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Finite Element Analysis of Weld pool generated by Welding of Dissimilar Metals (Copper-Nickel) using Laser Welding

Abhijeet Singh Bachu [1], Dilbag Singh Mondloe [2], Ajay Singh Paikara [3]
[1]M. Tech Student, Dept. of Mechanical Engineering, Government Engineering College Jagdalpur, Chhattisgarh, India
[2, 3]Asistant Professor, Dept. of Mechanical Engineering, Government Engineering College Jagdalpur, Chhattisgarh, India

Abstract: Laser beam welding is a welding technique used to join pieces of metals or thermoplastics through the use of a laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. This process is widely used in high volume applications such as Turbo machinery, Automotive industry, Aeronautics and Space science etc. The combination of dissimilar metals possesses a good combination of mechanical properties, high tensile strength, ductility, formability and weldability.

There is no deny in the fact that welding of dissimilar metals offer more flexibility in design and production of the commercial and industrial component.

Very few researchers studied laser welding of dissimilar metals experimentally and numerically. In this paper investigation is carried out for simulation of welding two dissimilar metals viz., (1) copper and (2) nickel. Finite Element Analysis is used to study the distribution of temperature field induced during welding process. The Finite Element model was established using two types of elements containing three dimensional volume elements SOLID70 with eight nodes each. In this paper the weld pool geometry obtained through FEA and that obtained experimentally are compared.

Keywords: Laser beam welding, dissimilar metals, finite element analysis, weld pool geometry, temperature field.

I. INTRODUCTION

Laser Beam Welding is a welding technique used to join multiple pieces of metal through the use of laser. The beam provides a concentrated heat source, allowing for narrow, deep welds and high welding rates. Laser Beam Welding is widely used of small components such as microwave enclosures, batteries, and other packages which require high electrical and electronic reliability in aerospace, telecommunications, and medical industries.

Engineers today are facing the challenge to join dissimilar metals as they are seeking to create new structures or machine parts in various industries. Joining of dissimilar metals is very attractive for many applications as we can use more costly metals only where necessary. In fact, dissimilar joining could be frequently faced in many scenarios including automotive, aerospace, electronic and ship building industries.

The demand for dissimilar metal joints is continuously increasing due to their advantages as it provides various mechanical properties and good cost reduction.

Combination of dissimilar metals may provide different mechanical properties and other advantages. For example; high stainless steel can be combined with an anti-corrosion metal such as nickel to withstand the mechanical load and chemical corrosion in high pressure containers.

A. Laser Beam Welding

Laser Beam Welding process is a unique welding technique used to join multiple pieces of metal through the heating effect of a concentrated beam of coherent monochromatic light known as LASER. It is a high energy density welding process and well known for its deep penetration, high speed, small heat affected zone, fine welding seam quality, low heat input per unit volume, and fibre optic beam delivery. Laser processing is free of electromagnetic fields and is, thus suitable for welding dissimilar couples. With flexibility in the power intensity, power distribution, and scanning velocity, laser welding is emerging as a major joining process. With appropriate process control and the typical laser deep welding effect, it is possible to form only a minimum inter metallic phase and achieve better mechanical properties of the joints.

B. Finite Element Analysis

Finite element analysis is to be used to estimate temperature distribution of the specimen in the welding process. Though the geometry, boundary conditions and the heat source were symmetric but full work piece was chosen for the calculation using the commercial program using ANSYS because of dissimilar joining. The FEA model is to be established using two types of metals containing three dimensional volume elements SOLID70 with eight nodes. The three dimensional element was used for the basic body structure and the thermal surface effect element for the boundary between the structure and the environment.

II. LITERATURE REVIEW

A. Rodrigo Gómez Vázquez et al. [1] Welding of dissimilar metals in general is a complicated task that involves many difficulties. Currently one of the most challenging problems is the formation of inter-metallic phases in the joining interface. In this paper we introduce a simulation model aimed to support the study of laser dissimilar welding by providing useful information on the process characteristics (e.g thermal distribution, species mixing) including inter-metallics formation.

B. Nilanjan Chakraborty et al [2] The effects of turbulence on momentum, heat, and mass transfer during laser welding of a copper–nickel dissimilar couple are studied by carrying out three-dimensional unsteady Reynolds Averaged Navier Stokes (RANS) simulations. The turbulent transport is modeled by a suitably modified high Reynolds number k–ε model. The solid–liquid phase change is accounted for by a modified enthalpy porosity technique. In order to demonstrate the effects of turbulence, two sets of simulations are carried out for the same set of processing parameters: one with the turbulence model, and the other without activating the turbulence model

C. Kamal Abderrazak et al [3] Heat transfer from the laser keyhole to the weld pool and details of the fluid flow play an important role in determining weld shape and size. In this work, both the experiment and the finite volume method (FVM) are utilized to investigate the thermal phenomena during continuous laser keyhole welding. Firstly, the experiments are carried out to examine the effects of laser welding parameters on the pool dimensions. Secondly, 3D FVM model is developed using the hydrodynamic software FLUENT to simulate the keyhole and pool formation during the interaction between continuous laser and AZ91 magnesium alloy sheet.

D. Liqun Li et al. [4] A laser welding–brazing (LWB) technology using Mg based filler has been developed for joining Mg alloy to mild steel and Mg alloy to stainless steel in a lap configuration. Microstructure and mechanical properties of laser welded–brazed lap joints in both cases were comparatively studied. The results indicated that no distinct reaction layer was observed at the interface of Mg/mild steel and subsequently the interface was confirmed as mechanical bonding, whereas an ultra thin reaction layer with a continuous and uniform morphology was evidenced at the Mg/stainless steel interface, which was indicative of metallurgical bonding.

E. Caiwang Tan et al. [5] Laser-tungsten inert gas (TIG) hybrid welding has been developed for joining Mg alloys to Zn coated steel in a lap joint configuration. The joint could not be produced in laser or arc welding only, while acceptable joints without obvious defects were obtained with a relatively wide processing window in the hybrid process. Two reaction layers were observed to form at the interface and were identified as Mg–Zn eutectic structure (α-Mg + MgZn) and Fe_3Al phase by TEM analysis. In some cases, Al_6Mn phase also formed adjacent to the Fe–Al reaction layer. The tensile-shear strength attained the maximum value of 68MPa, representing 52.3% joint efficiency relative to Mg base metal.

III. THEORITICAL BACKGROUNG

Theoretically the welding process can be considered either using a thermal or a mechanical analysis. Thermal stress induce during a welding process may be obtained from the temperature distribution by thermal model. In recent years, most articles about dissimilar welding simulation have been concerned with mechanical and thermal properties. Main focus of research is to prove that dissimilar metal joining is better than single metal joining from economical point of view as well as mechanical and thermal advantages. However in my report the simulation for joining two dissimilar metals with continuous moving heat source is main concern. In this simulation two dissimilar metals Copper and Nickel is used.

Following assumptions is made:

1) Convection heat loss is neglected through the surface.
2) Both copper and nickel blocks are taken dimensionally symmetric.
3) The temperature of work piece is initially at 300K.
4) The surface of weld pool is flat.
5) Density and Emissivity material properties are constant.

In modeling the heat transmission during welding, the effects of weld pool stirring are ignored. Moreover, k is assumed to be isotopic in all directions, the temperature gradient in the depth direction of the work piece is supposed to be sufficiently small that it can be neglected, and the heat flow is assumed to take place in two dimensions only.

Principle of Laser Welding of two different metals copper and nickel is shown in fig. Two metals are placed adjacent to each other and there geometry is symmetric. Surface of the two metals is taken flat. Laser torch is placed just above the line of contact of two metals and laser is shot over it. Work piece is moved in direction of line of contact.

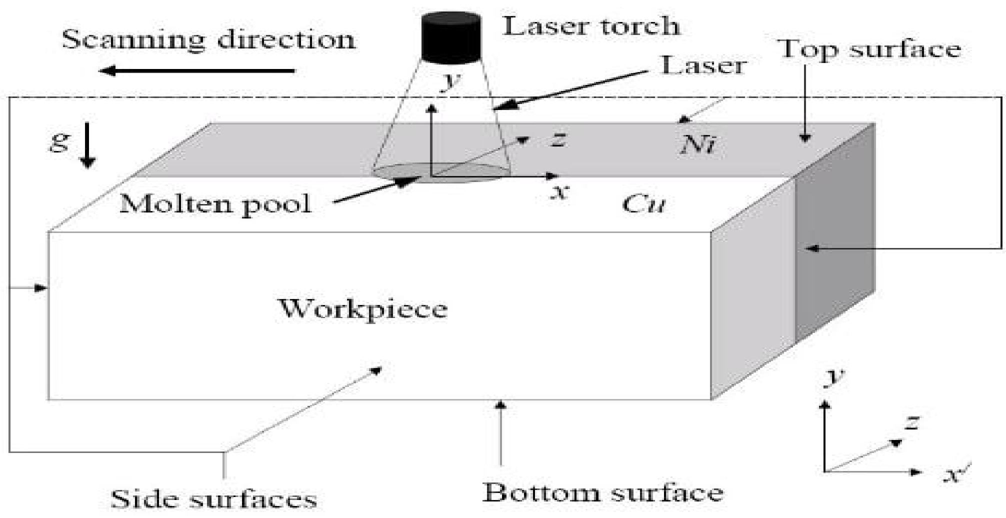

Fig.: Working Principal of Laser Welding

IV. CONCLUSION

From this review paper following points can be summarized

A. Laser Beam Welding processes are widely used for the welding of dissimilar metals and alloys.
B. Significant parameters in Laser Beam Welding are power of the laser source, welding/scanning speed, and beam spot diameter.
C. Laser welding of two dissimilar metals Copper and Nickel has been studied using a 3D transient numerical model.
D. Simulation results are presented to illustrate the importance of laser beam velocities for weld pool formation during laser welding of dissimilar metals
E. Important properties which are studied by the researchers in both LBW and FSW techniques when joining dissimilar metal pairs are tensile strength, shear strength, microstructure and hardness.

V. ACKNOWLEDGEMENT

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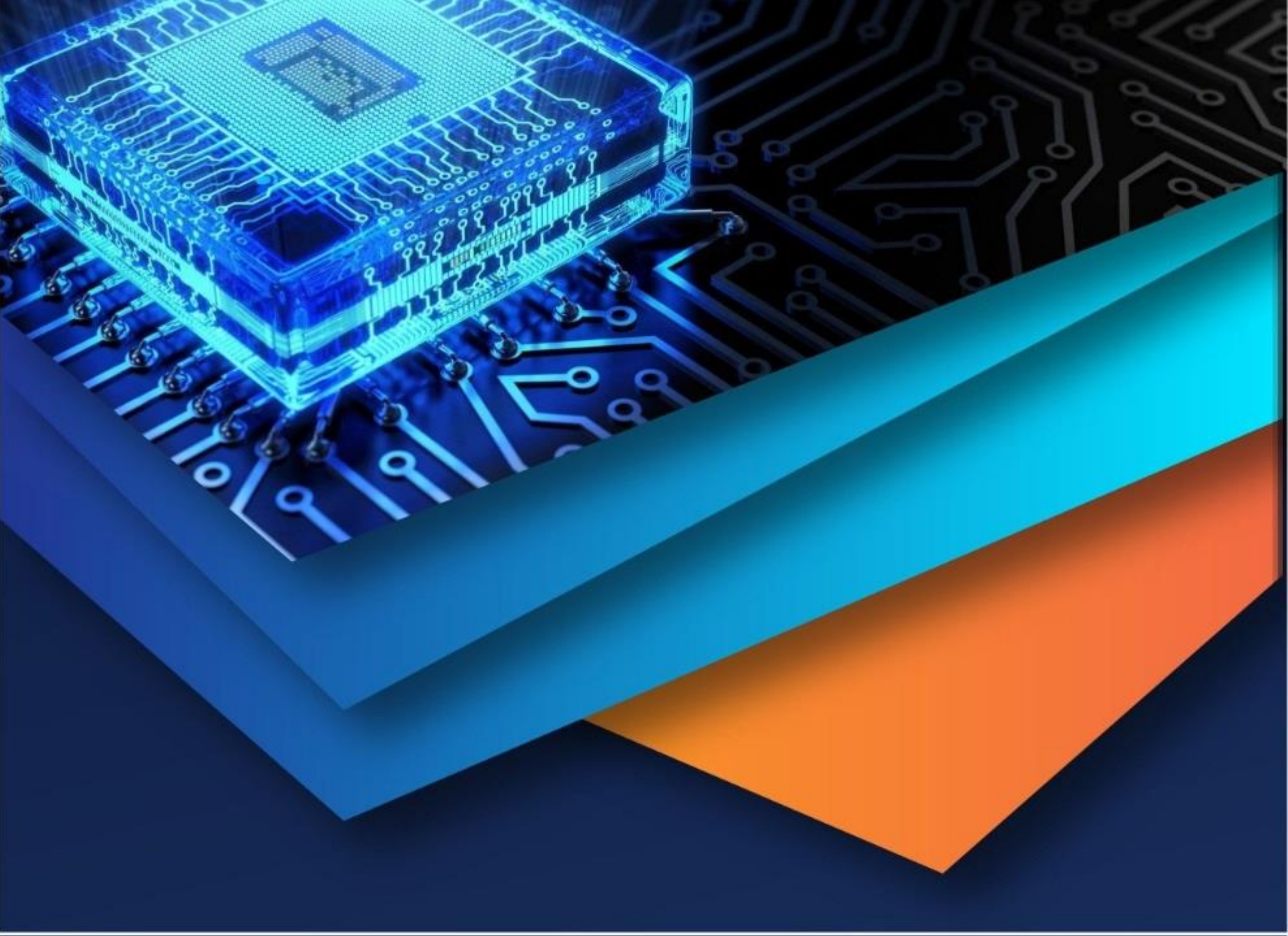

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