Modeling and Optimisation of Laser Micro drilling

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ABSTRACT

To optimize a machining process, the choice of input variables is to be set at an optimal value and one has to take up experimental methods, which are not feasible at times. As such, optimization techniques can be used as they provide a cost-effective method. Laser microdrilling is a machining process that can be used on metals and composites. Aluminium alloy as matrix and silicon carbide (SiC) as reinforcement is a widely used material having applications in aircraft and space industries. An attempt is made for the optimization of Nd: YAG Laser beam Micro drilling of Al/10%/SiCp metal matrix composite. In this work, experiments are conducted with input parameters pulse power, pulse frequency, assist gas pressure, and pulse width and the mathematical models correlating the desired response heat affected zone and the control parameters are established using Response Surface Methodology (RSM). These models give the factor effects of the individual process parameters. Finally, GA is applied to search the optimal machining parameters.

Keywords: Laser micro drilling, Nd: YAG, Heat affected zone, Genetic Algorithm (GA)

1. INTRODUCTION

Metal Matrix Composites (MMC's) are widely used in various fields and are very difficult to machine material due to the presence of hard ceramic particles [1–5]. Most of the research on the machining of Al/SiCp MMC has focused on cutting and facing while drilling has received less attention. Pulsed Nd: YAG laser micro drilling has become an essential tool for micro-hole drilling applicable to both conductive and nonconductive materials. In this material is removed by vaporization and physical ejection of molten material based on the absorption of laser energy from a series of laser pulses at the same spot [6]. The use of LMD in the manufacturing industry can be attributed to several advantages high production rate, no mechanical damage or tool wear due to non-contact processing, improved product quality, and low material wastage. Due to the short wavelength of Nd: YAG (compared with CO2 lasers), it enables the processing of highly reflective materials with less laser power [7]. Kuar et al. [8] experimentally investigated the influence of laser machining parameters on the heat-affected zone thickness and phenomena of tapering during CNC-pulsed Nd: YAG laser micro drilling of zirconium oxide (ZrO2) and performed parametric analysis through response surface methodology (RSM). Ghoreishi et al. [9] employed a statistical model to analyze and compare hole taper and circularity in laser percussion drilling on stainless steel and mild steel. Yilbas [10] conducted drilling experiments on three materials, stainless steel, nickel, and titanium, using a single pulsed laser beam. It has been shown that the extent of taper formation during laser percussion drilling of thin sections can be significantly reduced by suitable control of laser variables. In this context, it can be suggested that the required peak power should be preferably obtained by appropriate control of pulse energy and pulse duration. French et al. [11] used two-level factors in Nd: YAG laser percussion drilling to find the significant factors from a list of 17 factors. The main effects of factors and first- and second-order interactions were analyzed, and it was found that pulse shape, energy, peak power, focal position, gas pressure, and Nd: YAG laser rod were the most significant influences on the hole taper and circularity. The main effects of factors and first- and second-order interactions were analyzed, and it was found that pulse shape, energy, peak power, focal position, gas pressure, and Nd: YAG laser rod were the most significant influences on the hole taper and circularity.

2. PROCEDURE AND OPTIMIZATION

The control factors taken were Pulse Power (PP), Pulse Frequency (PF), Assist Gas Pressure (GP), and Pulse Width (PW). In multi-objective optimization, the loss in some quality characteristics is always expected as compared to a single-objective optimization but the overall quality always improves. Laser micro-drilling is used, especially when very small dimension diameter holes have to be obtained. The materials can be of various types like hard or extra-hard, very thin foils, glass, composites, etc. The quality characteristic of drilled hole mainly depends on HAZ (a thin region on hole walls), hole taper which was formed with the entrance end being enlarged,

hole circularity (which determines regularity of hole circle) and spatter (resolidified material normally found at the entrance and exit of the hole). The appropriate selection of different input parameters and their levels that affect these quality characteristics can improve hole characteristics. The theory of response surface methodology (RSM) was introduced by Box and Wilson [13] to develop the empirical models of complex processes. These models were used to represent the output characteristics. Hill and Hunter [14] reviewed the earlier work on RSM. RSM is a combination of mathematical and statistical techniques useful for modelling and analysing a problem in which several independent variables influence a dependent variable or response [15]. The successful application of RSM relies on the identification of a suitable approximation for the function. The necessary data for building the response models are generally collected by an experimental design [12]. One of the most popular of classes of the RSM designs is the central composite design, or CCD.

The concept of genetic algorithms (GA) was developed by Holland in the 1960s and 1970s [16]. The genetic algorithm is a probabilistic technique that uses a population of designs rather than a single design at a time. It is analogous to natural selection in the evolution of living organisms in that the fittest members in the population have a better chance to survive, reproduce and thus transfer their genetic material to the successive generations. The initial population is produced by a set of arbitrarily generated members. Each generation comprises of members whose constituents are the individual design variables that differentiate a design and these are entrenched in a binary string. Each member is estimated using the objective function and is assigned a fitness value, which is a sign of the presentation of the member proportionate to the other members in the population. A biased selection depending on the fitness value, decides which members are to be used for producing the next generation. The chosen strings are the parents for the next generation, which emerges from the use of two genetic operators namely crossover and mutation. These operators give a random displacement to the parent population and engender a new population of designs.

3. CONCLUSION

The laser micro drilling process (LMD) is substantial and successfully uses non-traditional machining technology overwhelmingly uses difficult-to-cut advanced engineering materials yielding tremendous flexibility and quality. Yet, the assortment of pertinent combinations of input parameters in LMD is exigent as the approach necessitates a considerable number of control parameters. The enduring analysis contemplated a methodology for LMD based on the RSM and GA to evaluate the optimal machining parameters and to accomplish magnificent production machined components. RSM is a powerful mathematical model widely used to examine and optimize the operational variables for experiment designing and model development whereas GA is a cost-effective soft computing technique for optimizing machining operation.

4. REFERENCE

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