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Artificial Intelligence apply for prediction of Laser Cutting Process – A review

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Abstract: There are many factors effective on performance of the laser cutting process. Identification of more effective factors requires which will give the significant effect on the cutting quality of materials. In recent years the researchers have explored the number of ways to improve the quality of cutting in the different lasers. This paper reviews the research work carried out so far in the area of laser cutting process and artificial intelligence. In artificial intelligence use for prediction model for given input data of laser cutting operation. Also artificial intelligence beneficial for the time saving because no next experiments are required for measuring output parameters.

Key words: *Artificial Intelligence, Neurons, Laser Cutting Processes.*

1. Introduction:

Laser:

Laser is the acronym of Light Amplification by Stimulated Emission of Radiation. Laser is light of special properties, light is electromagnetic (EM) wave in visible range. Main six processes are doing for Light Emission: Absorption, Spontaneous Emission, Stimulated Emission, Population Inversion, Gain and Loss.

A laser device is consisted of: (1) Laser medium like atoms, molecules, ions or semiconductor crystals; (2) Pumping process to excite these atoms into higher quantum mechanical energy levels; and (3) suitable optical feedback that allow the beam of radiation to either pass once through the laser medium or bounce back and forth repeatedly through the laser medium. Lasers have now found applications in almost every field of engineering, medicine, commercially etc. [1]

Laser Cutting Process:

Laser cutting is a technology that uses a laser to cut materials, and is typically used for industrial manufacturing applications, but is also starting to be used by schools, small businesses and hobbyists. Laser cutting works by directing the output of a high-power laser, by computer, at the material to be cut. The material then melts, burns, vaporizes away, or is blown away by a jet of gas, [1] leaving an edge with a high-quality surface finish. Industrial laser cutters are used to cut flat-sheet material as well as structural and piping materials.

There are **three main types of lasers** used in laser cutting.

(1) The CO_2 laser is suited for cutting, boring, and Scribing engraving.
(2) The neodymium (Nd) is used for boring and where high energy but low repetitions are required.
(3) Neodymium Yttrium-Aluminum-Garnet (Nd-YAG) laser is used where very high power is needed and for boring and engraving. Both CO_2 and Nd/ Nd-YAG lasers can be used for welding.

Advantages of laser cutting over mechanical cutting include easier work holding and reduced contamination of work piece. Precision may be better, since the laser beam does not wear during the process. There is also a reduced chance of warping the material that is being cut, as laser systems have a small heat-affected zone. Some materials are also very difficult or impossible to cut by more traditional methods. [2]

2. Artificial Intelligence:

Artificial Intelligence the branch of computer science that is concerned with the automation of intelligent behavior (Luger and Stubblefield, 1993) [3] also the art of creating machines that perform functions that require intelligence when performed by people (Kurzweil, 1990**).** [4] Artificial Intelligence is a branch of Science which deals with helping machines finds solutions to complex problems in a more human-like fashion. This generally involves borrowing characteristics from human intelligence, and applying them as algorithms in a computer friendly way. A more or less flexible or efficient approach can be taken depending on the requirements established, which are use for prediction of result and also save the time and money of experiment work.

Applications: [5]

- Control (air traffic),
- Design (computer configuration),
- Medical diagnosis,
- Instruction/training,
- Interpretation (speech),
- Monitoring (nuclear plant),
- Planning (mission planning),
- Factory scheduling,
- Prediction (weather),
- Repair (telephone).

Steps for Network Selection process for AI: [6]

1. Prediction,
2. Classification,
3. Data Association,
4. Data Conceptualization,
5. Data Filtering.

3. Literature Survey:

Prof D. M. Patel, Dipesh Patel. Parametric Analysis of ytterbium: fiber laser cutting process. In this report they mainly focus on cut quality and the cut quality mainly decided by surface roughness, kerf width, and perpendicularity. The experiment was carried out on 5mm thickness M.S. plate by varying the parameter like; laser power, gas-pressure, and cutting speed. The factorial design was used for design of experiment and for find out the percentage contribution of process parameter used Minitab 15 software. Surface roughness was measured by Surface roughness tester SJ-201 and kerf width was measured by equipment including digital camera and the UTHSCSA image tool version 3.0 program. [7]

K. Abdel Ghany, M. Newishy, explained the cutting stainless steel by pulsed and CW Nd:YAG laser, it was shown that the laser cutting quality depends mainly on the cutting speed, cutting mode, laser power and pulse frequency and focus position. The cutting parameters that provided dross-free and sharp cut surface during pulsed laser mode were: frequency = 200–250 Hz, duty cycle = 40%, actual applied power = 210–250W (i.e., programmed peak power, Pp = 880–1100W, cutting speed = 1–2 m/min, focus position = −0.5 to −1mm and nitrogen gas pressure = 9–11 bar. For CW mode, speed = 6–8 m/min and power = 900–1100W with the same focus position and gas pressure. Using nitrogen gave brighter and smoother cut surface and smaller kerf than oxygen, although it is not economical. Increasing the frequency and cutting speed decreased the kerf width and the roughness of cut surface, while increasing the power and gas pressure increased the kerf width and roughness. Best cut quality was found at CW mode at speed from 6 to 8 m/min. Then, pulse mode at low speed was 1–2 m/min. [8]

Dong-Gyu ANN, Gwang-won JUNG, explained the influence of process parameter on drilling characteristics of an AI 1050 sheet with a thickness of 0.2 mm using a pulsed Nd: YAG laser through numerical analyses (Software ABAQUS V6.5) and experiments. For numerical analyses parameters condition was Input voltage – 400v, duration time - 1.0 ms and 2.0 ms, frequency 4-12 Hz, Nozzle diameter - 0.7 mm and Velocity of assisted gas - 345 m/s. Laser drilling experiments were performed using a PC-NC controlled laser drilling system with investigate the variation of the diameter. The output parameters measured as the diameter of the drilling hole, shape and the taper angle of the drill hole. All those parameters were measured via a Scanning Electron Microscope (SEM), comparison between numerical analyses and experiment and find the optimal condition of drilling. From result, the optimal drilling condition was determined at a plus duration time of 1 ms and a pulse frequency of 12 Hz given the good result of drilling hole. [9]

Nabil Ben Fredj et. al. generated ANN model for prediction of surface roughness in grinding process using table speed, depth of cut, grinding wheel mesh size, dressing depth and number of passes as variables, with lowest calculated deviation percentage between the predicted and the actual values of the training data and the testing data, 2.47% and 4.13% respectively. They stated that the establishment of the regression models takes into account the responses averages and therefore, can give only an average model, which is not capable to detect a particular tendency corresponding to specific values or set of inputs. [10]

Ronny Pfeifer, Dirk Herzog, explained in this paper a suitable method to cut comparable thick 1mm Shape Memory Alloys sheets using an pulsed Nd: YAG laser system with a high average power is presented. The impact of different laser and process parameters on the cut quality and the material properties. A small kerf width (k = 150–300 µm) in connection with a small angle of taper ($\theta < 2°$) was generated. Compared to short and ultra short-laser processing of SMA, high cutting speeds (v = 2–12 mm/s) along with a sufficient cut quality (Rz = 10–30 µm) were achieved, offering the possibility to machine macro-SMA components (thickness: mm-range, cut length: cm/dm range) in an economic way. Compared to cw-laser machining a lower surface roughness can be achieved. In comparison to short- and ultra short-laser processing of SMA the drawbacks can be seen in the higher thermal impact of the laser–material processing on the SMA,

resulting in a HAZ (dimension: 6–30 μm) which again affects the material properties and the reduced accuracy of the cutting process. [11]

Luke Huang et. al. developed a multiple regression model for an on-line, real-time surface roughness prediction system. They concluded that with linear correlation coefficients of 0.940 and 0.933 for models MR16 and MR31, respectively, using the experiment data, the predictor variables, such as feed rate, vibration amplitude average, spindle speed, and depth of cut, have strong linear correlation with the predicted variable. Without the vibration data, the prediction accuracy of the proposed multiple regression model declines by about 1.55%. Therefore, the use of the accelerometer is valuable. The proposed regression model basically possesses accuracy of above 90% on predicting the in process surface roughness from feed rate, vibration amplitude average, spindle speed, and depth of cut. [12]

4. Conclusion and Discussion:

Laser power and Cutting speed are plays an important role in laser cutting. For cutting Mild Steel by pulsed and CW Nd:YAG laser, it was shown that the laser cutting quality depends mainly on the cutting speed, cutting mode, laser power and pulse frequency and focus position.

An Artificial Neural Network (ANN) for building a feasible predicting model for Laser Cutting Qualities. The Back-Propagation Neural Network with LM algorithm has been applied to construct a Mathematical Model wherein the laser-cutting qualities are expressed as explicit nonlinear functions of the laser control parameters. The GA is helpful to determine the best combination of laser-cutting parameters for optimizing a specified cutting quality. For applying AI we can use MAT LAB_2011 Software.

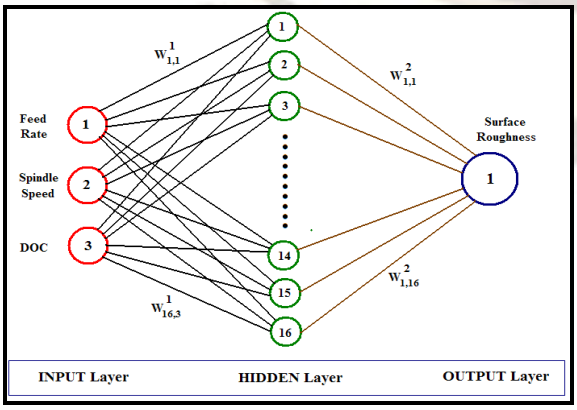

Fig.:1 LM16LP Model view with three layers.

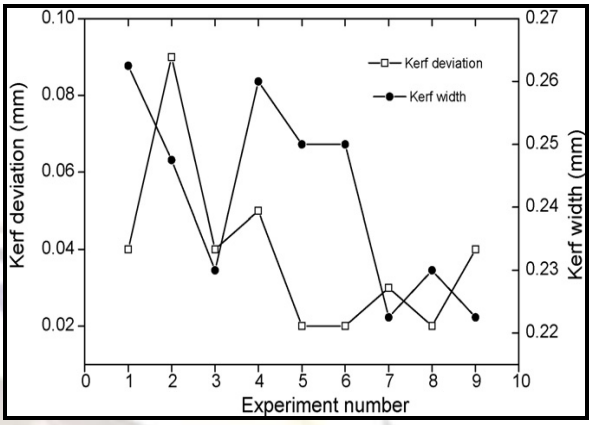

Fig.: 2 Variation of kerf deviation and kerf width with experiment number. [13]

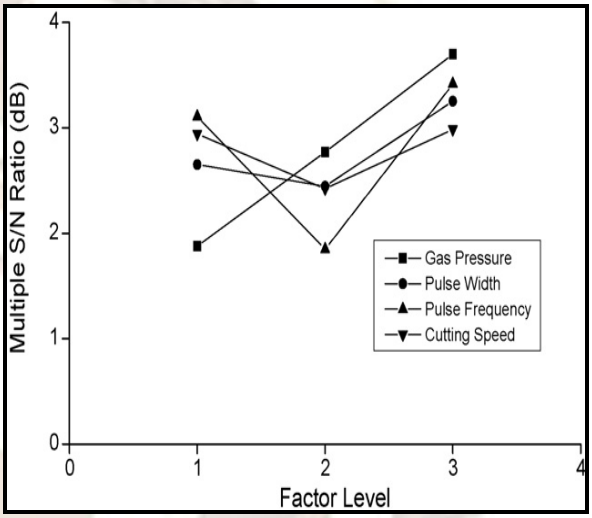

Fig.: 3 Effect of factor levels on multiple S/N ratio (0.9mm Al-alloy sheet). [13]

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