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ABSTRACT

ADVANCEMENT in material sciences has led to the development of smart engineering materials viz. composites, ceramics, polymers and super-alloys. These materials find exhaustive use in modern manufacturing industries, especially, in aircraft, automobiles, cutting tools, die and mold making industries. Higher costs associated with the machining of these materials besides stringent design requirements, which include precision machining of complex and complicated shapes and/or sizes, machining of inaccessible areas at micro or nano levels with tight tolerances are the major limitations which have led to the development of newer advanced non-traditional machining processes. Abrasive flow machining (AFM) is a novel technique having potential to provide high precision and economical means of finishing inaccessible areas and complex internal passages on otherwise difficult to machine material and components. AFM has been likened to a semi-solid flowing file wherein the media acts as a flexible cutting tool whenever it is subjected to any restriction; and perhaps its greatest advantage lies in its ability to finish, deburr, polish, radius and removing the recasted layers from complex internal passages or areas that are inaccessible to more traditional methods such as mechanical honing.

The vast potential applications and capabilities of the AFM process attract the attention of machinists and make it imperative upon researchers to overcome the major limitations of the process. The present research initiative identifies the limitations and gaps through exhaustive review of published literature on AFM technique with the intent to explore the possibilities for improving the efficiency and capabilities of the process/technique. It has been recognized that very few research studies have been conducted on the optimization of the process parameters for enhanced quality characteristics. Therefore, it is required to study the AFMed surfaces to get more insight into the real interaction between flowing abrasive particles and the target surfaces.

The present research initiative identifies the parameters of abrasive flow machining (AFM) process that significantly affect the quality characteristics, material removal (MR) and change in surface roughness (ΔRa), on machine components bearing multiple holes and the optimal setting of process parameters for overall enhanced quality characteristics have been identified. Practical Industrial components bearing multiple holes have been used as specimen work-pieces for the present study to explore the feasibility of integration of this charismatic technique with present day small scale industries. The novelty lies in the fact that there is hardly any research
initiative which has worked on simultaneous micro-machining of multiple holes for enhanced quality characteristics and improved production capability of the process.

Experimental investigations have been performed on the simple yet versatile abrasive flow machining setup designed and developed by the author with inbuilt provision for variation in process parameters to facilitate the parametric study for evaluation of the process. Silicon based polymer has been developed and its composition selected by application of Technique of Order Preference by Similarity to Ideal Solution (TOPSIS) coupled with Analytical Hierarchy Process (AHP) as SMART Visco-Elastic Medium which acts as a deformable grinding tool for obtaining enhanced quality characteristics.

Identification of all the possible AFM process parameters that may be influencing the capability and efficiency of the process, investigating the behavior of these process parameters, and investigation of the workable range and the levels of AFM process parameters has been obtained on the basis of results from the pilot experiments and the limitations imposed by our setup. The parameters selected for the present investigation are Extrusion Pressure; Abrasive Concentration; Abrasive Mesh Size; Number of Cycles; and Oil Concentration at three levels each. The following parameters were kept constant during the present experimental investigation: Work Material; Abrasive Type; Temperature of the Medium; AFM Configuration; Work-Piece Profile; and Medium.

TAGUCHI’s robust parameter design approach has been adopted for the present study and experiments are performed in accordance with L$_{27}$ Orthogonal Array (OA) which had been selected taking into consideration the number of selected parameters, their levels, and possible interactions of interest. The consistency of the experimental observations obtained on our developed setup on the selected quality characteristics viz. material removal (MR) and Change in Surface Roughness ($\Delta$Ra), was ascertained by Monte Carlo Simulation.

It has been established from statistical analysis of our experimental design that the effect of Extrusion Pressure, A; Abrasive Concentration, B; and Number of Cycles, D; are found to have significant effect on both the quality characteristics viz. material removal and change in surface roughness values while the effect of Oil Concentration, E is found to have significant effect on the material removal only. It is further established that Extrusion Pressure, A; and Number of Cycles, D; are the most significant factors influencing both the quality characteristics. While Abrasive Concentration, B; and Oil Concentration, E; in the medium also have some contribution in influencing the quality characteristics.

The beauty of the Taguchi technique lies in its ability to directly indicate an optimal setting of process parameters for any particular quality characteristic, although this
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