Abstract

NiTinol, an equiatomic Ni and Ti alloy with some outstanding properties, is a new and popular shape memory alloy that has numerous applications in medical, MEMS, hydrospace, aviation and aerospace fields among others. Because of the poor machinability of NiTinol and lack of its joining techniques through conventional routes, achieving good quality joints in making device and components made of NiTinol has become significant. Laser welding of NiTinol is a promising fabrication method for complex designed products. However, it has become very challenging to keep the superior qualities of NiTinol intact during laser welding and through investigation is required to achieve the desired properties.

Present investigation deals with how the different process variables affect the different bead-quality aspects of bead-on-plate laser welding of NiTinol sheets of 1 mm, 2 mm and 3 mm thickness. The measured quality aspects were bead geometry, changes in microstructure, variation of microhardness value, Ti/Ni ratio after welding, changes in tensile strength of the welded samples, corrosion behavior of welded and parent material. The in-depth study of the effect of laser heat input on various physical, thermophysical properties together with corrosion resistance behavior of the laser welded samples were one of the major objectives of this work.

The effects of process parameters on different quality aspects of the joint in laser butt welding configuration of 1 mm and 2 mm thick NiTinol sheets were also investigated. Modeling and optimization of the butt welding process were carried out using DOE and nature-inspired techniques. Optimization technique was applied in order to get the minimum bead area satisfying the condition of minimum deviation of microhardness of the bead from that of the parent material. This was formulated as a constrained optimization problem and solved using different recently developed metaheuristic techniques, and desirability function analysis. A good agreement was found between the results predicted by optimization tools and the experimental results.

An efficient forward and reverse model between the input and output parameters of laser welding of NiTinol sheet was developed with the help of artificial neural networks (ANNs) modeling technique. These ANNs were trained with the help of regression equation model and optimized by the use of five different meta-heuristic techniques separately for the development of both forward and reverse models. The developed model was capable enough in prediction of outputs, having good conformity with the experimental data, for both the forward and reverse models. The novelty of this study is the development and testing of feed-forward neural network and recurrent neural network tuned with five different meta-heuristic techniques for both the forward and reverse modelling of fiber laser welding of NiTinol alloys.

Keywords: Fiber laser welding; NiTinol sheet; Bead-geometry; Microstructure; Microhardness; Tensile property; Cyclic loading-unloading behavior; Corrosion study; Phase transformation temperature; Optimization methods; Neural networks; Forward modeling; Reverse modelling.