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FABRICATION OF ULTRASONIC WELDING MACHINE USING ULTRASONIC HORN AND GENERATOR

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Abstract: Ultrasonic welding is recognized as the one of the most often used method for joining of thermoplastics. In Ultrasonic welding avoiding thermal decomposition and increasing the weld area are divergent factors in order to enhance the strength of welded polymers. Aim of the project is to review the literature of ultrasonic welding of plastics along with different types of ultrasonic horn and ultrasonic generators used for welding process. Procurement of flat faced Ultrasonic horn and ultrasonic generator of 20kHz frequency, construction of Mild steel support structure along with roller to advance the joining plastic. Higher frequency mechanical vibrations are applied to two plastic parts to be joined through a flat faced ultrasonic horn, this generates heat and locally melts the plastic materials and joins the thermoplastics without filler material.

***IndexTerms*–USW, Ultrasonic Horn, Ultrasonic Generator**

I. INTRODUCTION

Welding is defined as the process of joining material with or without filler material and/or by means of pressure, heat or both. Usually welding is used for joining thermoplastics, metals and also for wood. Generally welded product is referred as weldment. In welding parts that are joined is referred as parent material and the material that is used to form the join is known as consumable or filler material. Usually material with similar composition to parent material is chosen while selecting the consumables/fillers in order to form homogenous weld and in specific applications where there is a requirement to add a filler material with different composition is required then it forms heterogeneous weld.

1.1 Features of Weld:

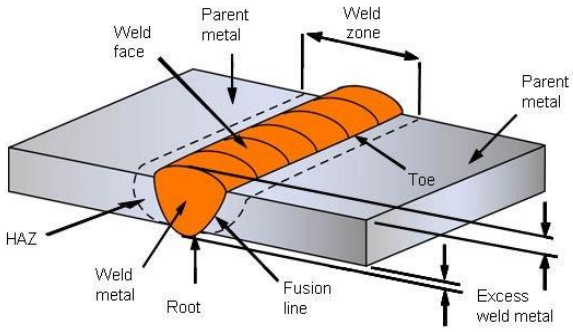

Fig.1.1 Features of Butt Weld

- Parent Metal
  In Welding metal to be joined is referred as Parent metal
- Filler Metal
  Material added to help in joining the parent metal is known as Filler metal.
- Weld Metal
  While applying heat all melted metal and metal remained in final product is known as Weld metal.
- Heat Affected Zone (HAZ)
  This is the zone/part affected on parent metal metallurgically while welding process, but not melted.
- Fusion Line
  This is the boundary between the Heat affected zone and the weld metal in a fusion weld.
- Weld Zone

This is the zone containing HAZ and the weld metal.

- Weld Face
  This is the surface of a fusion weld that is exposed on the side from where the weld has made.
- Weld Root
  Weld root is nothing but zone on the side of the first run that is furthest from the welder.
- Weld Toe
  This is the boundary between the runs or between the weld face and the parent metal. Weld Toes are the points of high stress concentration hence these are very major feature of a weld. Toes are bent smoothly into the parent/Base metal in order to reduce stress concentration. As shown in Fig.1.1.
- Excess Weld Metal
  This is also called as overfill/reinforcement. This is the weld metal lying outside the plane joining the toes.
- Run/Pass
  This is the metal deposited or melted during a passage of an electrode/torch/blowpipe.
- Layer
  Layer is the stratum of weld metal either consisting one or more runs.

II.ENERGY SOURCES FOR WELDING:

In order to meet the raising demand for precision, accuracy, low cost and bulk availability there are variety of different energy resources are there. Before 20th century forge welding was the only method used for welding/joining, with the beginning of 20th century different welding techniques like arc welding have been developed. Today there are several different techniques like Electric arc, lasers, gas flame, friction, electron beam and also ultrasound is used for joining of materials. But operator should take care of safety precautions since these energies may lead to electric shock, burns, exposure to radiation, damaged vision or inhaling of poisonous weld gases/flumes.
Following are the different types of welding:

2.1 Arc Welding

Arc welding includes number of automatic, manual and semi-automatic processes like

- Metal Inert Gas Welding (MIG)
- Stick Welding
- Gas Tungsten Arc Welding (GTAW)
- Gas Metal Arc Welding (GMAW)
- Metal Active Gas Welding (MAG)
- Flux Cored Arc Welding (FCAW)
- Submerged Arc Welding (SAW)

Arc welding is method used for the joining of metals including nickel, copper alloys, steel, cobalt, titanium etc. with a filler material. This type of welding is useful in power, automotive, aerospace along with oil and gas industries and more.

2.2 Friction Welding:

As the name indicates this method uses mechanical friction for joining of materials and this can be used for joining variety of materials including aluminium, steel and even wood. Heat is generated during mechanical friction which directly melts/softens the materials resulted in mixing and creating bond as they solidify. Following are the basic friction based welding techniques:

- Friction Stir Spot Welding (FSSW)
- Friction Stir Welding (FSW)
- Rotary Friction Welding (RFW)
- Linear Friction Welding (LFW)

It is evident that in friction welding any type of flux/shielding gas/ filler materials not required. Friction welding is ideal for joining non-Wieldable light weight Al alloys hence this can be used in aerospace applications. Also friction welding is also explored in wood applications without using adhesives/nails.

2.3 Electron Beam Welding:

Electron Beam Welding is a joining process which uses beam of high velocity electrons for joining of materials. Whenever highly energized electrons with higher kinetic energy impinges on the work piece it will be converted into heat causing work piece to melt together. Usually EBM method is carried out in a with the usage of Vacuum chamber to restrict the beam from dissipating. EBM has wide range of applications from joining of thick sections to industrial applications such as nuclear power, rail and automotive.

2.4 Laser Welding:

Laser welding is used to get concentrated heat for ideal barrow, high joining rates and deep welds, this can be used to join pieces if metals or thermoplastics. High volume applications like automotive industry usually requires automation, higher weld speed hence laser welding best suites the application. As with Electron beam welding where vacuum chamber is used in laser beam welding process is performed in air.

2.5 Resistance Welding:

Resistance welding because of its fast process can be used in automotive industries. There are 2 types of resistance welding namely

- Resistance Spot Welding- In this type heat is applied to a small area of the work piece which are clamped together by two electrodes.
- Seam Welding- This is similar to spot welding but here rotating wheels replaces electrodes in order to get leak-free weld.

2.6 Ultrasonic Welding:

In 1960s development of USW completely transformed the potential of manufacturing of plastic. Until this time, stable weld is generally used for welding/joining of hard plastic components. Resulted in limitations for use of plastics in manufacturing industry. Ultrasonic welding was developing in the early 1960s, using of ultrasound probes or ultrasonic emitting probe are used for converting plastic films into bags and tubes. in 1965 technique graduated soft to plastic of rigid and was put to use of the toy industry as well, making bulk produced plastic toys less price or cheap and accessible for 1st time. From 1969, USW has been used to bond plastics in the automobile industry, and then a list of grooving other sectors in the decades ensuing.

Now a days in automotivesautomotive,medical and electronic appliances for joining of thermoplastic parts ultrasonic welding is most commonly or widely used. The advantages using USW is fast, easily automated and economical. In this USW, 2 plastic parts to be joined are placed together on fixture before more frequency mechanical vibration is to be applied to the parts through an sonotrode.This creates or generates high heat at the joint area & locally melts of thermoplastics. When cooled, weld together the parts. The prime importance to efficiency and quality of USW is ultrasonic horn. While design of horn various studies has analyzed. Heating of thermo-plastic is essential to weld of accomplish.

The generation(heat) of mechanism have been investigated. There are 2 types of mechanism is used to generate the heat. Viscoelastic friction heating and interfacial friction heating at the joint interface. The distribution of temperature also to be studied in ultrasonic welding. Generation of heat directly affects the melting behaviour of the interface & is related to the interface of dynamic behaviour, such as elastic strain and displacement depending on vibration of horn.

USW is used in various specialist applications in different types of industries, USW technology has diversified & progressed greatly since.

These include:

1. Car & Aerospace Industry.
2. IT & Electronic Industry.
3. Medical Industry.
4. Packing Industry.

Why choose ultrasonic welding?

This is depending on type of MFG req. N number of key factors come into play that will help one to make up researcher mind. Following the determining factors, we can look now: type of material, part size, performance parameters, cost and part requirements. USW has various disadvantages and benifit compared with other methods, see below further details:

Part requirements: a big determining term pr factor is the type of components researcher are working with & the integrity of weld need to achieve. USW can comfortably create airtight form strong bonds and hermetic seals between very thin-walled parts. This makes it is a superior choice to other techniques of welding when dealing with components of fragile. Researcher can also reliably surface of internal weld. Some USW machines can handle curved joints or multi-level, but this much depends upon the component. If in doubt we recommend you chat with us about project REQ before making investment. The same applies if researcher require N no of parts per weld cycle. Ultrasonic welders can do this, but it is dependent of part.

- Like ultrasonic metal welding, ultrasonic plastic welding has a wide number of uses.
- These includes sealing bags and containers, attaching plastic components and embedding metal components in plastics.
- This last example deserves special attention.
- When a metal part requires to be attached to a plastic part, convention methods include moulding the metal component into the part when it is created, gluing the metal part to the plastic & locally melting the plastic component then inserting the piece into the allowing it to solidify and molten area.
- USW of metal to plastic works by using the ultrasonic head to vibrate the metal component against the plastic one. this softens and heats the plastic part and allows the metal part to be inserted. As the plastic cools, a very strong bond is made.

2.6.1 Performance Parameters:

USW has the cycle time is fastest of all the main welding methods. It can create strength weld is high, which is perfectly suitable for most components. USW is gives moderate level of stress resistance, superior to other technologies of welding.

Part size: USW can also be used for small to medium-sized parts. Where we need to weld large parts, researcher may need to consider a special purpose machine that can have multiple USW actuators either simultaneously or staged depending upon the requirements.

Metal compatibility: USW can used with a wide range of thermoplastic materials, semi crystalline (for small parts only), including amorphous plastics, plastics and fabrics\films.

Cost: USW is one of the most flexible and cheapest welding processes, making it ideal for projects with budgets of strict. In terms of energy, equipment, labour costs and tooling costs- USW is consistently cheaper than all the alternatives, hotplate, including vibration and laser welding.

2.6.2 Advantages of Ultrasonic Welding:

- It produces a high-quality bond and a clean, tight seal.
- Process time is short compared to other type of welding.
- Ultrasonic welding causes no or a little thermal damage to the specimen due to cold welding tools
- It consumes little energy hence high efficiency can be achieved

- Additives or any type of solvents are not mandatory for ultrasonic welding
- With wide range of welding parameters of ultrasonic welding reproducible and constant welding results are possible.
- Ultrasonic welding can be used for joining different thermoplastic materials.
- Since the welding tool do not heat up, tools can be changed quickly.
- Safety
- Due to its versatility, cost and effectiveness, there are a nearly infinite number or applications for ultrasonic welding.
- One of the most common is for the production of wiring connection.
- USW is ideal for this application for a number of reasons.
  1. One of these is that it produces a nearly perfect electrical connection.
  2. Second, it requires no consumables, such as solder.
  3. Third, it uses far less energy compared to other forms of connecting, such as welding of resistance, which is made difficult by the excellent electrical characteristics of wire of copper.

Finally, the USW process produces little heat, allowing it to be used near heat sensitive components.

III. PROBLEM DEFINITION:

Review of literature [1-11] suggest ultrasonic welding one of the as a potential technique to join metals as well as plastics. Although, there are few works has been conducted out on ultrasonic welding for joining of plastic materials without filler material. In this project ultrasonic welding apparatus assembled with steel flat faced horn of 20kHz frequency and Iron plate ultrasonic generator of 220V of 15-20kHz frequency along with Mild steel structure for advancing the plastic for joining of two dissimilar plastic materials without adding filler materials.

IV OBJECTIVES:

- Literature review of various types of Ultrasonic horn and Ultrasonic generators.
- Procurement of Flat faced Ultrasonic horn and ultrasonic generator of 20kHz frequency.
- Construction of Mild steel support structure.
- Assembling of Ultrasonic Horn, Ultrasonic Generator and Support structure.
- Joining of plastic materials without filler material.

V. ULTRASONIC EQUIPMENTS

5.1 Ultrasonic Horn:

Ultrasonic horn is also known as Sonotrode or ultrasonic probe or acoustic horn or acoustic wave guide. Ultrasonic horn is a tapering metal bar in design used for build up the oscillation amplitude which is provided by ultrasonic transducer operating at low end (15KHz to 100KHz) of ultrasonic frequency spectrum.

5.2 Specifications of Horn:

In this project Flat face ultrasonic horn is used for ultrasonic welding and specifications of the horn is mentioned in table 5.1.

Specifications	
Material	Steel
Size	110mm
Usage/Application	Industrial
Frequency	20kHz
Weight	10Kg

Table.5.1 Specifications of horn

Fig shows the flat face horn used in the project. As mentioned in section these horns are used whenever there is need to distribute the overall ultrasonic energy evenly across the surface of the part. As shown in Figure 5.1.

These type of horns used to prevent damage by distributing the ultrasonic energy evenly across the surface of the part to be joined/welded. Flat face horns have flat tip usually employed in welding materials with flat surfaces.

Fig.5.1 Flat face horn

5.2 Booster:

Boosters also called as booster horns are the mechanical amplifier used in ultrasonic welding to increase the amplitude from a converter. Booster gain can be defined as calculated ratio of mass above and below nodal point. There are standard and color coded boosters are there based on gain factor of 1.0, 1.5, 2.0, 2.5 and 3.0.

Booster provides mechanical advantage and amplifies the amplitude of vibration that is transmitted to flat faced horn. Design of booster is simple it has threaded attachment on both ends enables it to connect transducer and horn on each side. Size and shape of Booster varies depends on application also the type of material i.e., Titanium, Aluminium, Steel etc. used for booster

varies as per requirements such as frequency of ultrasonic vibration, size and shape of the horn and material being welded as indicated in Figure 5.2.

Selection of booster:

Following are the factors to be considered while selecting the booster.

- Type of plastic material both content and resin
- Energy requirements and type of weld
- Horn gain capacity and physical part size
- Required amount of Amplitude
- Medium to Large size parts- Gain should be 2.0 and above Ex. Semi crystalline resins
- Small to Medium size Parts-Gain should be 1.0 to 1.5 Ex. Amorphous resins.

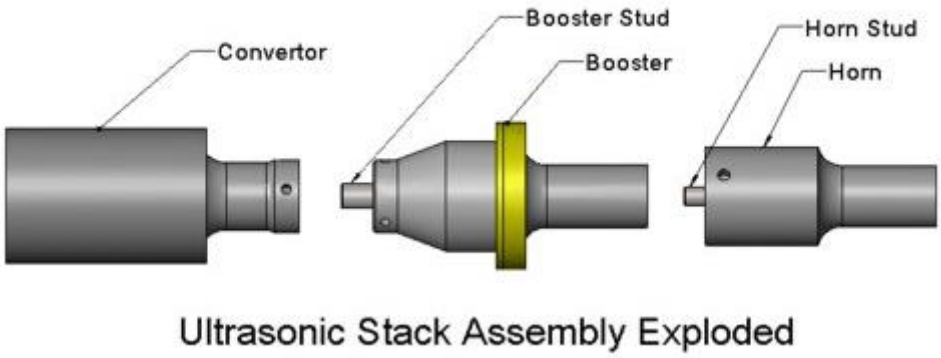

Fig.5.2 Ultrasonic Booster

5.3 Ultrasonic Generator:

Ultrasonic generator is a device that provides required electrical energy to power the ultrasonic transducers. Generally, it is used for converting the received electrical energy from power line into the required proper frequency, amperage and voltage for specific application to actuate the transducer. Usually, Power line provides 100 to 250 volts Alternative current at 50Hz or 60Hz depending on the location i.e., country. In order to drive an ultrasonic transducer power requirement varies but it is mandatory that generator should provide signal at voltage higher than it received from power line to achieve the proper results. Fig shows ultrasonic generator with input from power line and output to ultrasonic transducer, also it is indicated in figure that signal is amplified/raised in output than input parameters. As shown in Figure 5.3.

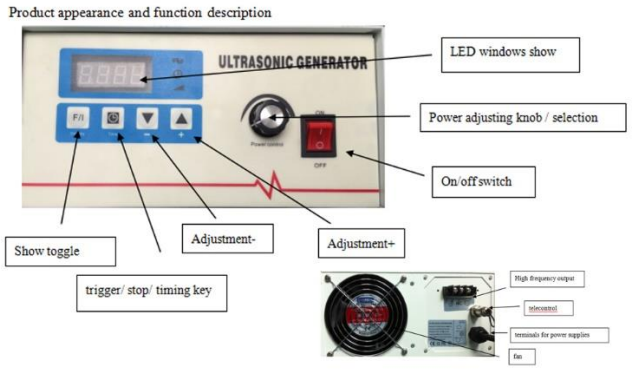

Fig.5.3 Ultrasonic Generator

Fig shows the ultrasonic generator used in this project and different switches and knobs for controlling the rate including LED windows show, On/Off switch power adjusting knob etc.

The central element of an ultrasonic cleaning system is the generator of an ultrasonic, the source that provides the energy of an electrical to the systems ultrasonic transducers. The job of the generator of an ultrasonic is to receive and convert energy from the power source to the proper frequency, amperage and voltage. Electrical current from the power line is transmitted at approximately 100-250 volts AC & a frequency of 50 or 60 Hz. The majority of ultrasonic generator to supply ultrasonic transducer at a significantly high voltage and the specific frequency intended for the system operation of an ultrasonic cleaning.

Specifications	
Material	Iron Plate Body
Size	H375mm L500mm W150mm
Frequency	20/15kHz
Voltage	220V
Power	2000/2600/3200w

Table.5.2 Specification of Ultrasonic Generator

Selection of ultrasonic generator should be depending on the specific cleaning prerequisite of the application so that the best results can be achieved. In addition to needing the frequency and power to match the requirements of transducer, the cleaning tank must be able to accommodate for the type of mechanical strength and contaminant of the parts involved in the application of cleaning. As mentioned in Table 5.2.

5.4 Support Structure:

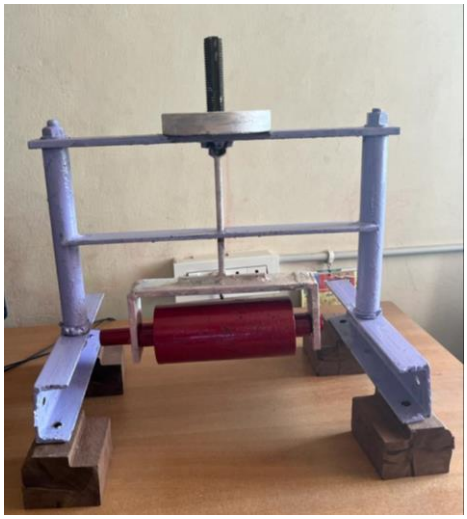

Fig.5.4 Support structure

Fig shows the support structure for ultrasonic welding used for advancing the material i.e., plastic to be joined into the ultrasonic horn in order to have a proper welding or joining of materials. Support structure consists mainly of spinning wheel, mild steel roller, wooden support along with side bars to hold the roller. Here roller can be raised or lowered by rotating the spinning wheel. Mild steel roller is placed within the bars and it can be turned backward and forward and can be fixed at any specific position and welding process can be carried out. As shown in Figure 5.4.

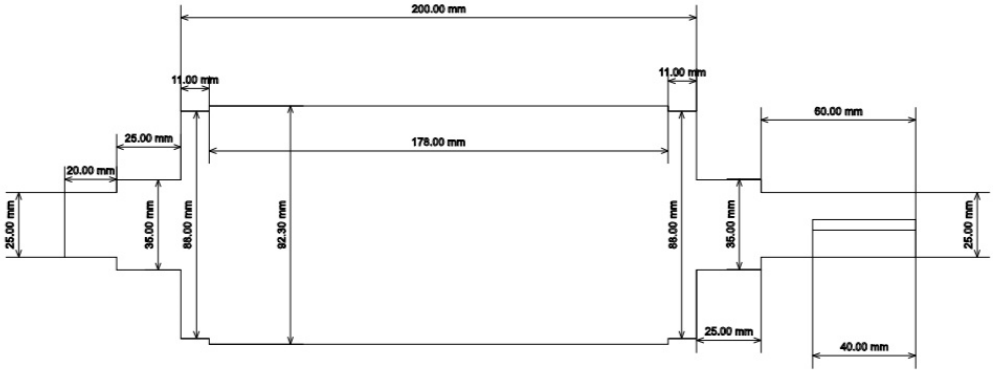

Fig.5.5 Dimensions of Mild steel roller

Fig.3.11 shows the dimensions for Mild steel roller which is attached to the spinning wheel that can be lowered or raised as required depends upon type of material, size and shape of material along with application as shown in Figure 5.5.

VI **WORKING PRINCIPLE**

USW equipment has 4 main parts. A supply of power converts low-frequency electricity (50 to 60 Hz) to high frequency electricity (20 to 40 kHz =; 1 kHz = 1000 Hz). Next, a converter or transducer changes the more frequency electricity into more frequency sound (ultrasound). A booster makes the vibration of ultrasound bigger. Finally, a Sonotrode or horn focuses the vibrations of ultrasound and delivers them to the materials to be joined. Besides these pieces, there is an anvil upon which the materials of welded are held and stacked. There is also some method to apply the force to hold the plastic together during welding time.

The welding times, temperatures and applied pressures are regulated by a microprocessor or computer within the welding setup. The friction between parts, heat rises the temperature of the metal surfaces to 1/3 of the melting temperature, but this heat does not melt the N type of metals. Alternatively, the heat removes metal films and oxides from the plastic surfaces. This permits the metal atoms to move B/W the 2 surfaces and form the bonds that hold the metals each other's or together.

In plastic welding, the horn produces vibrations are perpendicular to the plane of the materials & the frictional heat rises the temperature is enough to melt the plastics. Here, plastic molecules mixing together & form bonds. Upon cooling, welding together the plastic surfaces time of welding may vary, but the weld can form in as little as 0.25 sec.

The variables that vary in USW are the sound wave frequency (usually 20, 30 or 40 kHz), amount of pressure applied in order to hold the materials each other or together, & the time associated with which the ultrasound is applied (from actions of 1 sec to more than 1 second). As shown in Figure 6.1.

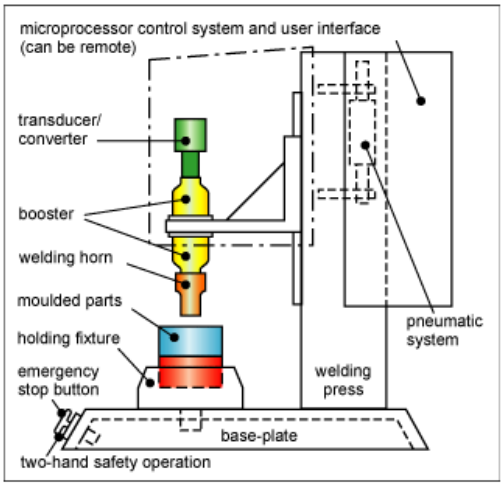

Fig.6.1 Ultrasonic Welding machine

PROCEDURE:

1. Plastic materials need to be joined/welded are placed in the fixture or anvil.
2. The horn makes contact with the parts to be welded. Next, the ultrasonic horn is used in order to vibrate the two pieces together at a rate of around 20,000 / 40,000 hertz, depending on the application.
3. External pressure is applied on the material to keep the contact with horn and to hold both horn and material together. The system then compresses the wires together with a force of between about 50 and several hundred PSI (pounds per square inch) in order to form a close connection between the 2 pieces.
4. When horn delivers mechanical vibrations it will heat up the plastic locally. And These vibrations move less than a millimeter either side-to-side or up-and-down.
5. The two plastic materials are joined together.
6. Finally the horn gets retracted and the joined materials are removed from the fixture/anvil.

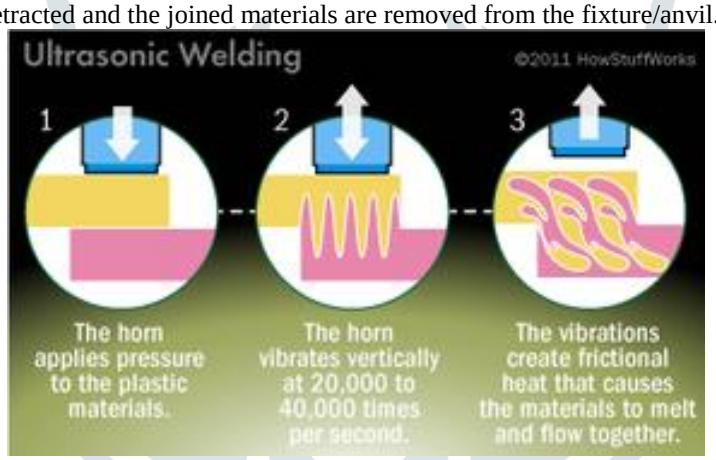

Fig.6.2 Ultrasonic welding steps

Basically, more – frequency sound (ultrasound) causes rapid vibrations in this materials to be joined. The vibrations cause the rubs the plastic to each other and the friction raises the temperature at the contract in the surfaces. This rapid frictional heat is what sets the conditions for the bind together of materials. As shown in Figure 6.2.

VII **RESULTS AND DISCUSSION**

The process involves applying pressure and ultrasonic vibrations to the plastics being welded, which causes localized melting of plastics and subsequent bonding of materials. Results of the process of ultrasonic welding of plastics may vary depends on various factors, including the type of plastic used for joining, process parameters of the welding, component design, type of horn and its material and quality of the equipment

Ultrasonic welding is recognized as a method of cutting edge joining that involves use of high-frequency vibrations in order to create stronger joints between thermoplastic materials and the results has been revealed that this is an effective and versatile solution for various industrial applications. Benefits of ultrasonic welding involves enhanced production efficiency, increased product quality, wide range of design possibilities and minimal impact on environment. Ultrasonic welding generally has applications in electronics, auto motives, packaging and medical devices.

Compared to conventional welding processes that rely on heat, Ultrasonic welding joins two dissimilar metals by localized vibrations.

Following are the outcomes from the ultrasonic welding of plastics:

- Speed and Efficiency: Compared to traditional welding methods ultrasonic welding is a fast process and high production rate can be achieved. It is a non-contact process requires minimal setup time, making it efficient for mass production.
- Strong bonding: ultrasonic welding can produce strongest and variable bonds between plastic parts. Bond strength if often comparable to the strength of the base material.
- No additional materials: in Ultrasonic welding there is no need of additional solvents, fasteners or adhesives, which can simplify the joining process and can reduce material costs.
- Minimal heat generation: heat generation in ultrasonic welding is concentrated on interface of plastic parts hence minimizing the risk of damaging sensitive warping or components the materials.

- Hermetic sealing: The process is capable of creating hermetic seal between the joining plastic parts which makes parts to be suitable for airtight and watertight seal applications
- Environmental Friendly: Ultrasonic welding does not produce any type of harmful by-products or fumes as compared to other joining techniques.
- Design Flexibility: Process can be used for joining complex geometries and shapes.

Although, there are several challenges associated with ultrasonic welding of plastics:

- Thicker parts may requires longer welding time and more energy.
- Parts with uneven surfaces may not bond effectively
- Uneven distribution of ultrasonic energy across the joint may result in inconsistent weld quality.
- Joint strength may varies based upon surface finish, materials properties and welding parameters.
- Tooling design should be proper to achieve reliable and consistent welds. Hence tooling may require to be customized for specific applications.

Hence it is important to remember that outcome may vary based upon type of material, process parameters and equipment. Hence it is required to conduct thorough testing and optimization for specific applications to obtain desired welding results.

VIIISUMMARY OF THE PROJECT:

8.1 Conclusion

From this work it Is observed that using ultrasonic welding for plastics improves efficiency, bonding strength and hermetic sealing also ultrasonic welding is environmental friendly. Also ultrasonic welding has its own limitations this scan be overcome by using the optimum process parameters for specific applications under proper conditions to achieve the better results. It is advised to conduct ultrasonic welding by optimization i.e., by using proper horn and generators based on type of application, this will improve the overall efficiency, bonding strength and helps in overcoming the uneven distribution of ultrasonic energy.

8.2 Scope for Future Work

Further improvement of the results can be achieved by powering the roller i.e., usage of gears/chain/belt for advancing material to be joined.

8.3 Outcome

- Selected Flat faced ultrasonic horn and 20kHz ultrasonic generator.
- Constructed Mild steel support structure along with roller.
- Assembled Ultrasonic Horn, Ultrasonic Generator and Support structure.
- Joined plastic materials without filler material.

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I am deeply honored to extend my heartfelt appreciation to our esteemed Principal, **Dr. HANUMANTHA REDDY,** for their unyielding belief in fostering academic growth and innovation. Your visionary leadership has created an environment where students are encouraged to explore and excel. Your unwavering support has been pivotal in making this project a reality.

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VISHWANATHA J H

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