Investigation of Optimum Welding Parameters in Ultrasonic Welding for Aluminium Foils

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Abstract— The use of welding in today's manufacturing technology is extensive. Welding is the process of joining similar or dissimilar material combinations. Ultrasonic welding (USW) is a solid state welding process used for rapidly joining a wide range of similar and dissimilar combination of metals and plastics in very short cycle time and without melting the materials being joined. This paper deals with the Ultrasonic welding of thin Aluminium foils. The main objective of this paper is to arrive at an optimum parameter window of ultrasonic welding variables for the above said material. The ultrasonic parameters considered are power, pressure, and weld time, which exhibit significant influence on ultrasonic welds. The effect of the selected ultrasonic welding parameters was studied by conducting adequate trials on the Aluminium foils of 0.05mm thickness. After conducting preliminary trials, twenty six trials were carried out. Samples were subjected to tensile load testing using Honsfield Tensometer to study the joint efficiency. The quantitative values from tensile load testing were analyzed. The independent as well as the combined effect of ultrasonic welding parameters on tensile load were arrived at using regression equations. The investigation resulted in identifying the optimum ultrasonic welding parameters for obtaining an acceptable ultrasonic joint, for 0.05mm thick Aluminium foils.

Keywords: Ultrasonic welding, Aluminium foils, welding parameter Optimization

I. INTRODUCTION

Ultrasonic welding is a solid state welding process wherein coalescence is produced by the local application of high frequency vibratory energy as the work parts are help together under moderately low static force, and ultrasonic energy is transmitted into the intended weld area. A sound metallurgical bond is produced without on arc or melting of the weld metal and without the cast structure associated with melting (3). There is minor thickness deformation.

II. PRINCIPLE OF OPERATION

Since vibratory action in ultrasonic welding breaks up and dispenses moisture, oxide and other coatings degreasing may be the only cleaning operation required before welding. Pieces to be welded are clamped between the welding tip and anvil. Actually, the coupling system and welding tip form a unit called sonotrode.

A frequency converter converts 50 cycle line power into high frequency electrical power and a transducer change the high frequency electrical power into ultrasonic vibratory energy, which is transmitted to the joint through the welding tip attached to the transducer. The tip oscillates in the plane of the joint interface. To start with, some triggering mechanism towers the weld head, applies necessary clamping force and starts the flow of ultrasonic energy.

Ultrasonic vibration combined with the static clamping force, induce dynamic shear stresses in the work pieces, then the local plastic deformation of the joint materials occurs at the interface. Oxide coating and other surface films are shattered and dispensed so that intimate contact and bonding of the work piece surface takes place (3).

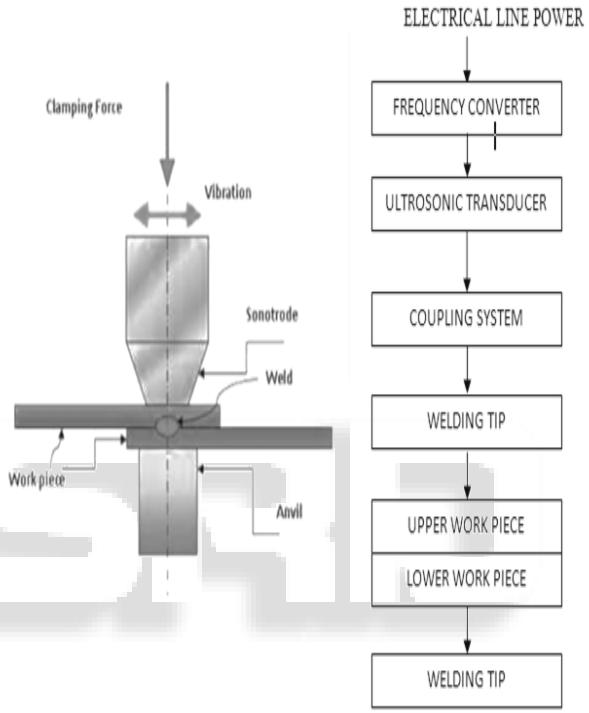

Fig. 1: Typical USW System and Energy Flow in USW System

III. PROCESS PARAMETERS

The process parameters in USW are the power, clamping force, welding time and frequency.

A. Power

The amount of power required for an ultrasonic spot weld can range from a few watts for wire welding, to as much as 16000 Watts for heavy section welding Seam welds are performed with power levels that range from 100 to 500 W. The operating power level of the ultrasonic welding machine measured in watts, multiplied by the time duration of the applied power, will determine the welding energy in joules.

B. Clamping force

The amount of clamping force used for welds can vary from less than 100 g to thousands of kilograms. Generally, clamping forces must be increased as the contact area of the

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weld zone increases. Insufficient force can result in tip sticking; too much forces increases power requirement.

C. Welding time

Ultrasonic spot welding is usually performed in welding cycles of 0.05 – 1 sec. More welding time indicate that not enough power is being used. Insufficient power, and longer cycles, will increases the possibility of tip sticking and increase heating of the work piece. Therefore it is desirable to use the highest possible power levels to minimize the welding cycle time. The parameter of time is controlled by traverse rate in ultrasonic seam welding.

D. Frequency

The last process parameter, frequency, is typically adjusted to match the natural resonance frequency of the coupling system and is then maintained constant to within 1.2% of its present value by a closed-loop control system. A high operating frequency results in lower amplitude and a corresponding decrease in process efficiency.

IV. APPLICATION OF USW FOR ALUMINIUM COMPONENTS

Aluminium is one of the widely used non-ferrous metals in the fabrication of electrical and electronic components. Aluminum has been called the wonder metal of twentieth century. Today aluminium is second only to steel as the most widely used metal and Aluminium is used more than all other non-ferrous metals combined and is widely being welded by ultrasonic welding process (1). The material used in ultrasonic welding is Aluminium exceeding 99.99% purity. The unique characteristics of Aluminium such as light, weight, highest strength, corrosion resistance, high electrical conductivity, non magnetic and non toxic makes Aluminium is most suitable for a number of applications (2).

V. LITERATURE REVIEW

Effect of welding conditions on the mechanical properties and the interface microstructure of the welded joint while joining mild steel sheet to aluminum alloy sheet containing magnesium has been Investigated . (4) Welding Current/Velocity Estimation Models developed for optimizing the parameters like weld current and weld velocity in tungsten inert gas (TIG) welding. (5) Experimental study made of copper wire bonding on Au/Ni plated Cu substrate at different bonding parameters. (6) Optimization of the process parameters using Taguchi method on Ultrasonic welding of copper metal carried out using of response surface method (RSM). (7) Genetic algorithm used for TIG Welding process for optimization of welding parameters to achieve desired height to width ratio.(8) Evaluation of the weldability and tensile shear failure load of a 2-mm-thick aluminum alloy sheet joined via ultrasonic spot welding at various energy levels were carried out and the temperature changes at the weld center were monitored during welding. (9)

VI. EXPERIMENTAL METHODOLOGY

Commercial pure Aluminium foil of thickness 0.05 mm was selected for this investigation. The samples were sheared from larger sheets of metal and then straightened by hydraulic press. The surface rust and scales were removed by the use of emery sheet. Finally the edges were cleaned properly using acetone to remove oxides and residues and rust. The welding trials are conducted with Aluminium foil of thickness 0.05mm. The foils to be joined are clamped between the welding tip and supporting anvil as shown in fig 1. The trials were made by adjusting the various parameters such as power, pressure, and weld time for finding exact parameter window. The two hand start button is pushed simultaneously to perform welding. The readings were tabulated.

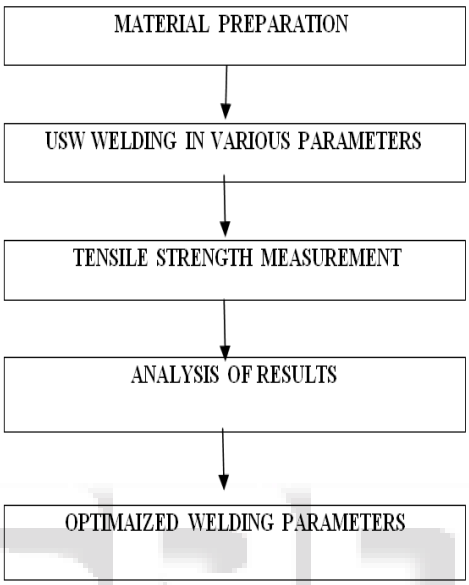

Fig. 2: Methodology

VII. RESULTS AND DISCUSSION

The effect of the selected ultrasonic welding parameters was studied by conducting adequate trials on the test material. After conducting the preliminary trials, Twenty six readings were carried out. After that the samples were subjected to tensile load testing using Honsfield tensometer to study the joint efficiency. The independent as well as the combined effect of ultrasonic welding parameters on tensile load were arrived at using regression equations. The investigation resulted in identifying the optimum ultrasonic welding parameters for obtaining an acceptable ultrasonic joint in the test material.

A. Effect of Pressure on Tensile Load

It has been observed that the best results could be obtained when the pressure is in between 1.5 bar to 3.5 bar. The pressure below 1.5 bar or above 3.5 bar will reduce the tensile strength of the weld. The regression equation was found from the graph 1 is $Y=0.8696\ X^2 + 4.302\ X + 1.5325$ where X is the pressure in bar and Y is the tensile strength in Kg.

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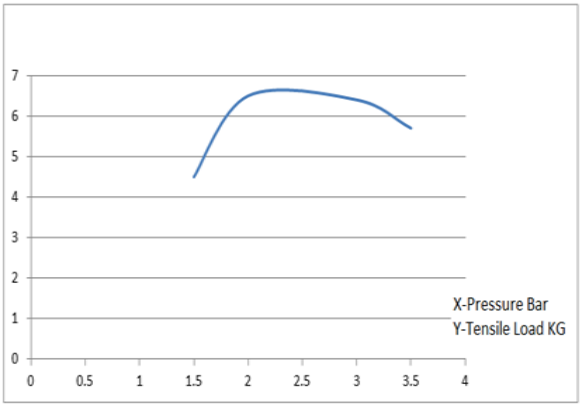

Fig. 2: Effect of Pressure on Tensile Load

B. Effect of Weld Time On Tensile Load

The best results are obtained when the weld time is in between 0.3 sec to 0.5 sec and 1.2 sec to 1.5 sec as shown in the graph. When the time is between 0.6 sec to 1.1 sec will decrease the tensile strength of the welded joint. The regression equation was found from graph as $Y = 4.9334\ X^2 - 9.4654\ X + 9.8619$ where Y is the tensile strength in kg and X is weld time in sec.

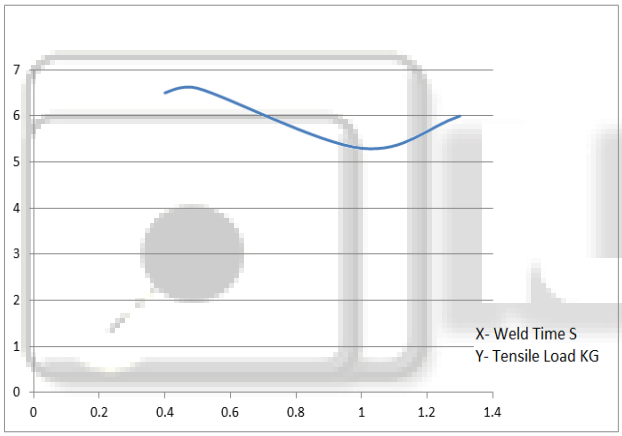

Fig. 3: Effect of Weld Time on Tensile Load

C. Effect of Power on Tensile Load

The best results are obtained when the power is in between 80 V to 120 V. It was found that when the power is below 80V or above 120V the tensile strength of the joint decreases. The regression equation is $Y = 0.0007X^2+0.143X-1.2211$ where Y is the tensile strength in kg and X is the power in volts.

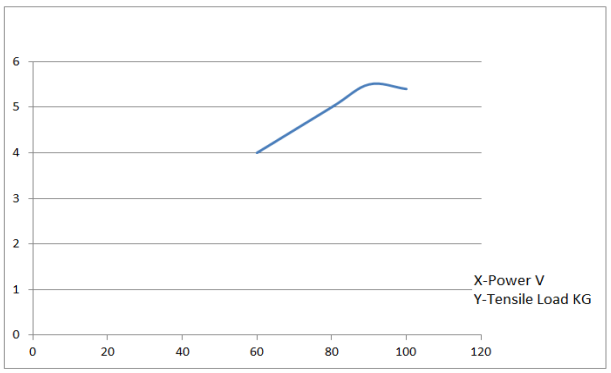

Fig. 4: Effect Of Power on Tensile Load

VIII. CONCLUSION

(1) The optimum parameters to weld aluminum of 0.05 mm thickness were established.
(2) The effect of welding parameters on mechanical property of tensile strength is examined.
(3) For welding of Aluminium foil of 0.05 mm thickness, the following ultrasonic welding parameters were found to be optimum
(4) Power : 60 volts
(5) Pressure: 1 bar
(6) Weld time: 1 Sec

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