A Study of Investigation and Optimization of Process Parameters On Ultrasonic Metal

Ramesh Babu Yeluri[1], Dr. P Manoj Kumar[2]

[1]Research Scholar of Sri Satya Sai University
[2]Research Supervisor of Sri Satya Sai University

Abstract

This paper speaks about the, joining of two delrin materials (plastic material) using ultrasonic welding. There are two types of parameters. They are machine setting initial parameters and running parameters. The running parameters have a large impact on the weld strength. The welding was carried out by varying its parameters such as weld time, weld hold time, weld delay time to evaluate the strength of the weld. After welding of the specimens, various tests were done on the welded materials to check the weld strength of the material. The tensile strength of the material gets better by optimizing the running parameters. The major application of this material is, it is used in impeller. Response surface method (RSM) with genetic algorithm (GA) RSM is utilized to develop an effective model to predict weld strength by incorporating process parameters such as pressure, weld time and amplitude. Experiments were conducted as per central composite face centered design for spot and seam welding of 0.2 and 0.3 mm thick copper and brass specimens. An effective second order response surface model is developed by utilizing experimental measurements. Response surface model is further interfaced with the GA to optimize the welding conditions for desired weld strength. Optimum welding conditions produced from GA is verified with the experimental results and is found to be in good agreement.

Keywords: *Ultrasonic welding, Delrin material, Influencing Parameters, Torsion test*

1. INTRODUCTION

Copper and brass alloys are extensively used in automobile industries, heat exchanger and electrical applications owing to its high thermal conductivity, strength and retention of strength at sufficiently elevated temperatures. The conventional welding process of copper and brass produces large heat affected zone (HAZ) and fusion zone (FZ), high shrinkage, variations in microstructures and properties, evaporative loss of alloying elements, high residual stress and distortion which calls for the development of a solid-state joining process in which metallurgical bonding between similar or dissimilar materials can be created without melting. One such solid-state joining process is ultrasonic metal welding (USMW).

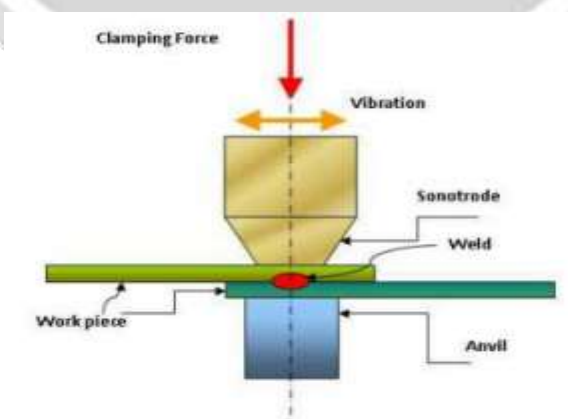

Figure 1 Schematic representation of ultrasonic metal welding

USMW is a process in which similar or dissimilar metallic components are joined by the application of high frequency vibrations which are in plane with the interface under moderate pressure as shown in Figure 1. The high frequency relative motion between the parts leads to solid progressive shearing and plastic deformation which causes a localized joining in few seconds without producing significant amount of heat and without causing changes in the properties of work pieces. In USMW at least one part must be relatively light, as it would take tremendous amount of energy to vibrate a heavy part at the necessary frequency which limits the applicability of the process to small components and wires. The process modeling by RSM using statistical design of experiments based on central composite face centered design is proved to be an efficient modeling tool. This method not only reduces the cost and time but also gives the required information about the main and interaction effects. In this study, a second order response surface (RS) model for predicting weld strength of ultrasonically welded copper to brass specimens is developed. The accuracy of the RS model is verified with the experimental studies. The developed RS model is further coupled with genetic algorithm (GA) to find the optimum welding conditions leading to the maximum weld strength. The predicted optimum welding condition by GA is validated with experimental results.

1. Ultrasonic Welding

Ultrasonic Welding is a classification among the Solid State Welding process, in which two work pieces are joined as a result of the pressure applied to the welded parts combined with application of high frequency acoustic vibration (ultrasonic).It causes friction between the parts, which results in a closer contact between the two surfaces with simultaneous local heating of the contact area. Inter atomic bonds, formed under these conditions, provide strong joint. Ultrasonic cycle takes about 1 sec. The frequency of acoustic vibrations is in the range 20 to 70 KHz.

2. Area of Use

Thickness of the welded parts is determined by the power of the ultrasonic generator. It is used mainly for bonding work pieces of smaller size in electronics, for manufacturing communication devices, medical tools, watches, in automotive industry. It is a quasi-solid-state process that produces a weld by introducing high frequency vibration to the weldment as it is held under high clamping forces.

3. Types

There are two types of USW, they are

1. US Roller welding and

2. US spot welding. We are using the US spot welding.

4. Basic Elements:

All ultrasonic welding systems consist of basic elements. The parts to be assembled are pressed, assembled under pressure and a nest or anvil where the parts are placed and allowing the high frequency vibration to be directed into the interfaces. An ultrasonic stack composed of an optional booster, converter or piezoelectric transducer and a sonotrode. All three elements of the stack are specifically tuned to resonate at the same exact ultrasonic frequency. There is a converter which converts the electrical signal into a mechanical vibration. The booster modifies the amplitude of the vibration which is standard systems to clamp the stack in the press. The sonotrode is used to apply the mechanical vibration to the parts to be welded. An electronic ultrasonic generator is used to deliver high power AC signal with the frequency matching the resonance frequency of the stack. The weld is produced without melting of the base materials. In some respects, ultrasonic welding is an infant process that still awaits thorough exploration. A greater understanding is needed of the processes that occur at the bond interface. Specifically, the interaction of the process parameters, as well as their role in bond development, needs to be better understood.

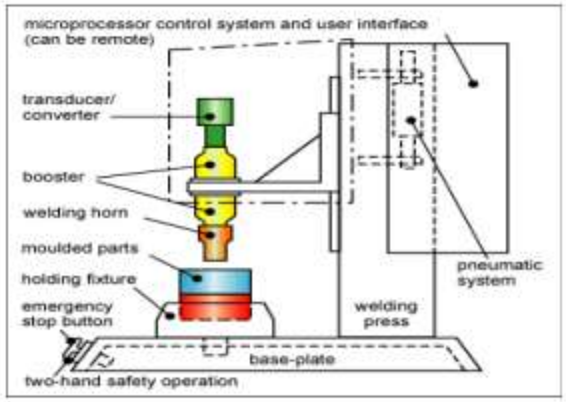

Fig.2 Schematic representation of USMW

2. LITERATURE REVIEW

J.Pradeep kumar et al [1] depicts experiments to copper wire with copper sheet using USM spot welding. The lateral drive system is used to perform experimental trials in this work. The experiment was conducted by varying weld pressure, amplitude and welding time. Here a suitable DOE based on Full Factorial design methodology was designed and executed for conducting trials. ANOVA is used to interpret the results from actual experiments.

Marius Pop-Calimanu et al [2] describe the problem faced by researchers and industry with respect to ultrasonic welding process in poor strength of the weld, due to improper selection of welding parameters. Here also the welding pressure, welding time and amplitude are selected as the optimal parameters. It was observed that welding pressure and welding time has a significant effect on the response.

Elangovan Sooriyamoorthy et al (2011) [3] proposed using Taguchi's design of experiments methodology, the weld strength is maximized for Al-Al welding by optimizing the process parameters like weld pressure, weld time and amplitude of vibration. A finite element analysis model is developed that is capable of predicting the interface temperature and stress distribution during welding process. Results of experimental work and FEMstudies are compared and found to be in good agreement. It is found from this study that as the weld time increases, the stress levels also increase indicating that the joint obtained at increased weld time show better strength.

S. Elangovan et al (2009) [4] described the joining of two materials together using high frequency vibrations in ultrasonic welding without producing significant amount of heat. During the ultrasonic welding of the sheet metal, the normal and shear forces act on the parts to be welded and the weld interface. These forces are the result of ultrasonic vibrations of the tool, pressed onto the parts to be welded. They carried out a study on model for the temperature distribution during welding and stress distribution in the horn and welded joints are presented. It is capable of predicting the interface temperature and stress distribution during welding and their influences in the work piece, sonotrode and anvil. An FEM based model for ultrasonic welding has been developed, which can predict the temperature developed during welding process with parameters like material thickness, clamping force, weld time and coefficient of friction. It also described that clamping force plays a major role in deformation area resulting in increasing the force in weld area.

3. UTM SPECIFICATIONS

1. Model: EGA 1526

2. Maximum capacity : 10 KN

3. Least count displacement : 0.1mm

4. Accuracy of load : 1% of indicated load from 4% to 100 of load cell capacity

5. Grip separation : 25 – 750mm

6. Straining rate : 1mm / min to 100 mm/min

7. Power : single phase 220V 50Hz AC

8. Motor : 0.5Hp

Fig.3 Ultrasonic Welding Setup

4. RESPONSE SURFACE MODEL FOR WELD STRENGTH

The Response Surface Methodology (RSM) is a collection of mathematical and statistical techniques useful for the modeling and analysis of problems in which a response of interest is influenced by several variables and the objective is to optimize this response. The second order mathematical models have been developed to predict the weld strength.

$$y_i = \beta_0 + \sum_{j=1}^{q} \beta_j x_j + \sum_{j=1}^{q} \beta_{jj} x_j^2 + \sum_{i<j}\sum \beta_{ij} x_i x_j \qquad (1)$$

where yi is the response, i.e. weld strength; xi represents pressure, weld time and amplitude; $\beta 0$,βj ,βjj and βij represent the constant, linear, quadratic and interaction terms respectively.

In this work, the CCF design is used which fits the second order response very accurately [2]. The axial and star points in CCF design allow quadratic terms included in the model which gives efficient estimation of response with curvature surfaces [3]. All coefficients are obtained by applying CCF using Minitab software package and second order mathematical model for predicting weld strength is developed.

5. OPTIMIZATION PROBLEM FORMULATION AND SOLUTION

Genetic algorithms are more likely to converge to global optimum than conventional optimization techniques, since they search from a population of points, and are based on probabilistic rules. The conventional optimization techniques are ordinarily based on deterministic hill-climbing methods, whichmay find local optima. The genetic algorithm solves optimization problem iteratively based on biological evolution process in nature (Darwin’s theory of survival of the fittest). In the solution procedure, a set values of parameter is randomly selected and the best combination of parameters leading to maximum weld strength is determined. New combination of parameters is generated from the best combination by simulating biological mechanisms of offspring, crossover and mutation. This process is repeated until weld strength with new combination of parameters cannot be further increased. The final combination of parameters is considered as the optimum solution. The principal steps in GA based optimization are listed below:

Step 1: Randomly generate an initial chromosome population.

Step 2: Decode the genes namely pressure, weld time and amplitude of vibration for all chromosomes.

Step 3: With specified values of sheet thickness, evaluate the predicted value of weld strength using the models based on RSM for weld strength.

Step4: Determine the fitness of all chromosomes and obtain the maximum (fitmax).

Step 5: If fit max ≤required fitness (fit required), then carryout following genetic operations:

(a) Selection based on expected number control method,

(b) Crossover, and

(c) Mutation, to generate new chromosome population and go to step 2.

else stop.

In this work, maximization of weld strength must be formulated in the standard mathematical format as given below for Cu- brass specimens.

6. CONCLUSION

The experiments were done on the similar plastic materials using ultrasonic welding. The influencing parameters while joining the materials were identified. These parameters were optimized using taguchi method to obtain the maximum weld strength. Parameters like weld frequency, weld pressure, Amplitude, Weld time, Weld delay time and Weld hold time has significant effect on weld strength. Experiment results proved that these parameter influence the weld strength and these parameters where optimized using taguchi method. From the experimentation, the weld strength is poor with low amplitude and high weld time and strength is good with low pressure and high weld time.

7. REFERENCES

1. J.Pradeep Kumar , K.Prakasan, Experimental Studies On Joining Copper Wire - Copper Sheet Using Ultrasonic Metal Welding, International Journal Of Mechanical And Production Engineering Research And Development (Ijmperd) Issn 2249-6890 Vol.2, Issue 3 Sep 2012 21-29
2. Marius Pop-Calimanu, Traian Fleser, The Increasing Of Weld Strength By Parameters Optimization Of Ultrasonic Welding For Composite Material Based On Aluminium Using Design Of Experiments, Nanocon, 2012
3. S. Elangovan, S. Semeer, K. Prakasan, Temperature And Stress Distribution In Ultrasonic Metal Welding—An Fea-Based Study, Journal Of Materials Processing Technology 209 (2009) 1143–1150
4. S. Elangovan, K. Anand, K. Prakasan, Parametric Optimization Of Ultrasonic Metal Welding Using Response Surface Methodology And Genetic Algorithm, Int J Adv Manuf Technology 0.1007 S00170-012-3920
5. Ganesh M, Praba Rajathi R, Experimental Study On Ultrasonic Welding Of Aluminium Sheet To Copper Sheet, International Journal Of Research In Engineering And Technology, 02 (2013) 161-166
6. V. Gunaraj, N. Murugan, Application Of Response Surface Methodology For Predicting Weld Bead Quality In Submerged Arc Welding Of Pipes, Journal Of Materials Processing Technology 88 (1999) 266–275
7. Cemal Meran, “Prediction Of The Optimized Welding Parameters For The Joined Brass Plates Using Genetic Algorithm,” Journal Materials & Design, Vol.27, 2006, Pp.356-363.
8. G.C. Onwubolu And Shivendra Kumar, “Response Surface Methodology-Based Approach To Cnc Drilling Operations,” Journal Of Materials Processing Technology, Vol. 171, 2006, Pp.41-47.
9. S. Elangovan, K. Prakasan And V. Jaiganesh, “Optimization Of Ultrasonic Welding Parameters For Copper To Brass Joints Using Design Of Experiments,” International Journal Of Advanced Manufacturing Technology, Vol.51, 2010, Pp. 163 – 171.

10. O. E. Canyurt, H. R. Kim And K. Y. Lee, “Estimation Of Laser Hybrid Welded Joint Strength By Using Genetic Algorithm Approach,” Mechanics Of Materials, Vol.40, 2008, Pp.825-831.
11. S. S. Habib, “Study Of The Parameters In Electrical Discharge Machining Through Response Surface Methodology Approach,” Journal Of Applied Mathematical Modeling, Vol.33, 2009, Pp.4397-4407
12. Astm International Codes, “Standard Test Method For Apparent Shear Strength Of Single-Lap-Joint Adhesively Bonded Metal Specimens By Tension Loading (Metal-To-Metal),” Astm International, Vol. 01, 2005, Pp. 52-55.