Abstract

Laser based bending is a process of bending of different workpieces by using a controlled moving or stationary laser heat source, which induces thermal stress to achieve the desired bending. Recently, laser bending has received attention for a wide variety of applications in industries due to its excellent bend quality with high productivity and flexibility. Researchers studied the effects of different process parameters related to the laser source, material and workpiece geometry on laser bending of sheets. In this thesis, experimental study and finite element method (FEM) simulations of various kinds of laser based bending are reported. The FEM was used to predict bend angle, edge effect, temperature variation, stress and strain. The focus of the work was to study the performance and robustness of the process for filling the research gap in the literature.

First, the bending of small sized steel sheets was carried out with stationary and moving laser heat sources. Effect of laser power, workpiece geometry (length and width), laser spot diameter and laser scan speed on the achievable bend angle in a single pass is studied numerically as well experimentally. Afterward, the multi-pass laser bending of steel strips was studied. Effects of process parameters on bend angle, edge effect, temperature distribution, stress, plastic strain, flexure strength, microhardness and microstructure was studied. It was encouraging to note that FEM could predict the bend angle with the maximum error of 11%.

Laser bending of friction stir welded aluminium alloy sheets was also studied. Considering the difficulty in obtaining the temperature dependent material properties, an inverse methodology was employed. The inverse methodology is based on the measurement of bend angle and temperature at two locations during laser bending. To reduce the computational time, the techniques of forced cooling and mesh optimization were used. The deviation between experimental and numerical simulation results was less than 10% in all except one case of 16% deviation.

Two techniques were employed for enhancing the absorptivity of sheet metal such as surface coating and surface roughening. One was employing cement coating in place of graphite coating. However, usually the coating gets removed after irradiation, which poses problem in multi-pass laser bending. Hence, another

technique of roughening the surface by friction stir processing was employed. Laser bending of uncoated raw, cement-coated and friction stir processed sheets of aluminum alloy and mild steel were compared. Among them cement coating performed the best, but friction stir processing was also not far behind. Microhardness and microstructure were also studied.

For obtaining large bend angle in a single-pass, laser assisted bending was carried out by applying mechanical and magnetic forces. Mechanical force was applied by hanging a weight at the free end of the cantilevered strip. The magnetic force was applied by means of permanent magnets and with proper design of setup it was used even for laser assisted bending of a non-magnetic material. For quicker estimation of bend angles, the application of an artificial neural network (ANN) model was also explored. ANN was trained by FEM model and validated through experiments. This was demonstrated for laser assisted bending by mechanical load. The same technique can be applied for other bending processes. ANN not only predicted the most likely values, but upper and lower bounds also. FEM modelling of magnetically assisted laser bending was also carried out. The simulation results agreed well with experiments.

Overall, this thesis accomplished the following tasks. Laser bending of small sized sheets, strips and friction stir welded sheets was studied. Laser assisted bending by mechanical and magnetic forces was studied. The study focused on the following aspects: (1) feasibility of achieving sufficient bending with good repeatability for a variety of jobs, (2) predictability of the bending processes by FEM and ANN tools, and (3) post-bend properties. In order to improve the performance and reliability of laser based bending, techniques to enhance the absorptivity were also developed. Appropriate measures were also employed for reducing the computational time of FEM based models of the processes. As the process is stress-controlled (instead of displacement-controlled), prediction models are very important for making the process industry-friendly.