Intelligent Modelling and Multi-Objective Optimisation of Laser Beam Cutting of Nickel Based Superalloy Sheet

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ABSTRACT

In the present study, a novel technique, namely, evolutionary non-dominated sorting genetic algorithm-II (NSGA-II) was used in conjunction with developed artificial neural network (ANN) model to select optimal process parameters for achieving the better process performance in LBC. First, ANN with backpropagation algorithm was used to model the LBC of nickel based superalloy sheets. The input process parameters taken were oxygen pressure, pulse width, pulse frequency and cutting speed. The performance characteristics of interest in nickel based superalloy thin sheet cutting are average kerf taper and surface roughness. The ANN model was trained and tested using the experimental data obtained through experimentation on pulsed Nd-YAG laser beam machining system. The 4-10-11-2 backpropagation architecture was found more accurate and generalized for given problem with good prediction capability. The results show that the developed modelling and optimisation tool is effective for process parameter optimization in LBC process. The optimisation of the process suggests that for achieving high cut quality characteristics the pulse width, pulse frequency and cutting speed are set to lower limit within the available range and gas pressure is set to a level which is sufficient to remove the molten metal from the kerf.

Keywords: *Artificial Neural Network, Genetic Algorithm, Intelligent Modeling, Laser Beam Cutting, Multi-Objective Optimization*

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1. INTRODUCTION

Laser beam cutting (LBC) is one of the advanced sheet cutting processes (ASCPs), which is widely used for cutting complex profiles in the sheet of any known engineering materials on the earth. The material to be cut may be fragile, brittle, electric conductors or non-electric conductors, hard or soft (Steen 1991). LBC is a non-contact thermal process, which is executed by moving a focused laser beam on the surface of the workpiece with appropriate scanning speed. It does not involve any mechanical cutting forces and tool wear. Due to converging–diverging shape of laser beam profile a kerf taper always exists in cut sheet specimens (Chryssolouris, 1991). Also, resolidified layers, adhesion of dross and heat affected zone (HAZ) are major problems for achieving better quality cuts. There are many input parameters affecting the quality of laser cutting such as laser type and power, type and pressure of assist gas, cutting speed, sheet material composition and its thickness, and mode of operation of laser beam (Continuous or Pulsed mode). To achieve acceptable level of cut quality characteristics, it is necessary to choose optimum combination of input process parameters. Nickel based superalloy sheets in general and SUPERNI 718 sheet in particular is used as casing for jet engines, aeroengine turbine blades, turbo charger and pump body parts. Due to the improved mechanical properties of nickel based superalloy sheet cutting is difficult by the conventional sheet cutting processes. Such sheetmetals can be easily cut by LBC with exceptionally good cut quality characteristics by tuning proper input parameters.

Modelling of any machining process will be beneficial for better scientific understanding of the process under various operating conditions. However, optimisation of the process will be helpful in selecting appropriate input parameters as well as finding optimum outputs with multiple objectives. Literature reports several attempts towards modelling and optimisation of LBC process using statistical techniques, such as response surface methodology (RSM), factorial analysis, regression analysis, analysis of variance (ANOVA) technique and Taguchi methodology (Almeida et al., 2006; Dubey & Yadava, 2008; Rajaram et al., 2003; Rao & Yadava, 2009). Rajaram et al. (2003) developed model for CO_2 laser cutting using regression analysis to describe the effect of process parameters (laser power and feed rate) on laser cut qualities (kerf width, surface roughness and the size of HAZ). From the analysis of results they found that power has a major effect on the kerf width, while feed rate a minor role. Decreasing power and increasing feed rate generally led to a decrease in kerf width and HAZ. Dubey and Yadava (2008) used a hybrid approach of Taguchi methodology and principal component analysis for multi-objective optimisation of pulsed LBC of nickel based superalloy (SUPERNI 718) sheet to achieve better cut qualities considering the four input parameters (gas pressure, pulse width, pulse frequency and cutting speed). They found that the kerf width deteriorates slightly but other two quality characteristics kerf deviation and kerf taper have been improved significantly. They also concluded that the loss in some quality characteristics is always possible as compared to single objective optimisation but overall quality is improved.

Rao and Yadava (2009) studied the effects of input process parameters (assist gas pressure, pulse width, pulse frequency and cutting speed) on kerf width, kerf taper and kerf deviation simultaneously during laser cutting of straight and curved profiles using hybrid approach of Taguchi methodology and grey relational analysis. They found the optimum level of process parameters for minimum kerf width, kerf deviation and kerf taper in both cases (straight and curved profile). Entropy measurement (EM) method was employed for finding the weights corresponding to each quality characteristics. Sharma et al. (2010) optimized three kerf quality parameters kerf width, kerf deviation and kerf taper individually using the Taguchi methodology during LBC of different cut profiles on nickel based superalloy sheet. They concluded that the optimum parameter levels for kerf width are same for straight and curved profiles while in case of kerf taper

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