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Laser Welding of High Performance Thermoplastic

Prof. Patel Chandreshkumar Vadilal

Assistant Professor, Mechanical Engineering Department, Sankalchand Patel University, Visnagar, Gujarat, India

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Abstract - *much research has been carried out of laser welding of metals but few work is done in the field of laser welding of composite materials. To compare Thermoset Plastics, High Performance Thermoplastics (HPTs) has possibility of realizing welding connections whereas riveting and adhesive bonding are used for thermoset. In order to cope-up with high material costs of High Performance Thermoplastics, production processes as well as semi finish products of composites required extensive analysis in three essential categories: Matrices, Carbon Fibers and Manufacturing Processes having potential of possible savings in cost and time. Hence the proposed research work has objectives of finding appropriate welding technique for High Performance Thermoplastic with the aim of cost reduction and time.*

1. Introduction of Laser

Light Amplification by Stimulated Emission of Radiation

One of the widest spread technical inventions of the last century. It is both subject of intense study from scientists and engineers to further expand the field of application and develop new and/or better laser system.

1.1 Basic Principles of Laser Generation

There are main three steps for light emission,

Absorption: A photon is incident on an atom, causing it to be exited in to a higher energy state.

Spontaneous Emission: An atom returns to a lower energy state, emitting a photon, in an entirely random manner.

Stimulated Emission: A photon interacts with an atom, causing into return to a lower energy state, emitting a second photon of the same frequency, phase and polarization.

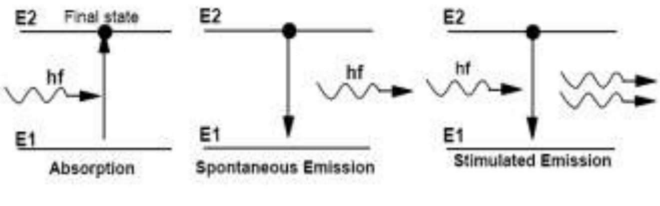

Figure: Process of light emission

1.2 Laser Welding Process

Laser beam welding (LBW) is a welding technique used to join pieces of metal or thermoplastics through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates.

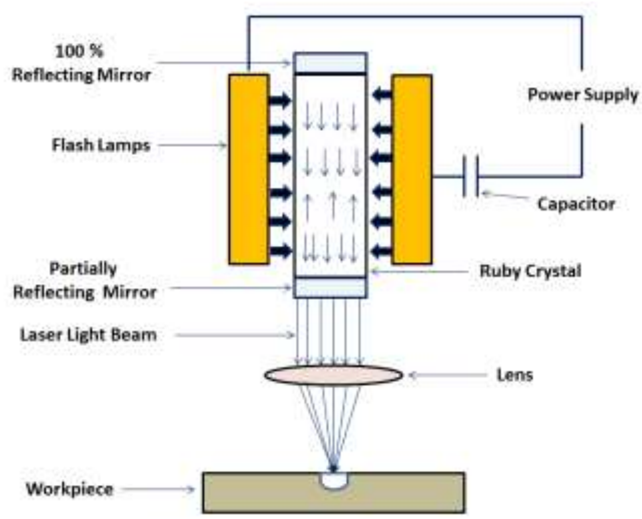

Figure: laser Welding

First the setup of welding machine at the desired location (in between the two metal pieces to be joined) is done.

After setup, a high voltage power supply is applied on the laser machine. This starts the flash lamps of the machine and it emits light photons. The energy of the light photon is absorbed by the atoms of ruby crystal and electrons get excited to their higher energy level. When they return back to their ground state (lower Energy state) they emit a photon of light. This light photon again stimulates the excited electrons of the atom and produces two photons. This process keeps continue and we get a concentrated laser beam.

This high concentrated laser beam is focused to the desired location for the welding of the multiple pieces together. Lens are used to focus the laser to the area where welding is needed. CAM is used to control the motion of the laser and Workpiece table during the welding process.

As the laser beam strikes the cavity between the two metal pieces to be joined, it melts the base metal from both the pieces and fuses them together. After solidification we get a strong weld.

2. LITERATURE REVIEW

M.P.Prabakaran, In this investigation, the effect of post weld heat treatment on the dissimilar joint of AISI316/AISI1018 was investigated by using different temperatures 860 °C and 960 °C

Taguchi based grey relational analysis of CO2 laser welding process parameters on AISI 316/AISI 1018 weld has shown that for the given conditions, 2600 W of laser power, 1.5 m/min welding speed and focal distance 20 mm as the optimal parameters, resulting in tensile strength 442.848 MPa and Microhardness 442 HV.

The chromium carbide has been dissolved and not again precipitated in the grain boundary. Only a few amounts of carbides were present in the austenitic grain boundaries in the weld zone resulting in high corrosion resistance at 960 °C in comparison to 860 °C.

After PWHT the tensile strength is improved 462.241 MPa at 860 °C and 475.112 MPa at 960 °C. Weld zone (WZ) had a martensitic structure containing a relatively high strength. Bend test was passed at both conditions due to the elimination of chromium carbide and a decrease in grain size, there is no opening cracks was observed.

Hardness valve also slightly decreased 409 HV0.5 at 860 °C and 378 HV at 960 °C in the weld zone, and 423 HV0.5 and 405 HV0.5 in ASS 316 side, and 442 HV0.5 and 423 HV0.5 in LCS 1018 side, due to the dissolving of chromium carbide with martensitic structure and resulting improved the strength of the dissimilar joint.

Barton Mensah Arkhurst, In the present study, The effect of thermal oxidation on the joining strength of CFRP–AZ31 Mg alloy joints prepared via the LAMP joining technique was investigated. The conclusions are as follows:

The joining was carried out using a continuous wave (CW) diode laser with a line profile, focusing lens of focal length 100 mm, and maximum power of 3 kW. A set of as-received Mg alloy and CFRP specimens was joined under different laser powers and joining speeds.

The specimens were annealed at 500 °C for 2, 5, 10, and 20 min. joining speeds of 3, 6, 9, and 12 mm/s and laser powers of 1200, 1400, and 1800 W were chosen for the LAMP joining experiments.

The thermal oxidation of the Mg alloy sheets via annealing heat treatments before the LAMP joining process increased the joining strength of the joints significantly as compared with that of the joints prepared with as-received Mg alloy sheets. The optimum annealing durations and joining speeds that produced the best joint strengths were 5–10 min and 6–9 mm/s, respectively.

The joint interfaces were examined using scanning electron microscopy (SEM) and transmission electron microscopy (TEM).

Micro computed tomography (MCT) scans were performed on selected joint samples to provide an overview of the entire cross-sectioned joint interface.

X-ray photoelectron spectroscopy (XPS) analyses were carried out on the fractured surfaces of the Mg alloy and CFRP sheets of selected joint samples after the tensile shear tests.

Atom probe tomography (APT) analysis was performed on the interfacial regions between the polymer and MgO in selected joint samples.

M.P.Prabakaran, This study investigates the optimization of LBW process parameters through RSM based on CCD. LBW process parameters like laser power, focal distance and welding speed on the maximum weld strength of dissimilar metal joints were determined in this study.

A confirmation experiment was also conducted in order to validate the optimal process parameters values. The developed relationship can be effectively used to predict the weld strength of laser beam welded joints at 95% confidence level.

The maximum weld strength of the dissimilar butt joint is 458.214 N/mm2 on laser power 2600W, focal distance 25mm and welding speed 1.5m/min.

The exceptional weld appearance and mechanical properties indicate that CO2 welding of austenitic stainless steel AISI 316 to low carbon steel AISI 1018 sheet is feasible in power generation applications.

Microhardness at the weld zone was found to be maximum level. It was also found that the higher hardness values the samples. This might be perhaps due to carbon migration from the low alloy steel to AISI316.

N. Sivagurumanikandan, In this investigation, the studies on the effect of process parameters and their interaction effects on the tensile strength of Nd: YAG laser welded super duplex stainless steel lead to the following salient conclusions.

The optimum condition to attain a higher tensile strength is laser power: 550 W, laser frequency: 13 Hz, focal position: 0 mm and welding speed: 136 mm/min.

The deviation between experimental, regression and neural network model is very less. The developed models are, thus, statistically significant.

Neural network models predict the tensile strength more preciously than the regression model.

Characteristic ductile fracture and finer grains are witnessed in tensile fracture surface.

U.Nagaraju, In the present study, Design based experiments and analysis have been carried out in order to minimize the bead width and maximize the tensile strength of weld joint of dissimilar materials like AISI 304L and Mild steel using ND:YAG Laser beam welding setup.

First experiments were carried out by as per Central Composite Design (CCD) to substantially reduce the number of experiments.

The RSM is used to developed second degree polynomial models between the bead width and tensile strength of weld joint. Later a constrained optimization problem is formulated to minimize the bead width and maximize the tensile strength of joint.

The Genetic algorithm was able to reach near the globally optimal solution, after satisfying the above constraints.

The optimal values obtained by the proposed methodology could serve to conduct the welding operations with great ease to achieve the quality and production rate demanded by the consumers.

Angshuman Roy, In the present work, 1.5 mm thickness stainless steel sheet has been marked by the use of Nd: YVO4 laser system with a wave length of 1064 nm under varying process parameters. From the results obtained, following conclusions may be made.

Increase of laser power usually gives more heat energy, and hence, increases mark width and depth.

Increasing scanning speed decreases mark width and depth because of less heat input to the marking region.

Maximum mark width and mark depth can be obtained at a when laser power of 6.96 W, pulse frequency of 16.69 kHz and scanning speed of 6.60 mm/s.

Yang Liu, In this paper, the fabrication of AlSi10Mg alloy by powder-delivery laser powder deposition process was studied.

Based on the surface conditions and geometry of deposited single track, the deposition experiments were conducted as per L25 (54) orthogonal array with choosing process parameters like laser power, scanning speed, powder feeding rate and shielding gas flow rate as the process parameters.

The most significant one in those parameters was the laser power which has a contribution of 49.43% to the relative density of the LPD fabricated AlSi10Mg alloy, followed by the scanning speed with a contribution of 33.74%. The relative density first increased then slightly decreased with raising the laser power or slowing the scanning speed. And the relationship between energy density (determined by the laser power and scanning speed) and relative density was also investigated.

The optimal combination of process parameters was laser power of 150 W, scanning speed of 400 mm/min, powder feeding rate of 0.78 g/min, and shielding gas flow rate of 7 L/min.

3. CONCLUSIONS

Much research has been carried out of laser welding of metals but few work is done in the field of laser welding of composite materials.

Research on following composite materials has been studied, Glass Fibre Fabric Reinforced Polyetherimide (GF2 PEI), Polypropylene Matrix, Polyamide Matrix, Semi Crystalline Polyamide, Polyphenylene Sulfide, Carbon Fiber Polyetheretherketone (CF/PEEK), Carbon Fiber Polyetherimide (CF/PEI)

Joining of Basic geometric components in complex assemblies. So, the development of appropriate welding technologies for HPTs becomes more and more crucial.

Joining Techniques for Composite Materials

Joining Techniques	Advantages	Limitations
Adhesive Bonding	High Strength to Weight ratio.	Long Curing Time until joint reaches the final mechanical load capacity.
Mechanical Fastening	A little surface for Pretreatment is needed. Disassembling is possible.	Local stress concentration. Lower strength to weight ratio and damage of fibers.

In order to cope-up with high material costs of High Performance Thermoplastics, production processes as well as semi finish products of composites required extensive analysis in three essential categories: Matrices, Carbon Fibers and Manufacturing Processes having potential of possible savings in cost and time.

The highest possible savings are expected in production of HPTs which means both the cost of manufacturing and processing i.e. Cutting, Drilling, and Joining steps with prediction of overall 40% of "Cost Reduction".

Hence the proposed research work has objectives of finding appropriate welding technique for High Performance Thermoplastic with the aim of cost reduction and time.

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