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GENERATIVE ASPECT FOR CONCURRENT OPTIMIZATION OF LASER BEAM MACHINING CHARACTERISTICS

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Abstract: Optimization and influence of laser machining process parameters on the heat-affected zone, kerf width, surface roughness, material removal rate (VMRR), and dimensional accuracy of composites were studied. Al7075–SIC metal matrix composite was synthesized. The selection of optimal machining parameters in any machining process significantly improves the quality, production rate, and cost of a component. The work presents an evolutionary objective optimization approach to derive the optimal laser machining conditions for the input parameters. The machining experiments were conducted with the consideration of pulse frequency, pulse width, welding speed, and pulse energy as the process-control variables to evaluate the machining characteristics. Empirical models were developed in terms of the input variables using response surface methodology. The individual and interactive effects of the variables on the responses were also analyzed. As the influence of control variables on the machining characteristics is conflicting in nature, the problem is formulated as a multi-objective problem to simultaneously optimize the output parameters. The aim is to simultaneously minimize the kerf width and minimize the heat-affected zone. An efficient evolutionary algorithm called non-dominated sorting genetic algorithm II was applied to derive the set of Pareto-optimal solutions. The derived optimal process responses were confirmed with the experimental values.

Keywords: Laser machining, heat affected zone, Pareto function, Genetic Algorithm

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Introduction

In the present scenario, particulate-reinforced aluminum-based matrix composites have emerged as the trusted engineering materials with higher specific modulus, thermal stability, and good tribological properties. These types of materials find a larger application in emerging industries such as automobile, aeronautical, and structural construction [1-2]. Compared to other alternative cutting technologies, laser cutting offers significant advantages and possibilities such as the ability to cut complex geometries with tight tolerances, high cutting speeds, i.e. increased productivity, localized heat affected zone (HAZ), high quality, ease of automation, etc. [3], [4], [5]. Although initial capital investments in laser machining technology are high, operational costs are low making this technology economically competitive and cost-effective. Determination of machining process conditions based on continual optimization represents a higher-level approach.

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It consists of the development of an empirical model of a laser cutting performance characteristic and the application of an optimization method. Empirical mathematical models establish relationships between inputs (cutting parameters) and outputs (performance characteristics). To this aim regression analysis, artificial neural networks, and genetic programming are predominantly being used [3], [6], [7]. 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. The use of laser machining 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 CO_2 lasers), it enables the processing of highly reflective materials with less laser power [8]. Kuar experimentally investigated the influence of laser machining parameters on the heat-affected zone thickness and phenomena of tapering during CNC-pulsed Nd: YAG laser machining of zirconium oxide and performed parametric analysis through response surface methodology (RSM). 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. [9] 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.

Procedure and Optimization

The important materials that are frequently used for LBM are discussed below: Ferrous alloy materials are iron-based materials classified under stainless steel, low carbon ductile steels, and hardened steel. These alloys found their application in defense, automotive, chemical, construction, aircraft, and medical industries. Aluminum and its alloys possess important properties as a high strength-to-weight ratio, lightweight and better electrical, and thermal properties. The Nd: YAG laser is useful for the machining of these materials due to their property of short wavelength, well-focusing characteristics, and power [10, 11].

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 machining is used, especially when very small machining is to be obtained. The materials can be of various types like hard or extra-hard, very thin foils, glass, composites, etc. Manufacturers are interested in laser machining due to the optimization of the process parameters. The contribution of several process parameters makes laser machining a highly nonlinear and complex process. Well-designed model developed for different performance characteristics. The main parameters affecting laser are beam characteristics, laser characteristics, machining characteristics, quality characteristics, geometry characteristics, and metallurgical characteristics. Various Modeling and optimization tools are classified as hard computing methods and soft computing methods. The appropriate selection of different input parameters and their levels that affect these quality characteristics can improve machining characteristics. The theory of response surface methodology (RSM) was introduced by Box and Wilson [12] to develop the empirical models of complex processes. These models were used to represent the output characteristics. Hill and Hunter [13] 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 [14]. 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 classes of RSM designs is the central composite design or CCD. In this paper, a unique way of modelling kerf width using RSM is perceived. RSM is selected to map the experiments with a reduced number of trial runs to effectuate optimum responses. The discrete feature of RSM used extensively in the industrial world is used to examine and characterize problems in which input variables influence some performance aspect of the

product or process. This performance measure, or sometimes quality characteristic, is called the response. The concept of genetic algorithms (GA) was developed by Holland in the 1960s and 1970s. 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 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.

Conclusion

Laser machining is substantial and successfully used non-traditional machining technology overwhelmingly used for the cutting of conductive and non-conductive difficult-to-cut advanced engineering materials yielding tremendous flexibility and quality. Yet, the assortment of pertinent combinations of input parameters in laser machining is exigent as the approach necessitates a considerable number of control parameters. The enduring analysis contemplated a methodology based on the RSM and GA to evaluate the optimal

machining parameters and 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 cost effective soft computing technique for optimizing machining operations.

References

[1] M. Kathisan and T. Sornakumar: Journal of Minerals & Materials Characterization & Engineering Vol. 9(2010), No.1, P. 79 – 88.

[2] Arun Kumar Pamdy and Avanish Kumar Dubey: Optics and Laser in Engineering Vol. 50(2012), P. 328-335.

[3] M.J. Tsai et al.Optimal laser-cutting parameters for QFN packages by utilizing artificial neural networks and genetic algorithm J. Mater. Process. Technol. (2008)

[4]U. Caydaş et al.Use of the grey relational analysis to determine optimum laser cutting

parameters with multi-performance characteristicsOpt. Laser Technol.(2008)

[5]A. Sharma et al.Modelling and optimization of cut quality during pulsed Nd: yag laser cutting of thin Al-alloy sheet for straight profile Opt. Laser Technol.(2012).

[6] R. Attri et al. Application of preference selection index method for decision making over the design stage of production system life cycle.J. King Saud Univ.-Eng. Sci. (2015)

[7] A.K. Dubey et al. Multi-objective optimization of laser beam cutting process Opt. Laser **Technol.**(2008)

[8] C. Bagger, F. O. Olsen,"Pulsed mode laser cutting of sheets for tailored blank", J Mater Process Technol, 2001, pp. 31– 135.

[9] P. W. French, D. P. Hand, C. Peters, G. J. Shannon, P. Byrd, and K. Watkins, "Investigation of Nd: YAG laser percussion process using factorial experimental design", Proceedings of ICALEO, 1999, pp. 51-60

[10] Girish Dutt Gautam and Arun Kumar Pandey, 2018 Elsevier, Optics and Laser Technology 100, PP.183–215.

[11] A Bharatish, H N Narasimha Murthy, B Anand, K N Subramanya, M Krishna and P V Srihari, 2017 Elsevier, Measurement 100, PP.164–175.

[12] Maghsoud, A., Amir, N., and Komeil, G. 2008. Response surface Methodology and genetic algorithm in Optimization of Cement Clinkering Process. Journal of Applied Sciences, 8(15), pp. 2732-2738.

[13] Box, G. E. P., and Wilson, K. B. 1951. Experimental attainment of optimum conditions. J R Stat Soc [Ser A] 13, pp. 1-45.

[14] Hill, W. J., and Hunter, W.G.1966. A review of response surface methodology: a literature review. Technimetrics 8, pp. 571-590.

[15] Montgomery, D.C. 2001. Design and analysis of experiments. Wiley, Hoboken.