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Original research article

Prediction of laser welding quality by computational intelligence approaches

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A R T I C L E I N F O

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A B S T R A C T

In this investigation was established a model of laser welding quality prediction based on different input parameters. As the quality factors for the laser welding process lap-shear strength and weld-seam width were used. Laser power, welding speed, stand-off distance and clamping pressure were used as input parameters. Experimental test were used to acquire the training data for the computational intelligence methodologies. In this article support vector regression (SVR) was applied. The results from this study could be used as benchmark results in order to improve the laser welding process.

1. Introduction

Process of laser welding is a technology in number of industries for advanced manufacturing because of the laser versatility and adaptability. By this process laser beam penetrates to the upper part and the penetration is converted in heat by the connecting the lower part. The melting area is formed only in the controlled sections or only in the joining section of the both parts. The most important parameters for the laser welding process are laser power, welding speed, laser beam size on the work piece and pressure of clamping. There were many investigations which studied the parameters effects on the quality of laser weld.

In paper [1] was described a multi-sensor fusion system for monitoring disk laser welding process and the results showed that the integration of photodiode and visual sensing provided a more accurate estimation on the laser welding process. The present work deals with Modeling and analysis of laser machining and laser welding technologies which were commonly used in the recent past was presented in article [2] and the effects of each process's parameters on its performance measures were analyzed based on graphs which were plotted using the most accurate model. In the laser welding production, the selection and prediction of welding parameters is essentially important to guarantee weld quality [3]. The experiments showed that the Tensile strength of the weld was higher than that of the base material under certain conditions [4]. The tensile strength and elongation-to-failure of the laser-arc double-sided welding weld were increased by nearly 10 and 100% over the single arc welding, respectively [5]. During high-power deep-penetration laser welding of thick plate, the geometrical characteristics of weld cross section were investigated under different welding conditions [6]. Development of laser welding with hot wire can advance the multi-pass weld for an ultra-narrow gap joint [7]. Welding speed has been found as most influencing factor for welding strength [8]. To address control difficulties in laser welding, the idea of a self-learning and self-improving laser welding system that combines three modern machine learning techniques was proposed in [9]. Friction welding process parameter optimization using a hybrid technique of neural network and different optimization algorithms was analyzed in article [10]. Laser oscillating welding was employed in butt configuration and the improving

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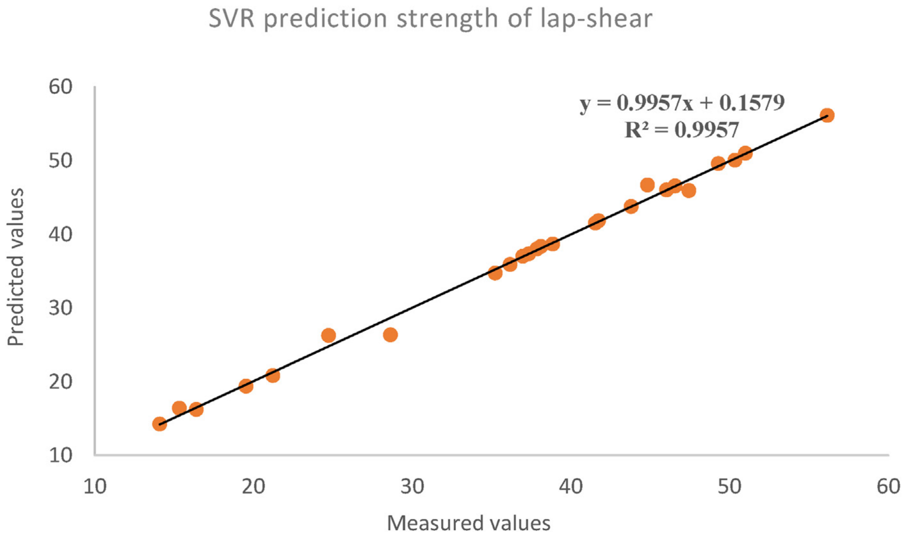

Fig. 1. Prediction of strength of lap-shear.

mechanisms of weld characterization were discussed by the beam oscillating effect on the behaviors of laser keyhole and melt flow [11]. External magnetic field has been favored in the welding, due to the beneficial effects on the weld pool dynamics. The application of the magnetic field can modify the weld bead appearance and microstructure of the weld by the Lorenz force and thermoelectric magnetic force induced in the molten pool [12].

The laser welding quality could be represented in relation to the bead geometry, mechanical properties and distortion of the weld. Proper definition of the input parameters is required in order to get defined laser weld quality and it could be very time consuming task. Therefore in this study was applied an empirical methodology to predict the quality of laser welding process based on the given input parameters. The main goal in this study was to avoid high nonlinearity of the mathematical approaches by using computational intelligence methodology. In this investigation support vector regression (SVR) [13–18] was used to predict the quality of laser welding process based on different input parameters.

2. Materials and methods

2.1. Experimental investigation

Coherent FAP-diode laser was used in this investigation. The system has maximal optimal power of 40 W and wavelength output of 810 nm. The optical irradiation was delivered by SMA905 connector. Two lenses were imagining module of the system at the end of the connector. To maintain the area of lapping constant a fixture was used. To ensure good contact between two welding parts a hydraulic clamp pressure was applied. The strength of the lap-shear was calculated for the maximum load to failure. The width of weld-stem was measured using Mitutoyo Tool microscope. The used inputs and outputs are presented as follows:

- input 1 – Power (W)
- input 2 – Laser welding speed (mm/min)
- input 3 – Distance of stand-off (mm)
- input 4 – Clamp pressure (MPa)
- output 1 – Strength of lap-shear (N/mm)
- output 2 – Width of weld-seam (mm)

2.2. Computational intelligence methodology

SVR working principle is based on the data mapping in defined spaces by nonlinear mapping. A linear algorithm performs in the feature space. If the inner product in the feature space is available as a function directly based on the original input points, it is possible to make nonlinear learning machine which is known as kernel function, K. The kernel function could implicitly chart the data to the higher dimensional feature space. In this study we used radial basis function as kernel function since it is the most common kernel function. The non-linear radial basis kernel function is defined as:

$$K(x, x_i) = exp\left(-\frac{1}{\sigma^2}x - x_i{}^2\right) \quad (1)$$