally, the rate and amount of material removal were measured and interpreted at different temperatures of the abrasive paste.

2- Methodology

The new tool was designed and fabricated in accordance with Fig. 1. The abrasive paste in this process is composed of silicon polymer for molding and Silicon Carbide (SiC) abrasive powder. This paste with 70wt% concentration of SiC and 400 mesh is used as chopped pieces with 100 grams of industrial oil number 40 and 50 grams of silicon carbide with 100 mesh blended with oil and it is referred to as abrasive paste.

3- Results and Discussion

The initial tests were designed based on different process variables and their values listed in Table 1 to

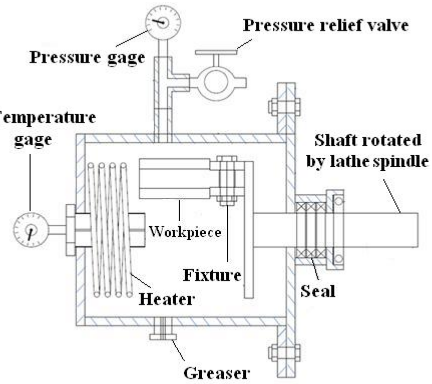

Fig. 1. Sectional view of the new AFRM tool

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find the optimal conditions of the process. The Magnitudes of MR and MRR are calculated by the following relations:

$$MR = \text{Piece weight}_{\text{before test}} - \text{piece weight}_{\text{after test}} \quad (1)$$

$$MRR = MR / \text{time} \quad (2)$$

Table 1: Process variables and their values

Variable	Level 1	Level 2	Level 3
Pressure (bar)	20	30	40
Rotational speed (rpm)	22.5	45	71
Time (min)	4	8	12

Fig. 2 shows that the MR increases with pressure. At lower pressures, the produced cutting energy is not sufficient to cut the roughness peaks. By increasing pressure from 20 to 30 bars the MR increases rapidly but after 30 bar pressure, the slope of the MR curve is reduced which may be due to the fact that at higher pressures, the flexibility of the abrasive paste decreases and the probability of abrasive particles compression to the workpiece surface are reduced as well.

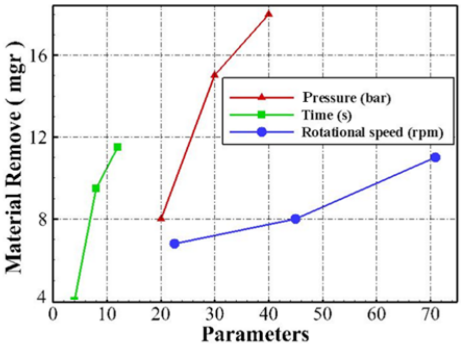

Fig. 2: MR variations at different pressures, times and rotational speed

Also, with increasing time, the amount of MR increases and in the second interval (from 8 to 12 minutes) the slope of the curve decreases slightly and after 12 minutes only the paste temperature rises. By increasing the rotational speed of the workpiece the MR increases which can be due to the higher probability of the active abrasive particles' collision with the surface of the workpiece at higher rates.

According to Fig. 3, after 8 minutes of initiating the test, the temperature of the abrasive paste starts increasing, but the MR is almost constant which indicates that the MR amount is independent of the time after a certain time from the start of the test. Comparison of the curves in Fig. 3 shows that after a certain time interval, the chipping ability of the abrasive grains is reduced so that they will no longer be able to remove deeper or wider roughnesses.

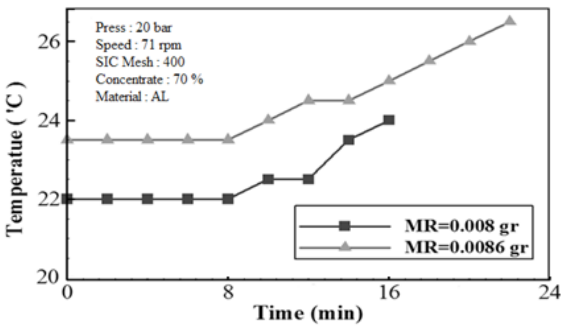

Fig. 3: Increasing the temperature of abrasive paste in new AFRM tool

In another test series, six samples of aluminum xxx7 were prepared and tested. Average initial and final surface roughnesses of the samples were 2.39 and 0.43 (Ra-μm) respectively which indicates the proper performance of the new tool.

Fig. 4 presents the reduced amount of MR with an increase in temperature. This can be due to plastic deformation of the roughness peaks during their contact with the abrasive particles at high temperatures rather than being cut and removed.

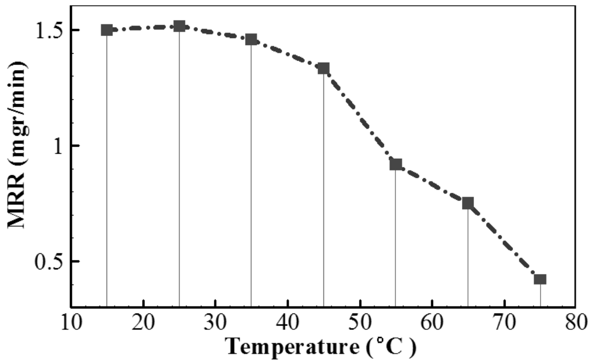

Fig. 4. Decreasing the MRR with rising temperature in the AFRM process

4- Conclusion

The following conclusions are notable:

1) Performance of the AFRM process is evident with the use of the new tool on a more industrial scale than the previous proposed one; larger samples with surface finish and MRR consistent with the same values in AFM are machined in the conducted experiments.

2) AFRM does not significantly change the abrasive paste temperature during the useful machining time and therefore has no significant effect on the MRR which is considered as the advantage of AFRM relative to AFM. However, due to the exothermal nature of the machining process, if the process is prolonged and the paste temperature increases, this variable will have a negative effect on the MR, and to achieve stable machining, the temperature must be controlled during the process.

3) Although due to the tool strength and safety considerations, the maximum pressure of the abrasive paste is considered as 40 bars, the values presented for each of the effective variables can be used as machining conditions in the AFRM process. It is suggested to analyze the results of the process at higher pressures in future designs.

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