ANALYSIS AND OPTIMIZATION OF LASER CUTTING PROCESS FOR STRUCTURAL STEELS

Abstract

Laser cutting is a widely used technology for precision cutting of various materials, including mild structural steel. It involves the use of a high-powered laser beam to melt, burn, or vaporize the material, resulting in a clean and accurate cut. This doctoral thesis presents a comprehensive investigation of the laser cutting process for mild structural steels. To understand the thermal effects on the steel workpiece, an analytical model for the laser cutting heat source is proposed, which takes into account laser source geometry variation along the cut edge thickness. A modified heat source based on a Gaussian distribution is used to model the heat flux as a combination of laser beam and heat produced by the reaction of oxygen with iron. The proposed model allows the laser cutting process to be simulated as a function of cutting speed, laser power, and shape of the heat flux. The FE method is employed to predict both temperature and stress fields in the cutting section considering the solid-state phase transformation during and after the laser cutting process. Optical microscopy, scanning electron microscopy and microhardness measurements are employed to observe morphological and metallurgical changes in the cutting sections, and the stress is detected using the X-ray diffraction methodology. The residual stress field surrounding the cutting edges is experimentally examined, and the results are compared to those anticipated by the developed model. An accurate temperature distribution field is obtained and validated by microstructural solid phases of the cut specimens. Consequently, residual stresses are also validated by comparing experimental measurements and outputs of the FE model.

The study also investigates the optimization of laser cutting parameters for achieving, in agreement with the standard EN ISO 9013, quality cut surface requirements, such as roughness and perpendicularity. The trial-and-error method used in the past is incompatible with environment-friendly processes. Hence, to study the effects of cutting parameters on the target parameters and to collect data, an experimental campaign is carried out on a 12 mm thickness low carbon steel grade S235 cut by a 4kW fiber laser. A multi-objective optimization based on both a genetic algorithm and Kriging method is carried out to investigate the correlations between input and target parameters as well as to find the optimal laser cutting parameters to achieve the minimum roughness and perpendicularity. The applicability of the Kriging method to laser cutting processes is highlighted by the agreement between predicted cut quality and experimental results, provided by additional specimens cut with laser parameter sets obtained by a Pareto front. Overall, the investigated model offers important details on the physical procedures that occur during the laser cutting process and provides useful insights for selecting the optimal sets of laser cutting parameters for different applications.

Keywords

[Laser cutting process, Heat flux, thermomechanical analysis, Optimization]