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Experimental Investigation for Welding Strength of Ultrasonic Welding Process using Taguchi

Mohd. Hashmi[1], Kuldeep Kaushik[2], Dushyant Dwivedi[3]
[1, 2, 3]Mechanical Engineering Department, RGPV Bhopal, M.P. India

Abstract: In recent years there have been several researches concerned with aspects of the ultrasonic bonding (welding) mechanism. In this paper, welding characteristics of 20 kHz ultrasonic welding system was performed using aluminum sheets specimen. Aluminum plate specimen of 0.5 mm in thickness and 20 mm in width were successfully welded. I found, ultrasonic weld formation always begins around the perimeter, but that no two-time equivalent patterns are exactly the same. And found, weld location should be considered in ultrasonic lap joint welding, due to effect of thermal conductivity of metals weld location also affect the welded quality.

Keywords: Al, Taguchi, Voltage, Current, Pressure, S/N Ratio, Ultrasonic Welding, Weld Strength.

I. INTRODUCTION

Different energy sources can be used for welding, including, gas flame, electric arc, laser, Electronic beam, and friction and ultrasonic. While often an industrial process, welding can be done in many different environments, including open air, underwater and in space. Regardless of location, however, welding remains dangerous, and precautions must be taken to avoid burns, shock, poisonous fumes, and overexposure to ultraviolet light. The comparative analysis of ultrasonic welding and characteristics of 20 KHz ultrasonic welding system was studied. The effect of weld time, weld energy on the weld strength by changing the various parameters of ultra-sonic welding have studied. The welding characteristics of 0.5 mm thickness and 15 mm width of aluminium specimen with different weld energy, weld time and different location of weld have been studied. In recent years there have been several research in finding the characteristics of various ultra-sonic metal welding system, that may help to improve the performance and quality of weld of ultrasonic welding system.

In ultra-sonic metal welding the time mode is more suitable for welding. Ultrasonic welding is an established technique for assembling the metal parts, is drawing lot attention these days, in fact in the push of mass produce all aluminium vehicles. Ultra sonic welding is a highly promising and low cast joining method. The ultra-sonic welding has already proven its effectiveness in a wide range of application, including wire hardness, automotive parts, medical devices, rechargeable batteries and copper tubing HVAC equipment. Joining dissimilar metal in a split second, ultra sonic welding eases problematic assembling and this cost effective technique may be key to mass producing fuel efficient. Ultra sonic metal welding is applicable for welded almost all metal specimens and is used for similar and different metal specimen in various industrial field including electronics and microelectronics. The welded joint of ultrasonic welding is limited to a very thin area and the clear melted structure cannot be observed. Similar and different lapped metal welding specimens have joined successfully in a short time. 20 KHz welding system using one dimensional vibration locus can only be used to join metal foil or thin plates specimen and cannot be used for thick metal plates more than 2mm thick. Aluminium plate of 0.5 mm thick was successfully joined with such weld strength that could be broken in plates under shear test of welded area.

A. Overview Of Types Of Welding

The different processes for joining metal parts can be systematically subdivided into different categories depending on their action principle. Their bond can be form-closed, frictional or positive-substance bond (figure 1.1). Very often, it is not possible to make a clear distinction between closing shape and frictional bond, as some processes render a clear distinction between operating principles impossible. A positive substance bond is mostly inseparable, and the bond takes place only by using additional material or consumables. The most frequent types of joints in this category are adhesive, soldered, brazed and welded joints. When welding materials, one has to distinguish between fusion welding and pressure welding.

Until the ending, of the 19th century, the only welding process was forge welding, which blacksmith had used for centuries to join metals by heating and pounding them. Arc welding and oxy fuel welding were among the first process to develop late in the century, and resistance welding followed soon after welding technology advanced quickly during the early 20th century as world war I and world war II drove the demand for the reliable and inexpensive joining methods.

B. Ultrasonic Welding

Ultrasonic welding is an industrial technique whereby two pieces of plastic or metal are joined together seamlessly through high-frequency acoustic vibrations. One component to be welded is placed upon a fixed anvil, with the second component being placed on top. An extension ("horn") connected to a transducer is lowered down onto the top component, and a very rapid (~20,000 Hz), low-amplitude acoustic vibration is applied to a small welding zone. The acoustic energy is converted into heat energy by friction, and the parts are welded together in less than a second.

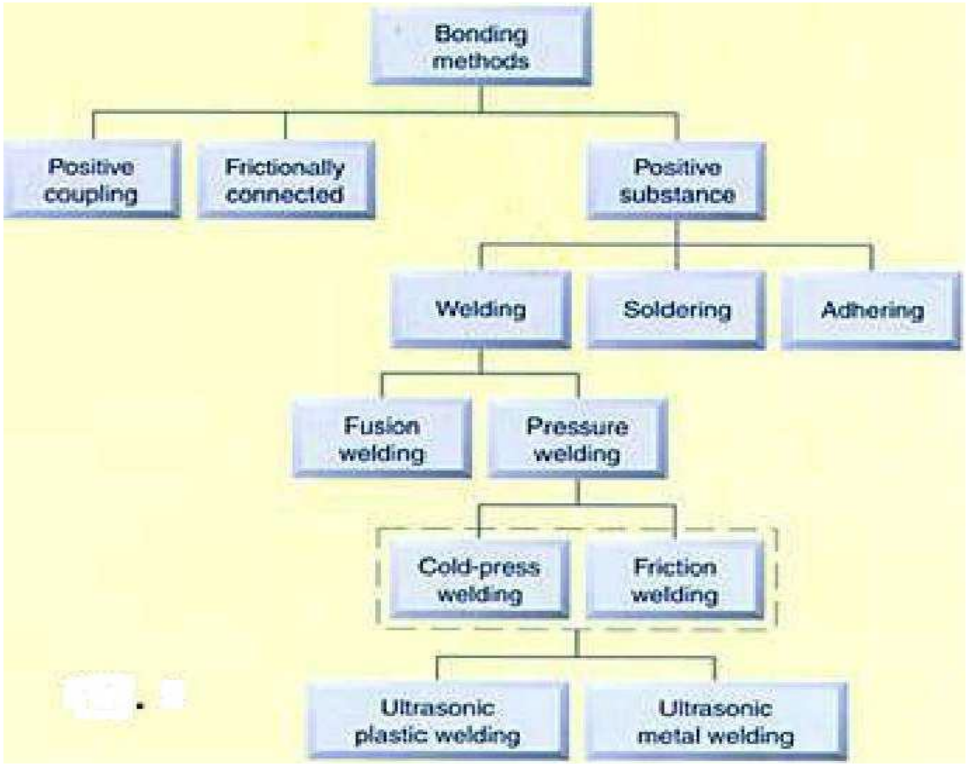

Figure 1.1: Classification of welding by their action principle.

One of the newest and most interesting fields of joining technology is ultrasonic welding. In this process, high frequency vibrations are combined with pressure to join two materials together quickly and securely, without producing significant amounts of heat. These factors give it many advantages over traditional heat based welding techniques. These include the ability to weld metals of significantly dissimilar melting points; metals that normally form brittle alloys at the weld junction; and weld that are in close proximity to heat sensitive components, such as electronics or plastic components. Finally, ultrasonic welds are made without consumables, such as solder or filler that would ordinarily be used for the connection and with far less energy usage than traditional joining techniques. There are some restrictions on the types of joints that can be made with ultrasonic welding. One of these is that it is restricted primarily to nonferrous metals and plastics. Another is that at least one of the parts must be relatively light, as it would take a tremendous amount of energy to vibrate a heavy part at the necessary frequency. This restriction, unfortunately, limits the process to small components and wire.

The extension of ultrasonic metal welding to automotive and aerospace structures and components requires advances in current welding systems, as well as new systems able to address the materials and quality and production conditions of these industries. This presentation will detail recent advances to increase ultrasonic metal welding power capability, develop alternative welding configurations to meet vehicle joint configuration requirements, and implement more robust process control. Specifically, the development of new high power 5.5 kW welding transducers, high “Q” tooling, and digital power supply control strategies; the application of a 10 kW ultrasonic torsion welding system to automotive alloys; and the development of 11 kW push-pull, 7 kW over-under, and one-sided ultrasonic metal welding systems will be presented. A 5.5 kW peak power ultrasonic transducer has been developed to meet the high power requirements of thick section metal welds and is being applied to lateral drive and push-pull ultrasonic metal welding systems. Power supply modifications, as well as high Q tooling, have been used to achieve more robust process control. Dual transducer systems (push-pull and over-under) have been developed to expand the power output, and hence types and thicknesses of materials that can be welded. One sided ultrasonic metal welding systems have been developed to achieve tooling simplification, improved accessibility, and reduced cost, with weld performance comparable to that of traditional ultrasonic welding systems. Finally, through weld tooling modifications and parameter optimization, ultrasonic torsion welding has been developed for application to automotive aluminium sheet alloys. A new generation of ultrasonic welding systems, having higher powers, advanced controls and innovative means of delivering ultrasonic energy to the weld, is greatly expanding the potential applications of ultrasonic metal welding.

Ultrasonic welding is unique in that no connective bolts, nails, soldering materials, or adhesives are necessary to bind the two parts together. This saves greatly on manufacturing costs and creates visually attractive (i.e., unnoticeable) seams in product domains where appearance is important. Because ultrasonic welding is a largely automated process, all a technician needs to do is pull a lever and the welding is complete. The downside of ultrasonic welding is that it only applies to small components - watches, cassettes, plastic products, toys, medical tools, and packaging. The chassis of an automobile, for example, cannot be assembled with ultrasonic welding because the energies involved in welding larger components would be prohibitive. The technology of ultrasonic welding appeared in the early 90s and has been under rapid development since then. As the technology improves, the range of materials that can be joined together using this technique increases. At first only non-flexible plastics could be welded because their material properties allowed the efficient transmission of acoustic energy from part to part. Nowadays, less rigid plastics such as semi crystalline plastics can be welded because large amounts of acoustic energy can be applied to the welding zone. As the technology matures and becomes more versatile, it is likely to obsolete large classes of historical techniques for joining materials together. The technique of ultrasonic welding is ideally suited to the bonding of non-ferrous metals and ceramic and coated materials. Its main advantages being : Very short welding times The ability to weld together different materials No need for fillers Minimal electric transitional resistance values Helium tight welds Ultrasonic welding of automotive aluminium alloys is a complex solid state bonding process involving rapid frictional and shearing plastic deformation and heating at the faying surfaces, as well as at the tooling interfaces of the parts. While these mechanics-based conditions do not create a bond, they do bring about the conditions for subsequent metallurgical bonding, so that their understanding is critical to any full understanding, including modelling, of the ultrasonic welding process. Further, because forces, velocities and temperatures are all part of describing the process mechanics, they become potential measurement tools for sensing and control of welding Ultrasonic spot welding has been recognized as a promising technology in joining automotive sheet metal. Compared to conventional resistance spot-welding techniques, ultrasonic welding provides a low-energy bonding technique, and is especially suitable to join aluminium alloys. Ultrasonic vibrations of a specially designed welding tip can lead to a solid state bond across the interface between two components without any melting of the alloy.

C. History

Ultrasonic waves were first used to detect flaws and for cleaning after World War II. Ultrasonic metal welding as well as the joining of plastics using ultrasonic welding were first demonstrated in the 1950s. One of the first patents in ultrasonic welding was awarded to Aero projects Inc. in 1960. Ultrasonic welding was first used commercially to join fine wires for electronics. Practical application of ultrasonic welding for rigid plastics was completed in the 1960s. At this point only hard plastics could be welded. The patent for the ultrasonic method for welding rigid thermoplastic parts was awarded to Robert Sol off and Seymour Linsley in 1965. Sol off, the founder of Sonics & Materials Inc., was a lab manager at Branson Instruments where thin plastic films were welded into bags and tubes using ultrasonic probes. He unintentionally moved the probe close to a plastic tape dispenser and the halves of the dispenser welded together. He realized that the probe did not need to be manually moved around the part but that the ultrasonic energy could travel through and around rigid plastics and weld an entire joint. He went on to develop the first ultrasonic press. The first application of this new technology was in the toy industry. The first car made entirely out of plastic was assembled using ultrasonic welding in 1969. Even though plastic cars did not catch on ultrasonic welding did. The automotive industry has used it regularly since the 1980s. It is now used for a multitude of applications. Ultrasonic welding can use for both hard and soft plastics, such as semi crystalline plastics, and metals. Ultrasonic welding machines also have much more power now. The understanding of ultrasonic welding has increased with research and testing. The invention of more sophisticated and inexpensive equipment and increased demand for plastic and electronic components has led to a growing knowledge of the fundamental process. However, many aspects of ultrasonic welding still require more study, such as relating weld quality to process parameters. Ultrasonic welding continues to be a rapidly developing field.

II. LITERATURE REVIEW

1) Ultrasonic welding equipment by Johs n. antonevich. IRE transaction on ultrasonic engineering Reprinted from the 1959 [31]. This work has been reported on investigations into the basic principles of ultrasonic welding. Until these principles are understood, the development of ultrasonic welding equipment will continue to be empirical and the limitations of the process will remain unknown.
2) New methods of ultrasonic metal welding by Jiromaru TSUJINO 1995 [14] New methods of ultrasonic metal welding and characteristics of the welded specimens are studied. For welding of small specimens such as thin wire bonding, the bonding equipments designed using higher vibration frequency and complex vibration welding tips of 90, 120 and 190 kHz are significantly effective.
3) Process Innovations in Ultrasonic Metal Welding by Jay Sheehan, Elizabeth Hetrick, Janet Devine, Karl Graff, Joe Walsh, Larry Reatherford, David Scholl, Zachary Berg 1997. [20] The extension of ultrasonic metal welding to automotive and aerospace structures and components requires advances in current welding systems, as well as new systems able to address the materials and quality and production conditions of these industries. This presentation will detail recent advances to increase ultrasonic metal welding power capability, develop alternative welding configurations to meet vehicle joint configuration requirements, and implement more robust process control. Specifically, the development of new high power 5.5 kW welding transducers, high “Q” tooling, and digital power supply control strategies.
4) The Ultrasonic Welding Mechanism as Applied to Aluminium by GEORGE G. HARMAN, 1997 [26] This paper he has represents a review as well as an extension of previous work concerned with the mechanism of microelectronic ultrasonic welding for both aluminium and gold wires. A series of experiments was carried out to determine the mechanism of gold to gold ultrasonic bonding. These experiments, including lift-off pattern studies, clamped-wire studies, and bond deformation versus ultrasonic vibration amplitude studies, indicate that gold ultrasonic bonding takes place primarily by means of a deformation mechanism as opposed to a heating or sliding mechanism.
5) Complex vibration ultrasonic welding systems with large area welding tips.by J. Tsujino, T. Ueoka, T. Sano, S. Tanaka Ultrasonic Symposium, 2000 IEEE. [6] Vibration and welding characteristics of complex vibration ultrasonic welding systems of 27 and 40 kHz were studied. Complex vibration systems, which have elliptical to circular or rectangular to square locus, are effective for ultrasonic welding of various specimens including the same and different metal specimens, and for direct welding of semiconductor tips and packaging of various electronic devices without solder.
6) Welding characteristics of 40 kHz ultrasonic plastic welding system using fundamental and higher resonance frequency vibrations by Tsujino, J; Hongoh, M. ; Ueoka, T. Fac. of Eng., Kanagawa Univ., Yokohama, Japan Ultrasonics Symposium, 2002. [32] The welding characteristics of 40 kHz ultrasonic plastic welding system using fundamental and higher-resonance-frequency vibrations were studied. At high frequency, welding characteristics can be improved due to the larger vibration loss of plastic materials. The 40 kHz welding tip vibrates at a maximum velocity of more than 3.0 m/s (peak-to-zero value) at a fundamental resonance frequency and there are several higher resonance frequencies up to 107 kHz whose vibration velocities are more than one-fourth that of the fundamental frequency.

III. RESEARCH METHODOLOGY

A. Research Objectives

1) To preparing the specimen with Aluminum plate specimen of 0.5 mm in thickness and 20 mm in width.
2) Optimising the parameters i.e. voltage, current, pressure and strength of the material with the welding perimeter areas.
3) Analyse the effect of behaviour of thermal conductivity of the used material for welding with the Taguchi Method.

B. Taguchi Philosophy

Taguchi addresses design and engineering (off-line) as well as manufacturing on line quality. This fundamentally differentiates Taguchi methods from the Statistical Process Control (SPC), which is purely an on line quality control method. Taguchi ideas can be distilled into three fundamental concepts:

1) Achieving high system quality levels economically requires quality to be designed into the product. Quality is designed but not manufactured into the product.
2) Quality losses must be defined as deviations from target not conformance to arbitrary specifications.
3) Quality is best achieved by minimizing the deviation from a target.

C. Signal to Noise Ratios (S/N Ratios)

The S/N ratio is computed from the mean square deviation (MSD) by the equations:

$$S/N = -10 \log_{10}(MSD) \qquad \ldots\ldots(i)$$

For the S/N ratio to be large, MSC must have a value that is small.

If smaller is the best quality characteristic;

$$MSD = [(Y_1^2 + Y_2^2 + \text{----------------} + Y_n^2)] / N \qquad \ldots\ldots.(ii)$$

Where, Y_1, Y_2 ------------ Y_n are the quality characteristic.

If nominal is the best quality characteristic;

$$MSD = [(Y_1 - Y_0)^2 + (Y_2 - Y_0)^2 + \text{-------} + (Y_n - Y_0)^2 \qquad \ldots\ldots..(iii)$$

Where, Y_0 = target or nominal value

If larger is the best quality characteristic;

$$MSD = [(1/Y_1^2 + 1/Y_2^2 + \text{---------------} + 1/Yn^2)] /N \qquad \ldots\ldots..(iv)$$

The S/N ratio analysis is designed to measure quality characteristic. This is Taguchi's solution to Robust Product or Process Design.

D. Procedure And Steps Of Taguchi Parameter Design

1) *Step-1:* Selection of the quality characteristic

There are three types of quality characteristics in the Taguchi methodology, such as smaller-the-better, larger the- better, and nominal-the-best.

2) *Step-2:* Selection of noise factors and control factors

In this step, the controllable factors are Radial Force Component (RC), Lateral Force Component (LC)andConicity , which were selected because they can potentially affect the tyre uniformity. Since these factors are controllable in the production process, they are considered as controllable factors in the study.

3) *Step-3:* Selection of Orthogonal Array

There are 9 basic types of standard Orthogonal Arrays (OA) in the Taguchi parameter design (GEnichi Taguchi and Yu-in Wu, 1979). An L_9 Orthogonal Array is selected from Appendix B, 2nd edition, 2005, Taguchi Techniques for Quality Engineering. for this research. The layout of this L_9 OA is shown in Table 3.1.

4) *Step-4:* Conducting the experiments

Table 3.1 illustrates the experimental settings in this research for minimize variation of force which help to increase uniformity of tyre. The tools used in this experiment are Radial Force Component (RC), Lateral Force Component (LC) and Conicity . After the data were collected and recorded in Table 5.7, signal-to-noise ratios of each experimental run were calculated based on the following equation, which are listed in Table 5.8 with the experimental data and is defined as

$$S/N \text{ Ratio } (H_i) = -10 \operatorname{Log}_{10} [MSD] \qquad \ldots\ldots..(v)$$

Where, $MSD = [Y_1^2 + Y_2^2 + \ldots\ldots\ldots. Y_n^2]$;

The average response values were also calculated and recorded in Table 5.3.

5) *Step-5:* Analyzing the results and determining the optimum cutting conditions

a) *Analysis of Raw Data and S/N ratios:* After raw data were collected (Table), average effect response values (Table) and S/N response ratios (Table), respectively, we calculated. The steps to evaluate the following are discussed in Chapter.

b) *Determination of the Optimum Factor-Level Combination:* The S/N ratio indicates the degree of the predictable performance of a product or process in the presence of noise factors. Process parameter settings with the highest S/N ratio always yield the optimum quality with minimum variance. Consequently, the level that has a higher value determines the optimum level of each factor.

6) *Step-6:* Predicting Optimum Performance

Using the aforementioned data, one could predict the optimum combination of Radial Force Component (RC), Lateral Force Component (LC) and Conicity. With this prediction, one could conclude that which combination will got the minimum variation Between RC, LC CONYCITY help to increase uniformity of tyre in target achievement within the range of specified combinations of the variables. A confirmation of the experimental design was necessary in order to verify the optimum variables combination.

7) *Step-7:* Establishing the design by using a confirmation experiment

The confirmation experiment is very important in parameter design, particularly when screening or uniformity factorial experiments are utilized. The purpose of the confirmation experiment in this study was to validate the optimum force variation. Selection of Orthogonal Array

There are 4 basic types of three level arrays from standard Orthogonal Arrays (OA) from the Genichi Taguchi parameter design (Genichi Taguchi and Yu –in Wu, Offline Quality control, 1979). An L_9 Orthogonal Array is selected for this research work. The layout of this L_9 OA is as mentioned in Table 3.1. (2nd edition, 2005, Taguchi Techniques for Quality Engineering, Philip J Ross [14], Tata McGraw- Hill Publishing Company limited)

Experiment	X1	X2	X3
1	L	L	L
2	L	M	M
3	L	H	H
4	M	L	H
5	M	M	L
6	M	H	M
7	H	L	M
8	H	M	H
9	H	H	L

Table 3.1 the Basic Taguchi L_9 Orthogonal Array

IV. RESULTS

A. Welding in Perimeter

Of these, long bonding times certainly contribute to this inward growth as seen from the lift-off patterns, shown the welding at perimeter.

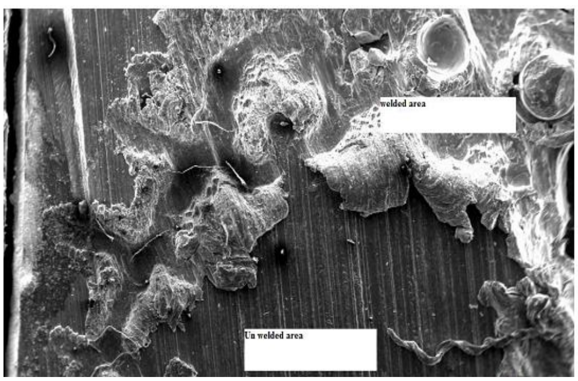

Fig. 4.1 Welded surface

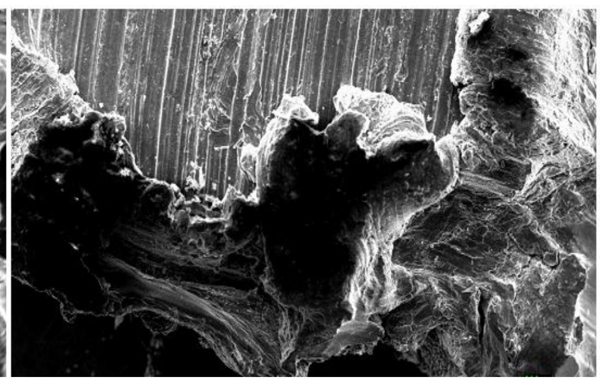

Fig. 4.2 Welded surface (in perimeter)

Fig. 4.3 Showing the welding at perimeter

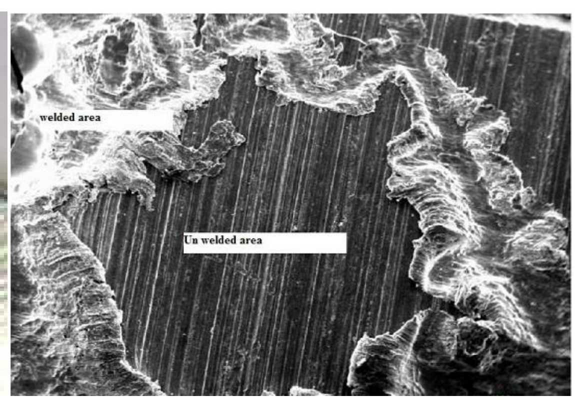

Fig. 4.4 Ultrasonically welded piece

Showing the welding at perimeter Deformation of weld area around the entire periphery of the bonded area similar to the welding in given figure. It has concluded that the observed peripheral damage to the substrates does not support a concept of the plates being scrubbed across the substrate surface during bonding.

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B. Welded Area Deformation with Vibration Amplitude

Welding area different for different vibration amplitude .by increasing vibration amplitude welding area is more deflected as shown in Fig. 4.5 Vibration may cause the fracture in welded area. Fig. 4.7 show that the softening of work piece at knurled line impression.

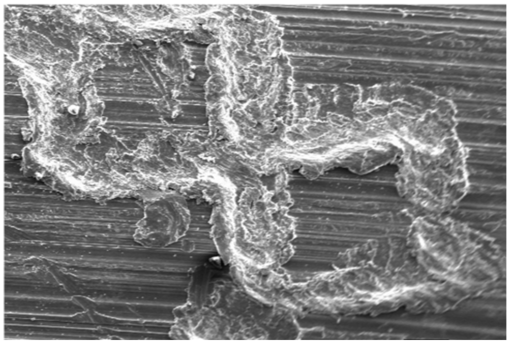


Fig. 4.5 Knurled line impression of sonotrode by Softening

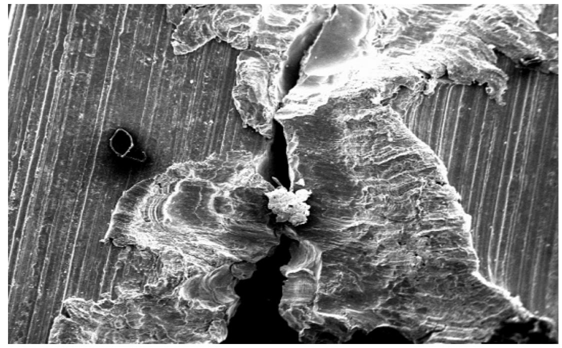


Fig. 4.6 Fracture during welding

C. Welding Parameter

A determination of optimum welding parameters is completed by the manufacturing before a decision on the tool design and the fixture is prepared. The parameters varied depending on variations in materials, dimensions, and surface contamination. Controlling and monitoring device that defined data with individual tolerances and adjusts the individual parameters during the welding process automatically.

D. Process-Variable

However, the following variable parameters can be controlled: Welding time and welding energy. Mechanical compression of the parts to be welded (difference in thickness before and after welding.

E. Temperature Rise In The Welding Area (No Fusion)

Ultrasonic welding is local type and it is limited to the shear forces and displacement of intermediate layers. There is no requirement of fusion if all the controllable factor like pressure force, amplitude and the welding time have been properly adjusted (as per requirement of product). However, optical and electronic microscopes make re-crystallization, diffusion and other metallurgical phenomena evident in Microscopic analyses. As there is no evidence of fusion (material melted). There is an initial quick rise in temp. (Steady temp. drop afterward) in intermediate layers, as monitored by highly sensitive device (thermal).

F. Joint Design And Weld Location

Parts which are ultrasonically welded designed with very small amount of extra material on the join line on one half, with a slight recess in the second half. This means when the parts are going to weld together, there is enough materials for the parts to fuse together with a strong strength joint. It means there are no addition adhesives or Connecting parts are required to create the joint, this is not only saving money but also makes the process quicker to carry out.

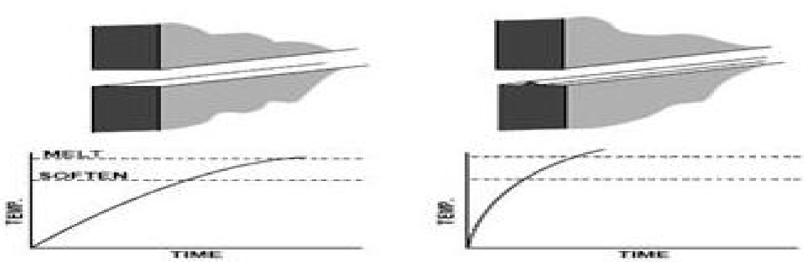


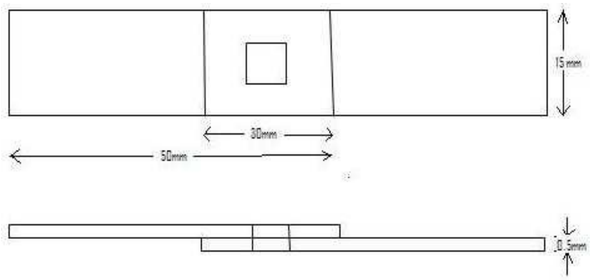
Fig. 4.8 Temperature profile for joint design

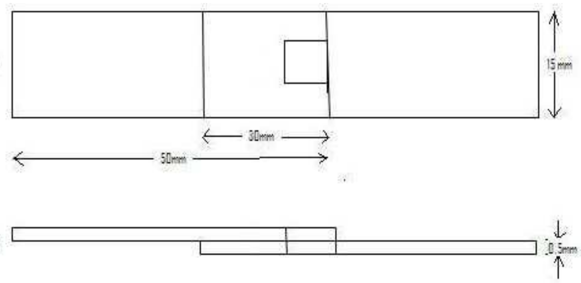
The prerequisite is that both working pieces have a near equivalent melting point. The joint quality is very uniform because the energy transfer and the released internal heat remains constant and is limited to the joining area. In order to obtain an optimum

G. Location Of Weld

During the welding, heat is generated by ultrasonic vibration, that heat is used to soften the work piece, in that soften it is easy to form a welded joint with the help of static pressure. If we weld (horn in middle) at middle of the lap then joint it may not use whole generated heat energy to form a strong joint ,but if we put horn at any end edge (either side)of the lap joint, we get strong welded joint than at middle if all parameters are same.

Top view





Front view

Fig. 4.9 welding at middle of lap

Fig. 4.10 Welding at end edge of lap

Reason behind that is at the middle of the lap, generated heat energy flow through the metal piece to be welded that is having high thermal conductivity. At middle the all directions are available for conduction of heat but if we put the horn at end edge of lap for the welding then direction available for the heat flow only one or two, in other direction air medium is there, that having very low thermal conductivity compare to metal pieces that are to be welded. The energy given to booster in form of vibration is converted in to the heat, that heat is responsible for the softening the material to be welded, but if generated heat is not used properly, weld joint may be weakened or not form the joint, so concentration should be on to best utilization of generated heat. So, it has been seen during ultrasonic welding that welding should be at the end edge of the lap for getting good quality of welding joint.

H. Experimentation And Data Collection

Symbols	Process parameter	Levels		
		Low	Medium	High
V	Voltage (Volt)	230-235	340-350	450-500
I	Current (amp)	1.5	4.5	7.5
P	Pressure (MPa)	.34	.50	.56

Table 4.1: - Parameters and their levels of experiment

I. Experimental Results

Experiment no.	Voltage (v)	Current (amp)	Pressure (MPa)	Strength (Kg)
1	230	1.5	.34	3.5
2	235	4.5	.50	9.5
3	235	7.5	.56	10
4	350	1.5	.56	11
5	350	4.5	.34	7
6	350	7.5	.50	8.5
7	500	1.5	.50	9
8	500	4.5	.34	13.5
9	500	7.5	.56	8

Table 4.2: - Consolidated design of experiment table

In this experiment of work, the controllable factors counted are Voltage (V), Current(I) and pressure(P). Since these factors are major contributor for affecting strength and welding operation and these factors are controllable in the ultrasonic welding process (adjustable in M/c), they are considered as a controllable factor.

J. Signal To Noise Ratio Or S/N Ratio

The response variable considered is strength, which is of greater in better kind. Therefore, signal to noise ratio is defined by

$$S/N \text{ ratio} = -10\log_{10}(1/N\sum Y_i^2)$$

Where Y_i is the individual measurement of strength at each location.

Experiment no.	Strength (Kg)	S/N ratio
1	3.5	-10.88
2	9.5	-19.56
3	10	-20
4	11	-20.82
5	7	-16.90
6	8.5	-18.59
7	9	-19.08
8	13.5	-22.60
9	8	-18.06

Table 4.3: - S/N ratio summary sheet

K. Analysis of Means and Response Graph For Strength

1) *Analysis of Means:* The analysis of each controllable factor (Volt, Current, Pressure) is studied and the main effect of these factors is obtained in table. Each factor has its effect at individual level i.e. at High, Medium and low level is equal to the mean of strength of all experiments with the factor at individual level.

The main effect of voltage (V) on strength at various levels calculated as follows-

L = (3.5+9.5+10)/3 =7.66 Kg, M = (11+7+8.5)/3 =8.83 Kg, H = (9+13.5+8)/3 =10.16 Kg

a) The main effect of current (I) on strength at various level calculated as follows-

L = (3.5+11+9)/3 =7.83 Kg, M = (9.5+7+13.5)/3 =10 Kg, H = (10+8.5+8) = 8.83 Kg

b) The main effect of pressure (P) on strength at various level calculated as follows-

L = (3.5+7+8)/3 = 6.16 Kg, M = (9+9.5+8.5)/3 = 9 Kg, H = (10+11+13.5)/3 = 11.5 Kg

Symbols	Controllable factors	Strength (Kg)		
		Low	Medium	High
V	Voltage	7.66	8.83	10.16
I	Current	7.83	10	8.83
P	Pressure	6.16	9	11.5

Table 4.4: - Mean response for strength

L. Response Graph For Means

The value observed from the response table is drawn (plotted) to visualize the effect of three parameters (V, I, P). From the means response graph observation finding are shown as follows-

1) Level III for voltage (V_3) =10.16 Kg indicated as the optimum situation in terms of strength.
2) Level II for current (I_2) =10 Kg indicated as the optimum situation in terms of strength.
3) Level III for voltage (P_3) =11.5Kg indicated as the optimum situation in terms of strength.

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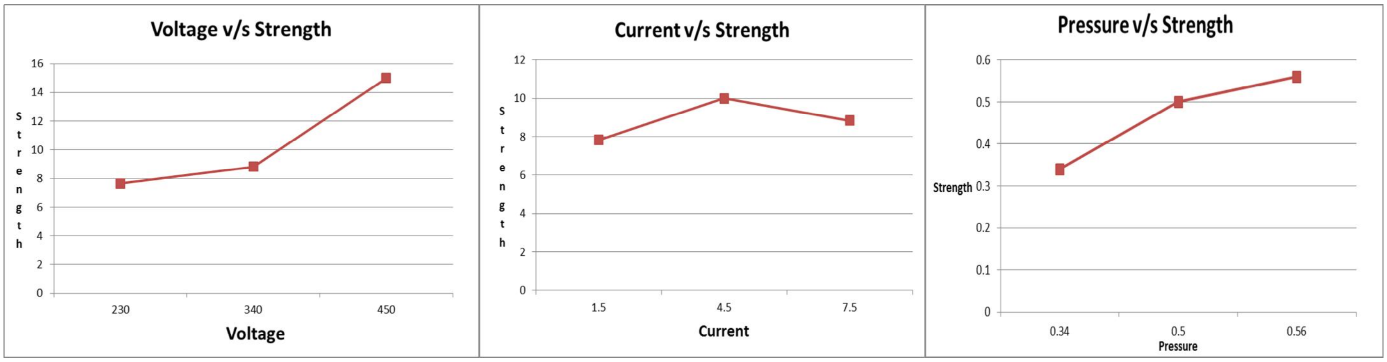
Main effect plot for Strength(Data means)



(a) Strength v/s Voltage (b) Strength v/s Current (c) Strength v/s pressure

Fig. 4.11 Mean response graph for strength

a) *Analysis Of Means And Response Graph For S/N Ratio:* The objective of using the S/N ratio as a performance measurement is to develop products and processes insensitive to noise factor. The S/N ratio indicates the degree of the predictable performance of a product or process in the presence of noise factors. The smallest S/N ratio always Yield the optimum quality with minimum variance.

(a) The main effect of voltage on S/N ratio at various level calculated as follows:

L = (-10.88-19.56-20)/3 =-16.81 dB, M = (-20.82-16.9-18.59)/3 =-18.77 dB, H = (-19.08-22.6-18.06)/3 =-19.91 dB

(b) The main effect of current on S/N ratio at various level calculated as follows:

L = (-10.88-20.82-19.08)/3 =-16.92 dB, M = (-19.56-16.9-22.6)/3 =-19.68 dB, H = (-20-18.59-18.06)/3 = -18.88 dB

(c) The main effect of pressure on S/N ratio at various level calculated as follows:

L = (-10.88-16.9-18.06)/3 = -15.28 dB, M = (-19.08-19.56-18.59)/3 = -19.07 dB, H = (-20-20.82-22.6)/3 = -21.14 dB

Symbols	Controllable factors	S/N ratio (dB)		
		Low	Medium	High
V	Voltage	-16.81	-18.77	-19.91
I	Current	-16.92	-19.68	-18.88
P	Pressure	-15.28	-19.07	-21.14

Table 4.5 Mean Response

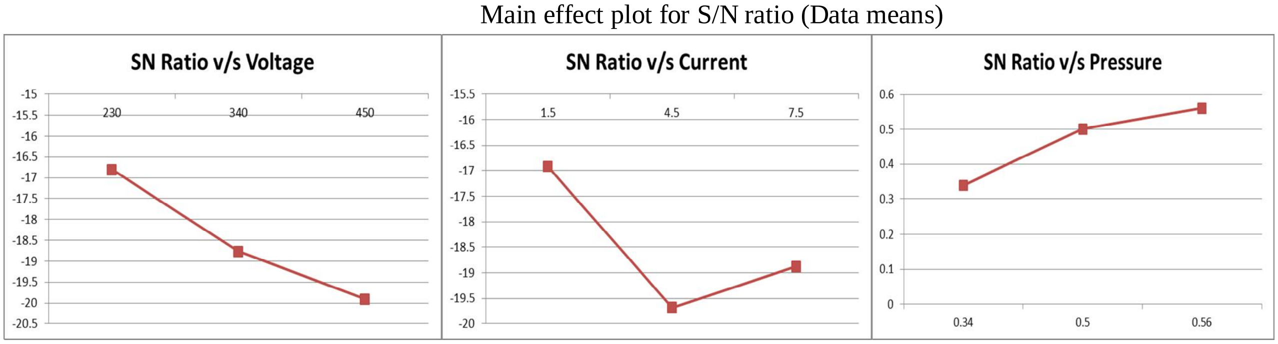
The value obtained from the response table are plotted to visualize the effect of three parameters. From the means response graph observation finding are illustrated as follows-

i) Level I for voltage (V_1) =-16.81 dB indicated as the optimum situation in terms of S/N ratio

ii) Level I for current (I_1) =-16.92 dB indicated as the optimum situation in terms of S/N ratio.

iii) Level I for pressure (P_1) =-15.28 dB indicated as the optimum situation in terms of S/N ratio

Main effect plot for S/N ratio (Data means)



(a) S/N ratio v/s voltage (b) S/N ratio v/s Current (c) S/N ratio v/s pressure

Fig. 4.12 Mean response graph for S/N ratio

V. CONCLUSIONS

From the experimental results following conclusion can be drawn: -

A. Welding characteristics of 20 kHz ultrasonic welding system was performed using aluminum sheets specimen. Aluminum plate specimen of 0.5 mm in thickness and 20 mm in width were successfully welded.
B. I found, ultrasonic weld formation always begins around the perimeter, but that no two-time equivalent patterns are exactly the same.
C. Found, weld location should be considered in ultrasonic lap joint welding, due to effect of thermal conductivity of metals weld location also affect the welded quality.
D. And welding at end edge of lap give comparative good welded quality and the more effectiveness of ultrasonic welding system.
E. With increasing energy, weld strength also increases up to a certain value further increase does not affect much weld strength with the Taguchi technique, so excessive welding energy should be avoided.

The weld formation occurs due to knurled lines of sonotrode. Weld time increases the welded area grows in ward from perimeter. Assemblers who are using these ultrasonic welding process, is not aware about the allotment of time for warm up or cool down, which is very essential in other joining process, such as hot plate welding. It is a solid-state process used for similar or dissimilar metals of both thin and thick cross section and the very important thing is that in this process energy consumption is low and weld time are short. Ultrasonic welding compared to resistant, arc welding, noted in welding lab try, it is an alternative joining process, resistant, arc welding tooling will typically need to be changed daily in an automated environment, and the electrode will need to be removed, dressed by mechanist and then realized in the fixture, which is time consuming.

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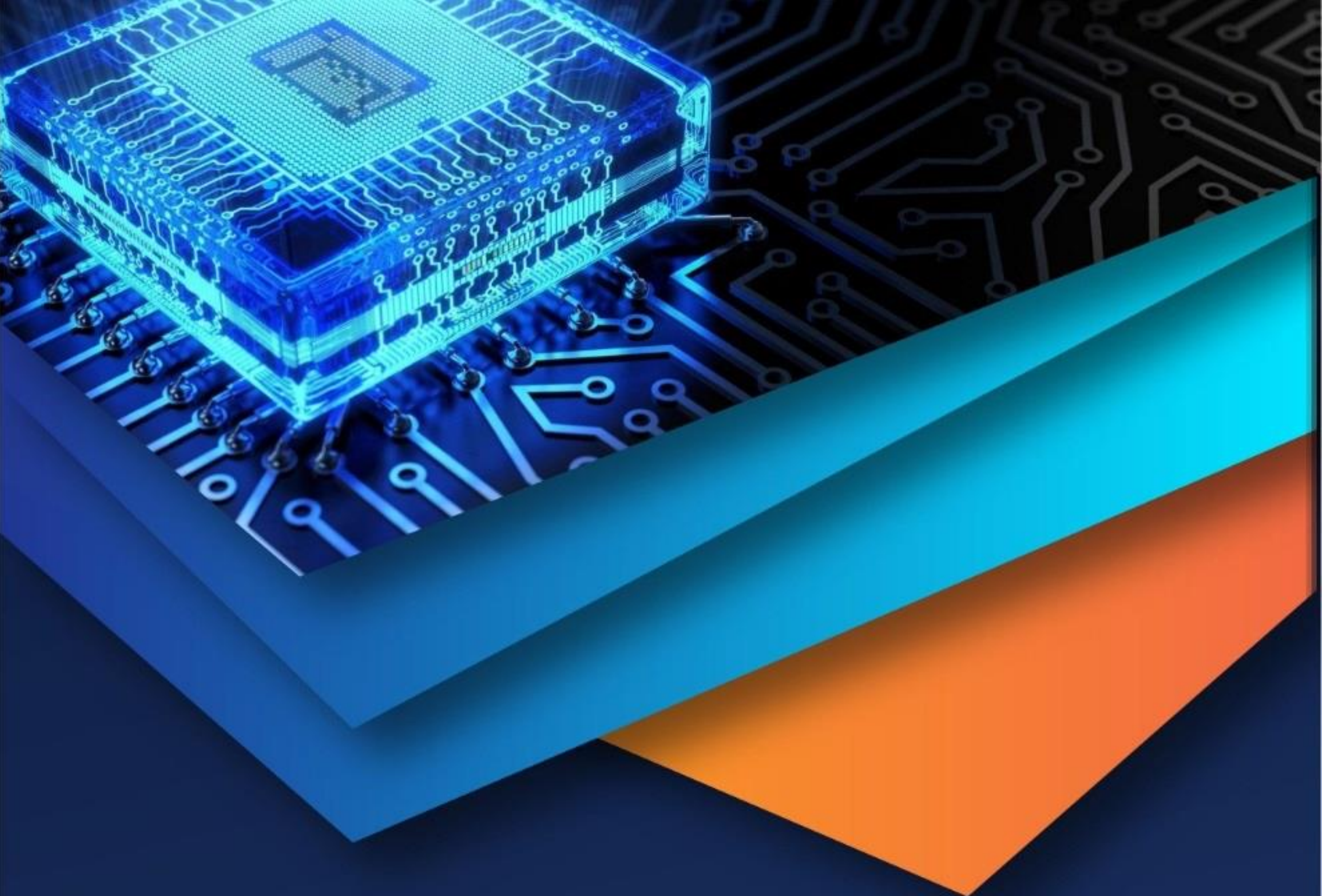

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