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Abstract—In the present scenario of developing plastic utility in engineering applications, demand for reliable and faster joining processes has been increased. Ultrasonic welding of thermoplastic is one of these joining methods which is based on application of high-frequency vibratory energy in the work pieces held together under pressure without melting. Ultrasonic welding of thermoplastic Composites has become an important process in industry because of its relatively low cost and high Quality resultant joints.

Key words: Orthogonal Array, Ultrasonic Welding Machine, Design of Experiments, Full Factorial, Minitab@16 Software

I. INTRODUCTION

A. Project Background

Welding is a fabrication process used to join materials, usually metals or thermoplastics together. During welding, the pieces to be joined (the work pieces) are melted at the joining interface and usually a filler material is added to form a pool of molten material (the weld pool) that solidifies to become a strong joint. In order to join two or more pieces of metal/non-metal together by one of the welding Processes, the most essential requirement are Heat. Pressure may be employed in some processes.

B. Principle of Operation

Ultrasonic plastic welding is, in principle, the joining of thermoplastics through the use of heat generated from high frequency mechanical motion. It is accomplished by converting high frequency electrical energy into high frequency mechanical motion. The mechanical motion along with the applied force creates the frictional heat at the mating surface of the plastic components.

Fig. 1: Ultrasonic Welding Principle

In effect, the plastic material at the joint surface melts and forms a molecular bond between the parts. The frequency of the frequency is around 20 to 40 kHz. Figure 2 depicts the line diagram of an ultrasonic welding machine. The electrical power supply provides high frequency electrical power to a typical piezoelectric based transducer creating a high frequency mechanical vibration at the end of the transducer. Next, the booster amplifies the mechanical vibrations produced by the transducer and supplies to the horn. Further, the horn (also known as sonotrode) transfers the amplified mechanical vibrations to the work piece.

C. Ultrasonic Plastic Welding

Most of the thermoplastic materials can be ultrasonic weldable. When bonding material through ultrasonic welding, the energy required comes in the form of mechanical vibrations. The welding tool (sonotrode) couples to the part to be welded and moves it in longitudinal direction. The part to be welded remains static. Now the parts to be bonded are simultaneously pressed together. The simultaneous action of static and dynamic forces causes a fusion of the parts without having to use additional material.

This procedure is used on an industrial scale for linking both plastics and metals. Here a. and b. both the figures are for ultrasonic welding for metal and plastic respectively.

Fig. 2: Difference between Metal and Plastic USW

II. LITERATURE REVIEW

Until recently many researchers have shown interest in the field of ultrasonic welding and the resulting joint strength. They have carried out numerous laboratory experiments and observations to illuminate the darkness of this field. Their findings and suggestions are reviewed here. Here I began a short literature review on the USW process and the parameter affecting the process. I found some likely research paper. When I read each, I wrote a paragraph description of each:


In this study, the control parameters like vibration amplitude, weld pressure and weld time are considered for the welding of dissimilar metals like aluminum (AA1100) and brass (UNS C27000) sheet of 0.3 mm thickness.

Based on its main effects results, the most influencing parameter on the response is the vibration amplitude as it occupies rank 1 followed by weld time and weld pressure. Observations indicate that the fuzzy modelling results a high FMPI value than GA. So, fuzzy technique could be an economical and better method for prediction of quality characteristics with respect to the process variables Tensile strength values also increase with weld time up to a certain point and then decreased due to formation of cracks around the weld zone.
B. Marius Pop-Calimanu, Traian Fleser. [2]

In this paper, welding parameters, like welding time, welding pressure and amplitude of the vibration are taken into account during the realization of ultrasonic welded joints of Al/20%SiC composite material under disks form, whose thickness are 1 mm. This work Sooriyamoorthy Elangovan & K. Prakasan & V. Jaiganesh. [3]

In this work welding parameters like welding pressure, weld time and amplitude of the vibration are considered while producing ultrasonically welded joints of copper whose thickness is 0.2 mm. A suitable experimental design based on Taguchi’s robust design methodology was designed and executed for conducting trials. The analysis of variance (ANOVA) and signal to noise ratio analyses are employed to investigate the influence of different welding parameters on the weld strength and to obtain the optimum parameters.

It is observed that weld pressure, weld time and amplitude has significant effect on the response (weld strength). The interactions between weld pressure and weld time and that between weld pressure and weld amplitude have significant effect on weld strength. The interaction between weld time and weld amplitude does not have significant effect on weld strength.

C. Harras, K C Cole. [4]

The ultrasonic welding of PEEK-carbon composites was studied in order to better understand the process and determine the optimum welding conditions. The parameters varied were the applied pressure and the welding time. The optimum applied pressure at the horn-sample interface was found. The joint properties were evaluated through fracture test in both Mode-I (opening) and Mode-II (shear).

It was found that the optimum welding time depends very much on the physical configuration of the specimens being welded: this effects the efficiency of conversion of the ultrasound into thermal energy in the composite. However, for the both types of specimen tested (Mode I and II) the optimum joint strength was found to correspond to a specific value of total energy input. It is noted that a variance of the energy by 10% in either direction resulted in a decrease in properties by about half. Hence the weld energy can be used as a reliable.


This paper focuses on the development of an effective methodology to determine the optimum welding conditions that maximize the strength of joints produced by ultrasonic welding using response surface methodology (RSM) coupled with genetic algorithm (GA). Experiments were conducted as per central composite design of experiments for spot and seam welding of 0.3- and 0.4-mm-thick Al specimens.

It is concluded that weld strength decreases with increase of pressure because increase in clamping force (pressure) reduces the relative motion between surfaces leading to reduced area of contact and hence reduced strength. Also, weld strength increases with increase of amplitude because increase in amplitude gives increased area for rubbing action between the metallic surfaces that leads to better bonding and increase of weld strength.

III. GAP ANALYSIS

GAP analysis means the analysis of the research done already and the possible work that can be done after today. This kind of analysis helps the researcher to find out the way of doing the research.

Here according to above research paper, it is noted that the since today all research was done on the ultrasonic welding for majorly on metals and also some on plastic materials. There are various methods which is used to optimize the parameters. Some of the researchers used the taguchi method else some used response surface method with ANOVA. ANOVA means analysis of variance. It is Statistical technique for comparing means for multiple (usually ≥ 3) independent populations. Here some research paper is following the GA-genetic algorithms.

By doing the literature survey it is found that, there are always two types of factor that affect any process one is the controlled and another is uncontrolled factors. Here in the USW, the controlled factors are welding time, welding pressure, input power, frequency, amplitude etc. the uncontrolled factor are that factors which can’t be controlled during process. In this paper, the uncontrolled factors are neglected and controlled factors are selected for study. It is noted that mostly affected parameters are welding time, welding pressure and amplitude of sonotrode.

As per the literature review consort, in many researchs the output parameter is the joint strength. It also known as the tensile strength of the welding joint. Ultrasonic welding is widely used in the automobile industries for weld the different parts. So it is require to have a good Strength of joint. All the studied research papers are providing the optimum values of their input parameters for maximizing the output parameter.

IV. EXPERIMENTAL SETUP

Ultrasonic welding was carried out using a conventional ultrasonic metal welding machine (2,500W, 20kHz) for different ranges of weld parameters. The experimental setup for the ultrasonic metal welding is shown in Fig. 7 with data acquisition system. Horn made of hardened steel (spot and seam type) and anvil made of steel with serrations at the top surface were used for this study. The horn area which comes in contact has serrations similar to the top surface of the anvil to prevent the work piece from sliding during welding.

Fig. 3: Ultrasonic machine – USP3000-2000

V. FACTORS INFLUENCING THE WELDABILITY

In ultrasonic welding, it is usually divided into two major groups: near field and far-field welding. Current industry
practice, which is based on the most extensively, used 20 kHz welding system. Considers applications where the distance between horn/part interface and the weld interface is less the 6 mm to describe applications where that distance is greater than 6 mm. At 20 kHz, the wavelength in the plastic component ranges between 6 to 13 cm depending on the specific polymer. Therefore, during near-field ultrasonic welding, the vibration amplitude at the weld interface is close to the amplitude at the horn face. For far-field welding, the amplitude of vibration at the weld interface depends on the ultrasonic wave propagation in the parts.

During the welding process, the sonotrode oscillates transversely to the direction of welding. Contact pressure that applied on the sonotrode interacts with the oscillating shear forces causes dynamic internal stresses at the interface between the two mating surfaces. The major adjustment process parameters are static pressure and welding time. Table 6 lists all input factors and their range.

### Table 1: Input factors and their range

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Factors</th>
<th>Description</th>
<th>Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Weld pressure (bar)</td>
<td>A</td>
<td>1 to 4</td>
</tr>
<tr>
<td>2</td>
<td>Weld time (sec)</td>
<td>B</td>
<td>0.5 to 3</td>
</tr>
<tr>
<td>3</td>
<td>Amplitude (%)</td>
<td>C</td>
<td>60 to 100</td>
</tr>
</tbody>
</table>

**References**


