Chapter 12
Optimization of Abrasive Jet Machining Processes Using Evolutionary Algorithms: A Computational Approach

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ABSTRACT

Abrasive Jet Machining is a non-traditional machining process with the considerable versatility of use, mostly in cutting, cleaning, and deburring hard and brittle materials. In AJM, optimal parameters involve such things as abrasive flow rate, pressure, and standoff distance, all of which are very important for attaining the appropriate performance metrics with respect to material removal rate (MRR) and surface finish. It applies evolutionary algorithms, specifically Genetic Algorithms (GA) and Particle Swarm Optimization (PSO), to the optimization of AJM processes. The evolutionary algorithms may efficiently locate optimal parameter combinations from computer simulations of various machining conditions into significant reductions in energy, wear, and increases in accuracy in machining. The computational approach given below provides a robust framework for achieving precision in AJM, beating traditional optimization techniques. Experimental verification has demonstrated the effectiveness of proposed EA-

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based models in optimizing efficiency in AJM.

INTRODUCTION

Abrasive Jet Machining (AJM) is a process of established non-traditional machining which is used mainly for precision cutting, cleaning, and deburring hard and brittle materials such as ceramics, glass, and composites. AJM does not follow conventional processes in the machining process, but rather uses a stream of high-velocity abrasive particles driven by compressed air or gas to avoid thermal or mechanical stress during machining and for making intricate designs with high-quality finishes. AJM also gets wide application due to processing of different range of material with less wear and tear on the tool(Pahuja et al., 2019).

Although the technique offers numerous advantages, the actual effectiveness of AJM largely depends upon a large set of process variables including Abrasive flow rate, Nozzle diameter, Standoff distance, and Jet pressure. These parameters have an immense influence on the key performance indicators: material removal rate, surface roughness, and the resultant efficiency of the process. Optimization of these parameters is really important in enhancing the quality of the machined product and decreasing the costs of production. Traditional optimization methods, such as trial-and-error and experimental methods, usually take a long time with much resource consumption; thus, they are less feasible today for more modern manufacturing demands. Therefore, there is a great need for systematic and efficient optimization techniques that can cope with the complexity of the interactions implicit in AJM processes(Natarajan et al., 2019).

Recently, evolutionary algorithms (EAs) emerged as likely to prove extremely potent tools for optimization, emulating the principles of natural selection and evolution to solve complex problems. These algorithms, including Genetic Algorithms (GA), Particle Swarm Optimization (PSO), and Differential Evolution, are particularly suitable for multi-objective optimization problems encountered in AJM. EAs use a population-based search mechanism and can thereby examine many parts of the solution space and drive convergence toward optimal or near-optimal solutions without explicit mathematical models of the system being optimized. The flexibility and robustness of EAs make them quite suitable for highly dynamic and complex environments of a manufacturing system where some traditional optimization methods may not function adequately(Misra et al., 2019).

In this chapter, we try to delineate the implementation of evolutionary algorithms in AJM process optimizations with special emphasis on their application for enhanced machining performance and efficiency. The initial stages of this work shall develop articulated views regarding the operating principles of AJM processes, key parameters, and several practical applications. This background material will serve as a launching point to analyze the theory of evolutionary algorithms, focusing on types, specially GA and PSO, which are gaining deep penetration in engineering optimization. The following section would be from the point of view of modeling and simulation in AJM processes: how such approaches can be applied for setting up the optimization problem. Then, the computational approach is elaborated, giving a demonstration of how EAs can be as capable in finding the optimal combination of machining parameters(Kalusuraman et al., 2020). Some case studies will be applied to allow the reader to better illustrate the practical implementation of GA and PSO to optimize AJM through empirical data to give an idea of how the improvement brought by these algorithms affected their key performance metrics.