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Influence of Machining Conditions on Friction in Abrasive Flow Machining Process – A Review

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Abstract. This paper presents a rage of variable machining factors which influence substantially friction directly or by the abrasive media wear developed in the cutting zone. Abrasive flow machining is method of machining surfaces of complex holes and curved surface. In the case of traditional stream treatment methods abrasive (AFM) it is difficult to obtain a uniform roughness radial decomposition during polishing complicated openings, which results from uneven distribution of abrasive forces. The group of direct factors include the work piece materials and abrasive media, changes in the fluid pressure, number of flow cycles, the medium flow frequency. In addition, it was proposed modifications in the amount and size of grains abrasives filling the abrasive medium to increase the value of the grain pressure force on the surface to be processed and obtained an even surface of complex holes in the process AFM processing. Special attention was paid to the abrasive media wear evolution and its pronounced effect on changes of the contact conditions. The experiment results also confirm that the rise in the medium flow frequency during the process will not affect the roughness changes work piece surface.

1 Introduction

Nowadays, polymeric materials are widely used in many different fields of technology. Polymer materials are increasingly replacing traditional construction materials; they can be used to make machine and mechanism elements or to use them as functional materials. The growing interest in modern polymeric materials means that scientific information related to specialist literature - regarding the complex chemical structure of plastics and the possibility of modifying their properties and properties during processing - can be useful for specialists in various fields of science and technology [1, 2]. Abrasive flow machining uses a deformable abrasive tool - the flexible media pressed under pressure to finish the inside surface of the machined holes [2]. An alternative to the standard medium, which has a high market price, are polymeric materials that can provide viscoelastic properties of abrasive pastes. Machining model and distribution of component forces during the AFM process are shown in fig. 1. The benefits of AFM method consist of convenient operation, lower manufacturing cost, complex shape machining, and higher polishing efficiency.

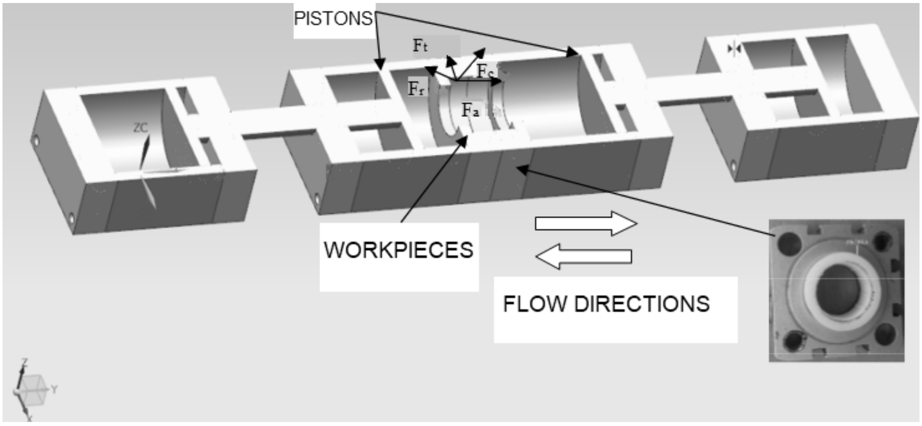

Fig. 1. The essence of abrasive flow machining: a) forcing the medium through the workpiece (Fa - force from the paste moving through the piston, Ft - force perpendicular to the surface, Fr - force from the viscoelastic paste, Fc - the total force of the abrasive grain, affecting the surface being machined) [13].

2 Experiment condition

Cross-linked polyvinyl alcohols can be successfully used as viscoelastic polymeric materials. In this case, the polymer medium is a non-Newtonian liquid and its viscosity changes during the process depending on the applied pressure [3]. The abrasive paste used in the machining process consists of a flexible medium (fig. 2) and abrasive grains (fig. 3).

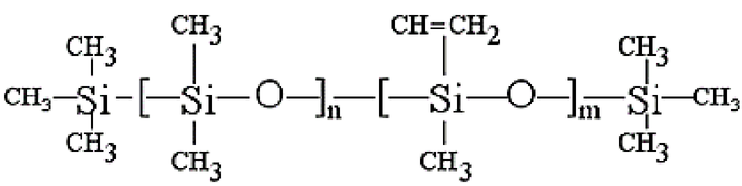

Fig. 2. Composition of the silicone polymer medium.

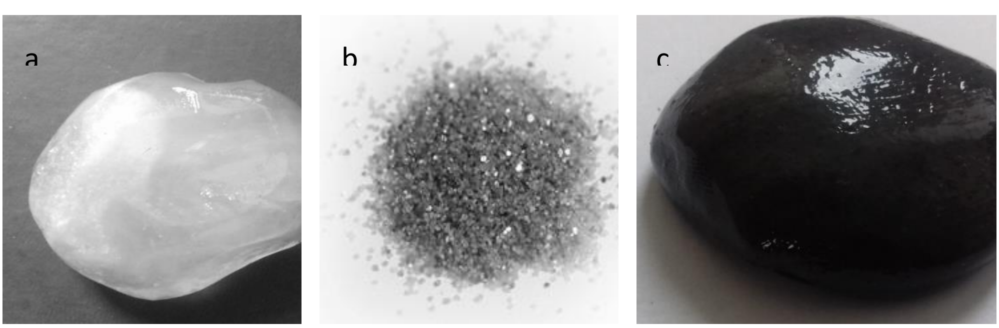

Fig. 3. Components (a– polymer medium, b- abrasive grains) and ready abrasive paste (c).

To obtain the desired quality of the machined surface, the type and size of abrasive grains made of polymer materials should be appropriately selected [4]. In publication [5], it was found that, when choosing grains for processing, one should take into account the amount of allowance to be removed and the contact surface of the grain and machined surface. If the grain size and concentration are too large in relation to the volume of the medium, then it is not possible to obtain a high-quality surface without damage [6, 7]. The principle of using larger grains in abrasive paste applies when removing a considerable amount of allowance from the workpiece and in the case of a large contact surface of the abrasive grain with the surface to be treated. However, the use of larger grains in abrasive paste creates problems with obtaining an adequate flow speed and grain wear due to friction inside the plastic mass volume [8]. Compressed stresses arise in the pressed plastic mass, which causes an increase in the concentration of active grains (in contact with the surface being machined). These grains are pressed against the surface to be machined and, as a result, micro-cutting process takes place [9]. Based on the work [9-11], it can be concluded that the problem of choosing the size and concentration of abrasive paste grains in relation to the desired finish quality of polymeric plastic products has not been described in sufficient detail. Also, due to the high price of the abrasive medium used in abrasive flow machining, there is a need to undertake research into the development of effective abrasive media for machining of the polymer materials.

2.1 Preparation of the abrasive medium

Products made of polycarbonate (PC) and acrylonitrile-butadiene-styrene (ABS) were selected as finishing objects. These are examples of machine holders. Viscosity of the obtained medium depends on the increase in shear stress (fig. 4). To determine the effect of the grain size used on the quality of the finishing of polymer products, their internal surfaces were machined using 12 polymer abrasive pastes with different grain sizes. The grain size of abrasives is given in tab. The concentration of abrasive grains in the paste was from 5%wt to 30 %wt. The abrasive grain size was determined according to PN-76/M-59107 (tab.1).

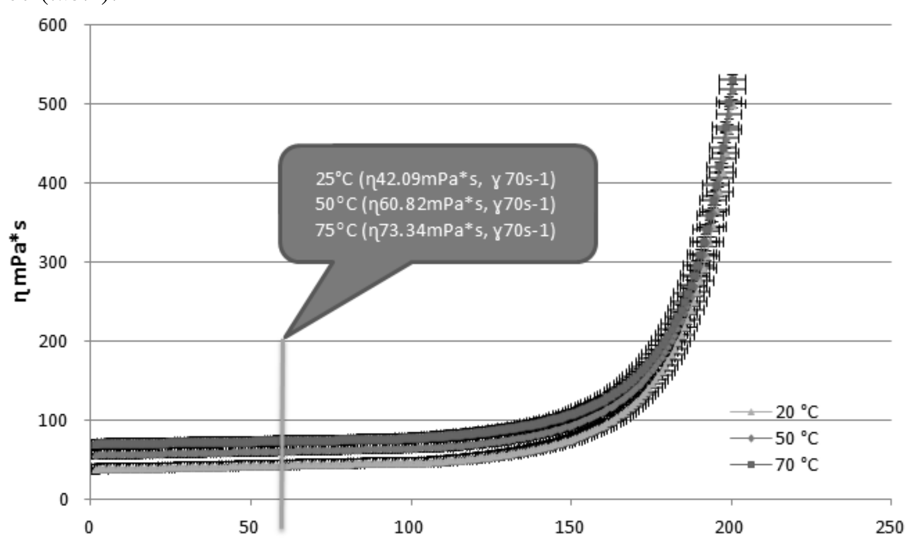

Fig. 4. Diagram of the viscosity of the medium polyborosiloxane in relation to the crosslinking temperature [14].

Table 1. Granularity of abrasive in polymer abrasive paste.

Mesh	Size of abrasive grain μm
220	60.5 -56.5
280	36.5-33.5
360	22.8-20.8
400	16.3-14.3

2.2 Machining process parameters

The experiments were carried out on a specially designed executed type abrasive flow machine. Figure 5 shows the procedure for producing the medium and for conducting the abrasive flow machining process. Machining was carried out at a stand designed to perform tests, presented schematically in fig. 1.

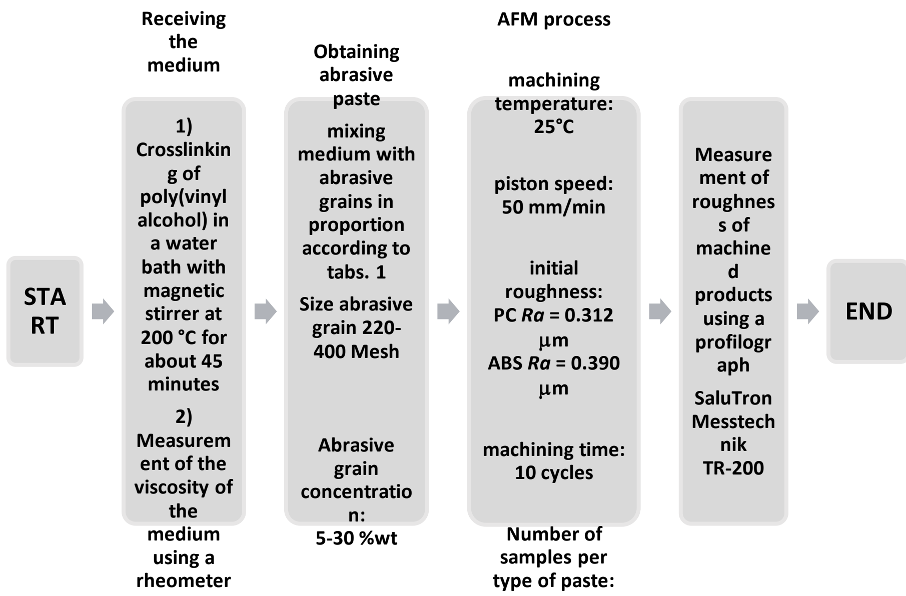

Fig. 5. Procedure for preparing abrasive paste and for carrying out the abrasive flow machining of polymer produces.

3 Results of experiments

The surface machining of the polymer product using each paste was performed for 10 samples. Achieved data sets were checked for normality using a chi-square test. In addition, the Q-Dixon test checked for a gross error in the result set.
Change in the roughness of the machined polymer surface can be described by the relationship in the form of the RIR (roughness improvement rate) [12]:

$$RIR = \frac{SR_{\text{original}} - SR_{\text{after machining}}}{SR_{\text{after machining}}} \ [\%] \qquad (1)$$

where: *SR_original* - surface roughness (*Ra*) of the product before AFM treatment, *SR_after_machining* - surface roughness (*Ra*) of the product after AFM treatment.
The roughness changes calculated on this basis after abrasive flow machining are shown in figs. 6 and 7.

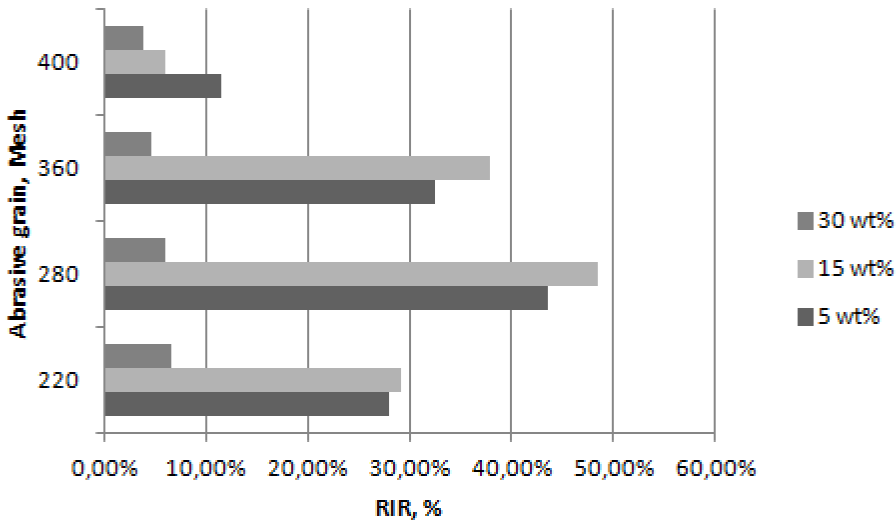

Fig. 6. Results of the size and concentration of abrasive grains in the medium on the RIR material (ABS).

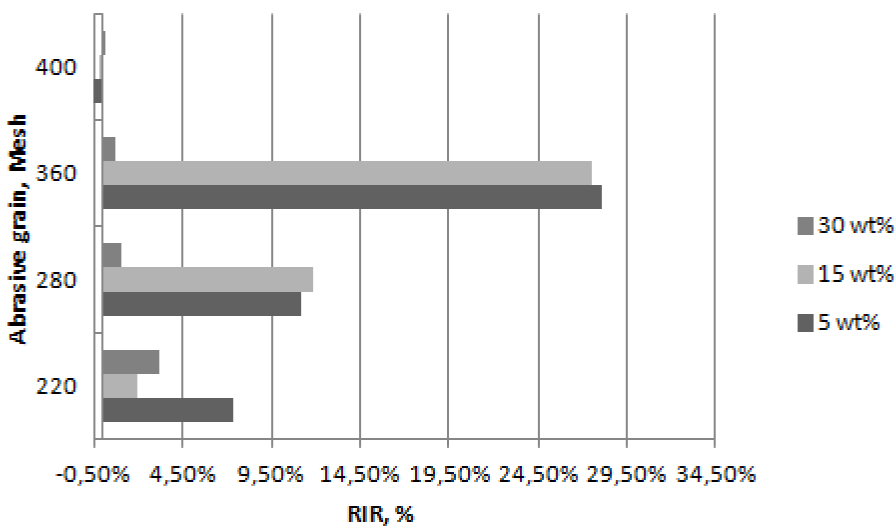

Fig. 7. Results of the size and concentration of abrasive grains in the medium on the RIR material (PC).

Analysis of the results of roughness measurements of polymer products confirmed that the use of 400 Mesh and 30 %wt grain in polymer paste did not improve the surface roughness. Although the 30 %wt paste was used, the surface roughness of samples made of ABS material was significantly reduced, but in the case of samples made of PC the surface

roughness increased. The reason for these discrepancies was the initial surface roughness value before machining: for ABS Ra = 0.390 μm, for PC Ra = 0.208 μm. The Ra parameter of the surface of the ABS product after application of the 400Mesh paste is about 11.5% RIR than before machining (0.208 μm). The reason for the low RIR in the roughness parameter are plastic deformations resulting from grooving consisting in the formation of scratches and pushing of a part of the material above the polished surface. The PC surface after 220 abrasive grain machining had a 7.35% RIR less roughness compared to the PC surface before post finish.
Obtained results indicate that in the case of surfaces machined with 5-15 %wt pastes, better roughness parameters (by 37% ABS and 28.15% PC lower) were obtained compared with 30 %wt pastes.
The best results regarding the reduction of the surface roughness compared to the surface roughness before machining are presented in tab. 2.

Table 2. Optimal RIR %.

Materials	**RIR [Concentration %wt, Mesh]**
ABS	48.5 [15%wt, 280]
PC	28.15 [5%wt,360]

4 Summary and final conclusions

Research and analysis of polymer plastic products lead to the conclusion that the use of abrasive flow machining allows for obtaining the desired surface quality of these products. It was confirmed that parameters of abrasive grains used in abrasive flow machining have an impact on the surface roughness of machined polymer products. The research results indicate that the size of abrasive grains in the polymer paste used for finishing should be equal to the unevenness of the sample surface. In addition, it can be stated that the polymer medium can be a component of the abrasive medium in abrasive flow machining.

Acknowledgments

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