ABSTRACT

During recent years industries have started using materials with high-strength to weight ratio such as aluminum alloys, composites, magnesium alloys, copper alloys and advanced high-strength steels. This is especially true in the case of automobile industry which is aggressively pursuing the development of high performance energy efficient vehicles. The assembly processes in such cases involve innovative solid-state joining in which metallurgical bonding between similar or dissimilar materials can be created without melting. One of the solid-state joining processes is Ultrasonic Metal Welding (USMW).

USMW is a process in which two metallic parts are joined by the application of ultrasonic vibrations which are applied parallel to the interface between the parts under moderate pressure. The high frequency relative motion between the parts forms a solid-state weld. It causes progressive shearing and plastic deformation between surface asperities that disperses oxides and contaminants. It also brings in an increasing area of contact and bonding of the adjacent surfaces.

Even though USMW has been known for a number of years, a complete understanding of the fundamental mechanism of the process is far from complete. This lack of understanding is particularly pronounced as it relates to the basic mechanics of the weld, and the relation of the weld

mechanics to the overall dynamics of ultrasonic welding system.

Aluminum alloys are extensively used in automobile industry because of its high strength to weight ratio and copper is used in electrical and electronic industry because of its excellent electrical and thermal properties. For this reason aluminum and copper alloys were selected for this study.

From the literature review it is concluded that USMW is a process of interest to several segments of manufacturing industry and there is enough scope to carry out research in the area of ultrasonic welding of metallic components. But an extensive literature survey reveals that only limited amount of work is reported wherein studies on optimisation of parameters for USMW of various metals are attempted with suitable experiments on measuring temperature at interface and strength of weld. Prediction of temperature field at the interface using FEA is found to be useful for industrial applications. Also, from an academic perspective solving the unsteady state heat transfer equation with the help of Finite Difference Method (FDM) will provide scope for applied research. This report is the outcome of a study that is carried out with the above mentioned needs identified. The observation from this study will add new knowledge in the area of USMW.

This work is divided into three important phases. Phase 1, is to carry out initial experiments to arrive at the maximum and minimum values of welding parameters (weld pressure, weld time, amplitude) for different materials. Materials selected are Al, Cu and brass. In phase 2, suitable design of experiments was planned based on Taguchi's design and Response Surface Method (RSM). Regression model obtained from RSM is used as fitness function in Genetic Algorithm (GA) to optimize the weld parameters. This approach will reduce the number of experiments to obtain the optimum values of weld parameters to maximize the weld strength. In this phase, weld strength of joints and the interface temperatures while welding (prepared as per the design of experiments) are measured using suitable equipment. From phase 2, the optimum values of weld parameters can be recommended to the industry to achieve maximum weld strength. In phase 3, temperature distribution at the interface is simulated using mathematical methods. For the benefit of industrial applications temperature field is simulated using FEA also. Results from experiments and simulations are compared. After completing this study the following salient points are highlighted as conclusions.

The optimum combinations of parameters for maximizing the weld strength and minimizing weld strength variation were identified using Taguchi method. The parameters for achieving the maximum weld strength are identified as pressure of 3 bar, weld time of 3 seconds and amplitude of vibration of horn 57 µm. The parameters for minimizing the variation in weld strength are pressure of 3 bar, weld time of 2.5 seconds and amplitude of vibration of horn 42.5 µm.

A second order regression model using RSM was developed to predict the maximum weld strength of seam and spot welds produced by USMW using aluminum, copper and brass sheets with various thicknesses. This yielded a relationship that can predict the weld strength for a given set of parameters. These predictions are in good agreement with observations from experiments. Also, influences of process parameters on weld strength were studied.

The developed response surface model was further coupled with GA to find the optimum welding conditions to maximize the weld strength. Further, the optimum welding conditions obtained from GA were compared with experimental results. It was found that the optimum conditions obtained from GA correlate well with the experimental results. This indicates that the optimization methodology proposed in this study by coupling the developed RSM and the GA is effective.

Temperature distribution during welding of Al and Cu specimens were predicted by solving one dimensional parabolic equation and using FEA. The results obtained show similar trend with experimental results. This study can provide useful inputs to the industry who use USMW in the manufacturing of alternators, rotor assembly, rectifier assembly and automobile body panels.