Laser Beam Machining Review

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*Abstrac*t— The domain of our project is Laser Beam Machining. LASER stands for light amplification by stimulated emission of radiation. Laser beam machining is a thermal energy–based advanced machining process in which material is removed by focusing the laser beam on the work surface at a constant distance to melt and vaporize the unwanted work material. There are three types of laser beam machining namely CO_2 laser machining, fiber laser machining and Nd: YAG i.e. vanadate crystal laser. The main advantages of laser beam machining are ease of automation for complex cutting patterns, absence of tool wear and breakage, ability to cut at shallow angles, and rapid cutting rates. As it is a noncontact process, energy transfer between the laser and the material occurs through irradiation. Laser beams are not designed to produce mass metal processes. Laser beam machining consumes a lot of energy. Deep cuts are difficult with workpieces with high melting points and usually cause a taper. LBM has various applications such as welding, cladding, marking, surface treatment, drilling, and cutting among other manufacturing processes. It is used in the automobile, shipbuilding, aerospace, steel, electronics, and medical industries for precision machining of complex parts.

Keywords— Artificial Neural Networks, Response surface methodology, Heat Affected Zone, Analysis of Variance, Deep Neural Network.

Introduction:

In the dynamic landscape of advanced manufacturing and materials processing, the exploration of cutting-edge technologies is paramount. This research project endeavors to contribute to this evolving field by undertaking an in-depth investigation into two prominent laser cutting methods – Fiber Laser and CO2 Laser. The specific focus is on evaluating their performance when applied to SS316 steel, a stainless-steel alloy recognized for its widespread industrial use and unique material properties. As industries increasingly demand materials with superior mechanical and chemical properties, the need for precision in manufacturing processes becomes critical. Laser cutting, a non-contact thermal process, has emerged as a promising solution, offering high precision and efficiency. However, the intricate nature of laser-material interaction, particularly on challenging materials like SS316 steel, necessitates a meticulous examination to unlock the full potential of these advanced technologies. A CO2 machine, also known as a carbon dioxide machine, is a device designed for various applications, including carbonation of beverages, environmental testing, medical procedures, and more. Typically, it consists of a gas cylinder or tank that stores compressed carbon dioxide, a regulator to control the gas flow, and a delivery system

such as hoses or pipes. The machine often includes safety features like pressure relief valves and gauges to monitor gas levels. Some models may have additional components for specific purposes, such as diffusers for dispersing CO_2 into liquids. These machines are used in a wide range of industries to provide a controlled source of carbon dioxide gas for diverse applications, contributing to efficient carbonation, laboratory testing, and medical procedures, among others.

A fiber laser beam machine is a high precision cutting and engraving tool that utilizes the principles of fiber laser technology. It typically consists of a laser source, which is often a diode-pumped fiber laser, that generates a concentrated and coherent beam of light within an optical fiber. This laser beam is then directed through a series of mirrors and lenses to the laser head, which is equipped with a focusing lens to achieve a small and intense focal point. The machine's computer-controlled motion system precisely positions the workpiece on a cutting or engraving bed, enabling the laser to create intricate patterns, cut through various materials like metal, plastic, or wood, and mark surfaces with exceptional precision. Additionally, an exhaust system is usually integrated to remove fumes and debris produced during the laser processing, ensuring clean and efficient operation. Fiber laser machines are widely used in industries such as manufacturing, aerospace, and electronics due to their speed, accuracy, and versatility in material processing.

Fig NO 1. CO2 Laser Machine

Fig No. 2 Fiber Laser Machine

LITERATURE REVIEW

- Laser cutting can offer an alternative machining method in which quality cut can be obtained by controlling different process parameters.

- Experimental results showed the presence of different interaction mechanisms such as: ablation, matrix burning and mechanical effect.

- OM/FE-SEM observation, EPMA analysis and nano-indentation hardness test were utilized to characterize the microstructure and evaluate the mechanical property. Results show that the HAZ width is dependent on the welding condition.

- According to the results the cutting speed has the highest influence on the HAZ forecasting (RMSE: 0.0553). Gas pressure has the smallest influence on the HAZ forecasting (RMSE: 0.0801). The results can be used to simplify HAZ prediction and analysis.

- In this study, the laser scanning speed used during laser surface processing of a Zr-based bulk metallic glass (BMG) was optimized to obtain amorphous structure in the melt zone and nanocomposite structure in the heat affected zone (HAZ).

- After the correlation between input and output parameters of the process is established, statistical analysis enables the determination of the influence of input parameters on output quantities and finally, appropriate process conditions for the regulation of depth of cut and kerf characteristics are derived.

- High laser power and low cutting speed produced worst surface roughness and wide heat affected zone. Therefore, it is recommended to use low laser power and high cutting speed to minimize the heat affected zone and the surface roughness.

- The results revealed that the nozzle transverse speed was the most significant factor affecting the top kerf width, the kerf taper angle.

- The model is composed of Long Short-Term Memory (LSTM) and Chimp Optimization Algorithm (CHOA). The latter is used as an internal optimizer to obtain the optimal parameters of the network model.
- Laser beam stealth dicing can remove kerf width and tapering, reducing defects.
- The results indicate that maintaining the melting temperature below 750 C is crucial for enhanced recovery, as high temperatures cause loss of low melting alloying elements and formation of dross and oxides These findings demonstrate the potential for sustainable and efficient aluminium scrap recycling in industrial settings.
- The results from the DoE are used to establish quadratic regression equations that can be used to predict the quality marks of surface roughness and the relative dimensional error.
- Analyses using random forest method and response surface method showed that the cutting environment, laser power, pulse frequency, and cutting speed had a significant influence on the dross formation.
- Using desirability approach of RSM for material Hastelloy C276, the value of the optimum response top kerf deviation and bottom kerf deviation are obtained.

CONCLUSION:

- In both the types of LBM, power and cutting speed are the most important factors.
- Maximum deviation occurs in performance parameters like kerf width (top and bottom), dross and kerf taper angle.
- Kerf taper angle with minimum error is obtained by optimized values of kerf taper.
- By using the desirability approach in Response surface methodology, we can obtain optimized values of performance parameters.
- Selection of process order (model) is important while carrying out DOE of any material.
- Deciding the no. of nodes in the deep learning is very challenging.

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