A

MAJOR THESIS

ON

ANALYSIS OF BONDING MECHANISM AND CHARACTERSTICS OF ULTRASONIC WELDING SYSTEM

SUBMITTED IN THE PARTIAL FULFILLMENT FOR THE DEGREE OF

MASTER OF ENGINEERING
IN
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Under the guidance of.
Prof. Dr. C.K. Dutta
Sr. Professer
Mechanical Engg. Dept.

Submitted by
Mr. Kedari Lal Dhaker
University Roll No : 10253

Mechanical Engineering Department
Delhi College of Engineering
(University of Delhi)
DELHI
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CERTIFICATE

DELHI COLLEGE OF ENGINEERING
UNIVERSITY OF DELHI
(Govt. of National Capital Territory of Delhi)
BAWANA ROAD, DELHI - 110042

Date:___________

This is certified that the work contained in this dissertation entitled "**ANALYSIS OF BONDING MECHANISM AND CHARACTERSTIC OF ULTRASONIC WELDING SYSTEM**" by **Mr. KEDARI LAL DHAKER** is the requirement of the partial fulfillment for the award of degree of **Master of Engineering(M.E.)** in **Production Engineering** at **Delhi College of Engineering**. This work was completed under my direct supervision and guidance. He has completed his work with utmost sincerity and diligence.

The work embodied in this major project has not been submitted for the award of any other degree to the best of my knowledge.

Prof. Dr .C.K.Dutta
Sr.Professer
Mechanical Engg.Dept.
Delhi College of Engineering
DELHI.

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"If brain is the nucleus of thoughts, teacher is the source of energy to run the operation of solving cross puzzles of doubts that often poise the mind of students."

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KEDARI LAL DHAKER
M.E. Production Engineering
College Roll No. **05-Pro -2006**
University Roll No: **10253**
D.C.E. DELHI.

Abstract

In ultrasonic welding, high frequency vibrations are combined with pressure to join two materials together quickly and securely. Ultrasonic welding can join dissimilar metals in a split second , ultrasonic welding eases problematic assembly and this cost effective technique may be key to mass producing fuel efficient.

In this work effect of various parameters on weld strength have been studied .welding of .5 mm aluminum plates were successfully welded by 20 khz ultrasonic welding system . One dimensional vibration system for ultrasonic lap spot welding of metal plate of aluminum have studied .The relationships between weld strength and the variables of weld energy, duration of weld cycle, have studied Experiment on S.E.M.(scanning electro micrograph) was carried out to determine the mechanism of aluminum- aluminum and aluminum –copper plate bonding. These experiment, including effect of amplitude and pattern of bond formation.

Key words: Ultrasonic welding, SEM, 20 khz welding system, weld location.

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INTRODUCTION

1.1 General

Different energy sources can be used for welding, including ,gas flame, electric arc, laser, electronic beam, friction and ultrasonic .While often an industrial process, welding can be done in many different environment, 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 aluminum 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.ultra sonic 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 aluminum 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 hardnesses, automotive parts, medical devices, rechargeable batteries and copper tubing HVAC equipments.
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 specimen 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 can not 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. Aluminum 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.

1.2 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). 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

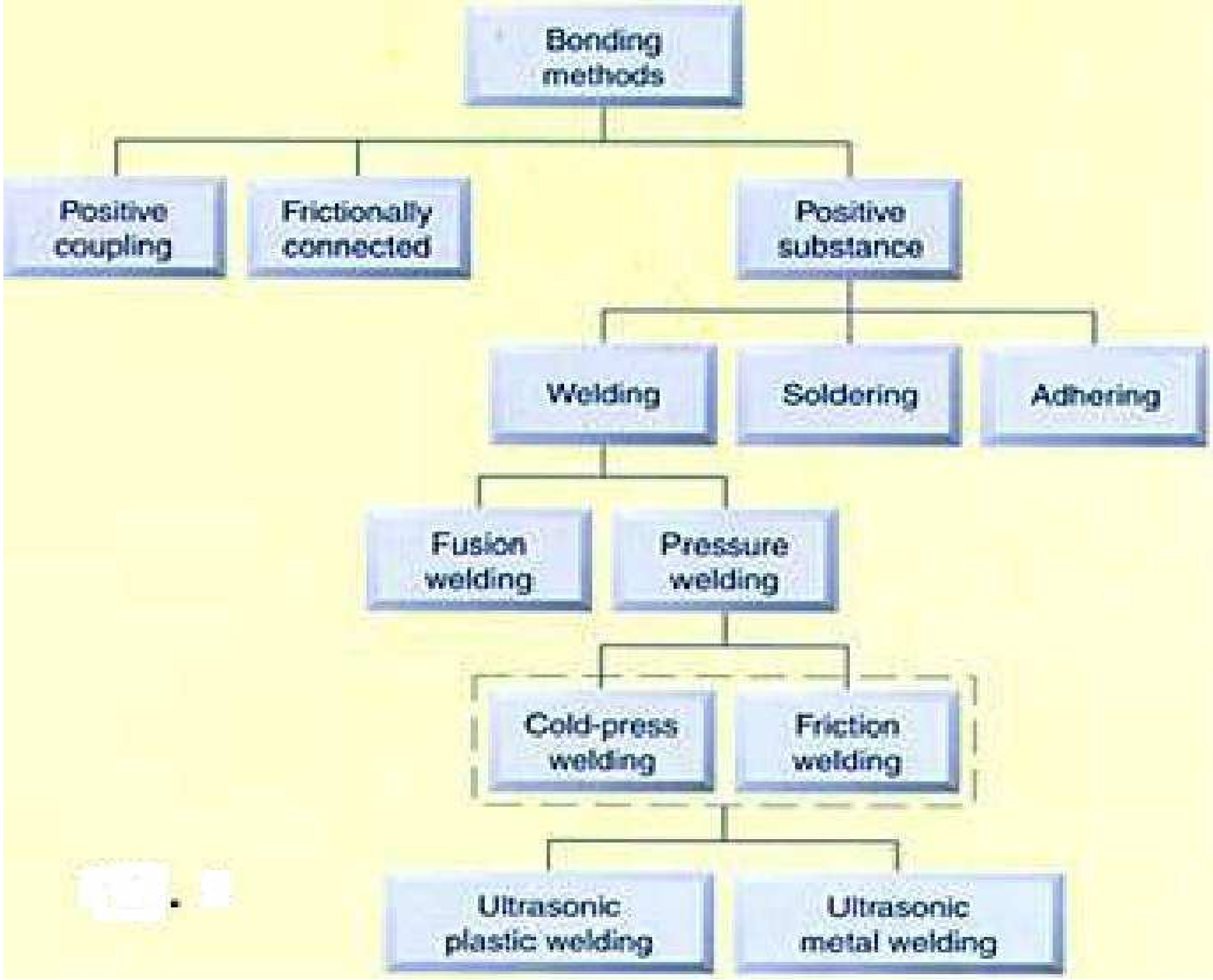

***Figure 1**: classification of welding by their action principle*

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1.3 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.

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 welds 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. Onesided 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 aluminum 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 ubsequent metallurgical bonding, so that their understanding is critical to any full
understanding, including modeling, 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 aluminum 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.

1.4 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 Aeroprojects 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 Soloff and Seymour Linsley in 1965. Soloff, 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 unintentially 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 multitiude of applications.

Ultrasonic welding can used for both hard and soft plastics, such as semicrystalline 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

Chapter:2

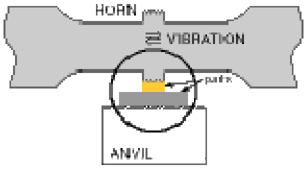
ULTRASONIC WELDING

2.1 Principle

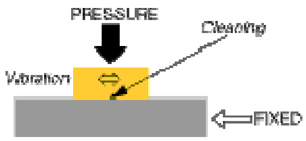
Ultrasonic welding is unique in that no connective bolts, nails, soldering materials, or adhesives are necessary to bind the two parts together. This saves greatly on manufacturing costs and creates visually attractive (i.e., unnoticeable) seams in product domains where appearance is important. Because 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.

Ultrasonic metal-welding is an advanced technical process for combining nonferrous metals, stranded wire and many metal-alloys. It is a cold-phase friction welding technique; there is no melting, no high-temperature buildup. The surfaces being joined are subjected to high-frequency mechanical oscillations while being rubbed together under pressure. The molecules of the surfaces begin to swirl and intermingle with one another, creating a firm and lasting bond. Improvements in quality and efficiency, reduced energy requirements and positive environmental factors are the decisive advantages of this new technology.

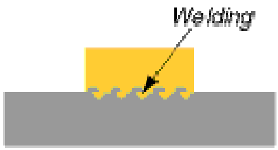
Ultrasonic Welding is a process whereby mechanical energy, developed through the transformation of high frequency alternating current into mechanical vibration (by piezoelectric ceramic transducers) is transmitted through a metal tool called a horn (or sonotrode) to the interface of two overlapping surfaces to be joined, supported by a static suitable anvil, producing intimate contact and welded joint.



The process of ultrasonic metal welding uses high-frequency vibrations. Ultrasonic metal welding works by placing the parts to be welded on the anvil.



Next, force is applied to the parts. Then the upper part is vibrated back and forth with the ultrasonic horn.



This causes the parts to rub together. The ultrasonic energy disperses oxide film layers (cleaning the surface) and results in the mixing of metal atoms, without melting the metals. The activated metal atoms join each other, causing a true metallurgical bond.

Ultrasonic metal welding is sometimes called "cold welding" because it works without melting the metals. It cleans and welds at temperatures lower than the melting point of the metals. It most commonly joins nonferrous metals, but can also be used with others, such as when welding aluminum to ceramics.

Fig.2.ultrasonic welding principle

2.2 Ultrasonic Metals Welding

The system that is used to scrub the pieces together consists of four major components. The first of these is the anvil. This is simply a piece of the machine, usually with a replaceable head, that holds one of the components still while the other is rubbed against it. The "business end" of the ultrasonic system consists of three major parts. The first of these is the ultrasonic transducer. This component takes an electrical signal from a power supply that is providing a 20khz AC signal and converts it to a mechanical motion at the same frequency as shown in fig 3. The vibration that results is at a frequency that is appreciably above the range of human hearing, hence the name ultrasonic. There is a power supply which elevates the frequency of the electrical current from the grid, then the transducer that transforms electrical into mechanical energy, then a booster that modifies the shape and magnitude of vibrations an finally the horn that vibrates the material to be welded, while it is clamped unto the stationary anvil.

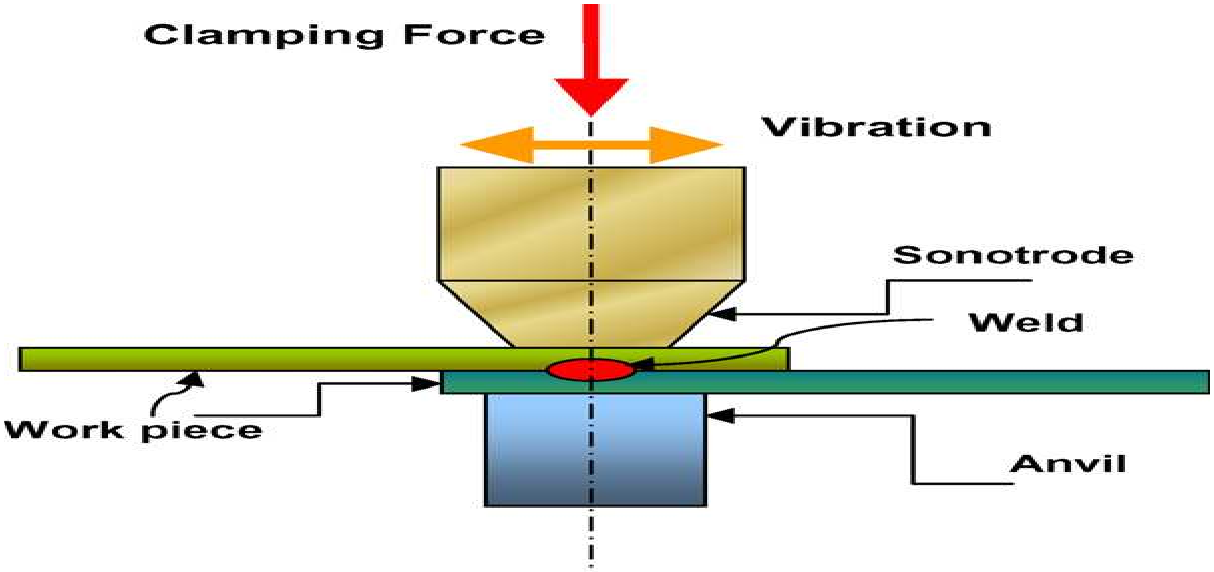


Fig.3. ultrasonic metal welding

This same principle is applied somewhat differently to plastic or to metallic materials.For plastics the vibrations under pressure are in the direction normal to the interface, the frequency is mostly 20 to 40 kHz (kilohertz or thousand cycles per second) and the amplitude of oscillations is in the range of 20 to 80 microns (thousandth of mm). This generates frictional heat at the interface, melting the materials together. Medical items are among the most demanding applications. Other uses are for Appliance, Automotive, Consumer, Electrical, Packaging and Toys. An annoying limitation is that large parts cannot be welded by this method**.**

The process of ultrasonic welding is fairly simple. It begins when the parts that are to be welded, such as two multi-strand copper wires for example, are placed together in the welding unit. The system then compresses the wires together with a force of between about 50 and several hundreds pounds per square inch to form a close connection between the two pieces. Next, the ultrasonic horn is used to vibrate the two pieces together at a rate of around 20,000 or 40,000 hertz, depending on the application.

2.3 Theory

In metallurgical terms, ultrasonic metal welding is classed as a cold welding process. Because of intense friction at the welding points the oxide skin is broken open and the two parts pressed together, while at the same time pressure is exerted. These processes trigger the action of atomic binding forces. The relatively small temperature increase is far below the melting temperature and makes little contribution to the bonding. As there are no structural changes to the base material, this process does not suffer from the adverse effects that such changes can bring.galling, and seizing are common terms frequently encountered in mechanical engineering. They describe various phenomena associated with friction. In general,fig.4 one or all of these phenomena can occur when material surfaces are made to slide over each other under a load. The factors determining which phenomena will be manifest are the contact pressure, temperature, and the physical and mechanical properties of the materials at or near the sliding interface. Although the common terms describing these phenomena are undesirable in reference to engineering equipment, they find use in engineering methods.

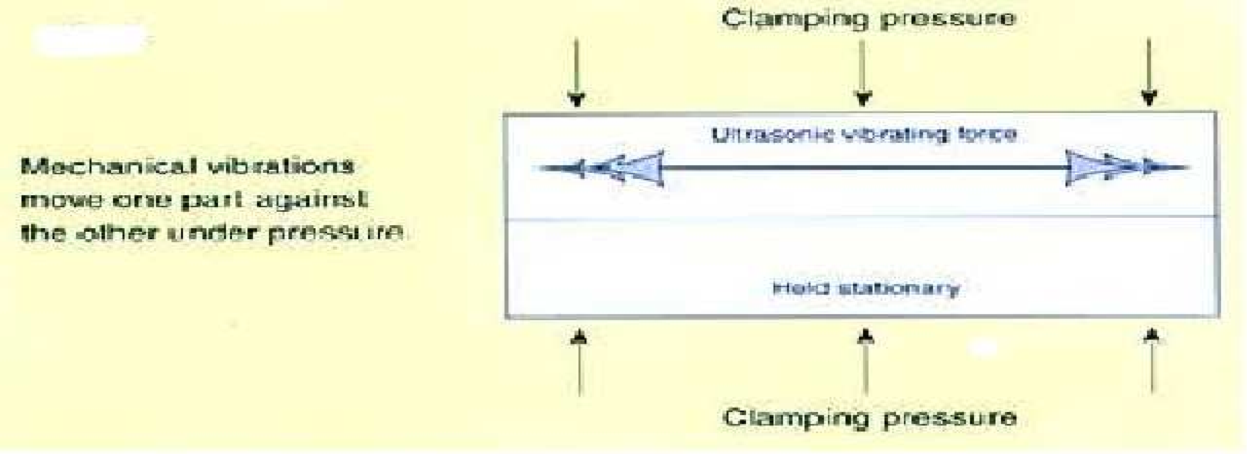


Fig.4 Mechanical vibration move one part against the other under perssure

The system that is used to scrub the pieces together consists of four major components. The first of these is the anvil. This is simply a piece of the machine, usually with a replaceable head, that holds one of the components still while the other is rubbed against it. The "business end" of the ultrasonic system consists of three major parts. The first of these is the ultrasonic transducer. This component takes an electrical signal from a power supply that is providing a 20khz AC signal and converts it to a mechanical motion at the same frequency. The vibration that results is at a frequency that is appreciably above the range of human hearing, hence the name ultrasonic.

Although this motion is very strong, it has a very low amplitude, or stroke length. This is not suitable for welding. The next part of the system, appropriately called the booster, increases the amplitude of the motion, at the cost of some of its force. This motion is then passed to the ultrasonic horn. This is the portion of the system that actually vibrates the work piece. In addition to providing the interface between the ultrasonic generator and the work piece, the horn also further amplifies the amplitude of the motion, again reducing its force. Like the anvil, the horn ends in a replaceable head. Before the interaction of the pieces at the interface can be explained, some basic molecular physics must be reviewed. The first principal is that when two clean pieces of metal are placed in intimate contact, they will begin to share electrons, thus welding together. Second, at an atomic scale even surfaces those that look perfect and smooth are very rough and impure. The majority of this impurity is in the form of metal oxides that were produced when the bare metal was exposed to the atmosphere. The second part of the contamination is in the form of ordinary dirt and oils. These impurities form a layer that prevents the electrons in the two parts from passing between them, thus preventing them from welding together. In addition, the rough surface prevents the metals from being in intimate contact, which also prevents the exchange of electrons.

2.3.1 Ultrasonic metal welding

Horizontal oscillation direction

Whereas in plastic welding, high-frequency vertical vibrations (20 to 70kHz) are used to increase the temperature and plastify the material, the joining of metals is an entirely different process. Unlike in other processes, the parts to be welded are not heated to melting point, but are connected by applying pressure and high-frequency mechanical vibrations. In contrast to plastics welding, the mechanical vibrations used during ultrasonic metal welding are introduced horizontally.

2.3.2 The mechanisms during ultrasonic metal welding

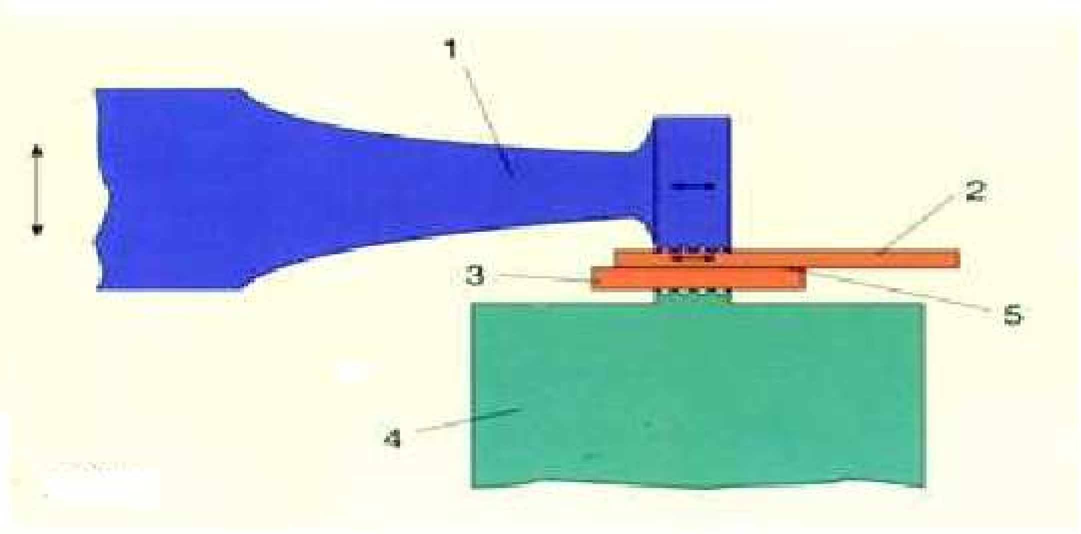


Fig.5 Ultrasonic welding mechanism

During ultrasonic metal welding, a complex process is triggered involving static forces, oscillating shearing forces and a moderate temperature increase in the welding area. The magnitude of these factors depends on the thickness of the workpieces, their surface structure, and their mechanical properties. The workpieces are placed between a fixed machine part, i.e. the anvil, and the sonotrode, which oscillates horizontally during the welding process at high frequency (usually 20 or 35 or 40 kHz) (figure 5).

The most commonly used frequency of oscillation (working frequency) is 20 kHz. This frequency is above that audible to the human ear and also permits the best possible use of energy. For welding processes which require only a small amount of energy, a working frequency of 35 or 40 kHz may be used. Before the interaction of the pieces at the interface can be explained, some basic molecular physics must be reviewed. The first principal is that when two clean pieces of metal are placed in intimate contact, they will begin to share electrons, thus welding together. Second, at an atomic scale even surfaces those that look perfect and smooth are very rough and impure. The majority of this impurity is in the form of metal oxides that were produced when the bare metal was exposed to the atmosphere. The second part of the contamination is in the form of ordinary dirt and oils. These impurities form a layer that prevents the electrons in the two parts from passing between them, thus preventing them from welding together. In addition, the rough surface prevents the metals from being in intimate contact, which also prevents the exchange of electrons

2.3.3 Fusion and pressure welding

Strong plastification

Fusion welding leads to a welding of the pieces by applying heat at the point of connection which fuses the pieces together and even joins a material. After the hardening of the mixed components, a solid joint occurs. Unlike fusion welding, pressure welding depends on the application of high pressures and/or high temperatures, resulting in a strong plastification and a local deformation of the pieces to be joined in the welding area so that a bond between both pieces is made. The energy required for the welding process is of a different kind for both types of procedure .The metallurgical bonding mechanism of ultrasonic welding has not been clearly established. It appears to be identical to the mechanism causing galling or seizing between two surfaces subjected to frictional forces .Indications are that the bonding mechanism is recrystallization and or a fusion process at the interface.

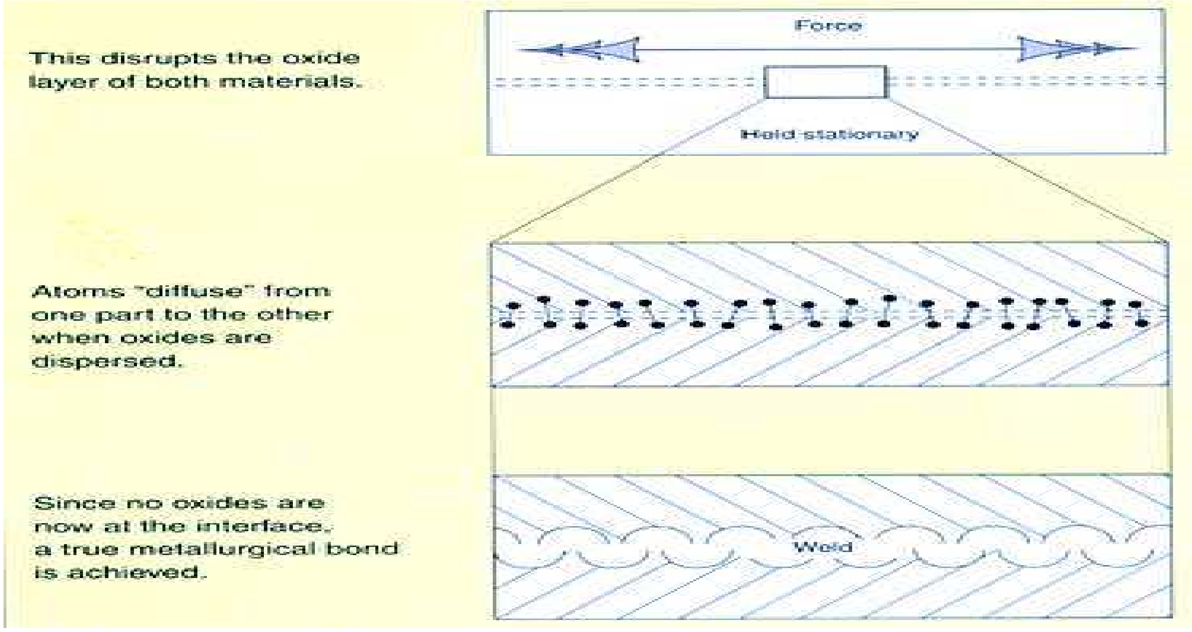


Fig.6.metallurgycal bonding of ultrasonic welding

The mechanics of ultrasonic welding are relatively simple. Then material surfaces are to be welded they are made to slide in contact with each other under a compressive force. The compressive force produces intimate contact, and the **work** done in sliding heats the interface to a temperature at which the materials will interact metallurgically to eliminate the interface. This metallurgical interaction may be fusion between materials or cohesion from intimate contact that causes the interface to become a grain boundary between the materials.

In metallurgical terms, ultrasonic metal welding is classed as a cold welding process. Because of intense friction at the welding points the oxide skin is broken open and the two parts pressed together, while at the same time pressure is exerted. These processes trigger the action of atomic binding forces. The relatively small temperature increase is far below the melting temperature and makes little contribution to the bonding as in fig.6. As there are no structural changes to the base material, this process does not suffer from the adverse effects that such changes can bring.

To gain an understanding of the steps in them mechanism which might lend to an ultrasonic weld, consider a sphere plates system. The sphere is made to slide relative to the plate while the two are clamped together. During the first few cycles of sliding, the contacting surfaces are abraded, removing oxide layers from the interface and reducing the number of asperities, so the total metal to-metal contact area is increased. frictional heating raises the temperature, so that lower yielding forces are required to deform surface asperities and the contact area increases. Thus, under conditions of elevated temperature and high pressures, the surfaces are brought into an intimate contact which can lead to a metallurgical bond. When yielding ceases, contacting areas begin to bond. If the strain initially used to produce sliding is maintained beyond the elastic limit of the materials, the bonded area will be worked and the strain relieved by fatigue of the weldment.

2.3.4 Rough surfaces prevents slippage

The sonotrode and anvil (welding tools) usually feature rough surfaces or have a milled or ground structure (cross-ribbed or grooved structure, etc.) to grip the parts to be joined and prevent unwanted slippage fig 7.

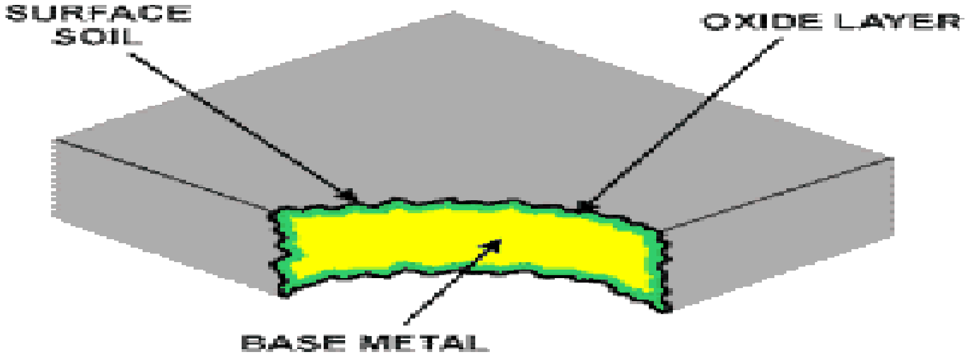


Fig.7.typical surface condition

2.4 Locally Limited Metal Deformations

The static pressure is introduced at right angles to the welding interface. Here, the pressure force is superimposed by the high-frequency oscillating shearing force. As long as the forces inside the workpieces are below the limit of linear elasticity, the pieces will not deform. If forces surpass a given threshold value, local material deformation will soon take place. These shearing forces, at high frequency, break down contamination, remove it and produce a bond between pure metal interfaces. The further oscillation makes the interface deformation grow until a large welding area has been produced. At the same time, there is an atomic diffusion in the contact area and the metal re-crystallizes into a fine grain structure having the properties of a cold-worked metal (figure 8)

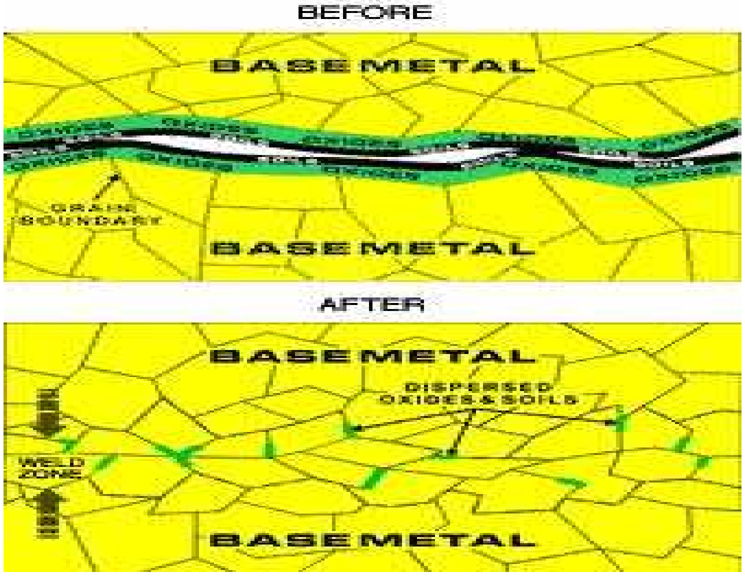


Fig.8 Bond formation of ultrasonic welding

Ultrasonic welding is featured that the same and different materials are possible to weld easily in short welding time, the characteristics of the weldment such as weld strength and fatigue strength are superior to the other welding methods, welding area is limited to very narrow area and being applied for joining various materials.

2.5 The Differences Between The Various Metal Welding Processes

In the friction welder, one or both pieces rotate while they are pressed together. The frictional heat which emanates together with the static pressure causes the bond between the pieces. The back pressure required for joining the pieces in comparison to cold-press-welding is drastically reduced because of the additional rotational energy. The matching of the surfaces promotes plastification and local deformation of the pieces being welded.

During ultrasonic metal welding, the rotational motion is replaced by mechanical linear vibrations. The welding surfaces are periodically scrubbed during the welding process. This further reduces the required welding pressure compared to friction welding, the final value being only about 1% of that required for cold-press welding Proven energy sources here are gas, arc welding, light, electron or plasma beams.

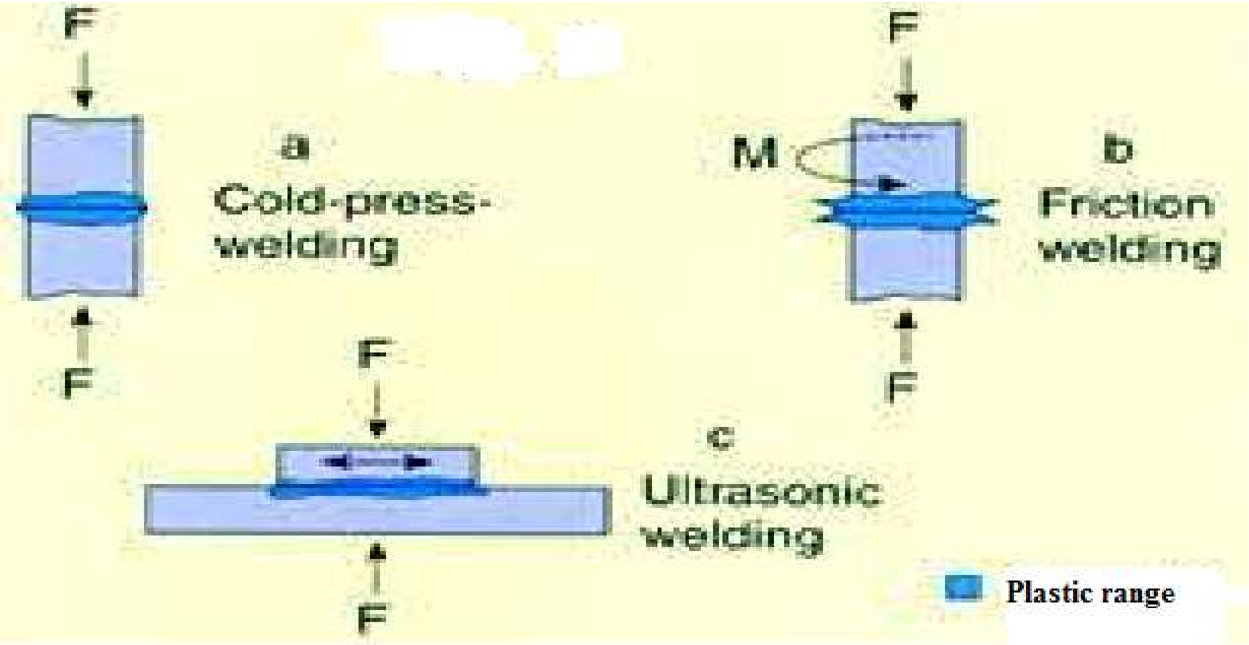


Fig.9 The differences between the various metal solid welding processes

Ultrasonic welding belongs in the category of pressure welding and uses motion and kinetic energy for welding pieces together

Depending on the kind of motion, a distinction in metal welding between cold-pressed welding, friction welding and ultrasonic welding can be made. All three procedures show a high similarity. Ultrasonic metal welding is a combination of cold-press welding and friction welding because of its mode of action.

Figure 9 shows the different principles of cold-press, friction and ultrasonic welding. Cold-press welding takes place at room temperature. By applying high pressures to both pieces the materials weld together. A strong material deformation at the welding zone accounts for the bond

Ultrasonic welding is uses friction to heat the parts being welding (not to be confused with friction welding). In ultrasonic welding, the parts being welded are clamped together between a stationary anvil and a vibrating horn. The horn vibrates at ultrasonic frequencies and hence the name Ultrasonic welding. This process is commonly used for welding certain thermoplastics and soft metals. The inner workings of the power supply used for welding is the same for both plastics and metals. The difference is in the way which the energy is delivered to the parts. To weld metals, the horn vibrates parallel the weld interface; for plastics, the horn vibrates perpendicular to the weld interface.

The fundamentals of the processes are often confused with friction welding, since it appears that the two metal parts are being rubbed against each other. In reality the parts do not have any relative motion between the two at the weld interface. The heat, and subsequent softening, is produced by internal friction, i.e., the atoms of the parts vibrating against each other at high frequency and amplitude. Once the parts are softened, the atoms across the interface are brought in intimate contact by the action of the welding force and are able to form a solid-state bond. Ultrasonic welding is not a cold welding processes. The parts do get quite hot, though not as hot as in other fusion welding processes. The critical parameters for metal ultrasonic welding are:

1. Ductility of the metals being welded

2. Size of the metal piece in contact with the vibrating horn

3. Surface cleanliness and coatings

2.6 Temperature Rise In The Welding Area.

2.6.1 No fusion.

Ultrasonic metal welding is local and limited to the shear forces and displacement of intermediate layers. However, a fusion does not take place if the pressure force, the amplitude and the welding time have been properly adjusted. Microscopic analyses using optical and electronic microscopes make re-crystallization, diffusion and other metallurgical phenomena evident. However, they provide no evidence of fusion (melted interface). The use of highly sensitive thermal sensing devices in the intermediate layers shows in initial quick rise in temperature with a steady temperature drop afterwards.

It is apparent that, weld strength is directly proportional to the minimum temperature reached during a meld cycle. The temperature is n function of the rate of energy dissipation, where the energy dissipated per second can be expressed as

$$E = 2pKNfX,$$

where

pK = ccefficient of kinetic friction,
N = clamping force,
X = sliding distance between surfaces,
f = frequency of sliding

It is apparent that, weld strength is directly proportional to the minimum temperature refichecl during a meld cycle.

2.6.2 The temperature profile can be controlled

The maximum temperature obtained is a function of the process settings at the welding equipment. An increase in welding energy likewise leads to an increase of possible maximum temperature. An increase in the static force also leads to an increase of the initial temperature, but at the same time limits the possible maximum temperature. Consequently, the temperature profile can, within certain limits, be influenced by proper machine adjustments. Variation of temperature in work piece with thickness during USW. Fig.10.

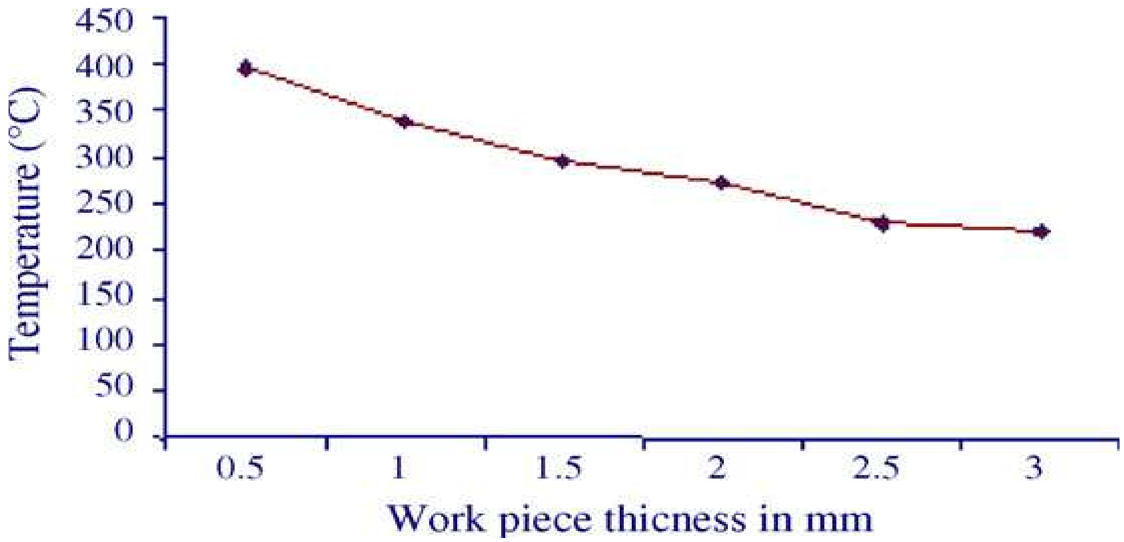


Fig.10 Variation of temperature in work piece with thickness during USW

The temperature in the intermediate layer is, of course, also a function of the properties of the material. The basic rule is that the temperature obtained is higher for materials with a low thermal conductivity such as iron, and lower for metals with a higher thermal conductivity such as copper and aluminum. Variation of temperature in work piece with coefficient of friction during USW .Fig.11

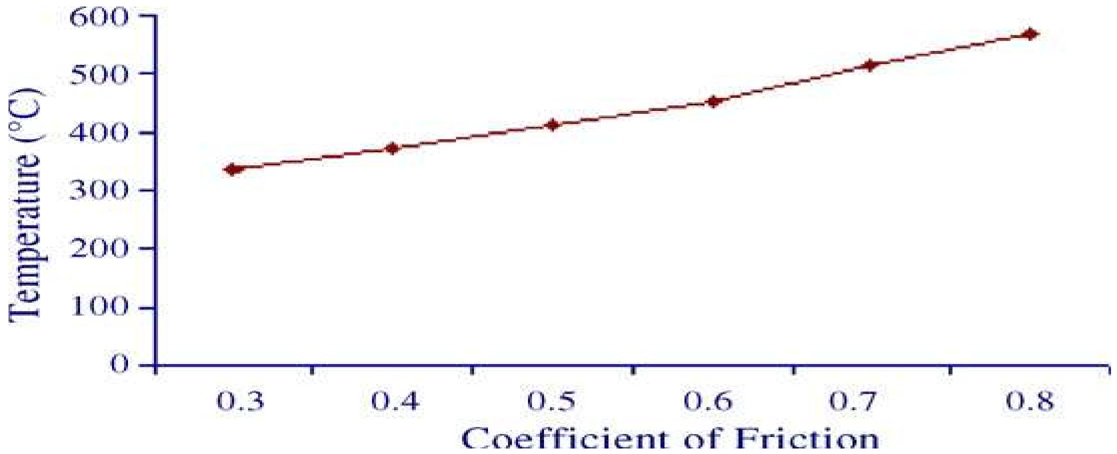


Fig.11 Variation of temperature in work piece with coefficient of friction during USW.

Temperature measurements carried for different materials with widely varying melting points have shown that the maximum temperature in the welding interface will not exceed some 35 to

50% of the melting temperature of the individual metal, provided that the proper welding parameters have been selected

2.7 Homogeneous And Lasting Joints Diffusion

Ultrasonic metal welding is not characterized by superficial adhesion or glued bonds. It is proven that the bonds are solid, homogeneous and lasting joints. If, for example, a thin aluminum sheet is ultrasonically welded to a thin copper sheet, it can easily be ascertained that after a certain period of weld time, copper particles appear on the back side of the aluminum sheet. At the same time, aluminum particles appear on the back side of the copper sheet. This shows that the materials have penetrated each other -- a process which is called diffusion. This process takes place within fractions of a second.

2.8 Metal vs. Plastic Ultrasonic Welding

Is the process of joining aluminum parts with ultrasonic any different than it is with other materials, such as thermoplastics**?**

The ultrasonic metal welding process (whether aluminum or other metals) is *fundamentally different* from welding plastics in how the ultrasonic energy (or vibrations) is delivered to the weld, and in how the actual weld is created as shown in Fig 12.

First, ultrasonic metal welding delivers vibrations to the zone via transverse vibrations that are parallel to the weld surfaces. Ultrasonic plastic welding delivers vibrations to the zone via longitudinal vibrations that are normal (i.e., at right angles) to the weld surfaces.

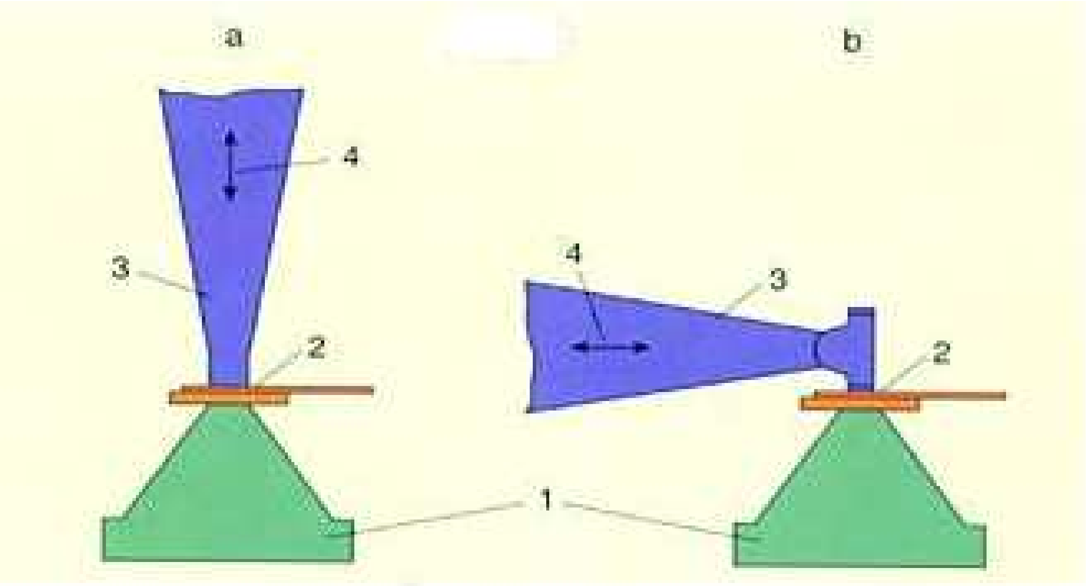


Fig.12 Differences in the process for welding plastics and metals with ultrasonic

Second, ultrasonic metal welding creates the weld via a frictional action of the surfaces that creates a solid-state bond without any melting of the material. Ultrasonic plastic welding is based on melting and fusion of the material (in a sense, like many metal welding processes, such as arc, resistance or laser), but at much, much lower temperatures than experienced in metal fusion processes.

There are two slightly different ways of delivering the ultrasonic vibrations to the weld zone: "lateral drive" and "wedge-reed." While each has selected special advantages, they both end up getting the vibrations to the weld zone in a transverse vibration action. With this fundamental distinction between ultrasonic metal and plastic welding in mind, then one has ultrasonic welding of all metals done in the same way. Weld Arial in all cases are very fast-- on the order of 0.2 to 0.5 seconds.

The shape of the horns that transmit the ultrasonic vibrations into metal and plastic welds are quite different, although they are designed from the same principles of acoustics. The fundamental driving transducers for both ultrasonic metal and plastic welding are quite similar, as are some of the coupling horns (often called boosters) between the transducer and welding tool.

Most ultrasonic metal welding companies are in both plastic and metal welding, since much of the underlying technology is similar, including power supplies. Nevertheless, as ultrasonic metal welding tries to meet new challenges, especially in welding thicker materials, there will be increasing differentiation between metal and plastic welding apparatus.

Are high or low frequency levels typically used for metal and plastic welding applications**?**

Most ultrasonic metal welders work at 20 KHz, similar to plastic welders (40 KHz metal welders are available as well). In moving to higher power, it would not be surprising to see some drop in frequency, to say 15 KHz, as has occurred in plastic welders.

Ultrasonic welding is based on acoustic and solid-state phenomena, and not fusion phenomena, so users may not make sufficient effort to acquaint themselves with this "animal." Assuring set-up of a good, robust set of welding procedures is very important. This becomes especially so for first-time users, since they may not have a backlog of past experience to guide them in setting up the process.

Static or clamping force happens to be a very important ultrasonic metal welding parameter. One must be aware of overall part vibrations induced by the ultrasonic welding action. Control of these matters lies in clamping and placement of welds so that resonant conditions are not encountered.

A user may set up a process that works at as low a force as possible (maybe to avoid material deformation), not realizing the process is at the "ragged edge" of that parameter. Then, a slight variation of incoming material in surface finish, hardness or cleanliness may throw it "over the edge" resulting in no, or poor welds. When that happens, the user is faced with a new process that was never used before (and that was not trusted too much to begin with) that isn’t working. This, however, is not untypical of many other processes.

2.9 Applications Of Usw

The applications of ultrasonic welding are extensive and are found in many industries including electrical and computer, automotive and aerospace, medical, and packaging. Whether two items can be ultrasonically welded is determined by their thickness. If they are too thick this process will not join them. This is the main obstacle in the welding of metals. However, wires, microcircuit connections, sheet metal, foils, ribbons and meshes are often joined using ultrasonic welding. Ultrasonic welding is a very popular technique for bonding thermoplastics. It is fast and easily automated with weld times often below one second and there is no ventilation system required to remove heat or exhaust. This type of welding is often used to build assemblies that are too small, too complex, or too delicate for more common welding techniques

2.9.1 Electrical and Computer Industry

In the electrical and computer industry ultrasonic welding is often used to join wired connections and to create connections in small, delicate circuits. Junctions of wire harnesses are often joined using ultrasonic welding. Wire harnesses are large groupings of wires used to distribute electrical signals and power. Electric motors, field coils, transformers and capacitors may also be assembled with ultrasonic welding. It is also often preferred in the assembly of storage media such as flash drives and computer disks because of the high volumes required. Ultrasonic welding of computer disks has been found to have cycle times of less than 300ms.

One of the areas in which ultrasonic welding is most used and where new research and experimentation is centered is microcircuits. This process is ideal for microcircuits since it creates reliable bonds without introducing impurities or thermal distortion into components. Semiconductor devices, transistors and diodes are often connected by thin aluminum and gold wires using ultrasonic welding. It is also used for bonding wiring and ribbons as well as entire chips to microcircuits. An example of where microcircuits are used is in medical sensors used to monitor the human heart in bypass patients.

One difference between ultrasonic welding and traditional welding is the ability of ultrasonic welding to join dissimilar materials. The assembly of battery components is a good example of where this ability is utilized. When creating battery and fuel cell components, thin gauge copper, nickel and aluminum connections, foil layers and metal meshes are often ultrasonically welded together. Multiple layers of foil or mesh can often be applied in a single weld eliminating steps and cost.

2.9.2 Automotive and Aerospace Industries

For automobiles, ultrasonic welding tends to be utilized in the assembly of large plastic components and electrical components such as instrument panels, door panels, lamps, air ducts, steering wheels, upholstery and engine components.[17] As plastics have continued to replace other materials in the design and manufacture of automobiles, the assembly and joining of plastic components has increasingly become a critical issue. Some of the advantages for ultrasonic welding are low cycle times, automation, low capital costs, and flexibility.[18] Also, ultrasonic welding does not damage surface finish, which is a crucial consideration for many carmakers, because the high-frequency vibrations prevent marks from being generated.[19]

Ultrasonic welding is generally utilized in the aerospace industry when joining thin sheet gauge metals and other lightweight materials. Aluminum is a difficult metal to weld using traditional techniques because of its high thermal conductivity. However, it is one of the easier materials to weld using ultrasonic welding because it is a softer alloy metal and thus a solid-state weld is simple to achieve.[20] Since aluminum is so widely used in the aerospace industry, it follows that ultrasonic welding is an important manufacturing process. Also, with the advent of new composite materials, ultrasonic welding is becoming even more prevalent. It has been used in the bonding of the popular composite material carbon fiber. Numerous studies have been done to find the optimum parameters that will produce quality welds for this material

2.9.3 Medical Industry

In the medical industry ultrasonic welding is often used because it does not introduce contaminants or degradation into the weld and the machines can be specialized for use in clean rooms. The process can also be highly automated, provides strict control over dimensional tolerances and does not interfere with the biocompatibility of parts. Therefore, it increases part quality and decreases production costs. Items such as arterial filters, anesthesia filters, blood filters, IV catheters, dialysis tubes, pipettes, cardiometry reservoirs, blood/gas filters, face masks and IV spike/filters can all be made using ultrasonic welding. Another important application in the medical industry for ultrasonic welding is textiles. Items like hospital gowns, sterile garments, masks, transversal patches and textiles for clean rooms can be sealed and sewn using ultrasonic welding. This prevents contamination and dust production and reduces the risk of infection.

2.9.4 Packaging Industry

Packaging is perhaps the application in which ultrasonic welding is most often used. From tubes of toothpaste to diapers to ammunition it is amazing how many items are used on a daily basis that are packaged using ultrasonic welding. Sealing containers, tubes and blister packs are some common applications.

Ultrasonic welding has also found application in the packaging of dangerous materials such as explosives, fireworks and other reactive chemicals. These items tend to require hermetic sealing but cannot be subjected to high temperatures. One simple example of this application is the container for a butane lighter. This container weld must be able to withstand high pressure and stress and must be airtight to contain the butane. Another example is the packaging of ammunition and propellants. Again, these packages must be able to withstand high pressure and stresses in order to protect the consumer from the contents. When sealing hazardous materials safety is a primary concern. Thus, the reliability and automation of this process are strong benefits for companies.

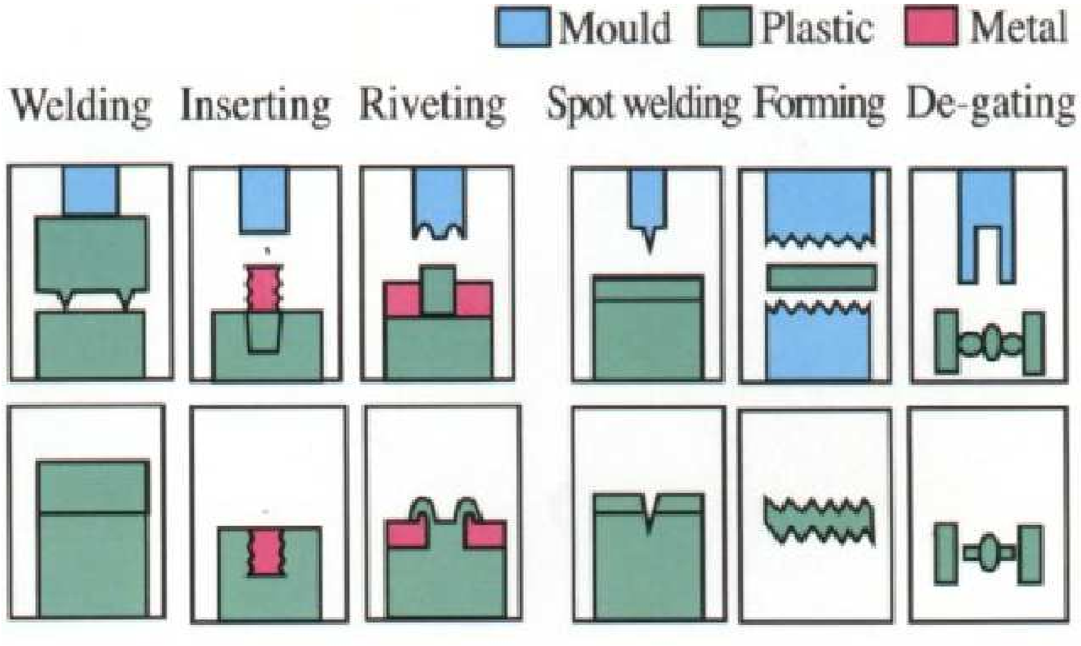


Fig.13 Ultrasonic welding application

2.9.5 Some other application

(1) Toys:

Remote car & boat, Plastic doll, Toy gun, Water gun, TV game, phone....etc.

(2) Household:

Washer balance ring, Computer, TV shell, Remote unit, Steam iron.

(3) Electronics:

Cassette case, Video case, Calculator, Disc.

(4) Electrical Industry:

Connector, Transformer, Relay.

(5) Automobile Industry:

Head light, Tail light, Brake light, Lunch Box, Rearview, oil filter.

(6) Food Industry:

Thermos-bottle, Thermos cup, Food container.

(7) Stationery:

Pencil case, PP file, Staple, Ink bottle, Pen stand.

Chapter: 3

LITERATURE REVIEW

During ultrasonic metal welding (USMW), plastic deformation, elastic hysteresis and friction generate heat at the face of parts to be joined. In the following sections results are presented from previous work of researchers who have measured and explained the temperatures at the interface during welding and Bonding mechanism of USW.

3.1 Temperature And Stress Distribution In Ultrasonic Metal Welding*:*

In this study a model for the temperature distribution during welding and stress distribution in the horn and welded joints are presented. With the knowledge of the forces that act at the interface it is possible to control weld strength and avoid sonotrode welding (sticking of the sonotrode to the parts). The presented finite element model is capable of predicting the interface temperature and stress distribution during welding and their influences in the work piece, sonotrode and anvil. The study also included the effect of clamping forces, material thickness and coefficient of friction during heat generation at the weld interface.

Ultrasonic welding has the ability to weld metals of significantly dissimilar melting points; metals that normally form brittle alloys at the weld junction, and joints that are in close proximity to heat sensitive components. Finally, ultrasonic welds are made without consumables, such as solder or filler that would ordinarily be used in conventional joining processes 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. It is restricted primarily to the joining of non-ferrous metals and plastics.

3.1.1.Modeling of temperature distribution

Modeling of temperature distribution in weld interface of work piece is attempted in this study. Two-dimensional rectangular.

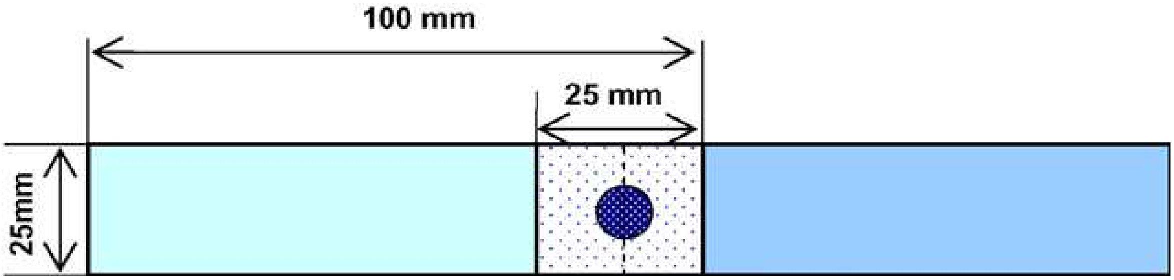


Fig.14 Standard specimen (weld coupon)

The partial differential equation governing heat transfer in axis symmetric geometry (Lienhard and Lienhard, 2006) is given by

$$k\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right)+Q-\rho c\frac{\partial T}{\partial t}=0$$

3.1.2 Heat generation and conduction at the weld

During USMW heat is generated at the weld interface andthe surrounding area as well as at the sonotrode top surface owing to plastic deformation and friction. This generation of heat and the subsequent change of temperature have a significant impact on the properties of the welded joint.

It was observed that in the initial phase of welding, plastic deformation occurs at the interface between sonotrode and work while the knurls on the sonotrode engage into the top surface of part. By this, heat is generated as well. But it was found that a typical welding cycle is 20–25 times longer than the initial phase. Therefore, this initial heating phase at the sonotrode has been neglected. For practical purposes the heat input due to plastic deformation and due to friction has been separated. The heat input due to plastic deformation has been confined to the deformation zone area (i.e. the sonotrode area *A*S in this model) and the heat input due to friction is confined to the friction area *A*FR surrounding the weld area.

3.1.3 Heat generation due to deformation

To model the heat input into the parts and temperatures that occur during welding one has to take a closer look at the distribution of the heat sources across the deformation zone and their development during the weld cycle. At the beginning of the weld cycle the deformation islands occur randomly across the deformation zone. Because of the high thermal conductivity of aluminum the temperature will even out very rapidly across the deformation zone. From this it is understood that the total power developed in all deformation islands is distributed evenly over the entire volume of the deformation zone.

This model explains the influence of material properties and surface conditions as well as process variables such as amplitude of vibration and normal force on theweld behavior.It can also be understood from his study that concentration of temperature ismore near to thework piece than the sonotrode owing to the fact that more heat is generated in thework piece where ultrasonic energy is focused. This temperature distribution decreases progressively as the periphery of the work piece is reached. ***S. Elangovan, S. Semeer, K. Prakasan .****2008*

3.2 *The Ultrasonic Welding Mechanism as Applied to Aluminum*

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 aluminum 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. This is substantially the same result previously obtained from studies on the aluminum ultrasonic bonding mechanism. Further, it is shown that a deformation mechanism also holds for other forms of solid phase microelectronic bonding. Specific examples are taken from electric discharge “tweezer welds” and from thermo compression bonds. The role of contaminant removal and certain reliability aspects of, ultrasonic bonding are also discussed.

The present paper reviews past work on ultrasonic welding and develops a consistent phenomenological explanation. New experiments presented in Sections IIMECHANISM OR MODEL FOR ULTRASONIC SOFTENING OF METALS, various reliability aspects of ultrasonic bonding are considered. ***GEORGE G. HARMAN, 1997***

3.3 New Methods Of Ultrasonic Metal Welding

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. For medium size welding specimens, complex vibration welding tips are also very effective, and one dimensional complex vibration systems are developed to simplify the complex vibration systems. For welding of large specimens, ultrasonic butt welding methods joining thick metal specimens end to end are effective. Using the methods and large capacity vibration sources and power amplifiers of *5* to 50,100 kW, thick and large various metal plate specimens are successfully welded. Ultrasonic welding methods using two vibration systems are also very effective, but not mentioned here.

Author has explain Vibration characteristics of one dimensional longitudinal-transverse vibration converter and also Relationship between weld strength; measured temperature and elongation at tensile test of pure aluminum plate specimens.

He got following ultrasonic welding methods of metal materials were proposed and their effectiveness was shown.

1) For ultrasonic bonding of small specimens such as thin wires, the bonding equipments using higher vibration frequency than 40 or 60 kHz which is used in the conventional wire bonding systems, and using complex vibration welding tips vibrating in (a) elliptical to circular loci or (b) rectangular to square loci were proposed and it was shown they are very effective.

2) Formedium size welding spec imeng, complex vibration welding tips vibrating in (a) elliptical to circular loci or (b) rectangular to square loci were shown very effective same as the bonding of thin wire specimens. ***Jiromaru TSUJINO*** 1995

3.4 Ultrasonic Welding Equipment

Little or no 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. What is believed to be the first fundamental study of the mechanisms involved in ultrasonic welding has been started. On the basis of observations made in this study, it is postulated that this new welding process is a form of pressure or friction welding, in which material surfaces subjected to a clamping force are welded when made to slide in contact with each other. The process appears to be related directly to the frictional phenomena of galling and seizing.

The relationships between weld strength and the variables of clamping force, duration of weld cycle, ultrasonic motion, and temperature, have been obtained for a Model sphere welded to a copper plate.

His study shows that the essential components of an ultrasonic welder are: 1) an arrangement to clamp together members to be welded, 2) an arrangement to couple vibratory energy to one of the members being welded, 3) a controllable source of vibratory energy, and 4) a timing circuit to control the duration of clamping force and vibratory energy. On the basis of conditions found necessary to produce a weld, the problems encountered in designing welder components are discussed and method of circumventing them is presented.

He has concluded that, general relationships between weld strengths and most weld variables are known. This knowledge, coupled with available equipment capable of controlling mechanisms involved in the ultrasonic melding process, permits the design of welders useful for many industrial applications. Present indications are that practical butt, seam, and spot welders can be designed. However, they would be limited in application to welding thin-gauge sheets or small components of relatively ductile materials. Ultrasonic welders are designed, many of the design problems related to generating and coupling ultrasonic energy efficiently will be solved, and the ultrasonic welding process is expected to become a practical one for joining material.

***JOHS N. ANTONEVICHt* 1959**

Chapter :4

ULTRASONIC 20 kHz WELDING SYSTEM

4.1 General

During ultrasonic metal welding, a complex process is triggered involving static forces, oscillating shearing forces and a moderate temperature increase in the welding area. The magnitude of these factors depends on the thickness of the workpieces, their surface structure, and their mechanical properties.

The work pieces are placed between a fixed machine part, i.e. the anvil, and the sonotrode, which oscillates horizontally during the welding process at high frequency (usually 20 or 35 or 40 kHz)

The most commonly used frequency of oscillation (working frequency) is 20 kHz. This frequency is above that audible to the human ear and also permits the best possible use of energy. For welding processes which require only a small amount of energy, a working frequency of 35 or 40 kHz may be used.

Welding equipment consists of an ultrasonic generator, a booster for amplification and a horn to transfer energy to the component. The combination of the booster and horn is unique for each design. When using glass fiber reinforced thermoplastics, the horn needs a special surface treatment to prevent abrasion.

The process of ultrasonic welding is also a highly automated process. The welding information, such as time and frequency, is programmed into the welding machine so that each process carried out will be controlled by computer, ensuring they are all the same. This also means that all an operator needs to do is place parts on the anvil and push a button (Fig 5). The rest of the operation is carried out automatically and the operator simply needs to remove the welded part and install the next component

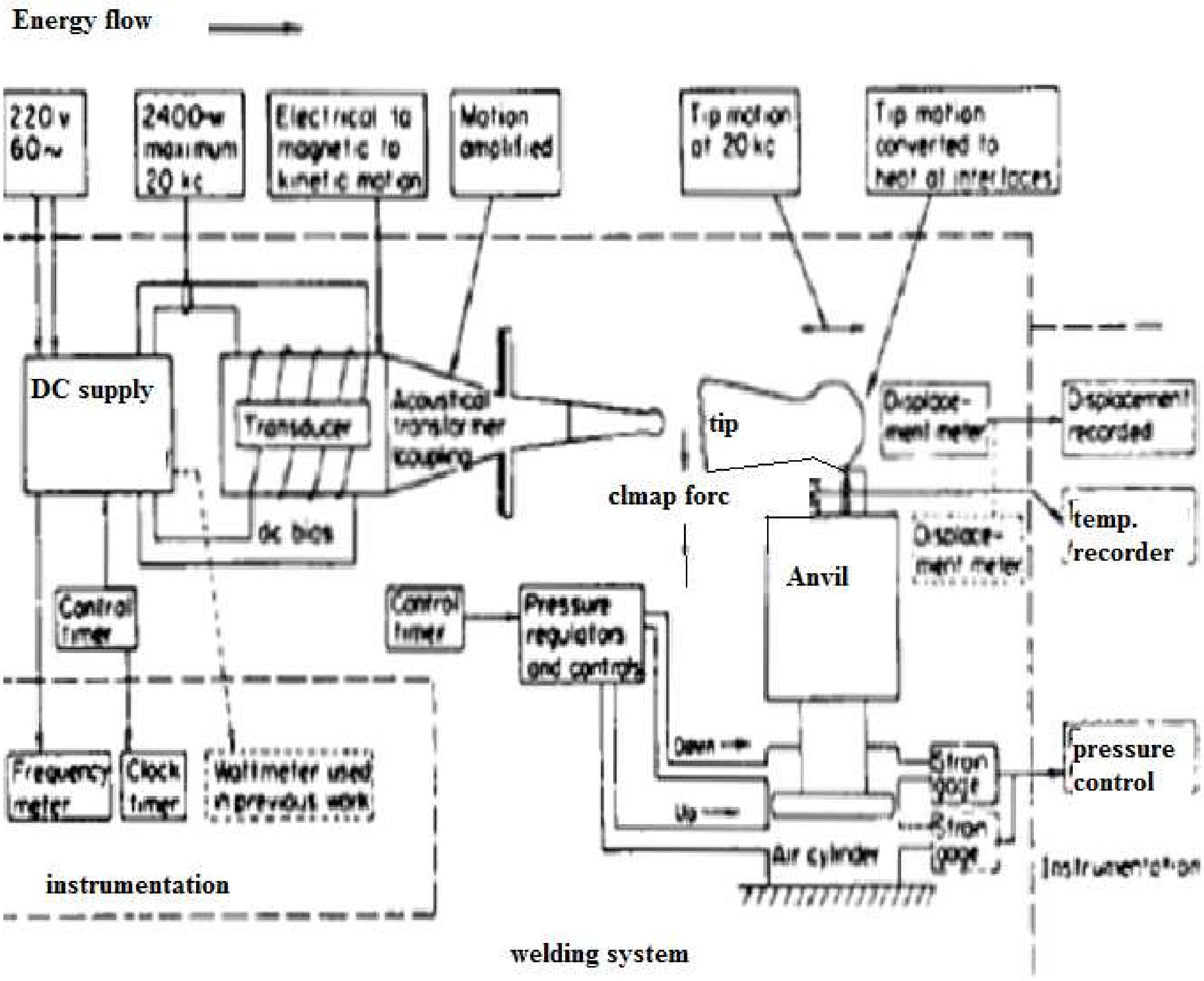


Fig.15 Block diagram showing ultrasonic welding system , instrumentation , and energy flow

4.2 Component

The essential components of an ultrasonic welder are:

1) An arrangement to clamp together members to be welded.

2) An arrangement: to couple vibratory energy to one of the member to being welded.

3) A controllable source of vibratory energy.

4) A timing circuit to control the duration of clamping force and vibratory energy.

The specific design or type of components required to make up an ultrasonic welder depends upon the type of weld desired, *e.g.,* spot weld, butt weld, or seam weld, and the portability desired. Instead of assuming a specific welder design, let us consider the functions of the components. Based upon their particular functions and the condition found necessary to produce a weld, general component designs can be discussed which are applicable to any form of ultrasonic welder.

4.2.1 Clamping arrangement

The function of a clamping arrangement is to provide a clamping force between members to be welded so that, when they slide against each other, energy is dissipated at their interface as in Fig 15. It must also provide compressive force between the members, which, in conjunction with the frictional heat generated, will cause welding. The design suggested is similar to an arrangement which might be used for pressure welding except that heating is accomplished by friction.

It can be pointed out here that ultrasonic and pressure welding can be considered as similar processes. The advantage of ultrasonic welding over pressure welding is the lower clamping pressure required to break down the oxides layers and obtain intimate contact between surfaces. This should be expected since, in pressure welding, the oxide layer or surface roughness is removed solely by pressure, whereas in ultrasonic welding. frictional forces do the work of fretting away oxides asperities. Since fretting and heating do occur, at least during the first few cycles of vibration, consideration might be given to methods of inhibiting oxide formation near the periphery or edge of a weld where bare metal at weld temperatures will oxidize. The oxide rim of the weld would tend to reduce weld strength. Oxide formation might be minimized or avoided by welding, in a vacuum or in an inert-gas stream.

In designing a clamping arrangement, there is the problem of maintaining one of the members rigid while the other member is free to slide. Fig.16 shows some typical welding arrangements. For butt welding, the two members could be butted together and vibrations imparted to one of the members by attaching the coupling arrangement to it. For seam or spot wildings, this arrangement would not be feasible since vibration energy must be restricted to the weld site only. If the entire mass of the sliding member were set in motion, the chances of fatiguing or breaking previously-made welds would be great. To avoid this, the coupling arrangement could be made an integral part of the clamping arrangement by clamping the members to be welded between the coupling arrangement and a rigid support or anvil.

If low-frequency vibrations were used, the design of a rigid anvil would offer little problem. However, at ultrasonic frequencies where the wavelength of sound is short and the available displacements are small consideration must be given to anvil dimensions.

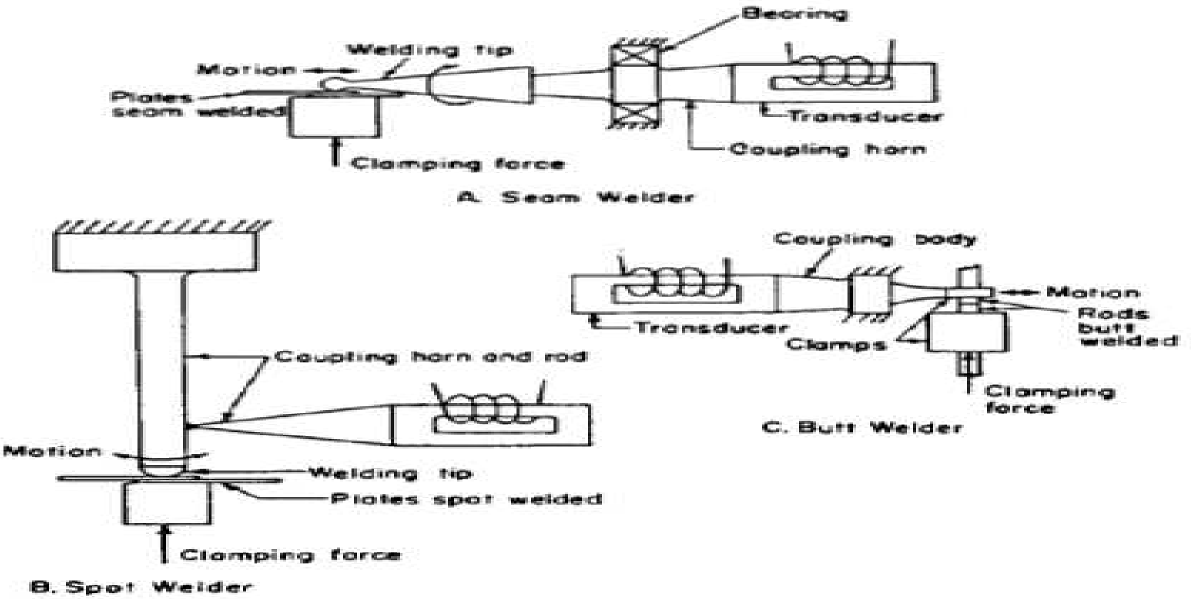


Fig.16 Ultrasonic welding arrangement

The anvil dimensions and those of its support should be such that, individually or in combination, they do not have a mode of vibration which would set, up resonances or be compliant to the vibration forces used in welding. To avoid this, the anvil could be made with dimensions less than a quarter wavelength of the frequency of vibration used and with a low slenderness ratio normal to the direction of motion.

To obtain maximum energy dissipation at the interface being welded, the coefficients of friction of the clamping surfaces should be high to avoid sliding and possible welding at the clamping surfaces. This can be done by roughening the clamping surfaces or by using appropriate materials that mould provide higher coefficients at clamping surfaces than those at the surfaces being welded. Although the former method is the simpler method, it would mar the surface of the members being welded. This might be undesirable.

Clamping forces for ultrasonic welding could be supplied by devices such as pneumatic or hydraulic cylinders or an electromagnet. An electromagnetic device would be perhaps the most desirable, because it is readily controlled and requires a minimum of accessory equipment.

4.2.2 Coupling Arrangement

The function of the coupling arrangement is to transmit vibrational energy efficiently from **t**ransducer or vibration generator to the interface being welded. Its design, particularly when ultrasonic transducers are used, is critical.

Generally, ultrasonic transducers are driven at their resonant frequency to obtain maximum efficiency. Hence, the coupling arrangement should be such that it and the system to which it is transmitting energy have the same natural resonant frequency as the transducer and are capable of withstanding the strains required for melding as in Fig 16.

If the clamping arrangement is designed properly, the coupling arrangement will supply energy only to the members being welded. If the members offer a frictional load, the resonant frequency of the transducer coupler arrangement will not be affected. Such a case, the design of the coupler resolves itself to designing coupling system resonant, at the same frequency or a harmonic of the transducer’s resonant frequency. The efficiency of energy transfer to the weld interface will be reduced. To circumvent this problem, the coupling arrangement could be designed so that it and the member expected to be welded mould resonate at or near the resonant frequency of the transducer. This would be a special duty welder .**A** welder design using a velocity transformer to transmit longitudinal vibrations direct.ly to a weld would probably be most efficient, and the simplest to design. In such a welder, the transducer generating elastic strains propagates them through two half-wavelength velocity transformers or horns. Conical, exponential, or double-cylinder transformers can be used. Several papers have been published describing the design of these horns.14.15 Their utility lies in the fact that relatively small displacements generated by a transducer can be amplified to the relatively large displacements required to produce sliding between members being welded. The choice of horn design will be governed by the displacement, required for welding and the stress they will be subjected to during welding. They should be made of materials such as Joined, having low damping properties to avoid losses and fatigue.

4.2.3 Ultrasonic Generators

A controllable source of vibrational energy is necessary in an ultrasonic welder because the energy levels required to produce welds vary from material to material. Although there are various types of transducers such as electrodynamics, fluid dynamic, magnetostrictive, piezoelectric, and electrostrictive, the most desirable would be those capable of providing ultrasonic vibrations.

This is desirable because noise would be at a minimum and greater rates of energy dissipation for low strains could be realized. To avoid fatigue in welds, low strains must be used in welding. Using sonic frequencies of vibration, the strain required to raise temperatures sufficiently for welding under moderate clamping forces would be prohibitive since they would cause cracks in the weld. However, it is possible that a welder could be designed that used supplemental heating with small sonic motions and high clamping forces Of the commercially available or easily fabricated transducers, those using the magnetostrictive or elect, restrictive effects are the most promising. For low-power welding such as welding wires, plastic films, or foils, labium titan ate crystals could be used most economically. Sickel transducers should be used in welders designed to join relatively heavy-gauged sheets or foils of metals having relatively high melting points. For a durable welder, a nickel-type transducer should also be considered because of its high mechanical strength.

Although both types of transducers would require cooling if designed to operate at high energy levels, the chances of permanent damage to the welder due to excessive heating are greater with barium titanate transducers. If a barium titanate transducer exceeds its Curie point of about 90°C, it will depolarize and permanently lose its electrostrictive properties, whereas nickel, if heated above its Curie point of about 500°C, will recover its magnetostrictive properties on cooling. Both types of transducers are commercially available. If a special-duty magnetostrictive transducer must be designed, there are various sources of design data. Ultrasonic transducers of the magnetostrictive or electrostrictive types can be driven with any of the conventional power oscillator circuits. For heavy-duty welders it may be more advantageous, from the standpoint of reliability and space requirements, to use rotary generators. One advantage of oscillator circuits is that they can be readily controlled by a feedback loop from the transducer to maintain optimum conditions of power transfer during welding cycles. Frequency control of rotary generators might require an elaborate control system.

4.2.4 Timing Circuit

In general, ultrasonic welding cycles are short. They can range from fractions of a second up to three or more seconds. Since the clamping force is the most effective means of controlling weld strength, the timing circuits controlling the duration of clamping force and ultrasonic motion could be designed for a fixed timing cycle. Conventional timing circuits or mechanical timers could be used to control weld cycles.

4.3 Parameter Control

Although the following process parameters are adjustable, they do not change during the welding process and are therefore not controlled:

- tool dimensions
- welding pressure
- trigger point
- amplitude

4.3.1 Process-variable

However, the following variable parameters can be controlled:

- welding time

- welding energy
- mechanical compression of the parts to be welded (difference in thickness before and after welding)

For ultrasonic metal welding equipment, various electronic monitoring devices are available. Most of them are also able to control the welding equipment and make it possible to readjust the welding time, so that the required energy and compression values will remain constant in production.

The selected welding parameters for ultrasonic welding are:

- *Welding pressure or contact pressure*

This is the pressure between the anvil and the sonotrode applied on the parts to be welded. The contact pressure must remain constant during the whole welding process. It is usually produced pneumatically and totals up to approximately 400-1500N

- *Welding time*

The welding time is defined as the duration of ultrasonic and can be both a constant parameter or a variable parameter adjusted with the help of quality control devices for an optimum weld. Depending on the application the welding time can be between 0.1 and approximately 4 seconds.

- *Trigger point*

The starting point of ultrasonic welding is adjustable. This point in time, which is called the trigger point, is usually selected as a function of the clamping and compaction of the parts -- sometimes also as a function of stroke length.

As soon as the sonotrode's work surface touches the work piece and a certain clamping force has been built up, the ultrasonic is automatically triggered according to the selected period of time (welding time). For some applications it is advantageous to initiate pressure onto the work pieces while the sonotrode is already oscillating or while the contact pressure is still low. For other applications, it is advisable to wait for the total pressure to build up before the oscillation is started.

Fig.17 Equipment for welding parameter control and adjustment (generator)

The adjusting element is a pressure-regulated valve for the activation of the air cylinders. The trigger point has to be chosen individually and determined by welding experiments. It is one element of the parameter welding time.

- ***Amplitude* Constant amplitude**

  The amplitude constitutes the oscillation length of the welding tool (sonotrode). The amplitude should remain constant throughout the welding process. With modern welding equipment a relatively large amplitude range is defined mechanically by the booster. Within this range, the fine adjustment of the amplitude is made electrically with a selective switch.

- This solution is important not only from the engineering point of view but also for operational reasons. Instead of time-consuming mounting and dismounting of the boosters with different amplitude transmission ratios, the amplitude can be adjusted electrically very quickly and, above all, very precisely. The amplitude at the welding point is usually between 15 and 45 microns for half a period (semi-wave).

The individual magnitude of the amplitude is determined by the shape and construction material of the welded parts. In addition, there is a correlation between welding time, welding energy and welding pressure. The proper magnitude of the amplitude should be determined during test weldings.

- *Welding tools*

  The design of the welding tools requires a considerable amount of process engineering know-how and is often the decisive factor for determining the quality of a weld. If the surface structure on the work surface(s) of the sonotrode begins to wear, it may be judicious to change one or several parameters until a reconditioning or exchange of the tool becomes necessary.

- *Ultrasonic frequency*

  The frequency, measured in cycles per second, remains largely constant and depends on the generator's working frequency. It is also decisive for the construction of the machine and the complete transducer system. Most equipment has a working frequency of 20 kHz, but for small-scale applications, equipment between 35 and 40 kHz is available.

4.3.2 Parameter adjustment with the help of test weldings

- Whereas the design of the welding tool and the working frequency is fixed according to the type of welder used, the welding pressure, welding time, trigger point and amplitude need to be adjusted according to each application. The parameters to be adjusted are in close relationship to each other. The exact ratios between the individual parameters have to be determined during test weldings with a focus on resultant welding quality
- A low welding pressure can, for example, be offset by using a larger amplitude and/or a longer welding time. On the other hand, a shortened welding time can be offset with a larger amplitude and/or a higher pressure.
- Optimum adjustment for each application is usually achieved quickly by using the proper workpieces and observing the requested specifications for a weld. In addition, experience and practice may help in fine-tuning the adjustments for optimum welding results

4.4 Influence Of The Welding Energy

The amount of ultrasonic energy to be transferred to the parts is nearly proportional to the welding time, the amplitude and the pressure force. By increasing parameters, the introduced welding energy will increase immediately. To weld workpieces together a minimum amount of energy is necessary. Once the welding process is started, it must be insured that a successful coupling between the sonotrodes and the upper welding part exists and that the removal of possible contamination and disturbing layers on the surface of the workpieces is guaranteed.

Avoid excessive welding energy

If an insufficient amount of energy is used, the bond between the parts will be weak. Welding force and amplitude have to be properly set for the weld time to be effective and to achieve a good weld.

The necessary minimum energy has to be insured by selection of proper values for pressure and amplitude. This is the only way to obtain optimum welds. An excess of welding energy leads to a severe deformation of the parts to be welded and thus to a reduction of the cross-section or even damage of the work-pieces. This weakens the bond and reduces the tensile strength.

4.5 Influence Of Mechanical Stress

A study of mechanical stress in the parts to be welded has to consider both the time of exposure and magnitude of the stress. The welding time dictates the number of oscillations acting on the parts to the welded.

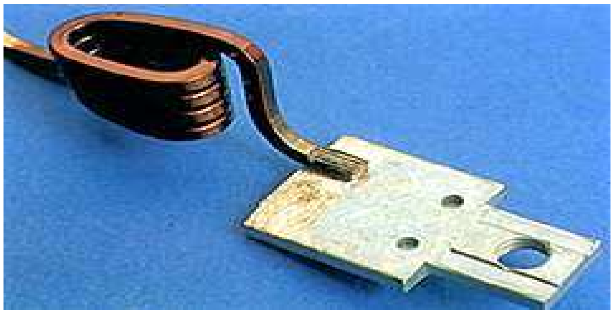


Fig.18 Mechanical stress on welded part

With an oscillation frequency of 20 kHz, the number of load cycles on the workpieces to be welded can be as much as 10,000 within 0.5 seconds. The parts to be welded are also subjected to large plastic deformation**s**. The longer the welding time, the higher the possibility severe damage will occur due to the cyclic load exerted by the alternation of traction and pressure. The magnitude of mechanical stress depends both on amplitude and mechanical pressure. The larger the amplitude, the stronger the displacement of the layers near the surface of the workpieces in the bonding area as shown in Fig 18.

If the boundary of elasticity is exceeded, it will either lead to material viscosity or to significant material damage. Unlike the dynamic oscillation load, the static load exerted by the mechanical pressure can be largely ignored.

4.6 Influence Of Thermal Stress

The thermal stress on the parts to be welded depends on a variety of influences such as welding time, oscillation length of the sonotrode (amplitude) and mechanical pressure. Due to the small frictional contact of the parts to the welded in the joining area, lower welding forces enable a higher relative movement between these parts. During this process, the majority of the supplied energy is transformed into frictional heat. The contact temperature starts to increase. Even longer welding times or greater amplitudes lead to an increase in temperature due to the higher release of energy into the parts to be welded as in Fig 19. On the other hand, the welding time and consequently the increase in temperature are decreased considerably when the amplitude increases.

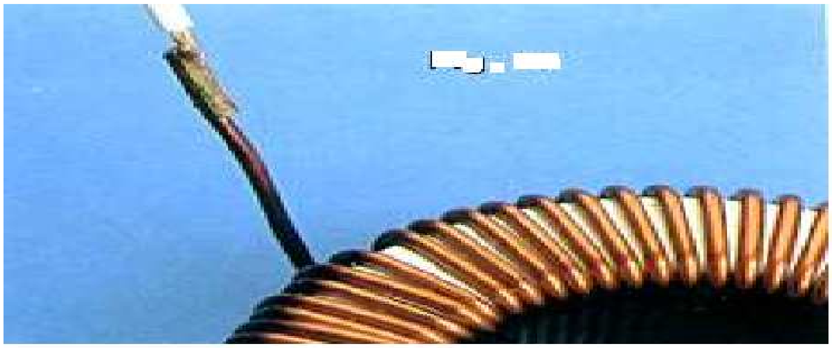


Fig.19 Thermal stress

Chapter:5

RESULT AND DISCUSION

5.1 Ultrasonic Welding Bonding Mechanism

I N recent years there have been several research concerned with aspects of the ultrasonic bonding (welding) mechanism. The energy density required to produce a given elongation in aluminum by utrasound is about 10' times less than the energy density required to produce an equivalent elongation using heat. After exposure to ultrasonic excitation, aluminum is work hardened (acoustic hardening) whereas equivalent thermal excitations leave the metal softer (annealed). Such work hardening in aluminum ultrasonic bonds has been experimentally verified by Coucoulas. Perhaps the major controversy in the early ultrasonic welding literature concerns the amount of heat generated during welding and the importance of heat in the formation of the weld. Although the metallurgical effect (work hardening) resulting from ultrasonic energy exposure is different from that due to thermal energy, some temperature rise does nevertheless, occur during bonding. It was asserted that high temperatures are an essential part of the ultrasonic welding process. The lower welding temperature measurements obtained with thermocouples have been challenged as giving average rather than peak temperatures, although most investigators have taken precautions to prevent.

5.2 Bond Left –off Patterns

The technique of studying ultrasonic bond formation by observing the patterns left on the bonding pad after the wire is removed has yielded considerable insight into the ultrasonic bonding mechanism of aluminum plats. Such patterns are obtained by establishing an optimum bonding schedule (ultrasonic power, bonding time, and clamping force), maintaining the clamping force and ultrasonic power constant and progressively decreasing the bonding time below the point that the wire will adhere. Fig. 20 shows lift-off patterns for 25+m diameter aluminum wire on 0.8~pm thick aluminum bonding pad.

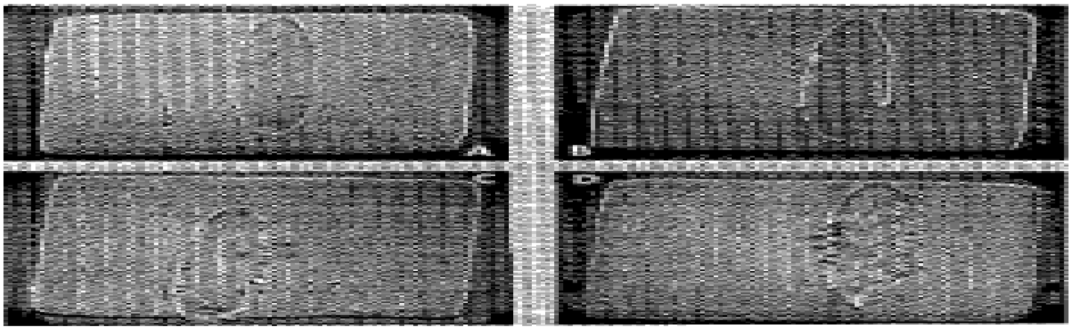


Fig .20 Scanning electron micrograph of bond lift-off patterns for 25-pm diameter-aluminum wire on OS-pm thick aluminum bonding pads. (a) Zero weld time (no ultrasonic energy). (b) 4-ms weld time. (c) 7-ms weld time. (d) lo-ms weld time.

Fig. 20(a) (zero weld time) shows the smoothing of the substrate due entirely to the force of the bonding tool impacting against the wire., Fig. 19(b)-(d) show the lift-off patterns made by applying ultrasonic energy for periods of 4, 7, and 10 ms, respectively. In the latter cases, the wire-to-pad welds formed only at points near the perimeter, but appear to be progressing inward.

5.3 Welding Around The Perimeter

Examination of many such aluminum aluminum patterns shows that weld formation always begins around the perimeter (Fig.20,21), but that no two time-equivalent patterns are exactly the same. The amount and location of the welding around the perimeter may show considerable variation. As the weld time increases the welded area grows inward from the perimeter to essentially cover the entire wire-substrate interface, except that in some cases the finished bond has a clearly defined unwelded area in the center. The exact conditions that result in different amounts of center welding in well-made microelectronic bonds are not completely understood, but appear to be related to the particular bonding machine, the tool shape, and the bonding schedule. Of these, long bonding times certainly contribute to this inward growth as seen from the lift-off patterns. In Fig.21 (digital camara image) show the welding at perimeter but in SEM image it is more clear to find out how weld formation occur at perimeter .

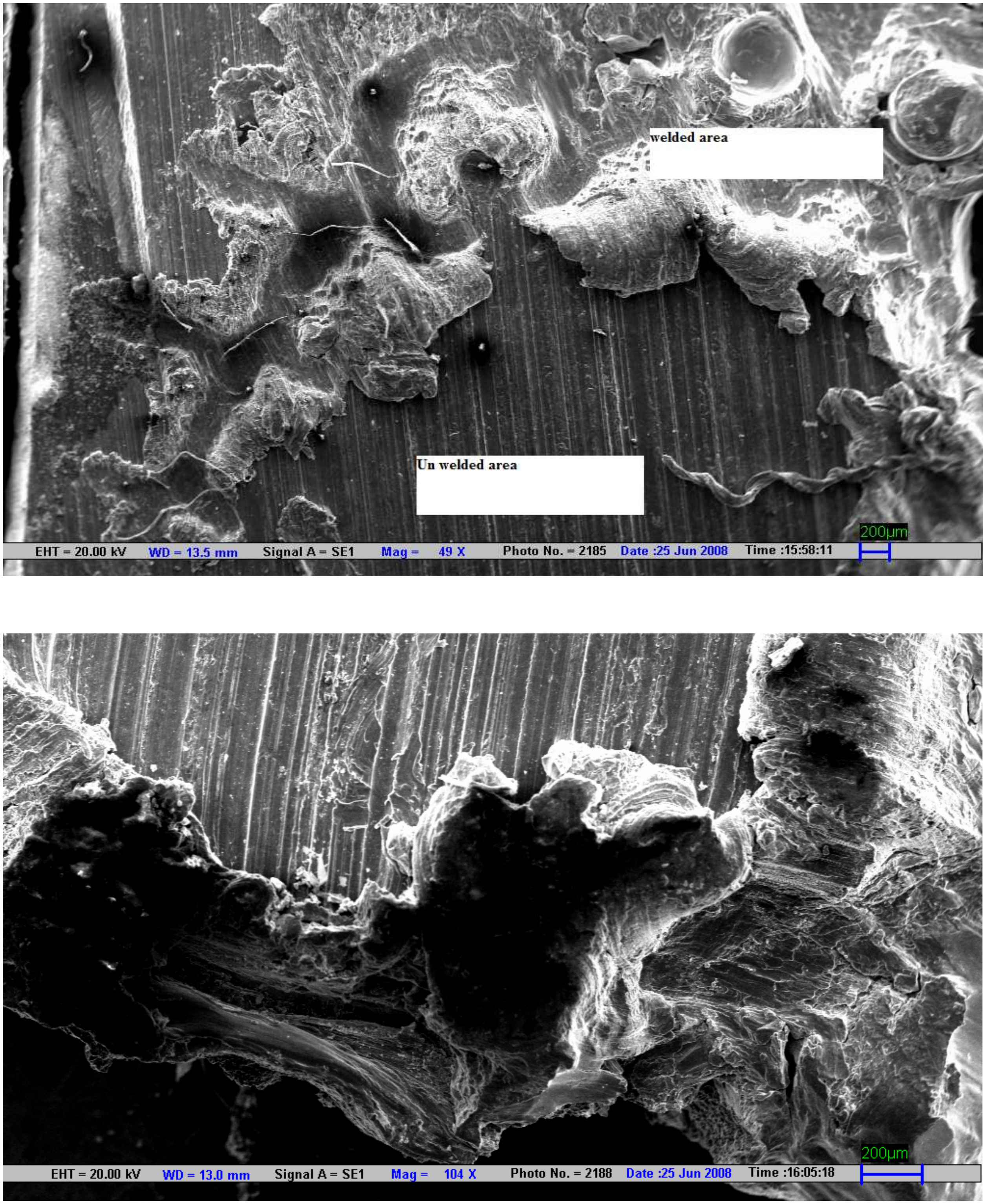


Fig. 21 Softening of welded area around the perimeter (Bond Left –off Patterns)

Fig.22 Showing the welding at perimeter (digital camera image)

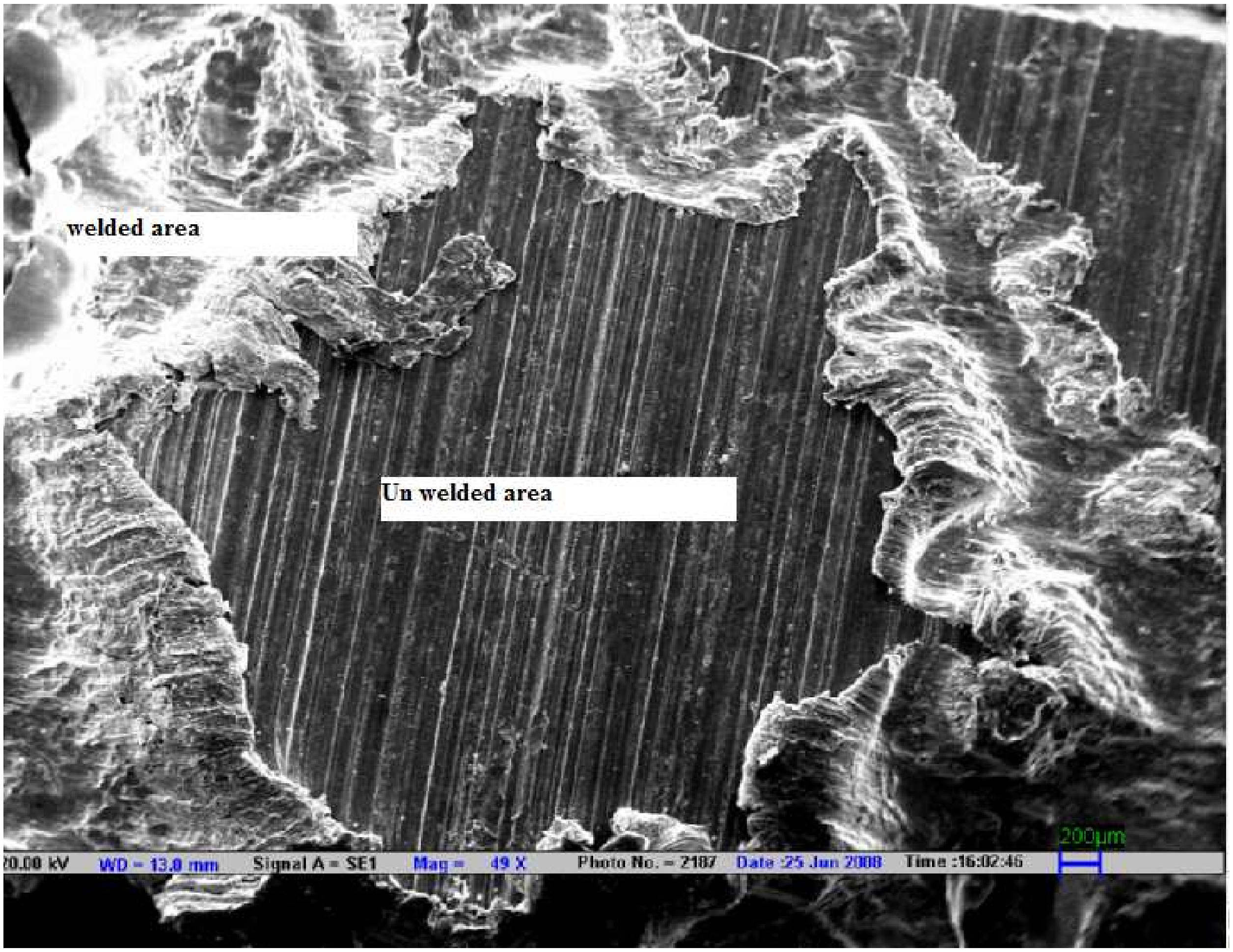


Fig.23 SEM of image ultrasonically welded

Showing the welding at perimeter

Deformation of weld area around the entire periphery of the bonded area similar to the welding in Fig. 23. It have 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.

Fig.24 Showing the welding at perimeter

5.4 Welding 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 24. Vibration may cause the fracture in welded area .Fig 25 show that the softening of work piece at knurled line impression.

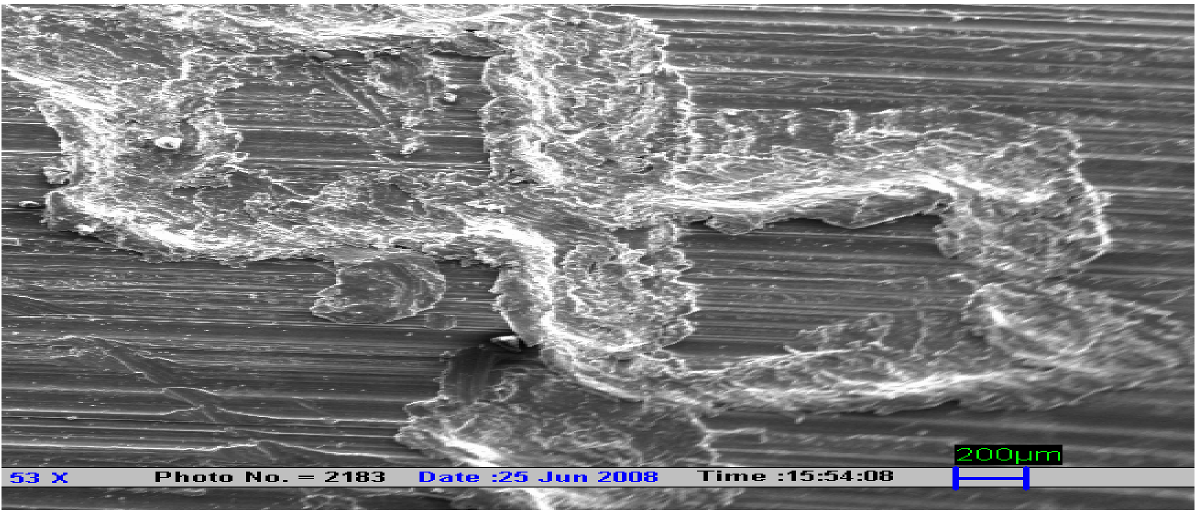


Fig.25 Softening of work piece at knurled line impression of sonotrode(SEM image)

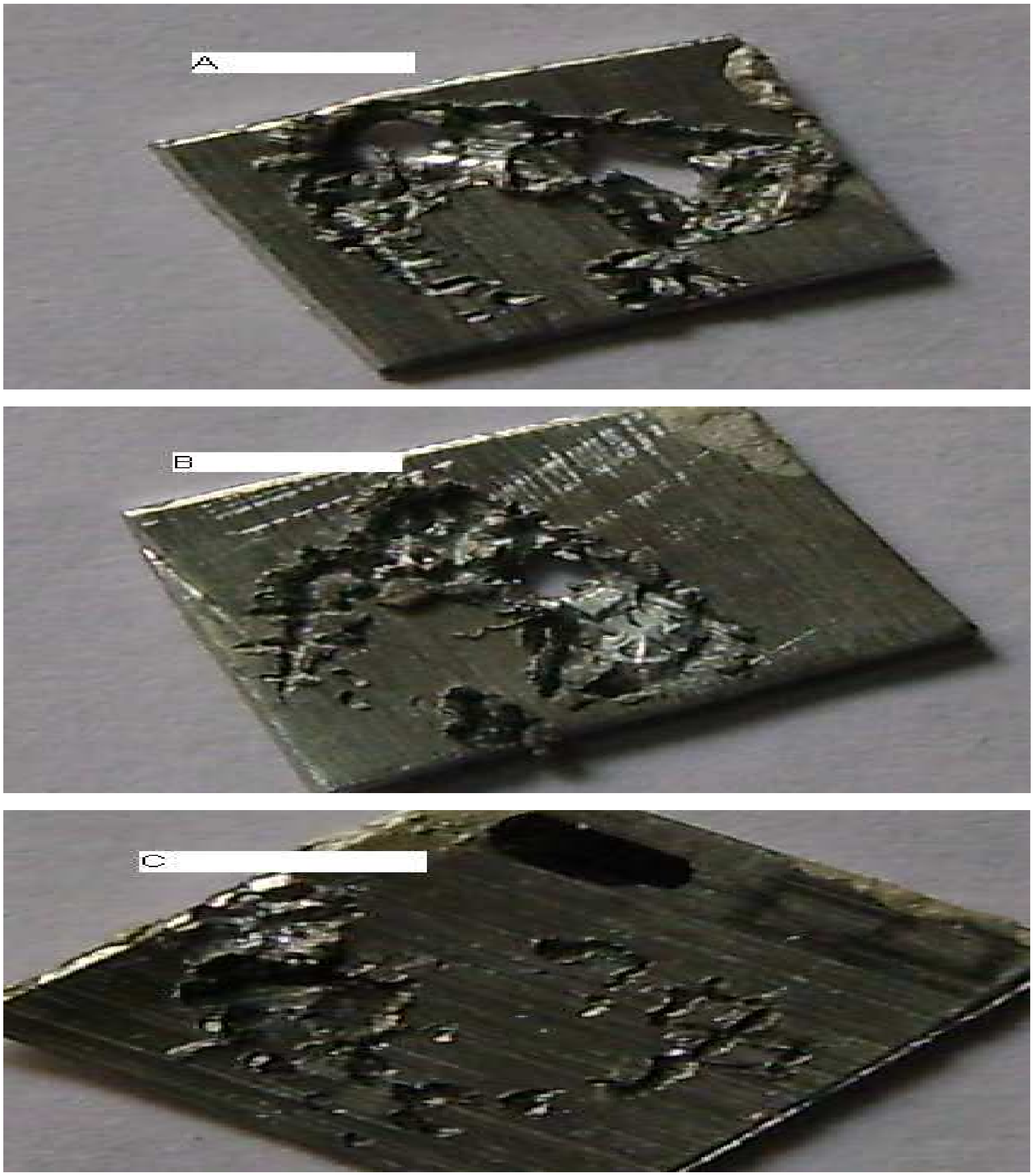


Fig.26 Welded area …(A)for 90% amplitude
(B) for 80% amplitude
(C) for 70% amplitude

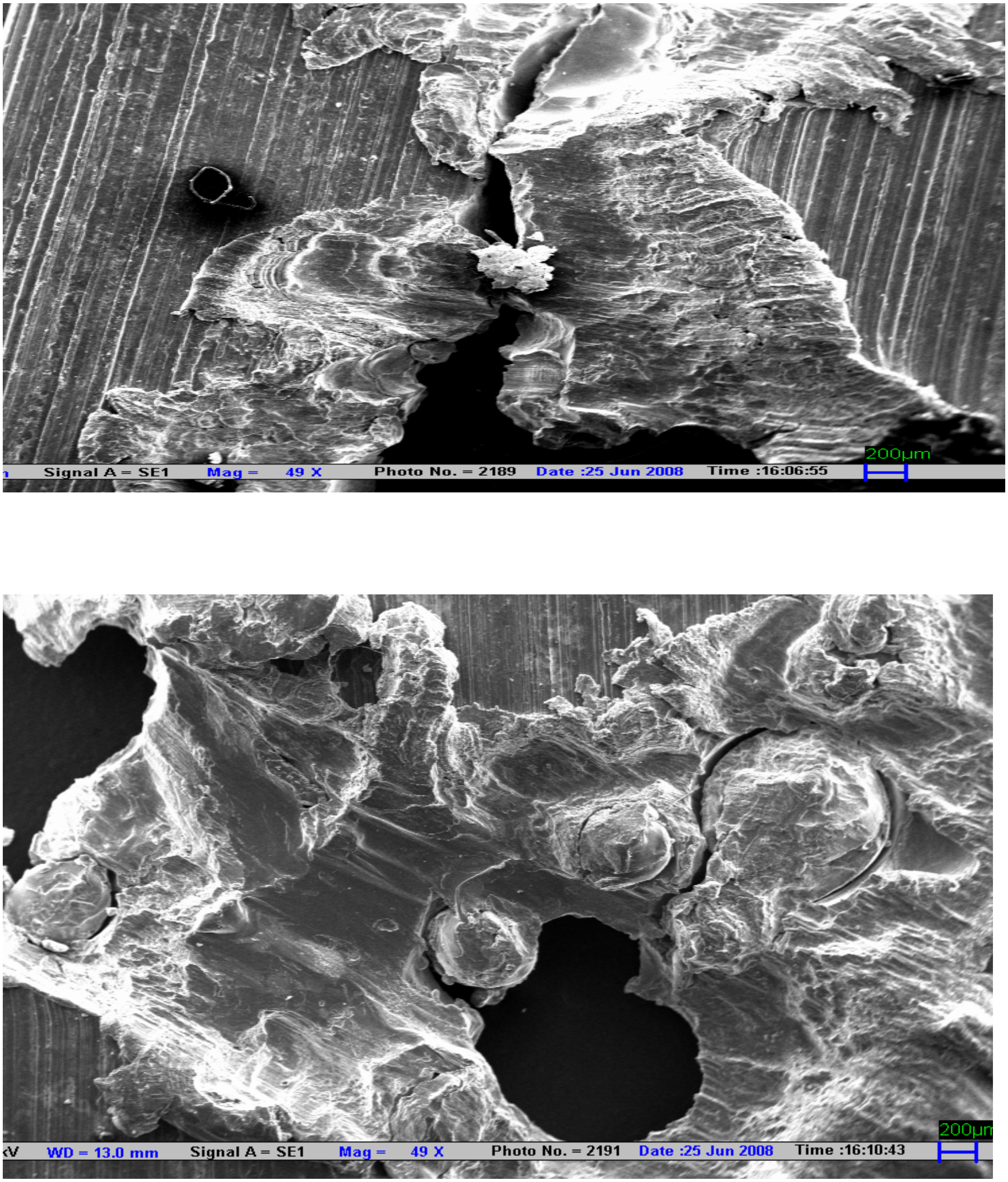


Fig.27 SEM images :Welded area fracture during welding

5.5 Contamination Can Affect The Welding Result

Contaminant removal in welding process

When parts are contaminated or excessively oily, their surfaces will be cleaned by the oscillating energy before the weld is made. The time required for this process depends on the amount of impurity and can therefore not be predicted. The remainder of the set process time (welding time) reduces by exactly this amount of cleaning time and is therefore not available for the actual welding process.

The most important part of all solid phase welding consists of removing contaminants from the surfaces of the weldments. This is primarily accomplished by softening one or both of the weldments with ultrasonic energy or heat. The resulting shear metal flow under compressive load pushes most contaminants, such as oxides, aside into debris areas] exposing essentially clean surfaces. Any remaining contaminants such as monolayers of water vapor or other gases serve as additional barriers for adhesion absorbed water on the surfaces constitutes a highly mobile film, difficult to remove from the interface and hence inhibiting the formation of intimate metal-metal contact.

5.6 Welding Parameter

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

Process-variable

However, the following variable parameters can be controlled:

- welding time .
- welding energy .
- mechanical compression of the parts to be welded (difference in thickness before and after welding.

5.7 Temperature Rise In The Welding Area

No fusion

Ultrasonic metal welding is local and limited to the shear forces and displacement of intermediate layers. However, a fusion does not take place if the pressure force, the amplitude and the welding time have been properly adjusted. Microscopic analyses using optical and electronic microscopes make re-crystallization, diffusion and other metallurgical phenomena evident. However, they provide no evidence of fusion (melted interface). The use of highly sensitive thermal sensing devices in the intermediate layers shows in initial quick rise in temperature with a steady temperature drop afterwards.

5.8 Welding in the energy mode

Welding in energy mode, i.e. with a constant energy setting, is known from ultrasonic plastics welding and can also be used for ultrasonic metal welding. To achieve a constant quality the welding time is automatically adjusted. Although this type of quality control is good with ultrasonic plastics welding, the approach has to be more carefully applied when it comes to ultrasonic metal welding.

Control of welding energy is not always sufficient

Considering that were applications which require only minimum welding energy, the total of all system-caused losses amounts to some 80% of the total necessary welding energy (leaving 20% effective welding energy), it becomes evident that small modifications in the workpieces to be welded require only a minor adjustment to the welding energy. The control of the welding energy in respect of welding time does not take into account possible insufficiencies and variations of the machine components. The tolerances are even higher when the workpieces to be welded are of different quality and have different service conditions. All these varying influences can have a considerable effect on the welding quality.

Group A

WELDING IN ENERGY MODE

Energy: 2000 ws
Weld location: at middle of lap
Amplitude: 70%
Pmax =300 w

PIECE NO.	WELD TIME IN SECONDS(T2)	%Pmax	T2*%Pmax	strength(WEIGHT) IN KG	
1	2.8	55	154.55	8.5	
2	3.26	53	179.46	8.5	
3	4.86	40	194.4	9	
4	3.2	62	198.4	9.5	
5	3.93	55	216.3	10	
6	43.64	62	225.8	11.5	

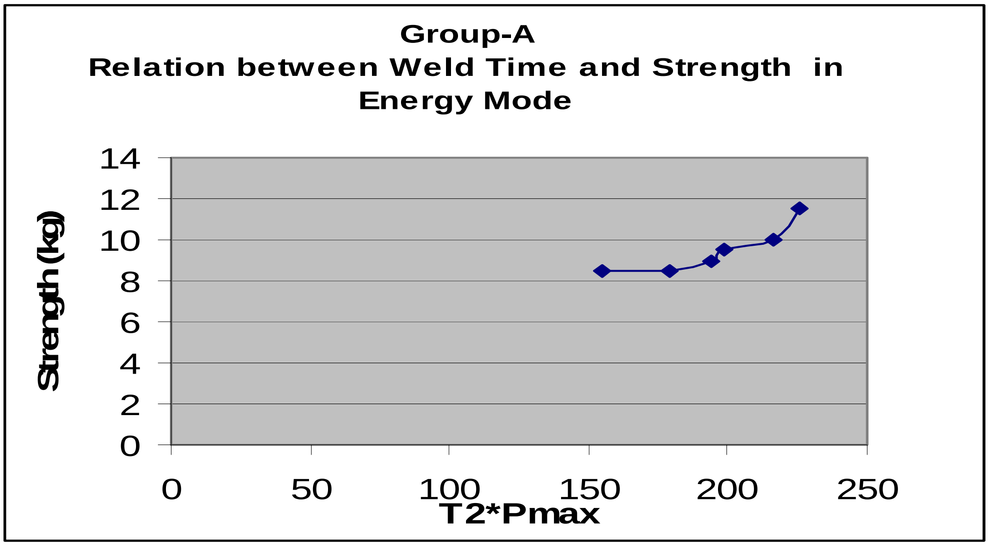


Fig.28 Relation between weld time and strength in energy mode

If an insufficient amount of energy is used, the bond between the parts will be weak. Welding force and amplitude have to be properly set for the weld time to be effective and to achieve a good weld.

By employing the constant US welding energy control (2000 ws) differences in US welding time will occur ,due to possible fluctuation in lien voltage ,in variation in pressure .material and geometry of part, temperature change ,friction looses.etc

The necessary minimum energy has to be insured by selection of proper values for pressure and amplitude. This is the only way to obtain optimum welds. An excess of welding energy leads to a severe deformation of the parts to be welded and thus to a reduction of the cross-section or even damage of the work-pieces. This weakens the bond and reduces the tensile strength.

At fixed welding energy Welding time and degree of compression are variable. The welding process ends automatically as soon as the nominal energy value is achieved. When the given tolerances for welding time or compression are exceeded, an alarm is raised. Optimum adjustment for each application is usually achieved quickly by using the proper work pieces and observing the requested specifications for a weld. In addition, experience and practice may help in fine-tuning the adjustments for optimum welding results.

5.9 Welding In The Time Mode

This is the most suitable mode for ultrasonic metals welding. Welding energy and rate of compression are variable, but we only consider the variation in energy because rate of compression does minor effect on weld strength subject to the deviations of the work piece. They should, however, stay within acceptable limits. The welding process ends automatically as soon as the nominal time value is achieved. The welding time is defined as the duration of ultrasonic’s and can be both a constant parameter and a variable parameter adjusted with the help of quality control devices for an optimum weld. Depending on the application the welding time can be between 0.1 and approximately 4 seconds. By employing the constant US welding time control (2000 ws) differences in US welding energy will occur ,due to possible fluctuation in lien voltage ,in variation in pressure .material and geometry of part, temperature change ,friction looses etc.

Group B

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at middle of lap
Amplitude: 70%
Pmax =300 w

Piece no	Weld energy. In WS	%Pmax	%Pmax*weld energy.	Strength(weight) In Kg
1	912	33	30096	3
2	1043	39	40677	4
3	1281	64	81984	10
4	1450	57	82661	10
5	1451	60	87060	10
6	1351.5	71	95556	10.5
7	1655	60	99300	11
8	1845	55	101475	11
9	1708	68	11644	12.5

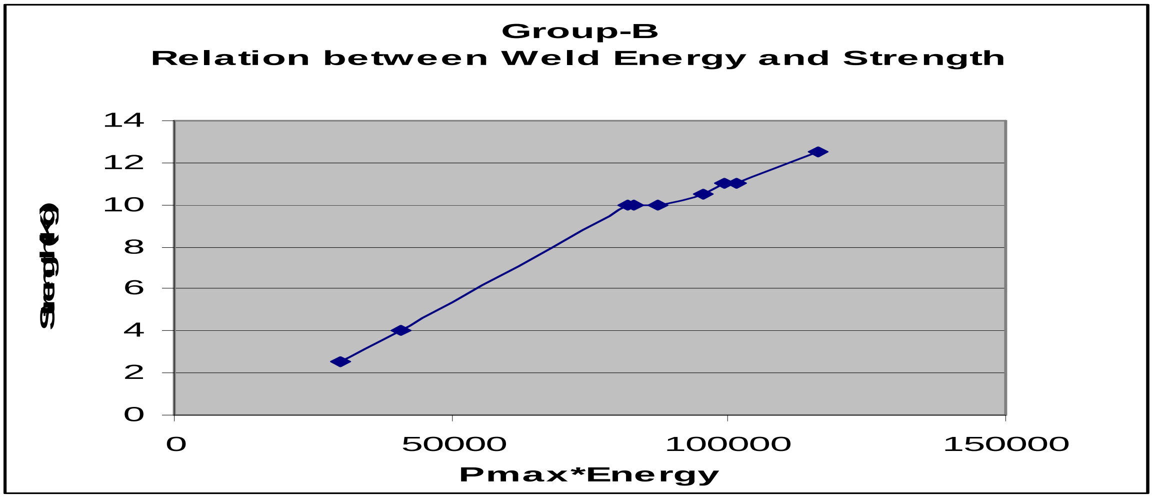


Fig.29 Relation between weld energy and strength at 70% amplitude

Group E

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at end edge of lap
Amplitude: 70%
Pmax =300 w

Piece no.	Weld energy. In WS	%Pmax	%Pmax*weld energy.	Strength(weight) In Kg
1	750	45	30750	6.5
2	680	47	31960	6.5
3	720	46	33120	6.5
4	754.5	52	39208	9
5	881	45	39645	9
6	816.3	50	40800	9
7	850	50	42500	9.5
8	964	51	49164	10

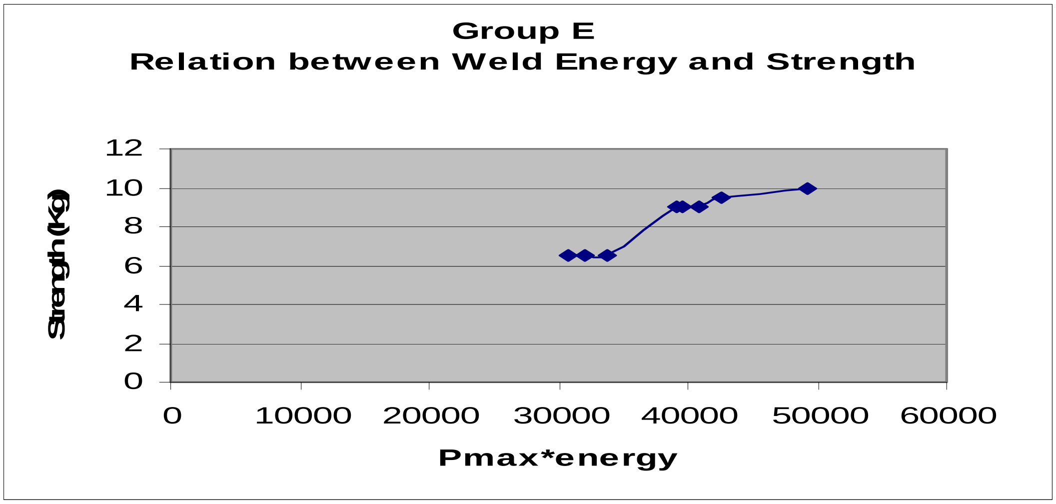


Fig.30 Relation between weld energy and strength at 70% amplitude at end

Group C

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at end edge of lap
Amplitude: 90%
Pmax =300 w

Piece no.	Weld energy. In WS	%Pmax	%Pmax*weld energy.	Strength(weight) In Kg
1	750	56	42000	6.5
2	957	54	51678	10
3	1092	57	62244	11
4	1180	56	66080	11.5
5	1259	54	67986	11.5
6	1177	61	71797	12
7	1638	61	99918	13
8	1492	68	101456	13

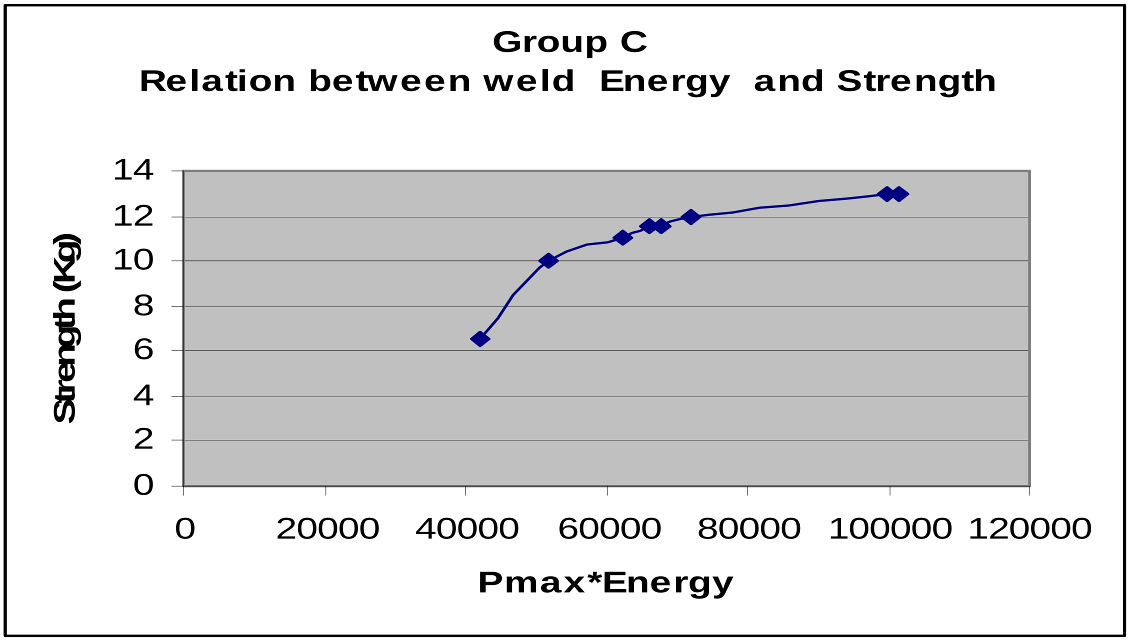


Fig.31 Relation between weld energy and strength at 90% amplitude at end

Group D

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at middle of lap
Amplitude: 80%
Pmax =300 w

Piece no.	Weld energy. In WS	%Pmax	%Pmax*weld energy.	Strength(weight) In Kg
1	925	45	41625	5
2	1000	50	50000	6
3	974.2	52	50640	6
4	1454	53	77062	7.5
5	1460	60	91980	9
6	1496	64	95772	9
7	1772	62	109864	9.5
8	1665	67	111755	10
9	1773.4	64	113472	10.5
10	1962	66	129492	11.5

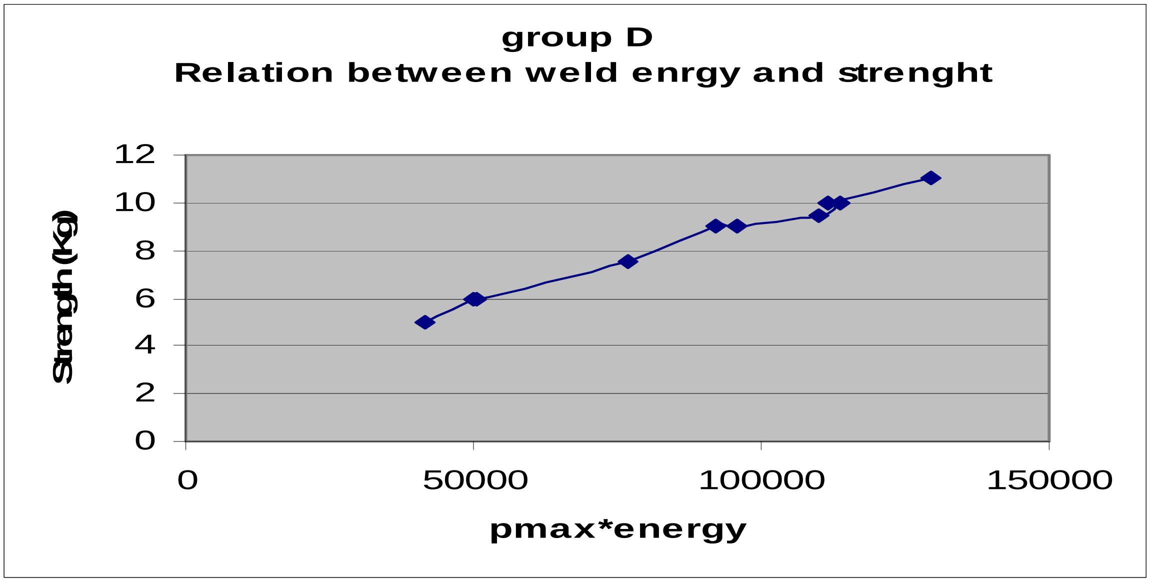


Fig.32 Relation between weld energy and strength at 80% amplitude at middle

Group F

WELDING IN TIME MODE

TIME: 2.5 s
Weld location: at middle of lap
Amplitude: 70%
Pmax =300 w

Piece no.	Weld energy. In WS	%Pmax	%Pmax*weld energy.	Strength(weight) In Kg
1	1419	51	72369	7
2	2000	46	92000	8
3	1568	62	97216	8
4	1535	75	115125	9
5	1980	61	120780	9.5
6	2000	64	12800	10
7	1939	67	129913	10
8	2124	69	146556	11.5
9	2136	70	149520	11.5
10	2307	72	166104	13

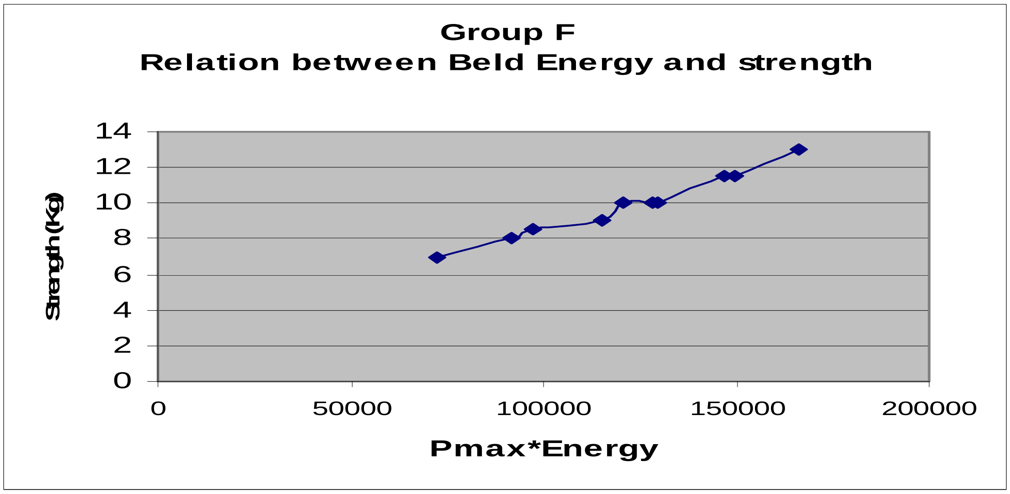


Fig.33 Relation between weld energy and strength at 70% amplitude at middle

With increasing of energy consuming by the e joint strength is also increase .. strength may also depend on load condition of generator ,joint alignment ,static pressure ,surface smoothness. In the time mode we have to set four time before to start of weld.

After pressing the TIMER key the four times which fun down successively can be displayed and altered.

TIMER 1 : ultrasonic start after this time has elapsed

TIMER 2 : ultrasonic welding time

TIMER 3: cooling time for plastic welding operation

Waiting time until shake off pulse for metal welding

TIMER 4 :shake off pulse time

5.10 Homogeneous And Lasting Joints Diffusion

Ultrasonic metal welding is not characterized by superficial adhesion or glued bonds. It is proven that the bonds are solid, homogeneous and lasting joints. If, for example, a thin aluminum sheet is ultrasonically welded to a thin copper sheet, it can easily be ascertained that after a certain period of weld time, copper particles appear on the back side of the aluminum sheet. At the same time, aluminum particles appear on the back side of the copper sheet. This shows that the materials have penetrated each other -- a process which is called diffusion. This process takes place within fractions of a second.

Further research into the process of ultrasonic welding is required before its basic mechanisms can be fully understood and its practical limitations ascertained. Nevertheless, general relationships between weld strengths and most weld variables are known. This knowledge, coupled with available equipment capable of controlling mechanisms involved in the ultrasonic melding process, permits the design of welders useful for many industrial applications. Present indications are that practical butt, seam, and spot welders can be designed. However it would be would be limited in application to welding thin-gauge sheets or small components of relatively ductile materials. More ultrasonic welders are designed, many of the design problems related to generating and coupling ultrasonic energy efficiently will be solved, and the ultrasonic welding process is expected to become a practical one for joining materials.

5.11 Joint Design And Weld Location

The thermal rise in the bonding area is produced by the absorption of mechanical vibrations, the reflection of the vibrations in the connecting area, and the friction of the surfaces of the parts. The vibrations are introduced vertically. In the contraction area, frictional heat is produced so that material plasticizes locally, forging an insoluble connection between both parts within a very short period of time result, the joining areas are prepared to make them suitable for ultrasonic bonding.

Parts that will be ultrasonically welded together are 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 that when the parts are welded together there is sufficient materials for the parts to fuse together with a strong joint . this process also means that no addition adhesives or connective parts are needed to create the joint .this not only saves money but also makes the process quicker to carry out.as it show in fig .32

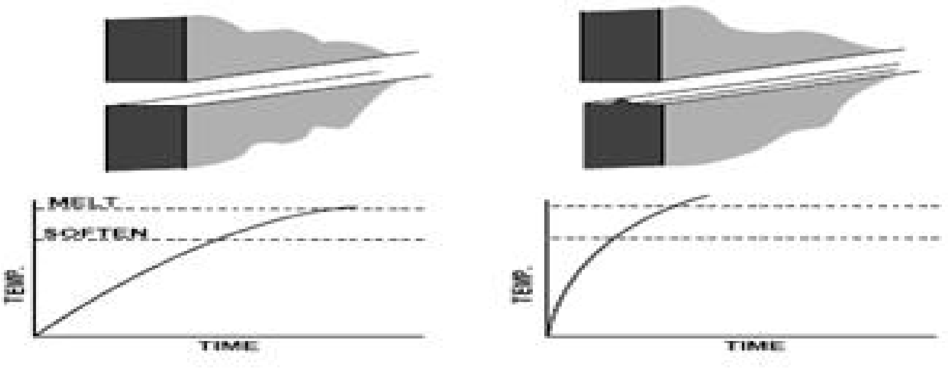


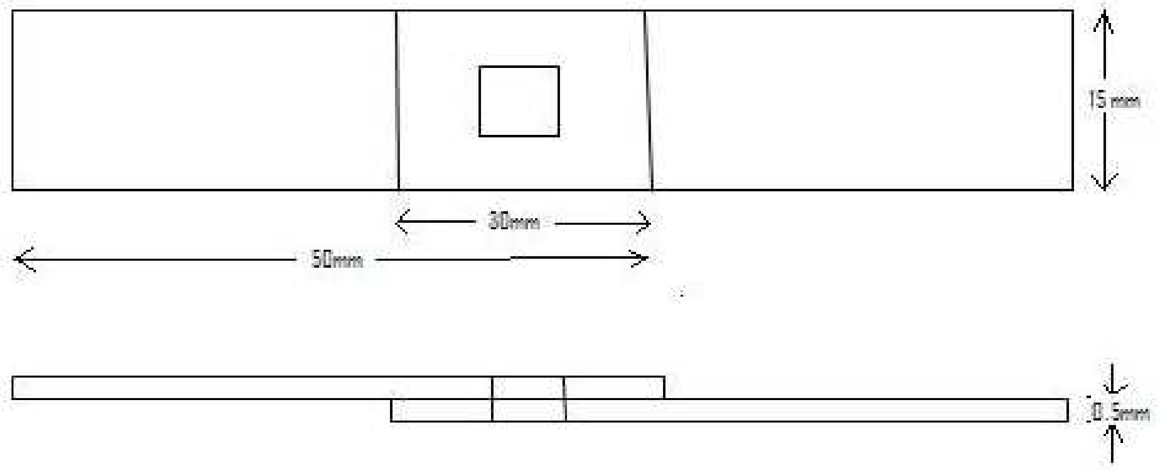
Fig.34 Temperature profile for joint design

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

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. 35 Welding at middle 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.

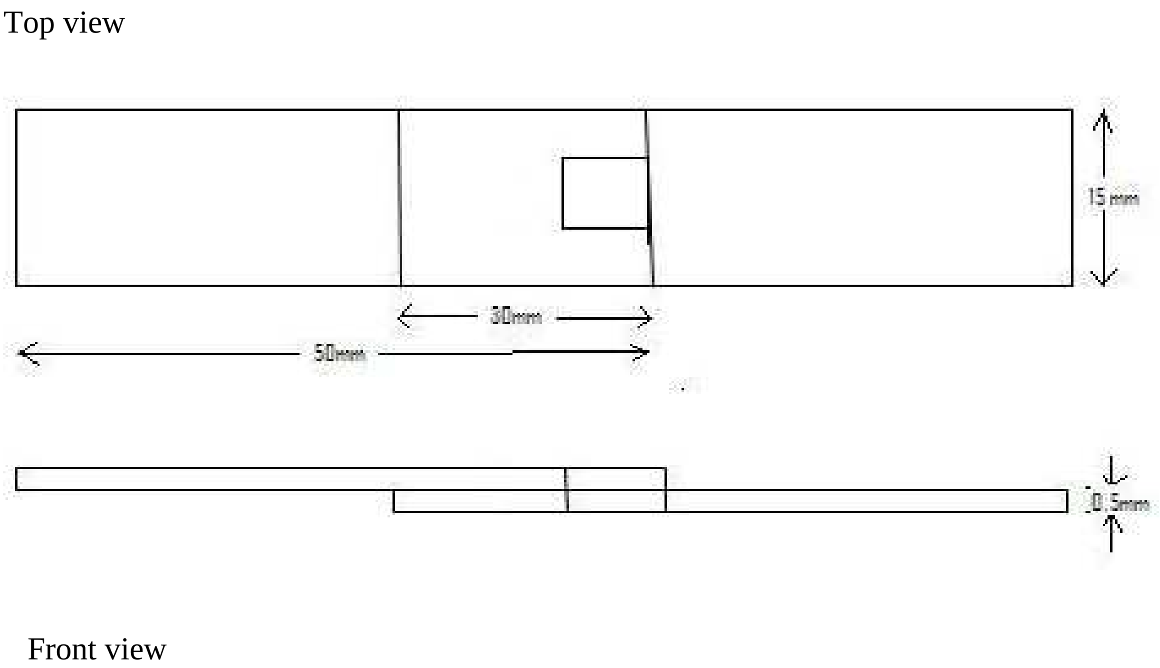


Fig. 36 Welding at end edge of lap

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 weaken 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 .

Chapter:6

CONCLUSION

From the experimental results following conclusion can be drawn . Welding characteristics of 20kHz ultrasonic welding system was studied using aluminium sheets specimen. Aluminium plate specimen of .5 mm in thickness and 15 mm in width were successfully welded at various welding parameters and welding modes . Study of Welding in two different mode.(1)Energy mode (2).Time mode

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- The time mode is more favourable mode for ultrasonic metal welding.
- In ultrasonic welding bond formation occur due to softening of work piece by help of static pressure at periphery of sonorode cross section area impression.
- By studding the SEM image of 49X mag. , ultrasonic weld formation always begins around the perimeter , but that no two time equivalent pattern are exactly the same.
- SEM image show that the weld formation occur due to knurled lines of sonotrode
- Study of sonotrode impressions(SEM image of 53X mag.) show that the softening of metal always be occur at knurled lines .
- Weld time increases the welded area grows in ward from perimeter.
- Assemblers who use this process don’t have to worry about allotting time for warm up or cool down ,which is must in other joining process , such as hot plate welding. Ultrasonic welding is a solid state process used for dissimilar metals of both thin and thick cross section , 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 .the electrode will need to be removed ,dressed by mechanist and then realised in the fixture , which is time consuming.
- In ultrasonic welding there facility to input time of weld by help of microprocessor ,by increasing weld time ,weld energy will also increase .With increasing energy ,weld

strength also increases up to a certain value Further increase does not affect much weld strength. So excessive welding energy should be avoided .

- 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. welding at end edge of lap give comparative good welded quality and the more effectiveness of ultrasonic welding system .

Chapter :7

REFERENCES

1. “Welding Technology and engineering”. Dr. R.S. Parmar
2. “Ultrasonic welding equipment”. Johs n. antonevich. IRE transaction on ultrasonic engineering Reprinted from the 1959 IRE NATIONAL CONVENRTEIOCNO RD,pt. 6, pp. 204-312 Battle Memorial Institute, Columbus, Ohio
3. “Transverse and torsion complex vibration system”. J.Tsujino ,T.Ueoka, T.Kashino. Faculty of Engineering, Kanagawa University, Yokohama 22 1-8686, Japan.
4. “Welding Characteristics Of Various metal plates ultrasonic seam and spot welding system using a complex vibration welding tip”. Jiromaru TSUJINO and Tetsugi UEOKA Faculty of Engineering, Kanagawa University, Yokohama 22 1-8686, Japan. 0-7803-7177-1/01/$10.00 © 2001 IEEE. 2001 IEEE ULTRASONICS SYMPOSIUM-670
5. “New Methods Of Ultrasonic Metal Welding”. Jiromaru TSUJINO, Tetsugi UEOKA, Ichiro WATANABE, Yusuke KIMURA Faculty of Engineering, Kanagawa University Yokohama 221, Japan. 1051-0117/93/0000-0405 $4.00 *0* 1993 IEEE. 1993 ULTRASONICS SYMPOSIUM - 405
6. “Recent development of ultrasonic welding” Jiromaru TSUJINO, 0-7803-2940-6/95/$4.00 *0* 1995 IEEE. 1995 IEEE ULTRASONICS SYMPOSIUM - 1051.Faculty of Engineering, Kanagawa University Yokohama 221, Japan.
7. “The ultrasonic welding mechanism as applied to aluminum” .George G. Harman senior member IEEE. Loten und Schweissen in der Elecktronik,” Munich, Germany, November 25-26, 1976
8. “Exploring the ultrasonic welding” . Katrina C. Arabe. The economics of ultrasonic assembley magazine aug .1, 2003
9. “Welding characteristics of 40 khz ultrasonic plastis welding system”. Jiromaru TSUJINO, Faculty of Engineering, Kanagawa University Yokohama 221, Japan.

10. “Temperature and stress distribution in ultrasonic metal welding”—An FEA-based study S.Elangovan, S. Semeer, K. Prakasan∗ Department of Production Engineering, PSG College of Technology, Coimbatore 641004, India. journal of materials processing technology x x x (2 0 0 8) xxx–xxx PROTEC-12027; No. of Pages 8.
11. “Ultrasonic Welding” by H. P. C. DANIELS* *ULTRASONIcs/October-ecember1965.* Philips Research Laboratories N.V. Philips' Gloeilampenfabrieken Eindhoven-Netherlands
12. “Predicting the Failure of Ultrasonic Spot Welds by Pull-out from Sheet Metal”. Bin Zhou,1 M. D. Thouless,1,2 and S. M. Ward3, *1Department of Mechanical Engineering, 2Department of Material Science and Engineering University of Michigan Ann Arbor, MI, 48109, 3Scientific Research Laboratory Ford Motor Company Dearborn, MI, 48124*
March 2006
13. “Process Innovations in Ultrasonic Metal Welding” *by Jay Sheehan, Elizabeth Hetrick, Janet Devine, Karl Graff, Joe Walsh, Larry Reatherford, David Scholl, Zachary Berg.*
14. “Mechanics and Mechanism of the Ultrasonic Metal Weld in Aluminum” *by Edgar de Vries, The Ohio State University’’.*
15. Http://Www.Joiningtech.Com/News/Ultrasonicwelding_26/.
16. Http://En.Wikipedia.Org/Wiki/Ultrasonic_Welding.
17. Www.Ieee.Xplore/Org.Com
18. Www.sciencedirect.com.