

ABSTRACT

Laser welding is an advanced joining method because of its narrow heat-affected zone, high power density, high welding speed, fine microstructure, and low distortion, resulting in high strength and ductile properties. Typically, the quality of a dissimilar weld joint is directly influenced by the laser welding process parameters during the welding process. Welding of dissimilar metals is one of the challenging and emerging fields of research as it involves in minimizing the use of high-cost materials. Dissimilar metal joining of austenitic stainless steel (AISI 316) and low carbon steel (AISI 1018) are extensively used in nuclear reactors, pressure vessels, boilers and heat exchangers of power generation industries and petrochemical plants.

In the present study, the laser welding of AISI 316 austenitic stainless steel and AISI 1018 low carbon steel was carried out at various thicknesses of 2 mm sheet and 6 mm plate joint. Welding trials were performed as per Taguchi L₉ orthogonal array design, with three parameters at three levels. The dissimilar butt joint trials were carried out, using 4 kW CO₂ laser welding by varying the laser power (W), welding speed (m/min), focal distance (mm) and constant shielding gas flow rate (20 Lit/min) for 2 mm sheet joining. Similarly, the dissimilar 6 mm plate welding is carried out varying of laser power (W), welding speed (m/min), shielding gas flow rate (Lit/min) and constant focal distance (20 mm). The varying laser welding process parameters were used to study the effect of the mechanical and metallurgical properties of the dissimilar sheet and plate joint. The optimum parameters have been derived by considering the responses of tensile strength and hardness of the dissimilar weld joint. The weld joint properties such as mechanical properties, microstructures, and chemical element distribution in the weld zone are directly influenced by the laser welding process parameters in the welding process.

Analysis of variance (ANOVA) results was analyzed for each thickness of sheet and plate of dissimilar weld joints and the influence of laser welding process parameters was identified. Mean grey relational grade value was used to rank the process parameters of dissimilar sheet and plate welding; the rank (1) indicates that laser power has a stronger effect on the dissimilar laser welding process followed by rank (2) welding speed, which has a medium effect, while in rank (3) the focal distance and the shielding gas flow rate has the least effect on the dissimilar sheet and plate welding process for multi-response characteristics.

Taguchi based grey relational analysis was used to identify the optimum process parameters at each thickness of the dissimilar sheet and plate welded joints. In dissimilar sheet welding, the highest grey relational grade (1.000) was achieved at trial number seven and this is the optimum process parameter, at the laser power 2600 W, welding speed 1.5 m/min and focal distance 20 mm. Similarly in the dissimilar plate welding, the highest grey relational grade (0.702) was attained at trial number nine and this is close to optimum process parameters. The optimal parameter combination was identified at laser power 3150 W, welding speed 1 m/min and gas flow rate 20 Lit/min of the dissimilar plate welding.

In this study, the microstructure of the weld zone and weld interface of the AISI 316 austenitic stainless steel and AISI 1018 low carbon steel sides were investigated. The dissimilar weld zone consisted of fine columnar dendrites which had been nucleated at the fusion line and grown toward the center of the molten pool, for both dissimilar sheet and plate welded joints. The dissimilar weld interface of AISI 316 stainless steel heat affected zone contained coarser austenite grains with twin structure, skeletal ferrite and little carbide precipitation due to carbon migration. The weld interface of AISI 1018 low carbon steel heat affected zone towards the fusion zone resulted in a mixed

structure of acicular ferrite, pearlite, bainite, and martensite structure along with enriched iron.

Post Weld Heat Treatment (PWHT) was performed at two different temperatures like 860°C for 2 hours and 960°C for 2 hours. After the heat treatment both joints, the mechanical and metallurgical properties were investigated. After heat treated at 960°C, the dissimilar weld zone results designate, dissolving of carbide precipitates, reducing the ferrite matrix grains, prominent and martensite structure resulted in better mechanical properties. Only a few amounts of carbide were present in the grain and grain boundary of the weld zone.

The chemical composition of the weld zone and the weld interfaces of AISI 316 stainless steel and AISI 1018 low carbon steel sides were investigated and successfully predicted the microstructures by using the Schaeffler diagram for both conditions like as-welded and heat-treated at 860°C and 960°C. The austenite and martensite (A+M) structure were observed in the weld zone and weld interface of the AISI 316 stainless steel sheet joint of as-welded condition. The martensite (M) structure was observed in the weld interface of the AISI 1018 low carbon steel sheet joint of as-welded condition. The dissimilar weld joints heat-treated at 860°C, resulting in the austenite and martensite (A+M) structure in the weld zone of dissimilar sheet joint and the martensite (M) structure in the weld zone of dissimilar plate joint. The martensite structure (M) was observed in the weld zone for heat-treated at 960°C of dissimilar sheet and plate joint.

The Vickers microhardness (HV0.5) analysis was conducted for both conditions - as welded and heat-treated at 860°C and 960°C. Comparing with the base metal, higher microhardness value was observed in the weld and weld interfaces of the AISI 316 stainless steel AISI 1018 low carbon steel sides due to enrichment of iron and martensite structure along with carbide precipitate. After

PWHT at 960°C, the microhardness values were decreased in the weld zone and weld interfaces of both sides due to the elimination of carbide precipitation, compare with 860°C. The mechanical and metallurgical properties were improved at 960°C compared to as-welded and heat-treated conditions 860°C.