understanding

Ultrasonic Plastics Assembly

V Kumar

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Ultrasonic Plastic Assembly

Web Edition

V Kumar B.E.

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Proprietor

nevik ultrasonics
Joining Thermoplastics with Ultrasonics

Design & Manufacture of Ultrasonic Horns, Boosters & Fixtures
Technical Support & Training, Job Work (In Nashik)

101-102, Eshan Plaza, Pipeline Road,
near Reliance Petrol Pump, Satpur, Nashik - 422 007.
Phone : (0253) 235 1935 Cell : +91 93202 69883
E -mail : nevik.ultrasonics@gmail.com Website : www.nevik.in

Ultrasonic Plastic Assembly

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Preface

Ultrasonic Plastic Assembly is commonly used in many countries around the world, but in India it is still not as popular.

Indian plastic processors seem to fear Ultrasonics -- too critical, too technical, too expensive, too difficult, ...

This fear, born perhaps out of an unhappy initial experience when trials conducted on existing products assembled by conventional methods did not meet expectations, is unjustified.

Had the trials been conducted correctly -- after understanding the specific needs of Ultrasonics -- their experience would surely have been happier, and there would perhaps be many more users in India today.

This book is intended to help processors Understand Ultrasonic Plastic Assembly, so they do things right the first time around, and succeed.

It covers topics from Basic Principles of Ultrasonics, Ultrasonic Techniques, Compatibility of Plastics and related Properties, Part & Joint Design, Equipments, Toolings (Horns & Fixtures) to Troubleshooting Applications, Sources of Supply world-wide, and Safety in Ultrasonics.

As production volumes increase and specs get tougher, weld consistency will become increasingly important. A poorly welded part is quite likely to fail prematurely, and this is simply unacceptable in todays highly competitive business environment.

Ultrasonic Plastic Assembly is a clean, consistent and reliable process that holds promise for the processor seeking to produce larger volumes, with improved quality, at reduced costs.

While initial costs may appear high, the benefits -- tangible and intangible -- far outweigh these.

Better Quality, Higher Productivity and Lower Costs -- could you ask for more ?

Switch to Ultrasonic Plastic Assembly, and enjoy the Benefits.

Good Luck !

About the Author

Mr Vinoo Kumar is a Mechanical Engineer, with vast experience in marketing Capital Goods. He has been actively involved in Plastics Assembly for close to 30 years -- primarily Ultrasonic Plastic Assembly.

During this period he has assisted numerous users switch from subjective, labour-intensive methods to semi-automated, consistent and reliable methods such as Hot Plate, Ultrasonic & Vibration welding methods.

His close interactions with users and leading companies worldwide has given him an overall perspective in plastic assembly methods, and he shares his hands-on experiences in this book.

His business venture -- nevik ultrasonics -- accepts Job Work (for Ultrasonic Welding), designs, manufactures and supplies Ultrasonic Horns & Fixtures, and offers several Technical Services, including sourcing Ultrasonic Plastic Welding Equipment, Troubleshooting Applications, Training and other such technical support.

His e-mail address is nevik.ultrasonics@gmail.com

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Sonobond Ultrasonics, U.S.A.
Sonics & Materials, U.S.A.
Branson Ultrasonics Corporation, U.S.A.
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Dukane Ultrasonics, U.S.A.
I P C L, Mumbai
Gharda Chemicals, Mumbai

We gratefully acknowledge their support.

understanding

Ultrasonic Plastic Assembly

Contents

Chapter 1 - Introduction

The Options Today

When you wish to Join Thermoplastics, you may choose from 12 options

1 **Mechanical Fasteners** (screws, nuts & bolts, rivets)

2 **Press & Snap** Fits

3 **Solvent** Bonding

4 **Adhesive** Bonding

5 **Heat** Sealing, also known as

- Impulse Sealing (when used for films)
- Hot Plate (when used for moulded parts)
- Hot Mirror (when used for pipes)
- Hot Wedge (when used with films, fabrics & geo-textiles)
- Hot Sword (when used for sheets)

6 **Hot Air** Welding

7 **Radio Frequency** Welding

8 **Spin** Welding

9 **Electro - Magnetic** Welding

10 **Ultrasonic** Welding, including

- Welding
- Insertion
- Staking
- Spot Welding
- Swaging & Forming
- Cutting & Sealing

11 **Vibration** Welding

12 **Laser** Welding

Ultrasonics is the most promising amongst these.

Ultrasonics is recommended when you wish to weld / assemble

- **Most Thermoplastics,** but especially,
- **Engineering Plastics** in
- **Large numbers**, to obtain
- **Leak Tight Seals**, with
- **Consistent**, **Repeatable** results

Ultrasonics enhances quality, increases productivity, and reduces production costs.

This book deals exclusively with the application of Ultrasonic Energy to Weld/ Assemble Thermoplastics.

It attempts to demystify the subject, and provides basic information on weldability of materials, compatibility, interface joint designs, variables that affect the welding process, range of equipments available, troubleshooting, reputed sources of equipment, toolings and associated services.

It is extensively illustrated and written in simple language for the lay user. It is intended to help you understand the process, appreciate its versatility, and benefit from its capabilities.

A Glossary is added to help understand technical terms.

Ultrasonics is the preferred method of assembly in today's competitive world.

THE BENEFITS

Ultrasonics is a clean, reliable, consistent and affordable process.

It needs no pre-weld or post-weld operations.

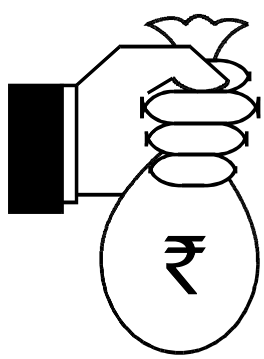
It uses no consumables of any nature, is user and environment friendly, and is a rapid, repeatable process. Invariably, ultrasonic assembly weld times are less than one second, far less than moulding times.

Ultrasonics eliminates all subjective elements in the welding process, ensuring consistent quality.

The consumption of energy is perhaps the lowest by any other process.

Set up is quick and easy. Its versatility enables change over from one set-up to another within a few minutes.

Toolings have long life, and need little or no maintenance.



Heat sensitive materials can be ultrasonically assembled without fear of damage to parts or contents, as welding is achieved by limiting the heat to extremely localised areas.

SUCCESS

Successful application of Ultrasonics in Joining Thermoplastics calls for a proper understanding of the process in terms of

- selection of **materials**,
- correct **design** of the weld **interface**, and
- use of appropriate **toolings.**

The success or failure of an Ultrasonic application is determined at the design stage, and not on the shop floor !

Careful design is of utmost importance in ensuring a satisfactory weld. However, very little is known or understood about the Ultrasonic process, and it still remains a big mystery to many.

So if you wish to switch to Ultrasonics -- successfully -- read on !

Application Areas

Ultrasonics can be used on Injection moulded, Blow moulded and Extruded parts, as well as on Films, Fabrics & Sheets.

It can be used to Join Thermoplastic to itself, or to assemble it to metal, paper, board etc.

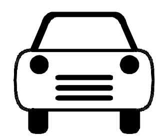
It can be used in intermittent or continuous modes.

It can also be Automated.

Market Segments

Ultrasonics is popular in almost every market segment where large numbers need to be produced each day, to a high, consistent quality. Typical segments are

Automotive

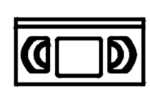


Dashboard Instruments, Door Fittings, Interior & Exterior Trim, Glove Box Door, Bumper Fittings, Number Plates, Tail Lamps, Fuel Filters, Air Filters, Carburetor Floats, Brake Fluid Reservoirs, Overflow Reservoir, Air Diverter Valve, Sensors

White Goods

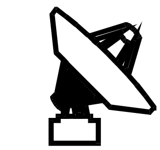
Refrigerators, Washing Machines, Dishwashers

Electronics



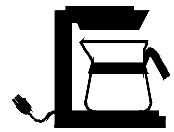
Dip Switches, Electrical Switches, Relays, Push Buttons, Mains Cables, Piezo Ringer Assemblies, Terminal Blocks, Connectors, Toggle Switches, PCB assembly staking, Audio & Video equipment

Telecommunications



Telephone Instruments - Desktops, Pagers, Cellular phones

Domestic Appliances

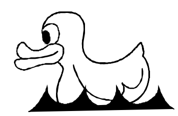


Food Processors, Blenders, Steam Irons & Vacumn Cleaners

Office Products

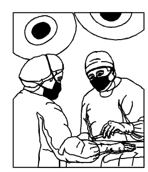
Computer Files, PP Folders, Staplers, Floppy Disks, Ribbon Cartridges, Nylon Ribbons for Dot Matrix Printers

Gifts & Novelties



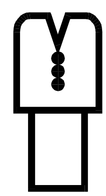
Key Chains, Paperweights, Pen Clips, Watches, Clocks, Jewelry Boxes, Toys

Medical



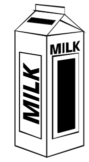
Non-woven Masks, Caps, Surgical Gowns, Diapers, Cardiometry Reservoirs, Blood/Gas Filters, IV Spike/Filters, Syringe Filters, Arterial Filters

Textiles



Thread Free Quilted seams, Cut & Seal Fabric edges without bead or bulk, Velcro attachments, Slitting of ribbons

Packaging



Dispensers, Blister Packagings, Juice/Milk Cartons, Laminate or Plastic Tubes for Toothpaste & Pharmaceutical products

Chapter 2 - Basic Principles

Ultrasonics

What is **Ultrasonics** ?

We are all familiar with Sound energy.

We are exposed to it most of our waking hours, when we talk or listen to others. Or just hear the noise around us !

The sounds we hear in our daily life have a frequency band between 20 Hz to 18,000 Hz ; there are other sounds around us with frequencies outside this band, but the human ear is incapable of hearing these.

Frequencies outside the range of human hearing are termed

- ***Infrasonic*** [below 20 Hz], and
- ***Ultrasonic*** [above 18,000 Hz].

Ultrasonic Energy has been put to good use in scientific, medical, industrial and military applications.

Cell Disrupters for Research, Medical Sonography, Thickness Testers, Industrial Flaw Detectors, Ultrasonic Cleaners, Plastic & Metal Welders, Machining of Ceramic and other brittle materials, Radar, Sonar, etc all use Ultrasonic energy to precisely detect, quantify and process designated parameters.

This book deals only with the application of Ultrasonics to Weld/Assemble Thermoplastics.

Principles Of Ultrasonics

How is all this done ?

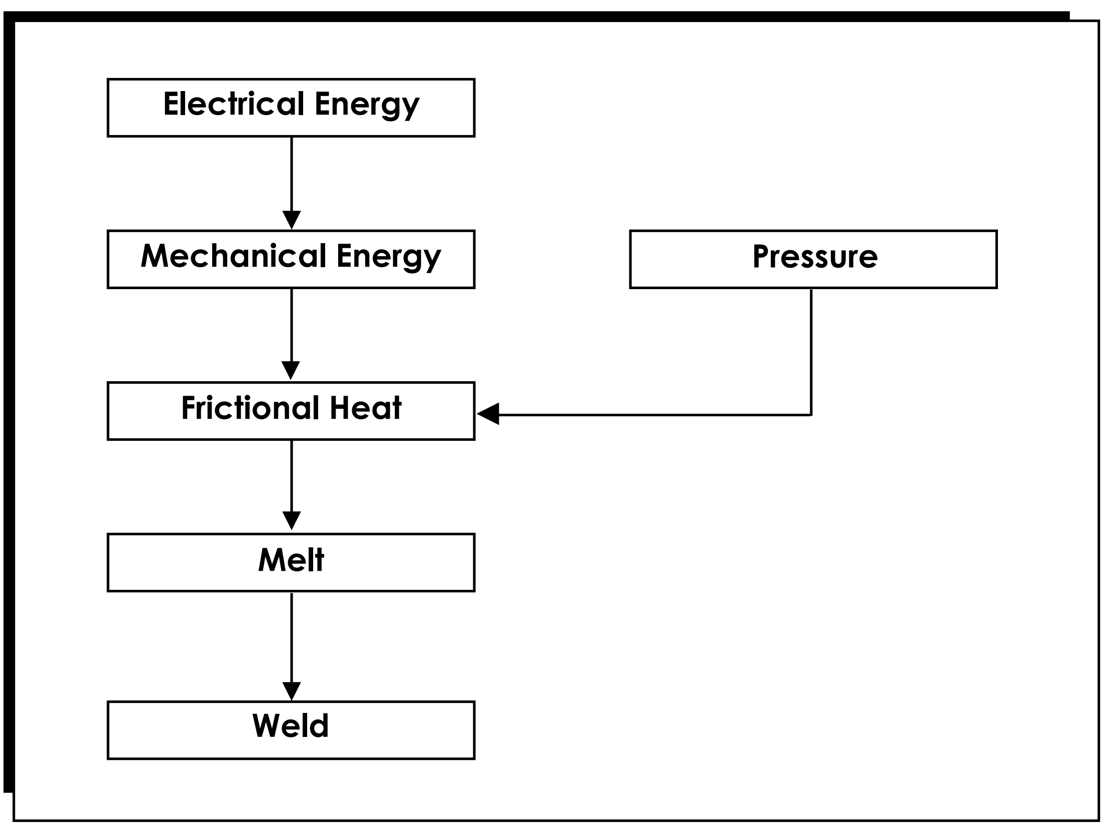
Vibrations produce Sound.

Sound is a form of mechanical energy and travels as a longitudinal wave. It requires a material medium for its propagation.

The first attempts to use ultrasonic energy to Join Thermoplastics were conceived in the '40s. Since then equipment has been built so rigid plastics can be welded ultrasonically.

The principles of Ultrasonic Assembly can be explained as the conversion of

- **Electrical** energy into
- **Heat** energy through
- **High Frequency** Mechanical **vibrations**.



SYSTEM ELEMENTS

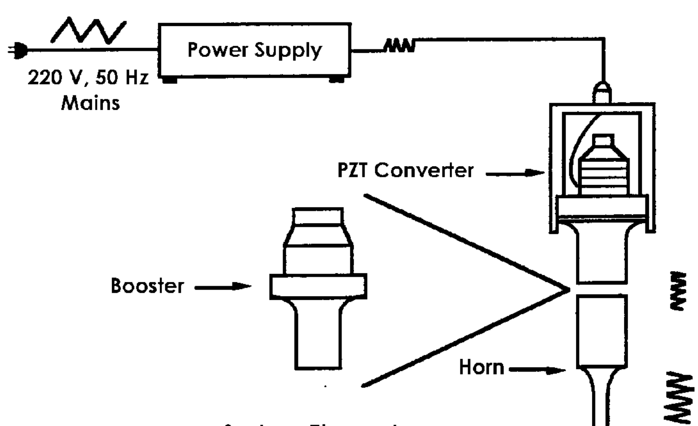
An Ultrasonic Plastic Welding System comprises

- **Power Supply** (incl Programmer, Protection Circuits & Micro processor,)
- Pneumatic **Actuator**
- **Ultrasonic Stack**, including
  Convertor
  Booster and
  Horn
- **Fixture**

The Power Supply.

A solid state electronic "black box" takes in 220 V, 50 Hz from the mains, and transforms it into 800-1000 Volts, 20,000 Hz electrical supply.

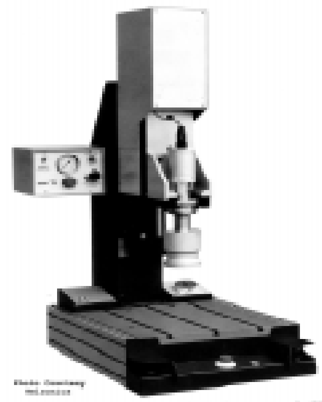
The electronic programmer, protection circuits & the microprocessor, if present, are all housed in the power supply cabinet.



System Elements

The Pneumatic Actuator

This Actuator provides the means to move the stack to contact the part and retract it during the welding process.



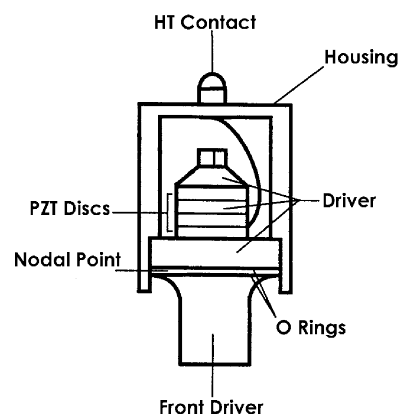
Normally, a pneumatic air cylinder, often self lubricated, is used (diameter between 50 to 75 mm, stroke 50 to 100 mm).

The cylinder is mounted on the machine frame, that also includes the base, and needs compressed air at 6-7 bar for operation.

The Ultrasonic Stack.

The High Frequency voltage from the power supply is “fed” into a Converter.

The Converter functions as an “Energy Changer” for converting Electrical energy at 20,000 Hz to Mechanical energy at 20,000 Hz.



Its heart is the transducer.

The transducer is a set of specially compounded ceramic discs (Lead Zirconate Titanate) that begin to vibrate when high voltage is applied across them.

The vibrations at this point have nominal amplitude (around 20 microns peak to peak), and a vibration frequency of 20,000 Hz.

The converter vibrates in an axial direction, and transfers this motion to an acoustically efficient Booster and Horn combination.

The Booster and Horn frequencies remain at 20,000 Hz.

The Booster is used to amplify the vibration amplitude. The horn also may amplify the amplitude, and is the final machine element that contacts the part and transmits ultrasonic energy to it.

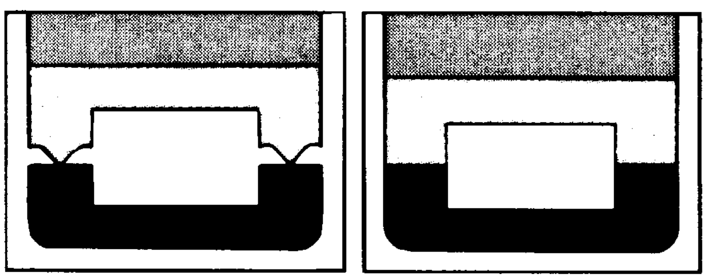
What happens to the Ultrasonic vibrations after they leave the horn depends upon which method of assembly is used.

There are 5 basic methods of Ultrasonic Assembly

- **Welding**
- **Insertion**
- **Staking**
- **Swaging & Forming**
- **Cutting & Sealing**

In **Ultrasonic Welding** the horn passes the ultrasonic vibrations to the plastic part. The part vibrates at 20,000 cycles per second down to the joint interface.

Mechanical energy is dissipated at the joint in the form of frictional heat, and a melt results at the joint.

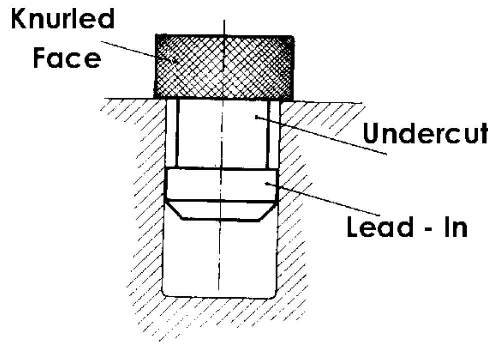


Ultrasonic Welding

Example : Transparent windows in Audio and Video Cassettes

Spot welding, Stud Welding and Scan Welding are variations used to weld at specific points.

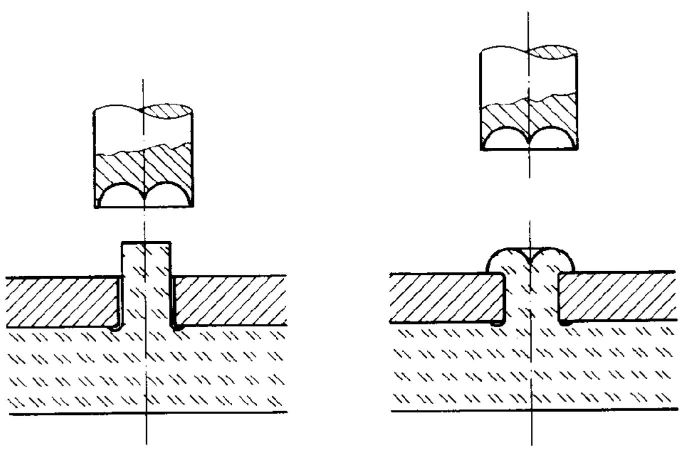
In **Ultrasonic Insertion**, energy is coupled into the contacted part (plastic or metal) and carried to the interface, where it is released, allowing plastic to melt and flow.



Ultrasonic Insertion

Example - Threaded Brass inserts in large housings to accept screws.

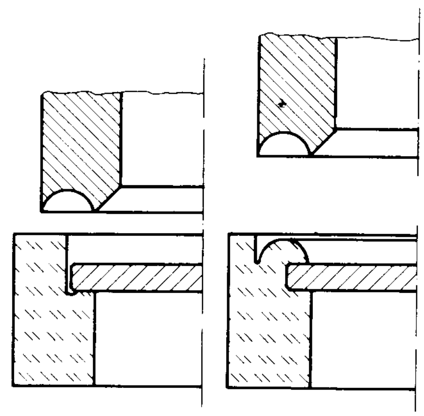
In **Ultrasonic Staking**, a hole, perhaps in a piece of metal, receives a plastic stud. Staking the plastic requires the release of vibratory energy at the surface of the plastic stud, thereby generating localised heat and reforming it into a locking head.



Ultrasonic Staking

Examples - Video Cassette Reel (Flange to Hub),
- Metal Carrier Plates to Plastic Housing.

In **Ultrasonic Swaging & Forming**, the Ultrasonic energy flow is also interrupted at the surface of the plastic, generating heat at the point of contact, to reform the plastic to capture another component.

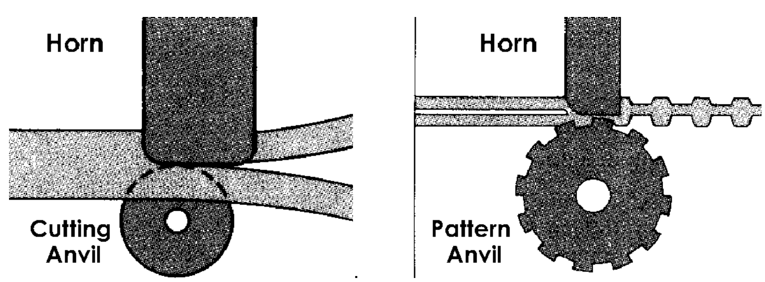


Ultrasonic Swaging

Example - Compact Mirror in a Plastic Housing.

In **Ultrasonic Cutting & Sealing**, ultrasonic energy is utilised to create clear pressure tight seals on thin thermoplastic fabrics & films compressed between a horn and rotating anvil.

The seal pattern is provided on the anvil, and many decorative items can be welded, adding considerable value to the seal.



Ultrasonic Cutting & Sealing

Example - Cut and seal of non-woven filters.

Chapter 3 - Assembly Techniques

We now review in detail the five assembly techniques to assemble compatible and non compatible plastics.

- **Welding** incl Spot, Stud and Scan Welding
- **Insertion**
- **Staking**
- **Swaging & Forming**, and
- **Cutting & Sealing** - Films & Fabric

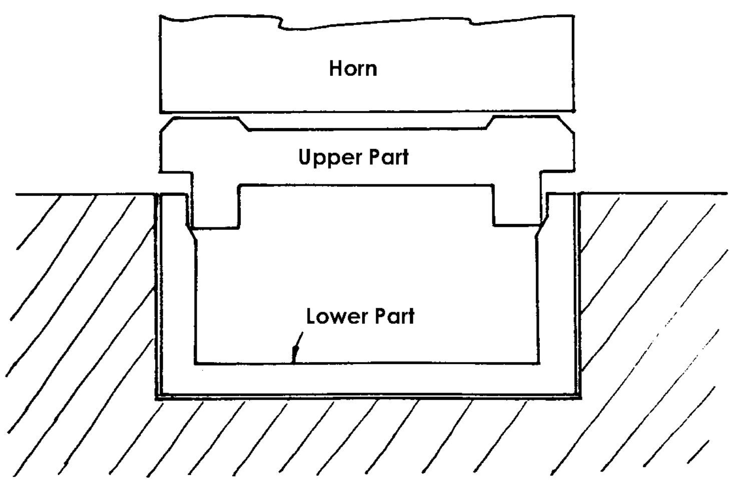
Ultrasonic Welding

When two plastic parts are bonded together through a heating, melting and resolidification process -- the conventional way we understand welding -- we refer to the process as Ultrasonic Welding.

Generally this is achieved when two ***similar*** plastics are bonded together, such as PS to PS, Nylon to Nylon, or PP to PP, or when two ***compatible*** plastics are bonded together, such as ABS to PS or SAN to ABS etc.

In welding, the Horn & Fixture are designed according to the part geometry. The Horn may need to incorporate reliefs, or match the contours of thepart it is to weld.

In Ultrasonic welding, one component is held rigidly in a fixture,the other placed over it, so it aligns itself, without external support.



Ultrasonic Welding

The horn contacts the upper part, couples to it and transmits ultrasonic energy, thereby vibrating it relative to the rigidly held lower part, and creates frictional heat, melt and flow at the joint interface.

When the ultrasonics is switched off, the melt resolidifies, and a weld bond is formed.

Each step, the application of pressure, the trigger and timing of ultrasonic energy, holding the assembly under pressure until resolidification is complete, is programmable and controlled by electronic circuits.

Variations of conventional welding are

[a] Spot Welding

Spot Welding, a process where plastics can be "spot welded", much as sheet metal is, without the need of specific joint design at the interface.

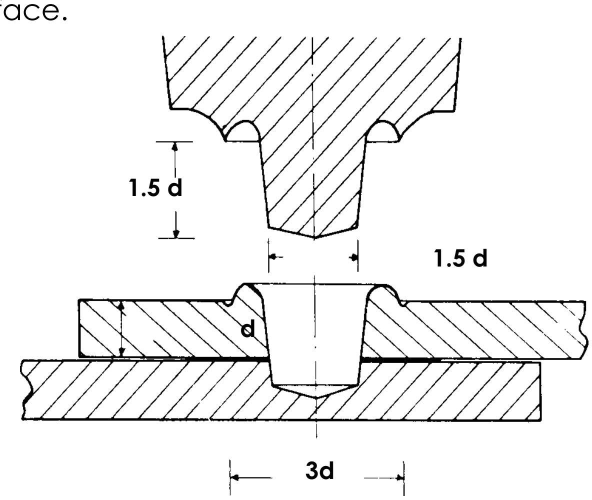
Spot welding is popularly used when strong structural welds are desired in large parts, sheets of extruded or cast plastics, and parts with complex shapes where accessibility is difficult.

It is also used to weld vacumn formed blister packs to provide tamper evident sealing.

Most thermoplastics can be spot welded.

In spot welding, a specially designed spot welding tip penentrates the top layer (the thinner of the two parts), and part way through the second layer, melting the plastic on its way.

The displaced melt is trapped into an aesthetic head on the top layer, and the weld occurs at the interface.



Ultrasonic Spot Welding

The diameter of this head averages three times the top layer thickness -- i.e. a 1mm thick upper part will have a raised ring, approx dia 3mm, and height upto 1mm.

The bottom side shows no indentations or markings.

Basic Guidelines for Spot Welding

- Low pressure
- Medium to high amplitude
- Rigid support directly under the weld area.

Tapped Catenoidal Horns with replacable tips are available as standard for spot welding applications.

Tip selection and use (in accordance with top layer thickness of part to be welded) is thus easy and simple.

Parts upto thickness of 3 mm (top layer) can be spot welded in this manner. The bottom layer may be any thickness greater than the top layer.

The Spot Welding process is versatile, fast and easy to use - the ultrasonic stack is often hand-held, and aligned manually.

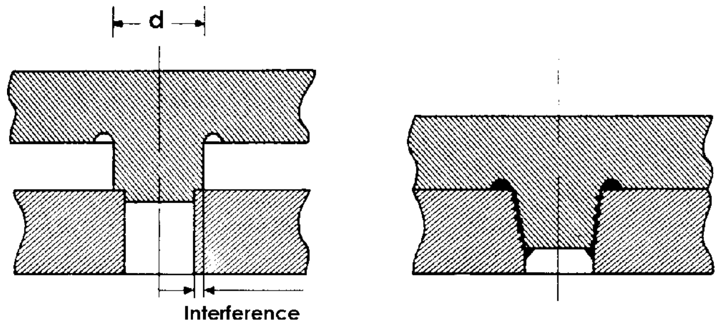
[b] Stud Welding

Stud Welding is another option when similar plastics parts need to be welded at single or multiple localised points that do not require a continuous weld.

When resin selection, size or part complexity inhibit use of other methods, Stud welding may provide a good solution.

A shear joint variation is used in stud welding.

An oversized stud is ultrasonically driven into a hole, and welding occurs along the circumference of the stud ; the weld strength is related to stud diameter and depth of weld.



Ultrasonic Stud Welding

Maximum tensile strength is achieved when the depth of weld equals half the stud diameter.

This method can be used to lock a dissimilar material in place. The studs can be moulded into the part or can be separate pieces.

Basic Guidelines for Stud Welding

- Low pressure / power
- High Amplitude
- Multiple stud welding is possible if the pitch is small.

This option can be used with all thermoplastics.

[c] Scan Welding

The continuous scanning of large flat parts at high speeds enables them to be ultrasonically welded with a standard, average-sized horn. Such large parts would be extremely difficult to weld otherwise, except at predetermined "spots".

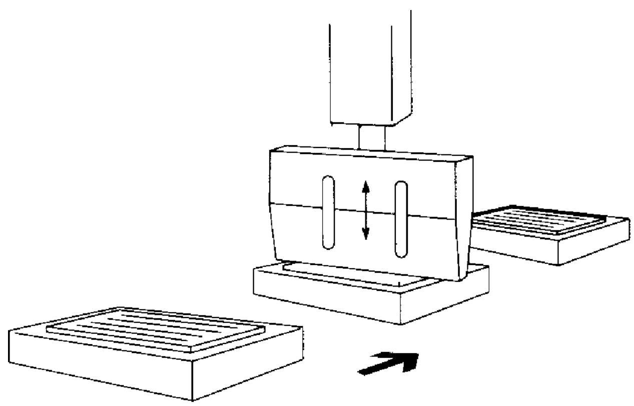
The flat parts are transported under the horn, and "scanned" ultrasonically.

Rigid thermoplastic parts with flat faces, and some film or fabric applications are suitable for scan welding. Typical examples are doors and panels for appliances, cabinets, furniture parts, etc.

Four Scan welding methods are feasible

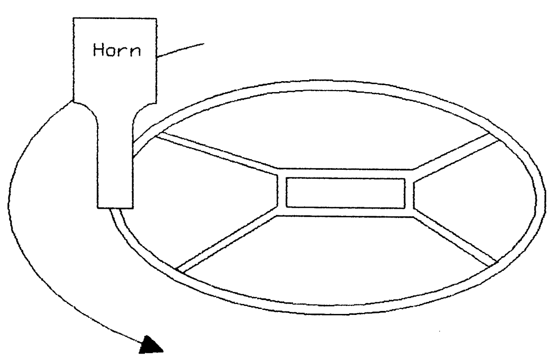
- **Linear Scan**
- **Rotary Scan**
- **Radial Scan**
- **Traverse Scan**

In **Linear Scan** the horn is stationary while the part and its supporting fixture are transported under it.



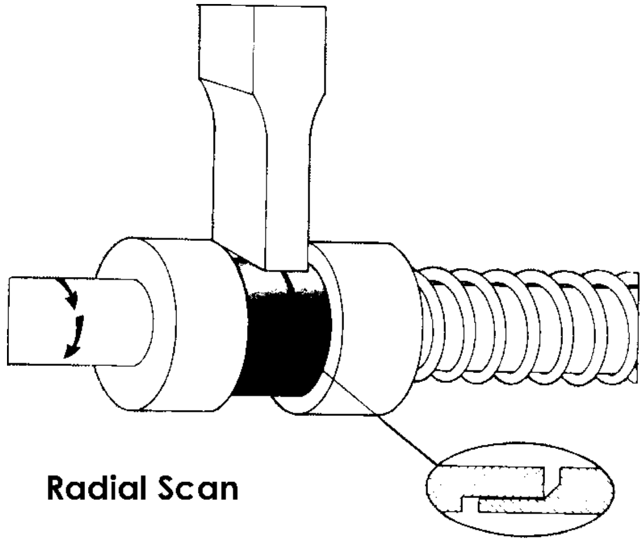
Linear Scan

In **Rotary Scan**, the part and its supporting fixture are rotated under the horn. This is applied to large circular parts.



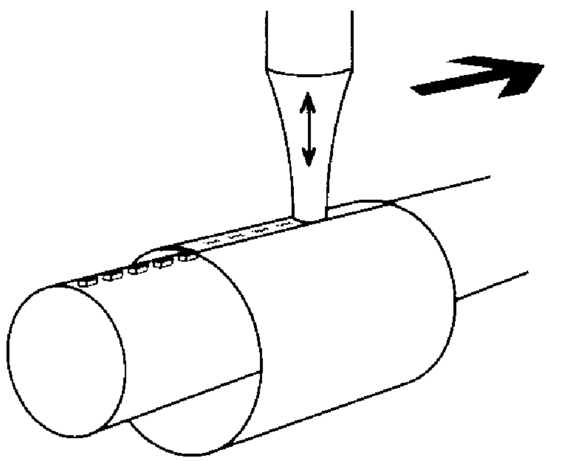
Rotary Scan

In **Radial Scan**, the horn is applied perpendicular to the circumference joint.



Radial Scan

In **Traverse Scan**, the part and the supporting fixture are stationary, while the horn traverses the length of the joint.



Traverse Scan

Depending on the part configuration, material and thickness, welding speeds upto several meters per minute are possible with scan welding.

Small parts too can be scan welded -- parts such as coin boxes, disposable torches and flash cubes can be scan welded conveniently in large numbers.

Ultasonic Insertion

Often a threaded bush needs to be encapsulated into a plastic part. This has traditionally been done by insert moulding.

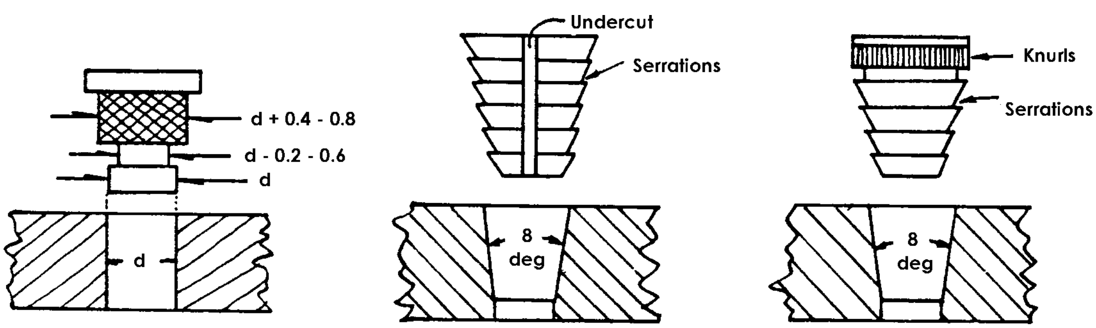
Insert moulding has disadvantages ; it slows down the moulding machine and increases the risk of mould damage due to an insert inadvertently falling off.

These problems increase when multiple inserts are necessary.

Ultrasonic Insertion makes it possible to encapsulate such inserts after the moulding is completed.

The moulding machine can then be run automatically, thus increasing productivity.

In Ultrasonic Insertion, a hole, marginally smaller than the O.D. of the insert, is pre-moulded in the plastic part. This serves to guide the insert while providing a certain degree of interference.



Ultrasonic Insertion

The insert is designed with serrations (for high torque strength) and undercuts (for high pull-out strength) or both (for high pull-out and high torque strength)

The ultrasonic energy applied to the insert travels to the interface, creates frictional heat and melts the plastic.

The melt flows into the serrations and undercuts of the insert, resolidifies and locks it into place, providing excellent torque and/or pull out strength.

Ultrasonic energy could be applied either to the metal insert or to the plastic component ; however, the horn life is adversely affected due to wear caused by metal to metal contact.

The noise level too increases during metal contact insertion.

To minimise wear and thereby increase horn life, hardened steel or carbide faced Aluminium/Titanium horns are used. Tapped Horns with replacable tips also offer cost effective solutions. Alternately, the horn may contact the plastic component, instead of the metal.

As with all ultrasonic applications, the process takes a second or less, creates less stress in the part, and calls for less critical dimensional tolerances.

Depending on insert size, distance between inserts, ultrasonic power available etc, multiple insertions can be made.

The starting load in insertion is rather high, and this is often a limiting factor in making multiple inserts.

Basic Guidelines for Ultrasonic Insertion

- Medium to high pressure
- Low amplitude
- Slow Downspeed
- Pre-trigger to avoid stalling
- A horn face that is 3 to 5 times the insert diameter

Common applications include threaded inserts, eye-glass hinges, machine screws, decorative trim, terminal connectors, etc.

▯ ▯ Ultrasonic Staking

Ultrasonic Staking is the process of melting and reforming a plastic stud to mechanically lock a material in place.

It provides an alternative to welding when

- Molecular bonding is not necessary -- mechanical retention of one part relative to another is adequate.
- Dissimilar materials (e.g. metal & plastic), that cannot be welded together, are to be joined/assembled.

The **Advantages** of Staking include

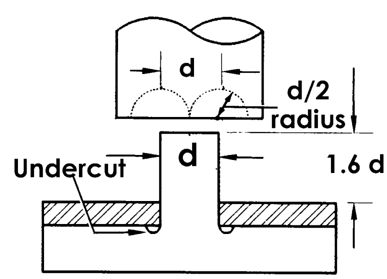
- Elimination of consumables (screws, rivets and adhesives)
- Multiple stakes simultaneously with one horn
- Short cycle times
- Tight assemblies (with no springback)
- Good process control
- Repeatability
- Simplicity of design

Attaching dissimilar material parts (often metal parts) to plastic parts is the most common staking application.

In Staking, a hole in the dissimilar material, receives a plastic stud.

Staking the plastic requires the release of ultrasonic energy only at the surface of the plastic stud.

As the ultrasonic energy dissipates, the stud face melts and reforms, within the contoured tip of the horn, to create a locking head over the dissimilar material.



Ultrasonic Staking

The geometric relationship between the stud and the horn cavity -- their volumes must be similar -- determines the integrity of the assembly.

Its design depends on the application needs and the size of the stud(s) being staked. A proper design produces minimum flash and optimum stud strength and appearance.

Inverse Staking -- when part configuration prevents regular staking, inverse staking may be adopted.

The staking profile is machined into the fixture, instead of the horn.

When a flat face horn contacts the part over the studs and staking cavities, the stud material melts and reforms per staking profile.

Alignment of the horn to the studs during inverse staking is not critical. A standard bar horn can be used for multiple staking, rather than a specially machined multi cavity horn.

Several standard stud and cavity designs are available. Five such designs are outlined here.

- **Standard Stake**

The standard profile satisfies most requirements.

It produces a head twice the diameter of the original stud, with a height equal to half the stud diameter.

It is designed to stake studs with flat heads and is recommended for stud diameters from 3 mm upwards.

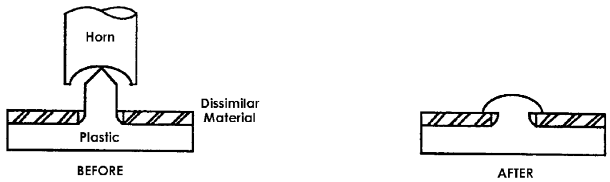
Standard Stake

This stake is ideal for staking unfilled thermoplastics -- rigid and non-rigid.

An optional low profile design produces a head one-and-a-half times the diameter of the original stud, with a head height a quarter of the stud diameter.

Dome Stake

The dome stake is used for thin studs, usually less than 3 mm diameter, or with multiple stakes where precise alignment is difficult.



Dome Stake

It is also recommended for glass/ talc filled resins where horn wear is likely to occur, because the horn cavity is easier to recondition.

Note the sharp end of the stud, like an inverted drill point ; this ensures a small initial contact area.

Knurled Stake

Where aesthetics is not important, as in concealed parts, the knurled stake is used for simplicity and quick assembly.

There is no horn cavity, and multiple stakes can be made, quickly and easily.

Knurled Stake

Replacable knurled tips are available in Coarse, Medium and Fine; these can be used with a standard Catenoidal Tapped Horn.

Flush Stake

When a raised head is not acceptable above the surface of the attached part, the flush stake is used.

Flush Stake

A countersunk hole is provided in one part, so that the volume of the melted stud fills it, locking the attached part. The stud is designed with a pointed end, as for dome staking. The horn has a flat front face.

- **Hollow Stake**

Hollow stakes permit the use of a screw for reassembly if the staked assembly ever needs to be taken apart for repairs. It can, however, be used only on studs larger than 4 mm. Hollow studs are advantageous in moulding too, because they prevent sink marks.

Staking a hollow stud produces a large strong head without having to melt a large amount of material. Ultrasonic cycle times are also lower as less material needs to be processed.

Hollow Stake

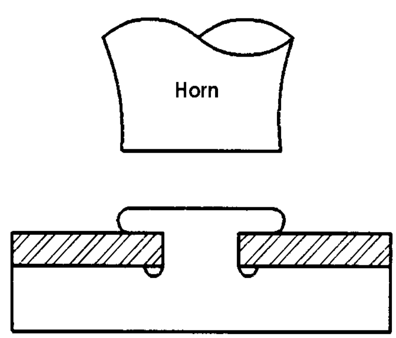
Basic Guidelines for Staking

- Light Horn pressure
- High amplitude
- Slow down speed
- Pre-trigger Ultrasonics (to create out-of-phase contact)
- High Hold time (to allow complete resolidification)
- A mechanical stop (to ensure minimum stud height)
- Generous radius at the base of the stud
- Good slip fit between the hole and the stud

Some semi-crystalline, high melt temperature resins, tend to form a weak, brittle head. In such cases, either of the following options gives higher strength and better results.

- High amplitude, high pressure, and high trigger pressure.
- Low amplitude, high pressure and high trigger pressure (using a flat faced horn to contact a flat-surfaced stud).

Under the combined effects of ultrasonics and high pressure, the material mushrooms just below the top of the stud, and forms a neat head with no flash and no recovery. Rigid support under the stud is important.



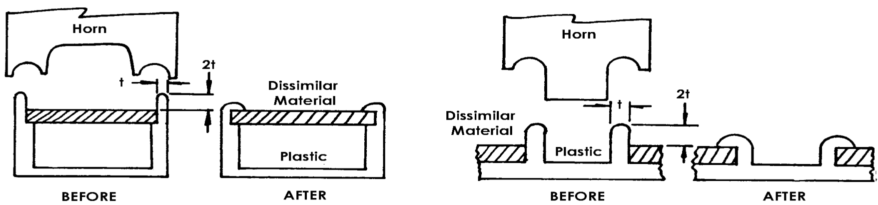
High Pressure Stake

Ultrasonic Swaging & Forming

Swaging involves the reforming of plastic to a desired contour to lock a dissimilar part in place.

It creates a tight assembly without creating a molecular bond.

Forming refers to the reshaping of a plastic part e.g. closing an extruded plastic tube at one end to form a test-tube or a cigar container, or flaring a tube end to prevent disassembly.



Ultrasonic Swaging

Advantages include

- Tight Finished assemblies
- Fast cycle times (faster than heat)
- Elimination of consumables such as fasteners or adhesives.
- No stress buildup and no material memory.

Specially designed toolings are required in both Swaging and Forming.

The horn profile determines the final shape of the reformed plastic.

Basic Guidelines for Swaging & Forming

- High initial trigger pressure
- Controlled down speed (to begin cold forming the plastic)
- Longer hold times than average

In general, low to medium stiffness (modulus of elasticity) resins can be formed more easily than high stiffness resins.

Materials that can be easily swaged or formed include Polypropylene, Polyethylene, ABS, High Impact Polystyrene and the Cellulosics.

Ultrasonic Cutting & Sealing of Films & Fabrics

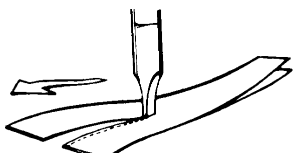
Effective use of Ultrasonics can be made to Bond and Slit Films and Fabrics.

This finds application in the Apparel, Non-woven, Packaging & Textiles industries.

The materials may be 100% synthetic, or Fibre blends with upto 35% non-thermoplastic fibre content.

Materials that can be processed include Polyester, Polyethylene, Polypropylene, Rigid Thermoplastics, Thermoplastic Polyurethane, some Vinyls and Thermoplastic coated Foils and Papers.

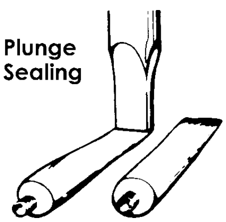
Three modes of sealing are common -- **Continuous**, **Plunge,** and **Traversing**



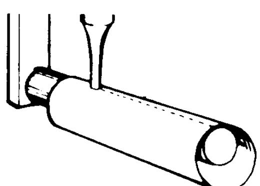
Continous Sealing

In the **Continuous** mode, the material is moved between a stationary ultrasonic horn and a rotating patterned anvil (generally in apparel & textile applications) to seal or cut and seal long lengths e.g. lace making machines.

Plunge Sealing



In the **Plunge** mode, the stationary material is contacted by the ultrasonic horn (often with a knife-edge and welding face) coming down under pressure to cut a specific profile and seal it all along its edge (as in Blister packaging, Tube Sealing, Filter Pads etc).



Traverse Sealing

In the **Traversing** mode, the ultrasonic horn traverses the weld area, while the material remains stationary.

Using appropriate toolings, materials can be bonded together, or slit.

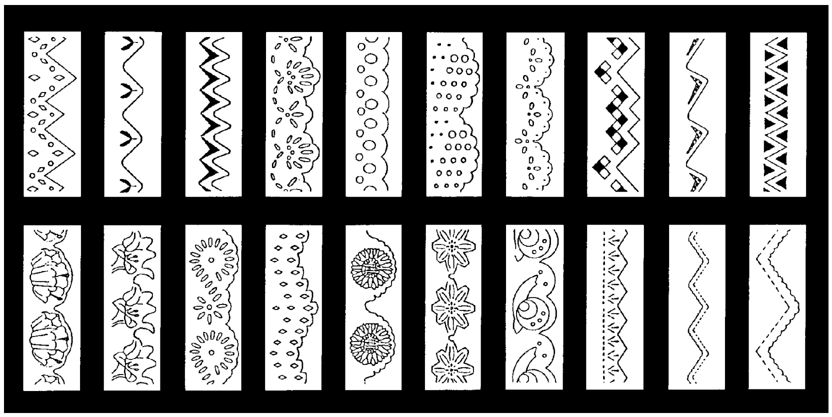
Ultrasonic Bonding uses no consumables whatsoever, and is energy efficient, as compared to thermal bonding.

In Ultrasonic Slitting, the edges seal simultaneously too ; this is beneficial for woven fabrics (prevents unraveling), while at the same time, the selve edge build-up is eliminated.

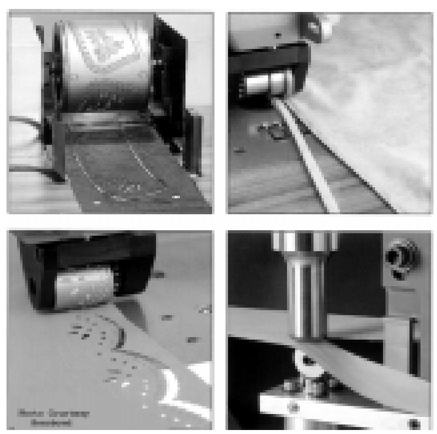
Speed of operation is a significant advantage. There is little or no downtime.

Welders have been configured as Sewing Machines for the textile and apparel industries.

Lace making machines (using Cut & Seal approach) are very popular, and intricate designs of laces can be generated very rapidly, with change over from one style to another taking just a few minutes.



Instead of a single anvil with a line pattern, a rotary drum with an intricate pattern to cut and seal a specific profile, such as a collar, or even a glove, is popular, when large numbers are to be produced.



Multiple ultrasonic heads have been combined to bond on long rotary drums, large width fabrics, such as bedspreads, blankets, sail cloths, upholstery and draperies. Films from 100 microns thickness to sheets upto 3 mm thickness can be processed easily and rapidly.

Only special toolings (Horns & Anvils and Feeders) are required, and semi-skilled operators can learn the operation rather easily.

Basic Guidelines for Cut & Seal in Film & Fabric processing

- Very Low pressure
- Adjustable Speed Feeders
- Spring Loaded Fixtures
- Continuous mode Ultrasonics
- Horns with easy “entry & exit” contours
- Fine adjustment for Horn Gap

The amplitudes required for the 5 different techniques are outlined below.

Amplitudes required for various Ultrasonic techniques

Welding	40 to 125 microns peak-to-peak
Insertion	25 to 65 microns peak-to-peak
Staking	75 to 125 microns peak-to-peak
Swaging	40 to 90 microns peak-to-peak
Spot Welding	75 to 125 microns peak-to-peak

Chapter 4 - PLASTICS

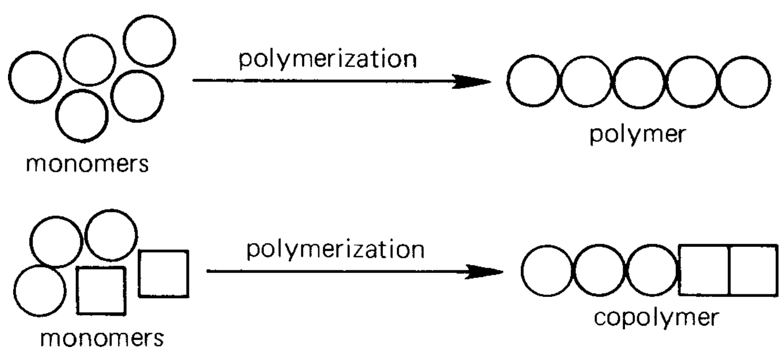
What are Plastics ?

Plastics are the ultimate tribute to man's creativity and inventiveness. They are true man-made materials.

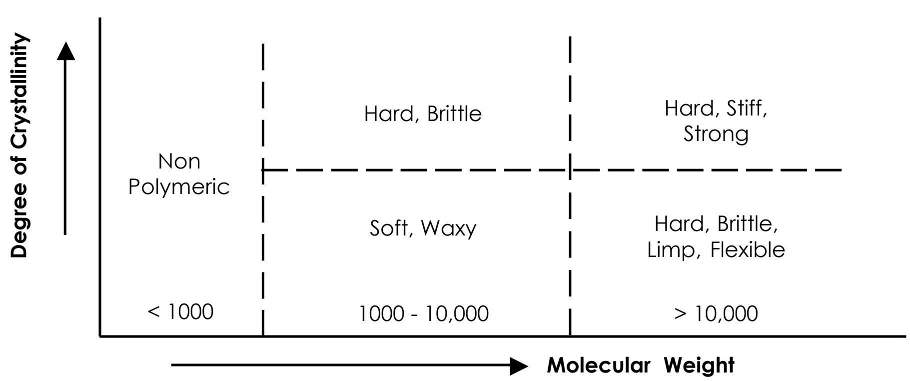
Carbon is the chemical foundation of nearly all plastics. Usually it combines on a one-to-four ratio with one or more of 5 common elements -- Hydrogen, Oxygen, Nitrogen, Chlorine, & Sulphur.

Plastics are referred to as Polymers or Resins.

Polymerisation is a chemical reaction where two or more molecules combine to form larger molecules of a substance.



Polymer molecules are long chains, five hundred to ten thousand times greater in length than in thickness. The molecular weight of a polymer is determined by the length of an average chain, and this influences the polymer properties as outlined in the diagram below.



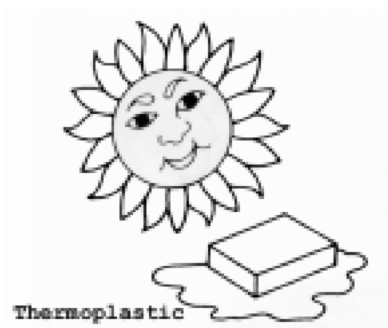
TYPES OF PLASTICS

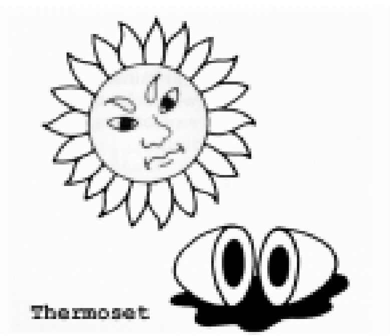
Plastics are classified as

- **Thermosets** &
- **Thermoplastics**

Ultrasonics can be applied successfully ONLY to Thermoplastics. The reason is simple.

Thermoplastics are materials that can be repeatedly heated and reformed, much as ice-cream, which melts on being heated, and resolidifies into ice-cream on freezing. This can be repeated any number of times.





Thermosets, on the other hand, cannot be melted and reformed -- heating leads to degradation.

This is very much like boiling an egg. A hard boiled egg cannot be “unboiled” -- once hard-boiled, it is permanently set, and remains set thereafter.

Molecular Structure

The physical properties of a Thermoplastic, such as melting and welding characteristics, are determined by its molecular structure.

The molecular structure is characterised as

- **Amorphous** or
- **Semi-Crystalline**.

In Amorphous Thermoplastics, the random arrangement of molecules enables most of the ultrasonic energy to be transmitted, with very little being absorbed.

So Amorphous plastics transmit Ultrasonic energy very efficiently.

Common Amorphous thermoplastics include ABS, Acrylic, PVC, Polycarbonate, and Styrene.

Amorphous Semi-Crystalline

Semi-Crystalline molecules, in contrast, have a very orderly and crystalline structure.

This tends to absorb ultrasonic energy, rather than transmit it.

The semi-crystalline plastics are therefore difficult to weld as the ultrasonic energy applied is largely absorbed by the material, and only a fraction is transmitted.

Semi-Crystalline thermoplastics include Acetal, Nylon, Polyester, Polyethylene, Polypropylene and Fluoropolymers.

Melt Characteristics

Amorphous plastics have a broad melting or softening temperature range that allows the material to pass from a rigid state, into a rubbery state, followed by a liquid flow in a true molten state.

Solidification is likewise gradual. Hot melt glue is a good illustration of the melt process.

Semi-Crystalline plastics have a sharp melting point.

Just as ice melts into water at $0^{\circ}C$, semi-crystalline materials also melt at a specific temperature.

The semi-crystalline material remains solid until it reaches the melt temperature, when it immediately becomes liquid. Solidification occurs just as rapidly from the liquid to the solid state.

A higher amount of energy is needed to melt semi-crystalline materials, and that is one reason they are more difficult to weld than amorphous materials.

Compatibility of Materials

A molecular bond can be formed between two plastics only if they are chemically compatible.

Polyethylene & Polypropylene, though very similar in nature and physical properties, are NOT chemically compatible, and therefore unable to be welded to each other.

Like thermoplastics (i.e. materials with the same chemical properties) will weld to each other e.g. ABS will weld to ABS, or to Styrene, Acrylic, SAN etc.

It is also important that the melt temperatures of compatible plastics are in close range -- normally $15^{\circ}C$ or less.

Generally speaking, only similar amorphous polymers have an excellent probability of welding to each other.

The unique chemical properties of semi-crystalline materials make each one only compatible to itself.

Tables 1 & 2 indicate compatibility of various polymers and their weldabilities.

Compatibility of Plastics		ABS	ABS/PC	PMMA	SBS	CA..	PPO	PA..	PC	PS-GP	PS-HI	PSU	PVC-U	PVC-P	SAN-NAS-ASA	POM	PET	PE	PPSU	PPS	PP	PBT	PEEK	PEI	PEK	PES
Acrylonitrile-Butadiene-Styrene	ABS	■	■	■						✥	✥		✥		✥											
ABS / Polycarbonate alloy	ABS / PC	■	■	✥					■																	
Acrylic	PMMA	■	✥	■			✥		✥						✥											
Styrene-Butadiene-Styrene	SBS				■					✥	✥															
Cellulosics	CA, CP, CAB					■																				
Poly Phenylene Oxide	PPO			✥			■		✥	■					✥											
Poly Amide/Imide	PA 6, 66, 12							■																		
Polycarbonate	PC		■	✥			✥		■			✥												✥		
Polystyrene - General Purpose	PS - GP	✥			✥		■			■					■											
Polystyrene - Hi Impact	PS - HI	✥			✥						■															
Poly Sulfone	PSU								✥			■														
Poly Viny1 Chloride - Rigid	PVC-U	✥											■													
Poly Viny1 Chloride - Plasticised	PVC-P													■												
Styrene-Acryonitrile	SAN-NAS-ASA	✥		✥			✥			■					■											
PolyoxyMethylene	POM															■										
Polyethylene Terephtalate	PET																■									
Polyethylene	PE																	■								
Poly Phenylene Sulfone	PPSU																		■							
Poly Phenylene Sulphide	PPS																			■						
Polypropylene	PP																				■					
Poly Butylene Terephtalate	PBT																					■				
Poly Ether Ether Ketone	PEEK																						■			
Poly Ether Imide	PEI								✥															■		
Poly Ether Ketone	PEK																								■	
Poly Ether Sulphone	PES																									■

■ **Fully Compatible** ✥ **Possibily Compatible** □ **Not Compatible**

Weldability of Plastics		Welding		Insertion	Staking	Swaging	Spot Welding
		Near Field	Far Field				
Acrylonitrile-Butadiene-Styrene	ABS	E	G	E	E	E	E
ABS / Polycarbonate alloy	ABS / PC	E	G	E	G	G	G
Acrylic	PMMA	G	F	G	G	G	G
Styrene-Butadiene-Styrene	SBS	E	G	G	G	F	G
Cellulosics	CA, CP, CAB	P	P	G	G	G	P
Poly Phenylene Oxide	PPO	G	G	E	G	G	G
Poly Amide/Imide	PA 6, 66, 12	G	P	G	F	F	G
Polycarbonate	PC	G	G	G	F	F	G
Polystyrene - General Purpose	PS - GP		E	E	G	F	F F
Polystyrene - Hi Impact	PS - HI	G	F	E	E	E	E
Poly Sulfone	PSU	G	F	G	F	F	F
Poly Viny1 Chloride - Rigid	PVC-U	F	P	G	G	G	F
Poly Viny1 Chloride - Plasticised	PVC-P	P	P	F	P	P	P
Styrene-Acryonitrile	SAN-NAS-ASA	E	E	G	F	F	F
PolyoxyMethylene	POM	G	F	G	F	F	F
Polyethylene Terephtalate	PET	G	F	G	F	F	F
Polyethylene	PE	F	P	G	F	F	G
Poly Phenylene Sulfone	PPSU	G	F	G	G	G	G
Poly Phenylene Sulphide	PPS	G	F	G	F	F	P
Polypropylene	PP	G	P	G	E	E	E
Poly Butylene Terephtalate	PBT	G	F	G	F	F	G
Poly Ether Ether Ketone	PEEK	F	P	G	F	F	F
Poly Ether Imide	PEI	G	F	G	F	F	G
Poly Ether Ketone	PEK	G	F	G	G	G	G
Poly Ether Sulphone	PES	G	F	G	G	G	G

E = Excellent G = Good F = Fair P = Poor

VARIABLES AFFECTING WELDABILITY

Even amongst compatible materials, several factors may affect the weldability of the parts.

These factors include

- **Colourants**
- **Fillers**
- **Flame Retardents**
- **Hygroscopicity**
- **Lubricants**
- **Mould Release Agents**
- **Plasticisers**
- **Regrinds**
- **Resin Grades** and
- **Stiffness**

- **Colourants**, whether liquid or dry, have **little effect** on weldability, unless the ratio of colourant to resin is very high. Occasionally weld parameters may need to be varied for different colours of the same part.

- **Fillers** improve weldability but can adversely affect joint strength and life of the ultrasonic toolings when used in excess (remember, the ultrasonic horn and fixture are commonly Aluminium -- a soft material with little wear resistance).

Fillers enhance the resin's ability to transmit ultrasonic energy, specially semi-crystalline plastics, and fillers between 10% - 20% **improve** their weldability.

When fillers **exceed 30%**, they cause welding several **problems**.

- As the filler does not weld (only the plastic welds), this results in inconsistent weld strength.

- Rapid wear of Aluminium Horns & Fixtures. Steel & Titanium toolings also suffer wear, though slower. So special heat treated steel, or carbide faced Aluminium or Titanium horns are used.

- Higher powered equipment is required to create sufficient heat at the joint.

- **Flame Retardents adversely** affect weldability.

Retardents are added to resins to keep temperatures below combustion levels.

However, these additives (Antimony, Boron, Halogens, Nitrogen & Phosphorous) tend to reduce the weld strength. The parts, therefore, need to be overwelded to achieve adequate strength, resulting in higher amplitude and power being used.

- **Hygroscopicity adversely** affects weldability.

Moisture absorbed by the plastics begins to vapourise, as the temperature increases during welding, and boils off at 100°C. This creates a patchy condition at the joint, giving leaky welds, poor cosmetic appearance, and low bond strength.

As a good practice, hygroscopic parts should be stored in sealed polybags or welded immediately after moulding. If this is not possible, they will need to be dried before welding.

- **Lubricants adversely** affect weldability.

The flow characteristics of resins is improved by the addition of lubricants such as waxes, zinc stearate, stearic acid, aluminium stearate and fatty esters.

They cannot be removed or restricted from the joint interface area, and inhibit friction at the interface, thereby directly affecting weldability.

- **Mould Release Agents adversely** affect weldability.

To facilitate ejection of injection moulded parts, sprays are sometimes used, and these tend to coat the weld area too, inhibiting frictional heat during the ultrasonic welding.

Their chemical contamination sometimes affects the formation of the weld bond.

It is possible to wipe clean the parts after ejection, but this adds a secondary operation and should be avoided.

However, when mould release agents are absolutely necessary, paintable/ printable grades that permit printing/silk screening should be used, because they cause least problems with Ultrasonic assembly.

As far as possible, use of aluminium and zinc stearate, fluorocarbons and silicons should be avoided.

- **Plasticizers weaken** the weld over time.

Plasticizers tend to migrate to the joint of a welded part after a period of time and weaken it.

Metallic plasticizers are more likely to migrate.

- **Regrinds** can **adversely** affect weldability, depending on their percentage

Care needs to be observed when adding regrind to virgin materials. It should be within 10 - 15% only. Excessive levels could affect weldability and strength.

Do not add the nth regrind !

- **Resin Grade** can **adversely** affect weldability.

The same resin in different grades can have very different melt temperatures, leading to poor welds or even incompatibility.

For example, cast sheets will not weld to injection or blow moulded parts.

As far as possible the same grade (even the same source) should be used in the ultrasonic welding process.

- Stiffness refers to the modulus of elasticity of a polymer. **Stiffer** materials transmit ultrasonic energy **well**.

PROPERTIES OF POPULAR POLYMERS

Here is a listing of properties of popular plastics -- their primary characteristics, their temperatures related properties, weldability, recommended amplitudes for optimum welding results, compatibility, ...

1. **ABS** [Acrylonitrile-Butadiene-Styrene]

Structure	:	Amorphous
Heat Distortion Temperature	:	75° to 100°C
Continuous Service Temperature	:	85° to 100°C
Water Absorption at 23°C	:	0.15 to 0.30 %
Density	:	1.08 gms/cc
Near Field Weldability	:	Excellent
Far Field Weldability	:	Good
Amplitude for Welding	:	30 - 70 microns peak to peak
Compatible Polymers	:	ABS & ABS / Polycarbonate Alloy Acylic & Acrylic Multipolymer SAN, NAS & ASA.

Common Trade Names for ABS

Tyolac
Terluran (BASF),
Novodur (Bayer),
Absolac, Cycolac

2. **ABS/PC** [ABS / Polycarbonate Alloy]

Structure	:	Amorphous
Heat Distortion Temperature	:	100° to 115°C
Continuous Service Temperature	:	90° - 100°C
Water Absorption at 23°C	:	0.6 to 0.7 %
Density	:	1.10 to 1.25 gms/cc
Near Field Weldability	:	Very Good
Far Field Weldability	:	Fair
Amplitude for Welding	:	70 - 125 microns peak to peak
Compatible Polymers	:	ABS & ABS / Polycarbonate Alloy Acrylic Polycarbonate

Common Trade Names for ABS/PC

Cycoloy 800
Bayblend (Bayer)

3. **PMMA - Acrylic** [Poly Methyl Meta Acrylate]

Structure	:	Amorphous
Heat Distortion Temperature	:	40° - 70° C
Continuous Service Temperature	:	60°C
Water Absorption at 23°C	:	0.35 %
Density	:	1.18 gms/cc
Near Field Weldability	:	Very Good
Far Field Weldability	:	Very Good
Amplitude for Welding	:	40 - 70 microns peak to peak
Compatible Polymers	:	ABS Acrylic & Acrylic Multipolymer, Polystyrene SAN, NAS & ASA.

Common Trade Names for PMMA-Acrylic

Diakon (ICI),
Gujpol (GSFC),
Plexiglass (Rohm).

4. **SBS K-Resin** [Styrene Butadiene Styrene]

Structure	:	Amorphous
Heat Distortion Temperature	:	65° to 78°C
Continuous Service Temperature	:	60°C
Water Absorption at 23°C	:	0.07 %
Density	:	1.01 gms/cc
Near Field Weldability	:	Very Good
Far Field Weldability	:	Good
Amplitude for Welding	:	50 - 90 microns peak to peak
Compatible Polymers	:	Polystyrene

Common Trade Names for SB K-Resin

Polystyrol (BASF),
Hostyren (Hoechst)

5. **CA, CP, CAB** [Cellulose Acetate, Propionate, Butyrate]

Structure	:	Amorphous
Heat Distortion Temperature	:	60° to 100°C
Continuous Service Temperature	:	-40° to 115°C
Water Absorption at 23°C	:	upto 4.6 % (CA)
Density	:	1.16 to 1.30 gms/cc
Near Field Weldability	:	Good to Fair
Far Field Weldability	:	Poor
Amplitude for Welding	:	65 -100 microns peak to peak
Compatible Polymers	:	Only to themselves

Common Trade Names for CA, CP, CAB

Cellidor (Bayer), Tenite (Eastman)

6. **PPO** [Poly Phenylene Oxide]

Structure	:	Amorphous
Heat Distortion Temperature	:	120°C
Continuous Service Temperature	:	80° to 100°C
Water Absorption at 23°C	:	0.05 to 0.07 %
Density	:	1.04 to 1.27 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Good to Fair
Amplitude for Welding	:	50 - 90 microns peak to peak
Compatible Polymers	:	Acrylic Phenylene-Oxide based resins, Polycarbonate Polystyrene SAN, NAS & ASA

Common Trade Names for PPO

Noryl (GE)

7. **PA 6, PA 66, PA 610, PA 11, PA 12** [Poly (Amid/Imide)]

Structure	:	Semi-Crystalline
Heat Distortion Temperature	:	80° to 120°C
Continuous Service Temperature	:	70° TO 130°C
Water Absorption at 23°C	:	0.4 to 3.5 %
Density	:	1.02 to 1.36 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Poor
Amplitude for Welding	:	70 - 125 microns peak to peak
Compatible Polymers	:	Only to themselves.

Common Trade Names for PA 6, PA 66, PA 610, PA 11, PA 12

Tufnyl (SRF),
Zytel (DuPont),
Gujlon (GSFC).

8. **PC** [Polycarbonate]

Structure	:	Amorphous
Heat Distortion Temperature	:	135° to 145°C
Continuous Service Temperature	:	-135° to 145°C
Water Absorption at 23° C	:	0.2 %
Density	:	1.2 to 1.42 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Good
Amplitude for Welding	:	65 - 100 microns peak to peak
Compatible Polymers	:	ABS / Polycarbonate Alloy Acrylic Phenylene Oxide based Resins (Noryl)

Common Trade Names for PC

Lexan (GE),
Merlon (Mobay)
Makrolon (Bayer),

9. **PS** [Polystyrene]

Structure	:	Amorphous
Heat Distortion Temperature	:	70° to 80°C
Continuous Service Temperature	:	75°C
Water Absorption at 23°C	:	< 0.1 %
Density	:	1.04 to 1.05 gms/cc
Near Field Weldability	:	Very Good
Far Field Weldability	:	Very Good
Amplitude for Welding	:	30 - 65 microns peak to peak
Compatible Polymers	:	Acrylic Multipolymer Poly Phenylene Oxide (Noryl) Polystyrene SAN, NAS & ASA

Common Trade Names for PS

Macstrene, Styropor (BASF), Hostapor (Hoechst)

10. **PSU** [Polysulfone]

Structure	:	Amorphous
Heat Distortion Temperature	:	180°C
Continuous Service Temperature	:	150° to 170°C
Water Absorption at 23°C	:	0.02 to 0.26 %
Density	:	1.24 to 1.40 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Good
Amplitude for Welding	:	65 - 100 microns peak to peak
Compatible Polymers	:	Polycarbonate Polysulfone

Common Trade Names for PSU

Udel (UC)

11. **PVC-U** (Rigid) [Poly Vinyl Chloride - Unplasticised]

Structure	:	Amorphous
Heat Distortion Temperature	:	70°C
Continuous Service Temperature	:	60° - 85°C
Water Absorption at 23°C	:	4 to 20 mg
Density	:	1.40 to 1.55 gms/cc
Near Field Weldability	:	Fair to Poor
Far Field Weldability	:	Poor
Amplitude for Welding	:	40 - 75 microns peak to peak
Compatible Polymers	:	ABS / PVC Alloy ABS

Common Trade Names for PVC-U

Corvic (ICI),
Indovin (IPCL),
Hostalit (Hoechst)

12. **PVC-P** (Flexible) [Poly Vinyl Chloride - Plasticised]

Structure	:	Amorphous
Heat Distortion Temperature	:	70°C
Continuous Service Temperature	:	60° - 85°C
Water Absorption at 23°C	:	5 to 20 mg
Density	:	1.21 to 1.35 gms/cc
Near Field Weldability	:	Fair to Poor
Far Field Weldability	:	Poor
Amplitude for Welding	:	50 - 70 microns peak to peak
Compatible Polymers	:	ABS / PVC Alloy ABS

Common Trade Names for PVC-P

Welvic (ICI),
Vinoflex (BASF),
Hostalit (Hoechst)

13. **SAN - NAS - ASA** [Styrene-Acrylo-Nitrile]
[Acrylonitrile-Acrylic Ester]

Structure	:	Amorphous
Heat Distortion Temperature	:	SAN 115 °C ASA 75° -100°C
Continuous Service Temperature	:	ASA 85° -100°C
Water Absorption at 23 °C	:	ASA 0.15 to 0.30 %
Density	:	SAN 1.08 gms/cc ASA 1.07 gms/cc
Near Field Weldability	:	Excellent
Far Field Weldability	:	Excellent
Amplitude for Welding	:	30 - 65 microns peak to peak
Compatible Polymers	:	ABS Acrylic / Acrylic Multipolymer Polystyrene

Common Trade Names for SAN - NAS - ASA

Lustran,
Luran (BASF)

14. **POM** [Poly Oxy Methylene]

Structure	:	Semi-Crystalline
Heat Distortion Temperature	:	upto 150°C
Continuous Service Temperature	:	-40° to 110°C
Water Absorption at 23°C	:	0.15 to 0.9 %
Density	:	1.41 to 1.56 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Fair
Amplitude for Welding	:	75 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for POM

Delrin (Dupont),
Ultraform (BASF),
Hostaform (Hoechst)

15. **PET** [Polyethylene Terephtalate]

Structure	:	Semi-Crystalline, Amorphous
Heat Distortion Temperature	:	120° to 140°C
Continuous Service Temperature	:	100° to 130°C
Water Absorption at 23°C	:	0.4 to 1.1 %
Density	:	1.31 to 1.54 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Fair
Amplitude for Welding	:	65 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PET

Arnite (Akzo), Rynite (Dupont)

16. **PE** [Polyethylene]

Structure	:	Semi-Crystalline
Heat Distortion Temperature	:	LD 80° to 90°C HD 90° to 95°C
Continuous Service Temperature	:	HD 70° to 80°C LD 60° to 75°C
Water Absorption at 23°C	:	< 0.1 %
Density	:	LD 0.915 to 0.940 gms/cc HD 0.940 to 0.965 gms/cc
Near Field Weldability	:	Fair to Poor
Far Field Weldability	:	Poor
Amplitude for Welding	:	90 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PE

Baylon (BASF), Alkathene (ICI), Indothene(IPCL), Relene (Reliance), Hostalen (Hoechst)

17. **PPSU** [Poly Phenyle Sulfone]

Structure	:	Amorphous
Heat Distortion Temperature	:	280°C
Continuous Service Temperature	:	260°C
Water Absorption at 23°C	:	1.8 %
Density	:	1.36 gms/cc
Near Field Weldability	:	Very Good
Far Field Weldability	:	Good
Amplitude for Welding	:	70 - 100 microns peak to peak
Compatible Polymers	:	Only to Itself

Common Trade Names for PPSU

Radel (UC), Victrex (ICI)

18. **PPS** [Poly Phenylene Sulfide]

Structure	:	Semi-Crystalline
Heat Distortion Temperature	:	upto 230°C
Continuous Service Temperature	:	200°C
Water Absorption at 23°C	:	0.01 to 0.05 %
Density	:	1.34 to 1.64 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Fair
Amplitude for Welding	:	80 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PPS

Tedur (Bayer), Supec (GE).

19. **PP** [Polypropylene]

Structure	:	Semi-Crystalline
Heat Distortion Temperature	:	100° to 130°C reinforced upto 150°C
Continuous Service Temperature	:	100°C
Water Absorptio at 23° C	:	< 0.1 %
Density	:	0.896 to 1.14 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Poor
Amplitude for Welding	:	90 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PP

Koylene (IPCL),
Novolen (BASF),
Noblen (Mitsui),
Repol (Reliance),
Hostalen (Hoechst)

20. **PBT** [Poly Butylene Terephtalate]

Structure	:	Semi Crystalline
Heat Distortion Temperature	:	150° to 200°C
Continuous Service Temperature	:	180°C
Water Absorption at 23°C	:	0.4 to 0.6 %
Density	:	1.29 to 1.50 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Fair - Poor
Amplitude for Welding	:	60 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PBT

Valox (GE),
Crastin (Ciba),
Ultradur (BASF)

21. **PEEK** [Poly Ether Ether Ketone]

Structure	:	Semi Crystalline
Heat Distortion Temperature	:	300°C
Continuous Service Temperature	:	200°C
Water Absorption at 23°C	:	0.15 %
Density	:	1.3 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Fair to Poor
Amplitude for Welding	:	65 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PEEK

Victrex (ICI), Ultrax (BASF)

22. **PEI** [Polyether Imide]

Structure	:	Amorphous
Heat Distortion Temperature	:	160° to 200°C
Continuous Service Temperature	:	150°C
Water Absorption at 23°C	:	0.18 to 0.25 %
Density	:	1.27 to 1.51 gms/cc
Near Field Weldability	:	Very Good
Far Field Weldability	:	Good
Amplitude for Welding	:	65 - 100 microns peak to peak
Compatible Polymers	:	Only to Itself

Common Trade Names for PEI

Ultem (GE)

23. **PEK** [Poly Ether Ketone]

Structure	:	Semi-Crystalline
Heat Distortion Temperature	:	upto 300°C
Continuous Service Temperature	:	upto 260°C
Water Absorption at 23°C	:	0.2 %
Density	:	1.32 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Poor
Amplitude for Welding	:	75 - 125 microns peak to peak
Compatible Polymers	:	Only to itself

Common Trade Names for PEK

Ultrapek (BASF)

24. **PES** [Polyether Sulfone]

Structure	:	Amorphous
Heat Distortion Temperature	:	200° to 250° C
Continuous Service Temperature	:	200° C
Water Absorption at 23° C	:	0.43 to 1.30 %
Density	:	1.36 to 1.58 gms/cc
Near Field Weldability	:	Good
Far Field Weldability	:	Good
Amplitude for Welding	:	65 - 100 microns peak to peak
Compatible Polymers	:	Itself

Common Trade Names for PES

Victrex HTA (ICI),
Ultrason E (BASF),
Gafone (Gharda)

Chapter 5 - Part & Joint Design

Good results can be achieved with ultrasonics ONLY if there is a correct joint design at the interface. This is CRITICAL to achieving optimum results.

Many manufacturers trying Ultrasonics for the first time tend to "convert" an existing application from solvents / adhesives / heat welding to ultrasonics, but are reluctant to modify their moulds to incorporate the joint design required for ultrasonics.

This leads to poor results, and an unhappy experience.

It must be understood and appreciated that each welding process has its own joint design requirements, and taking half measures during trials will not prove anything.

Ultrasonic Welding trials should be conducted with the right joint design, or not at all.

Here is basic information on Joint Designs to help you understand their importance in achieving good welding results.

The joint design selection is based on

- **Type of Plastic**
- **Part Geometry** and
- **Weld Requirements**

Two joint designs are generally used in Ultrasonics, and each has several variations

- **Energy Directors** &
- **Shear Joint**

JOINT DESIGN REQUIREMENTS

Good joint design enables the release of energy at the joint interface, with a controlled flow of material.

Three basic requirements in joint design ensure consistent results

- **Uniform Contact Area**
  The mating surfaces should be in intimate contact around the entire joint. The joint area should also be in one plane as far as possible.

- **Small Initial Contact Area**
  A small initial contact area should be established between the mating parts. Less energy, and time, are then required to start and complete the melt-down between the mating parts.

- **Means of Self-Alignment**
  The mating halves should not misalign during the welding operation. The parts should stand in their weld position without needing operator assistance.

  Alignment pins and sockets, channels and tongues are often moulded into parts to provide self-alignment.

  The horn and fixture only should not be used to provide part alignment.

The Energy Director
(and its variations)

The energy director is designed to provide a pre-determined volume of material to be melted, so that a good weld (optimum strength and minimum flash) is obtained.

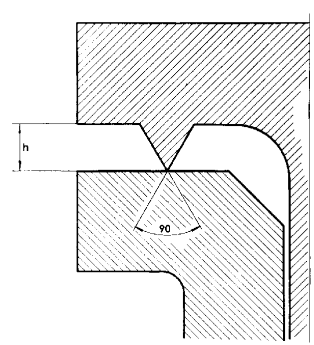
Welding without an energy director will NOT work.

The energy director "directs" the energy to the targeted area for dissipation. The high concentration of energy focussed by the energy director results in an almost immediate weld and a uniform flow in the joint area.

The energy director is a triangular shaped bead moulded on one part. Typically it runs continuously around the weld perimeter, but an interrupted energy director may also be used.

The basic design for an Amorphous plastic is a right angled triangle, with the 90° angle at the apex and 45° at the base. This facilitates machining in the mould, and easy filling of the energy director during moulding.

The actual dimensions of the energy director are related to wall thickness, with the base width being 1/4th the wall thickness, and consequently, the height being 1/8th wall thickness.



The actual dimensions can vary from 0.25 to 1.5 mm width, and 0.125 to 0.750 mm height.

When the wall is thick enough to produce an energy director larger than the maximum size, two smaller, parallel energy directors may be used. This design produces a good strong weld across the entire wall section.

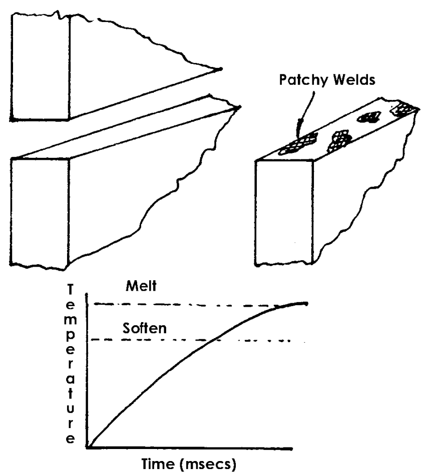
For some polymers, such as Polycarbonate, Acrylics and semi-crystallines, the energy director is an equilateral triangle, with all three angles being 60°. This makes the height 0.866 times the base width. The base width can vary from 0.20 to 1.25 mm.

In terms of the three basic requirements of joint design, the energy director meets two -- it provides

- a uniform, line contact at the start of each weld
- consistently a small initial contact area for each part

It however does not provide a means of alignment, or control of flash. These have to be added in the part design.

To better understand the role played by the energy director, let's first look at a flat butt joint, which most beginners want to weld.

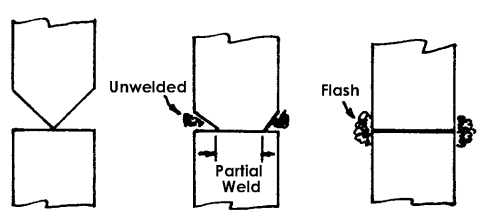


On mating two parts, initial contact will be made only at the high points -- which will vary from part to part.

This presents non uniform contact area for each weld, and a small or a large initial contact area. This will result in erratic and inconsistent welding.

Extending the weld time to increase the melt simply enlarges the original weld points and causes excessive flash outside the joint.

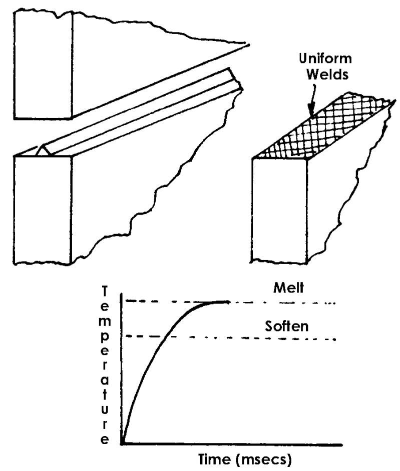
Bringing one of the surfaces to a point, as illustrated, produces welds with better appearance, but little strength.



Incorrect

When good strength is achieved, excessive flash ruins the weld appearance. So this is not a good option either.

The Energy Director is the preferred joint design for amorphous polymers.



For semi crystalline polymers, the energy director design can sometimes give poor results.

In semi-crystallines, the material displaced from the energy director often solidifies before it can flow across the joint to form a seal. This results in a leaky weld and low weld strength.

However, it may well become necessary to use an energy director on a semi crystalline plastic.

In that event, it needs be made larger and sharper. This reduces the amount of premature solidification and degradation, by allowing it to embed partially in the mating surface during the initial stages of the weld.

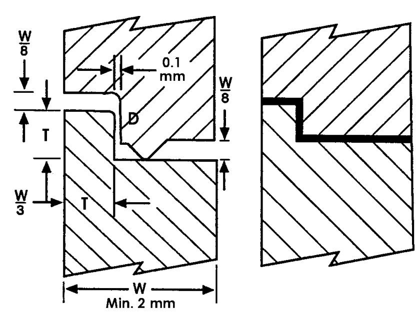
The larger, sharper design improves the strength and enhances weld quality.

Experience has shown the larger, sharper energy director also gives superior results with some amorphous polymers too, such as Polycarbonate & Acrylics.

Variations of the Energy Director

▯ The Step Joint

One variation of the energy director joint design is the Step Joint.



Step Joint

This meets all three basic requirements - it provides

- a uniform contact area
- a small initial contact area and
- a means of self alignment

Its strength, however, is relatively less than a butt joint, as only a part of the wall in a step joint is welded, but it hides all flash inside. The material from the energy director will typically flow into the clearance gap between the step.

It also provides a better, leak-tight seal.

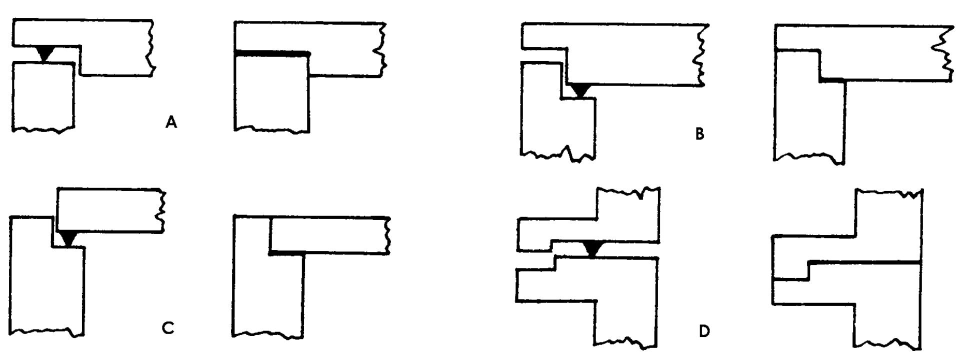
A Step joint needs a minimum wall thickness of 2 mm.

It is recommended when aesthetic appearance of the welded assembly is important, as flash is all contained within the weld. Dimensions of the energy director are similar to those on a butt joint.

The height and width of the step are each 1/3rd of the total wall thickness (T = W/3).

The clearance between the parts provides an easy slip fit, the order of 0.05 to 0.10 mm.

The step height should be marginally greater than the depth (D = T + 0.1 mm) ; this adds aesthetics to the welded assembly, and hides parallelism imperfections in the moulded parts.



Variations of the step joint

The Tongue & Groove Joint

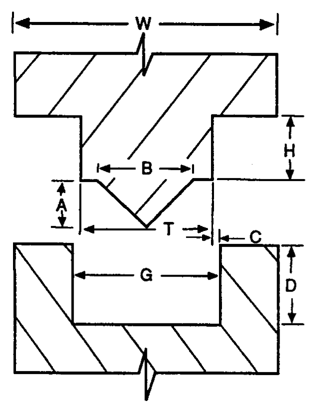
Another variation of the energy director is the Tongue-and-Groove joint.

Like the step joint, it meets all three requirements for a good joint design -- uniform contact area, small initial contact area and a means of self alignment.

It eliminates internal and external flash.

Where self location and flash are important, this design is used. It ensures low pressure leak tight seals.

Although the necessity to maintain clearance on both sides of the tongue makes it difficult to mould, interference between the parts must be strictly avoided. This clearance also provides space for molten material.



W= Wall Thickness
A= Energy Director Height
H= Tongue Height (W/3)
B= Energy Director Width (W/4)

T= Tongue Width (W/3)
C= Clearance (0.1 mm)
G= Groove Width (T + 0.2 mm)
D= Groove Depth (H + 0.25 mm)

Tongue & Groove Joint with Energy Director

Its weld strength is relatively lower -- only a third of the wall thickness is typically welded !

The minimum wall thickness recommended for a tongue-and-groove design is 3mm.

Dimensions of the energy director remain the same.

Both, the height and width of the tongue, are1/3rd the wall thickness.

The groove (G) is 0.1 to 0.2 mm wider than the tongue, and the depth of the groove (D) is 0.1 to 0.25 mm less than the height of the tongue.

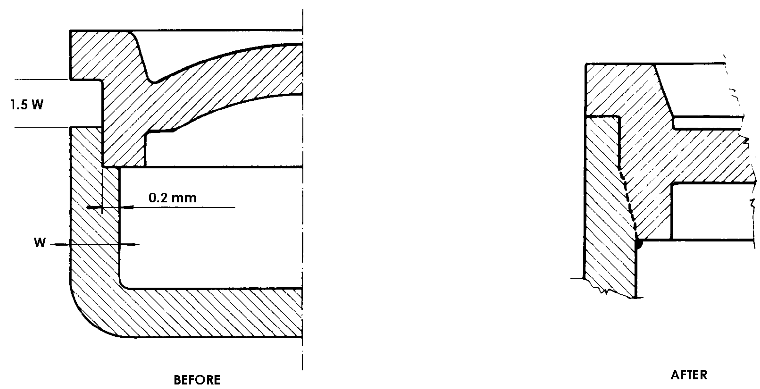
As with the step joint, the slight gap designed into the welded assembly provides for better aesthetics.

Recent experiences have shown that if the energy director mates with a roughened surface, as opposed to a normal smooth surface, the welding is quicker, and a better weld is achieved.

A matt surface is not a roughened surface, but a starting point. A textured surface with an average surface roughness value between 60 to 100 microns peak to peak is an appropriate roughened surface. This gives better welding results than obtained with traditional smooth or matt moulded surfaces.

THE SHEAR JOINT
(AND ITS VARIATIONS)

The Shear Joint is used when a strong, leak tight seal is desired, especially with semi crystalline polymers such as Nylon, Acetal, Thermoplastic Polyester, Polyethylene, Polypropylene and Polyphenylene Sulphide.



Shear Joint

A positive interference between the mating parts is a Shear joint. This interference can only be "melted away" with ultrasonic energy.

A Shear joint meets all three basic requirements for good joint design.

A locating recess helps self alignment of the parts, and the line contact provides uniform contact area, and small initial contact area.

On application of ultrasonic energy and pressure, the contact surfaces rub together, generate heat and begin to melt and enlarge, till the designed depth of weld is reached.

As the contact surfaces melt, welding is achieved.

The continuous smearing action of the mating surfaces at the weld interface fills all voids ; it also limits exposure to air, consequent premature solidification, and degradation.

The smearing action produces a leak tight weld and strong structural strength.

The fixture plays an important role in shear joint welding, and great care needs to be taken in designing it correctly.

It should prevent a "snap fit" due to flexing of the walls during welding. The fixture should rigidly support the walls of the fixtured part upto the joint interface.

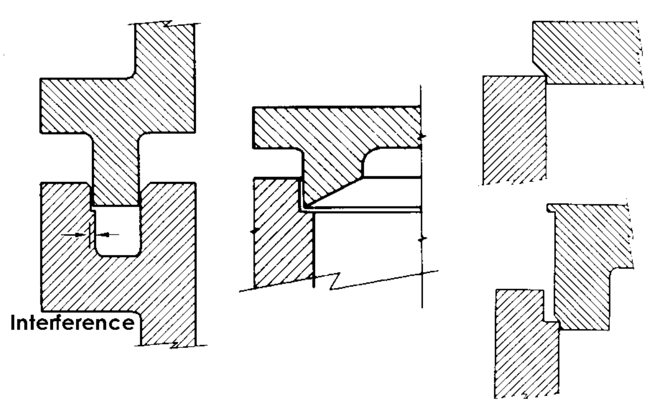
Sometimes a split design or an ejector may be necessary to eject the tightly squeezed-in welded assembly from the fixture.

Recommended values of the interference required in the shear joint are dependent on the size of the part, and are listed below

Maximum Diameter	Interference per side	Dimensional Tolerance	Locating Recess	Depth of Weld
< 18 mm	0.2 - 0.3 mm	+/- 0.025 mm	0.5 to 0.8 mm in all cases.	1.25 to 1.50**x** wall thickness
18 to 35 mm	0.3 - 0.4 mm	+/- 0.050 mm		
> 35 mm	0.4 - 0.5 mm	+/- 0.075 mm		

Minimum wall thickness 2.0 mm.

Variations of the Shear Joint design are illustrated below



Shear Joint Variations

OTHER CONSIDERATIONS

Several aspects need to be considered in deciding which part should make contact with the horn, and which part should be held stationery in the fixture.

Ease of assembly, handling the individual components, and the part geometry are factors to be considered. From the ultrasonics point of view, however, the material being welded is important.

Losses in transmission of ultrasonic energy through amorphous resins are low. The losses in transmission of ultrasonic energy through semi-crystalline resins are relatively higher.

This is because the orderly molecular structure of the semi-crystalline resins absorbs ultrasonics, whereas the random molecular arrangement of amorphous resins transmits ultrasonics well.

It is essential to understand Near Field & Far Field concepts in Ultrasonic Welding.

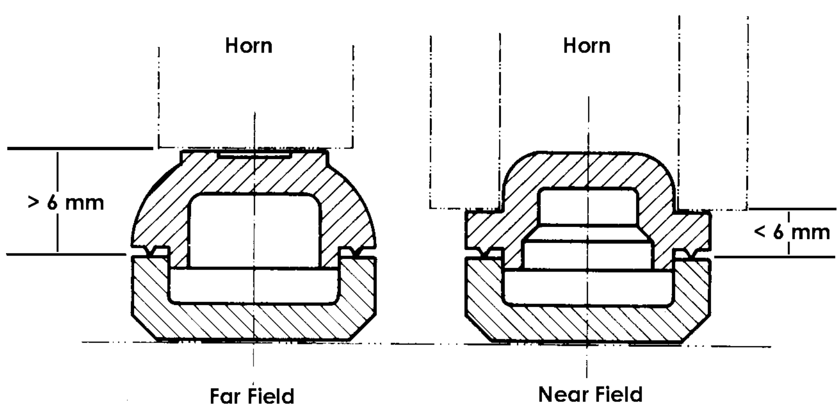
- **Near Field & Far Field**

Depending on part geometry, the horn is designed to contact the part at a specific point, and from this point, transmit ultrasonic energy upto the weld interface.

When the distance between the horn and the joint interface is greater than 6 mm, it is considered Far Field.

If this distance is less than 6 mm, it is considered Near Field.

Whenever possible, the preferred method is to weld Near field.



Far Field & Near Field Welding

To achieve a comparable weld, Far field welding demands relatively

- Higher Amplitudes,
- Longer Weld Times, and
- Higher Pressures

Far field welding may be considered for Amorphous resins ; Near field welding is the only option for semi-crystalline resins.

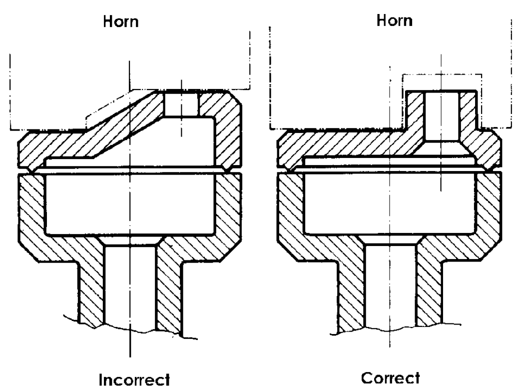
Other part design details to pay attention to are

Parallel Contact

The ultrasonic energy must travel the same distance to reach the joint interface, to obtain acceptable results.

This means the joint interface should be in a horizontal plane, parallel to the horn contact surface.

For the same reason, the horn should contact the part in a single plane, parallel to the joint interface.

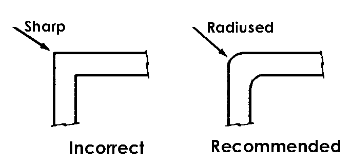


Horn Face & Joint Interface Parallelism

An example that does not meet these requirements, and reflects poor design, is illustrated. Correct design is shown alongside.

Sharp Corners

Stress, and subsequent cracks, develop at sharp corners. A generous radius on all corners and edges is recommended to reduce stress related failure.

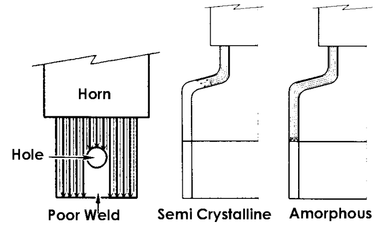


Corners should be Radiused

Holes and Voids

Angles, bends, holes, voids, etc obstruct the flow of ultrasonic energy. Little or no welding is achieved under such areas.

Part design, therefore, should eliminate all such obstructions from the ultrasonic flow path.



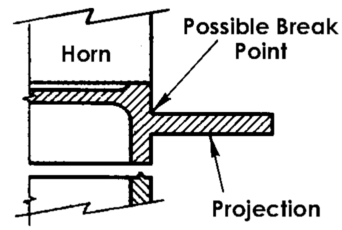
Welds under holes are poor

Appendages

Projections such as extensions, tabs etc are vulnerable to Ultrasonic energy, and have a tendency to break at the root, or "fall off".

The adverse effects can be reduced by

- adding a generous radius at the root
- adding support in these areas, and
- making the sections thicker, if possible.



Projections should be well radiused at roots

Diaphragmming

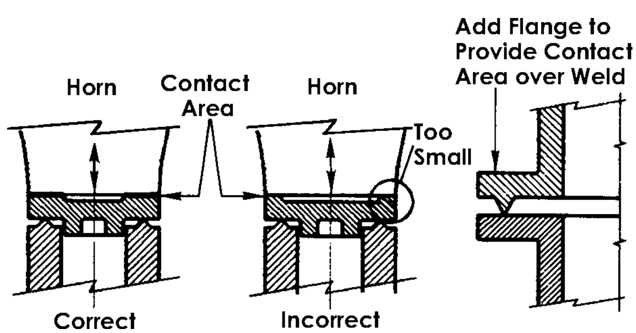
Thin circular parts flex when subjected to ultrasonic energy.

The energy focuses towards the center of the part, and causes a hole to burn through.

This can be offset by making the vulnerable sections thicker.

Horn Contact

The horn should contact the part directly over the joint -- this is especially important for semi-crystalline parts. The contact surface should be small, but larger than the weld area.



Horn Contact with Part

Chapter 6 - Equipments

There is a very wide range of ultrasonic equipments available today.

Their output power ranges from 50 Watts to 4000 watts and their output frequency ranges from 15 KHz to 50 KHz.

The systems range from simple Hand Held Welding Guns to sophisticated Microprocessor based equipments, fully capable of communicating through Computers, and churning out statistical data, including quality parameters.

The Range

Lets start with simple Hand Guns first.

These are available as 20 KHz and 35 to 50 KHz portable units, output generally 100 to 200 watts, maximum limit being 1000 watts.

They are primarily meant for spot welding large parts that cannot be brought to a bench mounted unit, or for welding / staking small parts.

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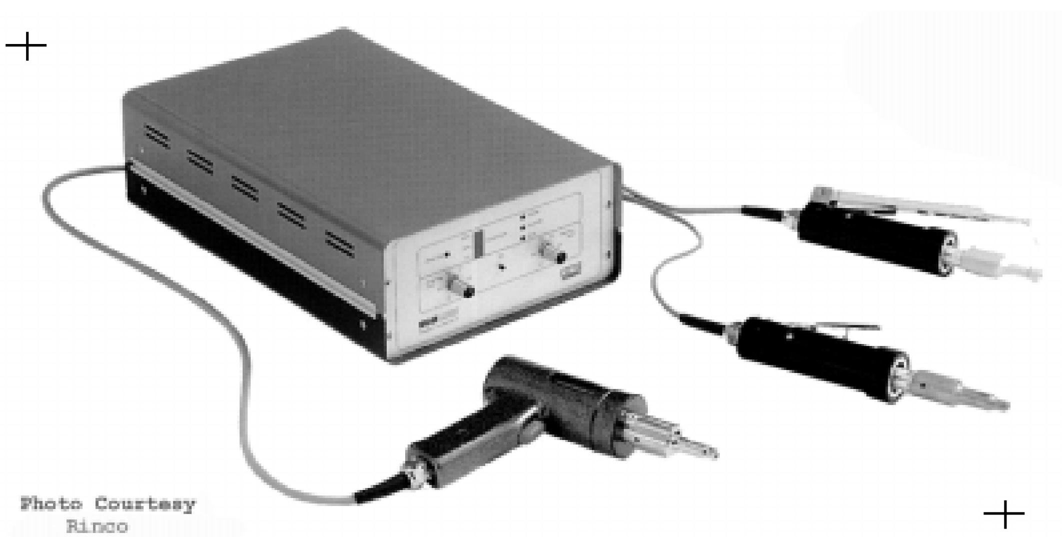


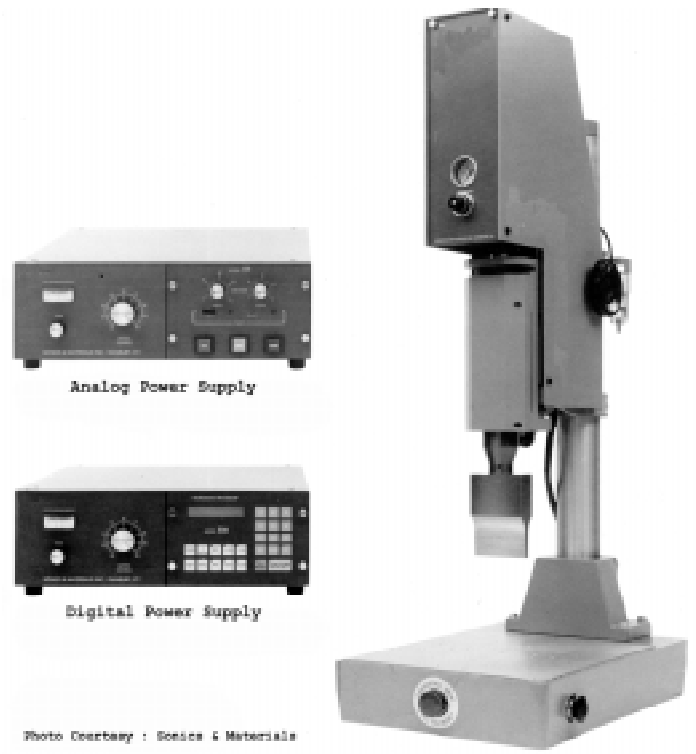
There is a simple power supply, sometimes with timers, and minimal protection circuits.

The ultrasonic stack is spring mounted, and pressure is applied manually by the operator. This triggers a limit switch that initiates ultrasonics. Weld and Hold time are controlled either manually or by a timer.

The Hand Gun is suitable for low power, small volume applications.

The most popular option is the **Bench-Top** unit, that sits on a regular work table.

This normally has a pneumatic actuator to move and hold the ultrasonic stack, and refined electronics in the power supply that include a programmer and auto-tune plus protection circuits.



The power supply may be housed separately or integrated in the Actuator Stand.

The timers, gauges and controls are all Analogue Controls.

Digital and Microprocessor versions are also available. The bench top versions are user friendly -- easy to use and maintain.

They make setting parameters more accurate and easy, with timer resolution being 5 msecs, energy increments of 1 joule, and distance resolution 2.5 microns. They incorporate Auto-Tuning, so changing any element of the ultrasonic stack does not entail re-tuning prior to use.

The Microprocessor based power supplies have ushered in a new generation of equipments that permit Computer Integrated Manufacturing, and enable welding modes other than the traditional time mode welding.

In these versions, one can choose to weld in either of several modes

- **Continuous Mode**
  Sonics triggered by On-Off Switch

- **Conventional Time Mode**
  Sonics controlled by electronic timer

- **Time with Energy Limits Mode**
  Fixed time to deliver energy within a predetermined band to each weld.

- **Energy with Time Limits Mode**
  Constant energy to be delivered within a predetermined time band to each weld.

- **Time / Energy Compensation Mode**
  Specific weld time and acceptable range of energy to be delivered to each weld.

- **Distance Mode**
  Ultrasonics to be terminated after a predetermined weld distance, measured either in absolute or relative terms.

Other models offer Linear Ramp Variable Soft Start, Electronic Gain setting for the booster, Dual Pressures (for weld and hold cycles), Alternate Time mode (for applications needing 2 welds, with different weld times, to complete), parameter storage memory for over 100 applications, and a host of such features.

Microprocessor based equipments invariably also offer self diagnostics, pre-settable alarm limits, alarms, set-up accuracy and repeatability, and communications interface with computers, printers, modems and other monitoring and controlling equipments.

These features offer outstanding process control, and optimum flexibility. Where even higher levels of process control are required, Advanced Microprocessor based power supplies offer electronic amplitude control, even during the weld !

Other features include measuring and storing horn frequency data (even at the end of every weld), selectable start rates to adapt to different horn and load conditions, load regulation (maintaining constant amplitude with power loading and line voltage variations), etc all of which result in better welds and lower rejects.

The bench top analogue, digital and microprocessor versions, are available individually too, for building into custom engineered systems or automated lines.

Thus the power supply is available as a stand-alone, stackable unit, or as a plug in; the actuator is available for mounting on I-Beams in a standard version or a narrow version, with or without integrated pneumatic controls.

A popular welder for continous welding of films and fabrics is the Sewing machine.

Many custom engineered equipments, alongwith associated material handling systems and special toolings, are available for popular applications -- eg manufacturing audio cassettes, axial blowers, disposable face masks and caps, cigarette gas lighters, laminate tube sealing, collar making machines, etc.

These "ready-to-use" equipments use proven technology and toolings and make project start-up that much easier.

AUTOMATION

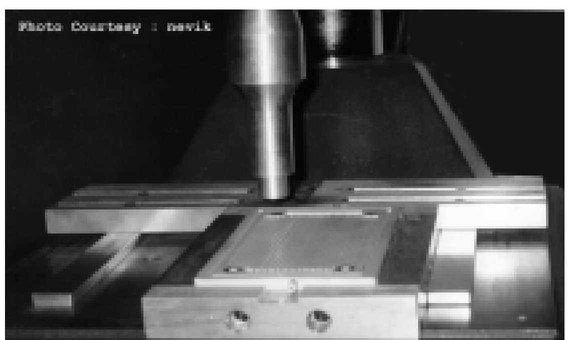
A vast majority of the welders use manual loading and unloading of parts.

Estimates show that within the total cycle time, the ultrasonic cycle time is less than 25%, and the operator time for loading, positioning and unloading is 75% or more.

Reducing the operator time can thus have a significant impact on productivity.

Automation can help reduce operation time

- **Sliding Fixtures** -- a simple sliding fixture (manual or pneumatic) enables the operator to move a large part and weld it in segments, or it could be a 2-station fixture so that the operator can unload a welded part and load an unwelded part for the next cycle, while the another part is being welded.



- **Auto Eject** -- An auto eject (pedal or pneumatic) of a welded part enables an operator to be ready to load the next part, and saves on unloading times.

- **Rotary Indexers** -- These are 6 or 8 station rotary tables, pneumatically indexed, to move the welded part out and bring in the next part and position it under the horn for welding.

  It is possible to test the finished component for weld integrity at a test station on the rotary table, prior to auto ejection, into a Good or Bad collection bin.

- **Hopper Feed** -- Small parts can be fed through a hopper, pre-assembled, aligned and fed to the weld station, thereby eliminating the operator completely.

In all such cases, the part/fixture triggers a limit switch or some such device to signal it is in "ready-for-weld" position, and this initiates the programmed ultrasonic cycle.

On completion, the horn retracts and triggers a "I-am-Home" limit switch to signal the indexing table to index and position the next part in the welding position.

Automated units or components can be purchased off the shelf or custom engineered by manufacturers.

However, automation can be expensive, with even simple automation costing between 30% to 60% of ultrasonic equipment cost.

It is advisable to evolve automation in-house, starting with simple building blocks to keep pace with increasing production volumes. This is a cost-effective and efficient approach in the long run.

Selection Aids

Once you are ready to invest in Ultrasonic technology, selecting the appropriate equipment and choosing a reliable supplier is the next challenge.

Primarily, you need to decide on the equipment power rating and frequency, and analogue/digital or micro-processor controls. And to evaluate the manufacturer and their support agent.

Factors that influence equipment selection relate to

- Materials to be welded
- Total weld area
- Type of weld -- mechanical or pressure tight welds
- Near field or Far field welding
- Numbers to be welded per day

Here are some steps to consider in selecting equipment

Survey the range of components you are likely to weld -- their materials, their dimensions and their geometry.

This will give you an indication of the frequency and power ratings of the equipment that will best serve your needs.

- **Equipment Frequency**

Lower frequency equipment such as 15 KHz, uses larger horns, higher amplitudes and higher power (upto 4000 watts).

Higher frequency equipments, such as 36, 40 or 50 KHz, use smaller horns, smaller amplitudes and lower power (upto 700 watts).

Small, delicate parts (upto 15 mm diameter) are better welded with higher frequencies (35, 40 or 50 KHz equipment).

Average sized parts (say upto 100-150 mm diameter) are better welded with 20 KHz equipment.

Large parts, say 200 mm dia or larger, are best welded with 15 KHz equipments.

Power Ratings

Amorphous plastics need lower power than Semi-crystallines.

A combination of weld material and part size needs to be evaluated in determining the output power of the welder.

For amorphous plastics of average size, a 1000 Watt welder would work well. A 1500/2000 Watt welder would provide for the future.

For large size parts, a 1500 or 2000 watt equipment would serve well. A 3000 watt welder would be selected only for extra large parts.

For semi-crystalline resins, a 1000 watt welder would be adequate for say, 25 mm dia parts.
Larger parts upto 50 - 60 mm would need a 1500 watt welder, and parts larger than 60 mm would generally need a 2000, or even 3000, watt welder.

The power ratings of different frequency equipments are not comparable on a linear basis -- a 350 Watt, 40 KHz equipment is not necessarily “weaker” than a 1000 Watt, 20 KHz equipment. They are just designed for different applications.

The marginal investment in higher powered equipment is often cost effective. Generally, for 15-20% higher investment, the power rating increases by 50% to 100%

Weld Specification

Pressure tight seals need higher power than seals that call for an interrupted weld, or a mechanical structural bond.

Near / Far Field Welding

Near field welding of amorphous resins consumes lower power than for semi-crystallines. Only the amorphous resins can be far field welded ; semi-crystallines cannot be far field welded.

- **Production Levels**

Higher powered equipment can sometimes result in shorter cycle times for the same application. If your numbers are likely to increase beyond 1500 - 2000 parts a day, this factor may be considered.

In addition to the above, basic decisions on the welder configuration have to be made.

- **Hand Gun or Bench Top**

For a first time user with small numbers and small parts e.g. staking or spot welding 100 parts at 3 points each, per day, a Hand Gun is a useful option to consider.

However, consistency may not be as high as with a Bench Top unit where all subjective elements are eliminated.

For higher volumes, or for parts needing pressure tight seals, a Bench Top is a better choice, as the weld quality is important.

- **Analogue / Digital or Microproccesor Power Supplies**

In Indian conditions, the analogue equipment has proven extremely rugged and reliable.

Digital equipment is dust and temperature sensitive, and care needs to be taken in this regard to avoid breakdowns.

Micro processors represent the state-of-the-art technology, and should be selected strictly on need basis.

If large volumes, tight specifications, SQC and a low reject rate imposed in a large scale production line are involved, such equipment will certainly contribute in achieving high levels of efficiency.

It must however be remembered all such equipments will need servicing and repairs at some time or the other, and local availability of spares, experienced staff and requisite instrumentation and skills for repairs is ensured.

While most equipments are of modular construction, and call for card level replacements to put them back into production, the defective cards need to be exchanged/repaired for future use.

These cards are expensive (can cost upto Rs 1,00,000.- each), and should be turned around quickly after failures.

- **Staff Training & Support**

This is an essential consideration in purchase of capital goods, and should be given due importance.

Once you switch to ultrasonics, you will be surprised how many additional applications keep surfacing, and technical support is needed for your Designers, Operational & Maintenance staff to be able to meet these challenges.

Continued support from the manufacturer is therefore important, and due weightage should be given to well established, well organised manufacturers.

Chapter 7 - Toolings

Ultrasonic Toolings refer to Ultrasonic Horns & Fixtures.

A "Horn" is an American term, so called because it transmits Sound energy. In Europe, it is referred to as "Sonotrode", a sound transmitting electrode, derived from electrode, as used in conventional welding.

A Fixture, or "nest", holds the plastic components during welding and provides adequate support to the weld areas. The fixture plays an important role in the welding process.

Horns

The Horn is often mistaken to be another mechanical tool.

It is not. It is an Acoustic tool.

▯ ▯ Horn Function

The primary function of the Horn is to transmit sound energy (mechanical vibrations) produced by the converter, to the part.

It must transmit this to specific areas of the part, for eventual transfer to the joint.

If need be, it should amplify the amplitude of the sound waves, just as the volume control does on a music system.

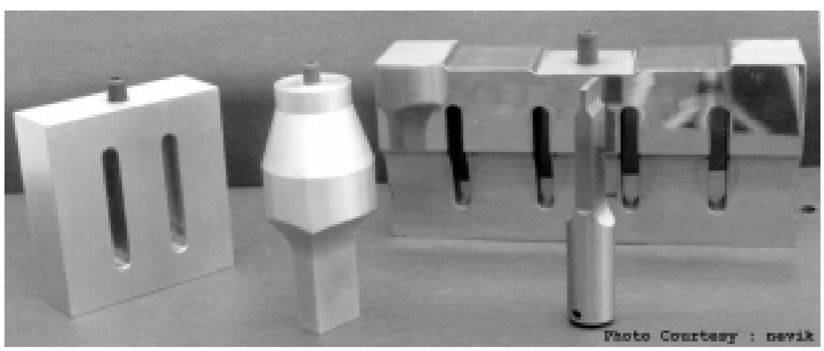
To do this efficiently, the horn must take a specific profile and conform to the part geometry.

Horn shapes

There are two basic Horn shapes -- Circular and Rectangular.

Circular horns may be solid or hollow, and have flat, tapped or contoured faces.

Rectangular Horns may incorporate reliefs for part projections, and may also be contoured faced.



Normally horns upto 75 mm linear dimension are unslotted ; longer dimensions are split into segments of 75 mm or less by vertical "Slots".

Slots are necessary to restrict the horn vibration along its longitudinal axis. Slots prevent vibrations in the transverse or diagonal directions by breaking up the wave path.

Vibration Mode

The horn can be likened to a spring when it vibrates longitudinally. When a spring contracts, both ends move inwards to shorten its overall length ; when subjected to tension, both spring ends move outwards to expand its overall length.

When a horn vibrates, it also contracts and expands like the spring. So both ends move out, or move inwards, simultaneously.

When the horn vibrates, both ends of the horn move in opposite directions. There is, however, one point somewhere mid-length of the horn, that does not move at all, at any given time.

This is called the Nodal Point ; this point does not vibrate or move at all, and is therefore subject to the highest stress, as forces try to move it inwards or outwards.

Horn Gain

The horn is *mechanically* linked to the booster at its upper end, and *acoustically* to the part at its lower end.

The amplitude at the upper end of the horn is determined by the booster.

The amplitude at its lower end is determined by the horn profile i.e. the material mass on either side of its nodal point.

The ratio of output amplitude to input amplitude -- its amplitude amplification ability -- is termed the Gain of the horn.

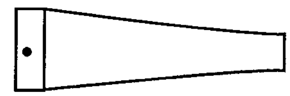
The booster is a horn of fixed gain -- boosters are designed to provide standard gain ratios, and colour coded. The commonly accepted colour codes are

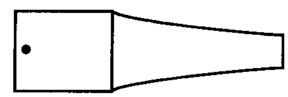
- **Blue** **1 : 0.6**
- **Green** **1 : 1.0**
- **Gold** **1 : 1.5**
- **Silver** **1 : 2.0**
- **Black** **1 : 2.5**

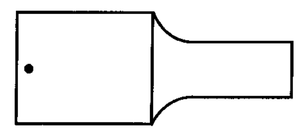
Horn Profiles

There are three standard horn profiles

- Exponential -- for low gain horns
- Catenoidal -- for medium gain horns
- Step -- for high gain horns


Exponential Horn


Catenoidnal Horn


Step Horn

Exponential & Catenoidal horns are sometimes tapped to accept replacable tips, specially for applications in Spot Welding and Staking.

Such horns are typically made in Titanium, and can accept Titanium tips only.

Although their initial costs are higher, they are cost effective because in the event of wear, only the tip needs to be replaced, at a fraction of the horn cost, instead of the entire horn.

Tips of varying sizes and contours can be also be used with a single tapped horn, thereby reducing inventory and investment levels.

Horn Materials

Because of the high stresses a horn is subjected to, it needs to be made of materials that have high strength and good acoustic properties (transmit sound energy efficiently).

Alloy Steel Horns are amongst the lowest strength horns. D2 Steel alloys are normally used (e.g. Bohler grades KNL 105 & 110).

Aluminium alloys are relatively stronger. Grades 2024, 6061 and 7075 are popularly used. T6 annealing is recommended.

Titanium alloy Horns are the strongest possible. Grades 6-4 and 7-4 are normally used for ultrasonic applications.

Unlike Steel & Aluminium alloys that are available in any conceivable profile and size, Titanium alloys are available in restricted sizes only, and therefore large Titanium horns are often not possible.

By virtue of its high strength and low cost, Aluminium is the most popular material used. It can be chrome/nickel plated, anodised or even carbide faced, if desired, to minimise wear when welding glass filled plastics.

Steel is used in low amplitude applications such as insertion, to minimise face wear due to metal to metal contact.

Titanium is used in high amplitude applications, where the horn is driven to its highest strength limits.

▯ ▯ Horn Sizes

In Ultrasonics, a small 20 KHz Circular Horn refers to a Horn of 10 mm diameter, an average horn is 50 - 100 mm dia, and a large horn would be 150 - 250 mm diameter.

Similarly, an average Rectangular Horn would be 100 mm length x 25 mm width, and a large one, 250 x 80 mm. The largest horn is 400 x 25 mm.

This shows the difficulties involved in welding large parts with 20 KHz horns -- one has to use multiple horns, held in a cluster, or resort to multiple strokes, to weld a largish part, say a 300 x 300 tray.

▯ ▯ Horn Frequency

The horn, as an acoustic tool, is length sensitive. Changing the length of a horn will change its natural resonant frequency.

A change in length of 1 mm could change the horn frequency between 10 - 400 Hz, depending on the horn profile.

During manufacture, a Horn is carefully tuned within a tight tolerance (usually 1%) of its nominal frequency.

So a 20,000 Hz horn would be tuned within a tolerance band of say, 19,850 Hz to 20,050 Hz.

The length of a tuned horn represents a half wavelength of the longitudinal sound wave, and this length is determined by the velocity of the sound wave through the specific material used for that particular horn.

$$\text{Wavelength } \lambda = \frac{\text{Velocity of sound in the medium}}{\text{Frequency}} = \frac{c}{f}$$

Typical values of Sound through horn materials and air :

Air	:	331 meters/sec
Aluminium Alloy	:	4960 meters/sec
Steel Alloy	:	5180 meters/sec
Titanium Alloy	:	5080 meters/sec

Regular horns are half wave-length long ; then there are full wave-length horns and composite horns that could go upto 1.1/2 wave-length .

The natural resonant frequency of the horn is affected even by the homogeneity of the horn material. Even the smallest variation in material homogeneity affects the tuned length of a horn.

It is a common experience when two horns are made from a single rod, on tuning it is found their tuned lengths can differ by 1 mm or even more.

Horns can, therefore, never be duplicated by reproducing them “in toto”, as is often attempted by lay users. Each and every horn needs to be tuned individually.

The material grade, its heat treatment, and even its source, plays a vital part in determining its natural resonant frequency, and therefore its final, tuned length.

Similarly, reconditioning a worn out horn is not simply a matter of surface grinding its face ; it needs to be retuned.

Damaged threading for the horn stud cannot also be simply enlarged -- this too will affect the horn frequency.

Horns can sometimes be retuned and reconditioned a few times ; at other times, this may not be possible even once. At all times, special skills and instrumentation are required for reconditioning horns.

When welding glass or other such abrasive filled materials, or in insertion applications where the horn contacts the metal insert, horn face wear is a serious problem.

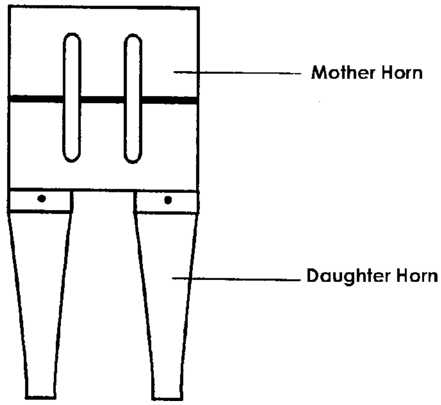
To limit horn wear and thereby increase horn life, Aluminium horns are nickel/chrome plated, anodised or carbide faced. Titanium horns too are carbide faced, whereas Steel horns are through hardened to Rockwell C 58 - 60.

These processes improve the wear resistance of the horns and thereby their working life.

Be aware that using a horn that has a frequency outside the permissible tolerance band, on a continuous basis, can and does cause failures in the electronic power supply, specially power transistor burnouts, which can be expensive.

▯ ▯ Composite Horns

Composite horns are horns coupled together to reach specific points inside a part, or to provide relief for large parts. Each horn is individually tuned, and one or more "daughters" is then coupled to a "mother" horn.

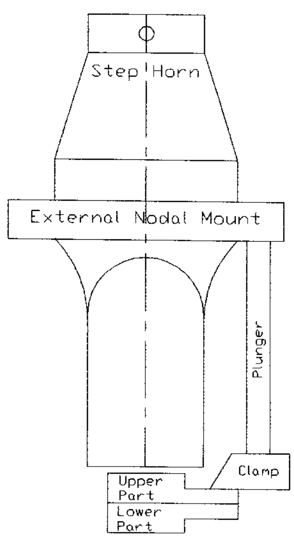


The mother horn is usually a large 200 mm square or round horn, and the daughters are typically 20 - 30 mm round or rectangular horns.

The total length of a composite horn is a 2 or 3 multiple of the *half wavelength*.

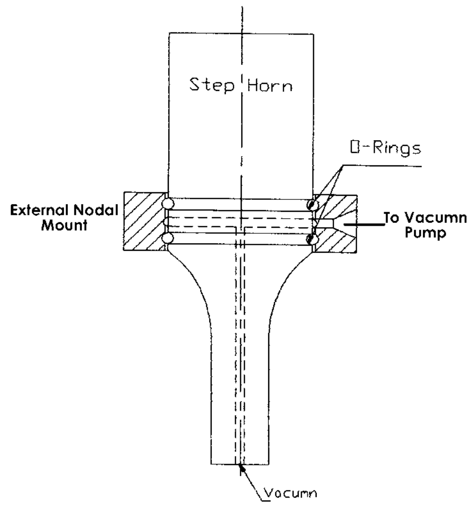
▯ ▯ Nodally Mounted Horns

Some applications call for a spring loaded part to be held down during the welding process. Hold down springs or clamps can be mounted at the horn node, since the horn does not vibrate at this point.



Nodal Horn

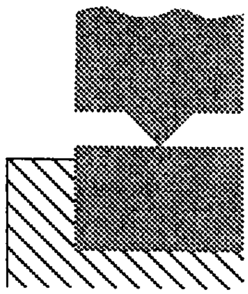
A vacumn attachment to hold tiny parts for welding or insertion of e.g. eyeglass hinges, can similarly be mounted nodally and connected to a vacumn pump to provide nominal suction pressure.



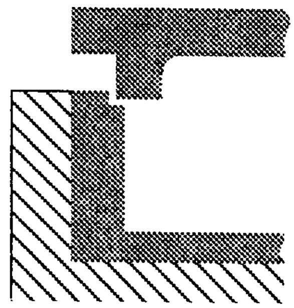
Vacumn Horn

Fixtures

The primary purpose of a Fixture is to hold the part rigidly during welding, and provide support around the weld area.



Support Under Base



Side Wall Support

Fixtures are generally two types

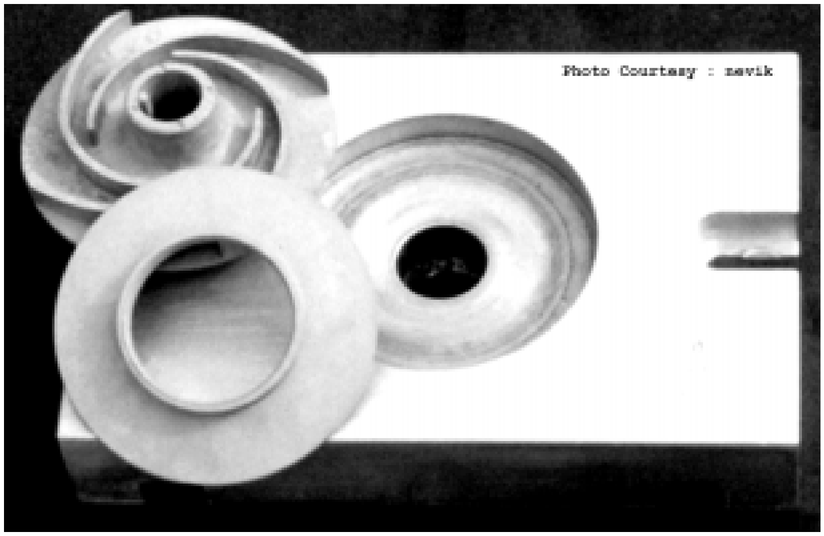
- **Resilient**
- **Rigid**

Resilient fixtures are typically epoxy based, and used for rigid amorphous plastics that incorporate energy directors. They are also popular when contoured parts are to be held.

A Common epoxy used for Resilient fixtures is polyurethane based epoxy like Ciba's Ureol poxy 6414A with Hardener 5117B.

For rigid fixtues, the epoxy recommended by Ciba is Cy 212 with Filler DT 078 and Hardener HY 951.

Rigid fixtures are used to weld flexible materials that use either energy director or shear joints, and all semi-crystalline materials.



Rigid fixtures are also used for all insertion, staking, swaging and spot welding applications.

Rigid fixtures are normally made in commercial grade Aluminium, and anodised or plated to prevent marking, or in Stainless Steel. Contoured parts often use a rigid epoxy fixture.

Unlike acoustic Horns that need special care and instrumentation to manufacture, Fixtures can often be made by users themselves, using basic guidelines.

The role of the fixture however, cannot be underestimated in the success or failure of the ultrasonic application, and it is often best to stick to single point responsibility for design and supply of a horn and fixture when introducing a new application.

Chapter 8 - Troubleshooting Applications

When it works, Ultrasonics works like a dream.

When problems arise, these could be due to equipment malfunction, or variations in the parts.

Ultrasonic equipment is generally very rugged - any equipment designed to work at cycle times of a few seconds must have this feature inherent in its design.

General experience indicates it is more often the part, rather than the equipment, that contributes to unsatisfactory results.

Trouble shooting is simple once you understand the influence of each parameter ; thereafter, trials on the welder can help you localise the problems, and take corrective actions.

Remember, in Ultrasonic Processing, there are just three variables to manipulate

- **Time**
- **Pressure**
- **Amplitude**

Ultrasonics generates frictional heat through mechanical vibrations - the same as you can do by rubbing your hands together.

When you rub your hands together, you rub them back and forth for a certain time, you apply pressure between the two hands, and you traverse a certain distance in each back and forth movement.

By ***rubbing*** your hands together ***longer***, you generate **more heat**.

By ***pressing*** your hands together ***harder,*** you generate **more heat**.

And by stretching your hands a ***greater*** back and forth ***distance***, you generate **more heat**.

So **increased time, pressure and amplitude** - all contribute to **greater heat** generation.

This is the only thing to remember when trouble-shooting an application (or during set-up).

You could have a weak, underweld (or non-uniform) situation, or a overweld, excess flash situation.

In the former case you need to increase the weld energy to improve the weld quality, and in the latter case you need to back off and reduce the weld energy.

"Time" is the most sensitive parameter than affects weld quality.

By changing the ultrasonic Time in small steps, you will see quick changes in the weld quality.

Next is **"Pressure"**.

When the pneumatic pressure in the cylinder is adjusted gradually, the results are soon visible.

It is also possible to adjust **"Trigger Pressure"** - in fact, this is often more sensitive than changes in the cylinder pressure.

The Trigger Pressure is the pressure at which ultrasonics is triggered after the horn makes contact with the part, This is controlled either by a timer (to allow the pressure to build up with time) or by an (adjustable) spring loaded micro-switch.

Increasing the trigger pressure means welding under higher average pressures, and therefore putting in more energy into the part, within the same time frame.

The **"Amplitude"** of vibration is fixed by the selection of the Booster and the horn design ; Boosters come in standard Gains of 0.5, 1.0, 1.5, 2.0 and 2.5 .

If adjusting Time and Pressure parameters does not help in resolving the problem, changing the booster should help as it makes a quantum difference in weld energy delivered to the part.

Care must be exercised in using boosters upto permitted Gain with each horn. If not, you will invariably drive a horn beyond its stress limit, and fracture it.

So here are some tips for trouble shooting applications

WELDING

Common faults experienced during Ultrasonic Welding are

- **Diaphragmming**
- **Flash (or non-uniform welding)**
- **Inconsistent weld**
- **Internal components welding / damaging**
- **Non-uniform weld around the joint**
- **Marking**
- **Melting/Fracture of part sections outside of joint**
- **Misalignment of welded assembly**
- **Overweld**
- **Underweld**

The reasons for these faults, and suggested responses, are discussed in the following pages.

Fault 1 : **Diaphragmming**

Reasons :
A. Too much energy into the part
B. Gate location
C. Horn type/positioning

Responses :
A1. Reduce Energy by reducing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

B1. Review gate placement (Change shape ?)
B2. Review plastics processing conditions
B3. Add stiffening ribs
B4. Increase material thickness behind the gate

C1. Check for Horn / Part contour fit
C2. Use Horn with nodal plunger to dampen energy

Fault 2 : **Flash (or non-uniform welding)**

Reasons :
A. Too much energy into the part
B. Oversized Energy Director / Shear Interference
C. Non uniform joint dimensions
D. Improper part fit / tolerances

Responses :
A1. Reduce Energy by reducing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

B1. Reduce dimensions of energy director
B2. Reduce Shear interference

C1. Ensure joint is uniform all around
C2. Review plastics processing conditions

D1. Loosen part fit
D2. Loosen part tolerances

Fault 3 : **Inconsistent weld results**

Reasons :
A. Cavity to cavity variations
B. Fillers - Non uniform or excessive
C. Incompatible materials
D. Incorrect Joint Design
E. Poor part fit / tolerances
F. Moisture in resins
G. Mould Release on weld area
H. Regrind / Degraded Material
I. Line Voltage fluctuations
J. Line Pressure fluctuations

Responses :
A1. Check for patterns to verify and correct
A2. Check for cavity wear
A3. Review plastics processing conditions
A4. Check dimensions and tolerances

B1. Review mould design
B2. Reduce filler content
B3. Change filler type e.g. long fibres to short

C1. Review Compatibility Charts
C2. Review Physical Properties Data

D1. Modify the interface joint design

E1. Check part dimensions
E2. Check part tolerances
E3. Review plastics processing conditions
E4. Tighten part tolerances

F1. Weld parts immediately after moulding
F2. Store parts in polybags for later welding
F3. Dry parts prior to welding

G1. If indispensable, use printable grade release
G2. Clean weld area prior to welding

H1. Check percentage regrind added ; reduce if high
H2. Review plastics processing conditions if parts degraded

I1. Use a Good Voltage Stabiliser in Line

J1. Add a buffer vessel near the welder
J2. Verify Compressor capacity to service all connections

Fault 4 : Internal components damaging / welding

Reasons :
A. Too much energy into the part
B. Internal components too close to the weld area.
C. Internal parts same material as housing

Responses :
A1. Reduce Energy by reducing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

B1. Mount internal components firmly
B2. Use nodally mounted device to dampen energy in their vicinity
B3. Consider, if possible,
a) Isolating these components from the housing
b) Moving them away from high energy areas

C1. Lubricate internal parts to inhibit welding
C2. Change material of internal parts, if feasible

Fault 5 : **Non uniform weld around the joint**

Reasons :

A. Energy director height fluctuates
B. Fillers non-uniform or excessive
C. Flexing of walls
D. Horn, part and fixture are not parallel
E. Inadequate support in fixture
F. Incorrect part alignment
G. Joint design interrupted by knock out pin marks
H. Mould release agent on interface
I. Parts are warped
J. Poor contact at interface
K. Poor horn / part contact

Response :

A1. Ensure uniform energy director height

B1. Review mould design
B2. Reduce filler content
B3. Change filler type e.g. long fibres to short

C1. Add ribs to enhance rigidity
C2. Modify fixture to prevent flexure

D1. Check part dimensions / tolerances
D2. Level fixture by shimming
D3. Verify actuator parallelism by placing reverse carbon between horn & part in fixture

E3. Add rigid support
E2. Redesign fixture to improve support
E3. Change from resilient to rigid fixture

F1. Add self alignment means in parts
F2. Check if parts move during welding ; prevent
F3. Check horn / part / fixture parallelism

G1. Ensure knock out pins do not leave indentations
G2. Relocate knock out pins

H1. If indispensable, use printable grade only
H2. Clean parts before welding

I1. Use high trigger settings
I2. Review plastics processing conditions

J1. Check part dimensions and tolerances
J2. Check for misalignment of parts
J3. Check for sinks
J4. Check for damage by knock out pins

K1. Check horn / part fit
K2. Check for complete support in fixture

Fault 6 : Marking

Reasons :

A. Aluminium Oxide from Horn
B. High Spots in Part
C. Horn heating up
D. Incorrect Horn Contour
E. Incorrect fit of part in fixture
F. Poor Parallelism
G. Raised lettering
H. Weld energy too high

Responses :

A1. Use Nickel or Chrome Plated Horn & Fixture
A2. Use thin plastic film (PE)

B1. Check part fit
B2. Check part tolerances

C1. Check for loose stack
C2. Check for loose horn stud
C3. Check & clean horn/booster interface
C4. Check horn for cracks
C5. Reduce weld energy, specially weld time
C6. Reduce duty cycle (weld less parts per min)

D1. Verify cavity to cavity variations
D2. Check part dimensions and warpage/distortions

E1. Inadequate support in fixture
E2. Redesign Fixture
E3. Check for cavity to cavity variations.

F1. Check parallelism between horn, part & fixture
F2. Check horn / part fit
F3. Check part / fixture fit
F4. Shim fixture to make part / horn parallel

G1. Recess lettering
G2. Provide relief in horn (risky !)

H1. Reduce energy by reducing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

Fault 7 : Melting/Fracture of part sections outside of joint

Reasons :
A. High Amplitude
B. Internal Stress
C. Improper processing
D. Sharp internal corners
E. Too much weld energy

Response :
A1. Change to lower booster

B1. Review moulding conditions (Cold joint ?)
B2. Review part design

C1. Review plastics processing conditions

D1. Radius all corners.

E1. Reduce energy by reducing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

Fault 8 : Misalignment of welded assembly

Reasons :
A. Inadequate support in fixture
B. Incorrect joint design dimensions
C. Poor part tolerance
D. Self alignment not incorporated in design
E. Walls not stiff

Responses :
A1. Shim fixture
A2. Add rigid backup in fixture
A3. Redesign fixture

B1. Redimension according to guidelines

C1. Tighten part tolerances
C2.Review plastics processing conditions

D1. Add self alignment in design
D2. Add alignment means in fixture

E1. Add ribs to stiffen walls
E2. Add rigid backup in fixture

Fault 9 : **Overweld**

Reasons : A. Too much energy into the part

Responses : A1. Reduce Energy by reducing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

Fault 10 : **Underweld**

Reasons : A. Too little energy

Responses : A1. Add Energy by increasing one or more of the following parameters
a) Weld Time
b) Pressure (also trigger pressure setting)
c) Amplitude (Use lower gain Booster or Horn)
d) Use Power Control, if available

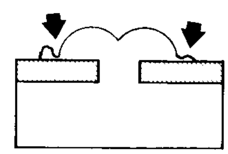
STAKING

Common faults experienced during Ultrasonic Staking are

- **Excessive flash around staked head perimeter**
- **Parts are loose after Staking**
- **Plastic flows between parts during Staking**
- **Ragged, non-uniform staked head**
- **Severe marking and distortion under staked head**
- **Stud base shows signs of melting and collapsing, just as the staked head begins to form**
- **Studs break off at the base during staking**
- **Stud not completely staked at end of cycle**

The reasons for these faults, and suggested responses, are discussed in the following pages.

Fault 1 : **Excessive flash around staked head perimeter**



Reasons :
A. Horn cavity is too small
B. Stud is too large
C. The stud and horn are not aligned

Responses :
A1. Increase horn cavity volume

B1. Reduce stud height / diameter

C1. Realign stud and horn

Fault 2 : **Parts are loose after Staking**

Reasons :
A. Horn travel is too short
B. Pressure released before stud resolidifies fully

Responses :
A1. Increase horn stroke length.

B1. Increase Hold Time
B2. Use nodal mounted device or external clamps

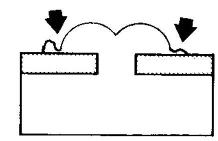
Fault 3 : **Plastic flows between parts during Staking**

Reasons : A. Improper seating of dissimilar part in plastic

Responses : A1. Use nodal devise or external clamp to seat parts

Fault 4 : **Ragged, non-uniform staked head**

Reasons : A. Horn cavity is too large
B. Stud is too small

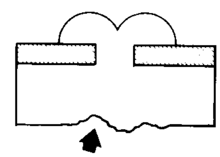


Responses : A1. Decrease horn cavity volume

B1. Increase stud height / diameter

Fault 5 : **Severe marking and distortion under staked head**

Reasons : A. Incorrect fixturing
B. Pressure too high

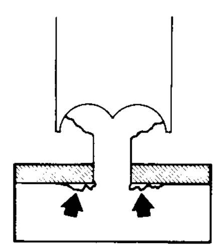


Responses : A1. Provide metal support under staking area

B1. Decrease pressure
B2. Improve heat dissipation under staked area (provide plated metal support under staking area)

Fault 6 : **Stud base shows signs of melting and collapsing, just as the staked head begins to form**

Reasons : A. Amplitude too low
B. Horn downspeed too high
C. Pressure too high

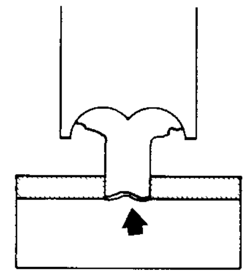


Responses : A1. Increase amplitude
— use higher gain booster

B1. Use slower downspeed

C1. Decrease pressure

Fault 7 : Studs break off at the base during staking

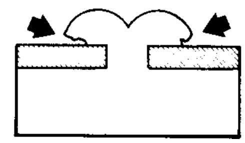


Reasons : A. Stress at root of stud
B. Stud and Horn are misaligned

Responses : A1. Radius stud roots

B1. Realign stud and horn so contact is at centre

Fault 8 : Stud not completely staked at end of cycle



Reasons : A. Inadequate weld time

Responses : A1. Increase weld time.

INSERTION

Common faults experienced during Ultrasonic Insertion are

- **Cracked or Stressed plastic parts**
- **Cycle time to drive insert too long**
- **Horn heating up**
- **Insert backs out of part after insertion**
- **Insert not seated to desired depth**
- **Plastic fills up the threaded bore insert**
- **Plastic flows over the top of the insert**
- **Poor Pull-Out strength of insert**
- **Noise level high**
- **Severe Wear on Horn face in short time**

The reasons for these faults, and suggested responses, are discussed in the following pages

Fault 1 : **Cracked or Stressed plastic parts**

Reasons :
A. Boss too delicate
B. Interference too high
C. Pressure too high
D. No Ultrasonics
E. Ultrasonics starts too late

Responses :
A1. Increase boss thickness / add ribs

B1. Decrease interference - increase hole diameteror decrease insert diameter

C1. Decrease pressure

D1. Use Pre-trigger to avoid cold pressing insert

E1. Decrease trigger setting
E2. Decrease horn downspeed

Fault 2 : Cycle time to drive insert too long

Reasons :
A. Horn downspeed too low
B. Inadequate ultrasonic power
C. Interference too high

Responses :
A1. Increase horn downspeed

B1. Use higher capacity equipment

C1. Decrease interference - increase hole diameter or decrease insert dia

Fault 3 : **Horn heating up**

Reasons :
A. Amplitude too high
B. Metal to metal contact

Responses :
A1. Decrease amplitude - use lower gain booster/horn

B1. Contact plastic, if feasible
B2. Add external horn cooling

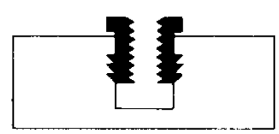
Fault 4 : **Insert backs out of part after insertion**

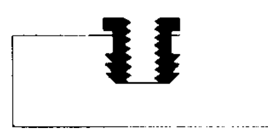
Reasons : A. Amorphous resins need longer time to resolidify

Responses : A1. Increase hold time

Fault 5 : **Insert not seated to desired depth**

Reasons :
A. Horn downspeed too high
B. Horn stroke length short
C. Insert longer than hole depth
D. Pressure / Power too low
E. ltrasonic time low





Responses :
A1. Increase horn downspeed

B1. Increase horn stroke length by
a) resetting limit switches
b) lowering actuator head

C1. Decrease insert length / increase hole depth

D1. Increase pressure / power

E1. Increase ultrasonic time

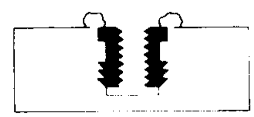
Fault 6 : Plastic fills up the threaded bore insert

Reasons : A. Insert hits hole bottom
B. Interference too high

Responses : A1. Increase hole depth / decrease insert length

B1. Decrease interference

Fault 7 : Plastic flows over the top of the insert



Reasons : A. Horn stroke too long
B. Interference too high
C. Ultrasonic time too high

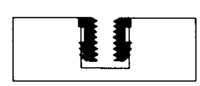
Responses : A1. Decrease horn stroke length by
a) resetting limit switches
b) raising actuator head

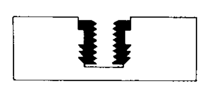
B1. Decrease interference

C1. Decrease ultrasonic time

Fault 8 : Poor Pull-Out strength of insert

Reasons : A. Horn stroke too long
B. Insert driven to below plastic surface
C. Interference too low
D. Retainer screw too long - hits hole bottom
E. Retainer washer rests only on plastic

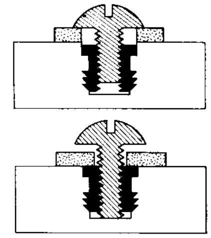




Responses : A1. Decrease horn stroke length by
a) resetting limit switches
b) raising actuator head

B1. Decrease horn stroke length by

a) resetting limit switches
b) raising actuator head



C1. Increase interference

D1. Use shorter screw

E1. Retainer washer should rest
on insert & plastic

Fault 9 : **Noise level high**

Reasons :
A. Amplitude too high
B. Horn downspeed too slow
C. Metal to metal contact
D. Pressure too low

Responses :
A1. Decrease amplitude - use lower gain booster/horn

B1. Increase horn downspeed

C1. Contact plastic not metal, if feasible
C2. Provide Sound insulated box
C3. Provide ear plugs to operator
C4. Use ultrasonic pretrigger

D1. Increase pressure

Fault 10 : **Severe Wear on Horn face in short time**

Reasons :
A. Amplitude too high
B. Abrasive filler in plastic
C. Interference too high
D. Metal to metal contact

Responses :
A1. Decrease amplitude - use lower gain booster/horn

B1. Use Nickel plated/anodised/carbide faced horn.
B2. Use Titanium horn with replacable tip

C1. Decrease interference

D1. Contact plastic, if feasible

Chapter 9 - Safety in Ultrasonics

Ultrasonics is like fire - a good friend but a nasty enemy !

Safety of personnel is a primary concern, and care needs to be exercised when using Ultrasonics - an accident can lead to first degree burns, and even loss of limbs such as fingers and hands.

Safety starts with the operator, who should be trained and well informed in safety measures.

The operator should observe and monitor safety measures, and be able to recognise the first symptoms of equipment malfunctioning, so as to initiate corrective actions early.

High Voltage

High voltage is generated in the power supply and fed into the converter.

The equipment should therefore be well grounded, and checked periodically.

At the first instance of an electrical shock being felt, howsoever mild, the equipment earthing should be checked and verified with an Insulation Tester if necessary.

A rubber mat under the operators feet is a good safety precaution.

If the equipment is malfunctioning, trouble shooting should be done by trained personnel only, who understand which components inside the power supply are safe to access or touch.

The power supply should *never* be switched on without the ultrasonic stack being connected.

Absence of the ultrasonic stack can cause a spark-over from the HT contact feeding the converter, to ground, and damage other components in the circuit.

Pressure / Force

The actuator uses a pneumatic cylinder, generally of diameter 50 to 75 mm to move the horn up and down.

Assuming an average cylinder diameter of 65 mm, and cylinder pressure of 30 psi, the horn, on contact with the part, builds up a total force of 67 Kg ; at 50 psi cylinder pressure, the total force on the part is 112 Kg !

If an operator's fingers should get caught between the horn and the part, the mechanical force itself would simply crush the fingers.

Every Ultrasonic welder is equipped with two palm buttons which have to be pressed simultaneously (within 0.1 secs) to initiate a cycle start. The start circuit is designed to force the operator to use both his hands to initiate the weld cycle, and thereby keep them away from the part and the horn.

These palm buttons switches should never be tampered with. If defective, they should both be replaced. NEVER short these, or use an external switch.

If a foot switch is being used instead of the dual palm buttons, proper guards should be added to protect the operators hands.

The operator should NEVER physically have to hold the parts in position before initiating the welding cycle.

Visitors / co-workers should similarly be discouraged from holding / aligning the parts to help the operator initiate the weld cycle by using both his hands.

In automated systems, safeguards also need to be built in to prevent horn to fixture contact, in the event of a missing part.

▯ ▯ Ultrasonics

A vibrating horn is as dangerous as an open flame - any contact with it generates tremendous localised heat, and burns human tissue almost instantly.

NEVER touch a vibrating horn.

If it is necessary to touch it, do it as you would to check if your electric kettle/iron is hot - just a quick, gentle, tiny touch. Never apply pressure to your touch.

Applying pressure while touching the horn will create instant heat, and cause burns and blisters.

Even if the operator is holding the part at a safe distance from the weld area in a largish part, this heat is instantly transmitted to the holding fingers, causing burns and blisters.

And if an operator's fingers should get caught between a part and a vibrating horn, chances are the fingers will be lost forever.
There are recorded cases of fingers having been amputated after such

accidents.

If the horn is being pre-triggered, as required in some applications, the operator must be aware of the danger of touching it, before or after it contacts the part.

So keep away from vibrating horns - the damage is instantaneous, and severe.

▯ ▯ Environment

Although ultrasonic frequencies are beyond the range of human hearing, some operators (specially young girls) are sensitive to the high-end frequencies and complain of headaches on continuous exposure. Due consideration should be given to such complaints, if received.

Sometimes the parts being welded vibrate at lower frequencies, (harmonics of the equipment's nominal frequency) and generate considerable audible noise.

At other times, applications like insertion involve metal to metal contact, and this generates frequencies within the audible range.

In such cases, the operator (and others working nearby) either need to be provided ear muffs, or the welder needs to be enclosed in a sound proof housing. Both are good, practical solutions.

Some plastics also emit gases during the welding process. Suction fans may be provided to vent the fumes away from the operator and co-workers.

▯ ▯ Equipment Safety

Safety of personnel is paramount, but safety of equipment is also important.

To keep your equipment in good working condition, meticulously follow the routine maintenance activities recommended by the manufacturer.

These are simple tasks, and will take less than 1 hour per week, but will extend the life of your equipment by several years.

Essentially these tasks relate to ensuring stable main supply and keeping the equipment dust free and heat protected.

Fretting at the converter stack interface is a major concern and impacts equipment performance directly. Keep the interfaces clean, use well tuned horns and you will have minimal equipment problems.

It is simple and easy to take all safety measures — do not be lax in this respect.

Chapter 10 - Sources of Supply

Here is a Listing of reputed companies active in Ultrasonic Plastic Assembly, in India, Far East, Europe & USA.

INDIA

1. **Nevik Ultrasonics, Nashik 422 007** www.nevik.in	**Specialist in Design & Manufacturer Horns & Fixtures**
2. **Branson Ultrasonics, Mumbai 400 059** www.bransonultrasonics.com	**Equipment Manufacturer**
3. **D Sonics Toolings Pvt Ltd** bhupesh@d-sonics.com	**Equipment Manufacturer** Associate of Sonics & Materials USA
4. **Imeco, Pune 411 011** www.imecoultrasonics.com	**Equipment Manufacturer**
5. **RINCO Ultrasonics India, Chennai 600 044** www,rincoindia.com	**Equipment Supplier**
6. **Roop Telsonics, Gandhinagar 382 044.** www.rooptelsonic.com	**Equipment Manufacturer** Associate of Telsonics Switzerland
7. **S K Overseas, Mumbai 400 002** www.skgroup.com	**Representatives** for King Ultrasonics, Taiwan
8. **Unimark, Mumbai 400 088** www.unimark.in	**Representatives** for Hermann Ultrasonics, Germany

Far East Countries

1. **Bensonic** — **Equipment Manufacturer**
   Taiwan
   www.bensonic.com.tw

2. **Evergreen Ultrasonic Co. Ltd.** — **Equipment Manufacturer**
   Taiwan
   www.evergreen-taiwan.com

3. **King Ultrasonic Co. Ltd.** — **Equipment Manufacturer**
   Taiwan
   www.ksonic.com.tw

4. **Seidensha Electronics Co. Ltd.** — **Equipment Manufacturer**
   Japan
   www.sedeco.co.jp

5. **Strong Ultrasonic Machinery Co.** — **Equipment Manufacturer**
   Taiwan
   www.st-rong.com

Europe

1. **Calemard** — **Equipment Manufacturer**
   France
   www.calemard.com
   Primarily for Cut & Seal on Films/Fabrics/Textiles

2. **Forward Technologies** — **Equipment Manufacturer**
   UK
   www.forwardtech.com

3. **Herrmann Ultraschall** — **Equipment Manufacturer**
   Germany
   www.herrmannultraschall.com

4. **Maschinenfabrik Spaichingen** — **Equipment Manufacturer**
   Germany
   www.ms-spaichingen.de

5. **Mecasonics KLN** — **Equipment Manufacturer**
   France
   www.mecasonic.com

6. **Rinco Ultrasonics AG** — **Equipment Manufacturer**
   Industriestr
   Switzreland
   www.rincoultrasonics.com

7. **S M Engineering AG** — **Equipment Manufacturer**
   Switzreland
   www.sm-engineering.com

8. **Telsonic A G** — **Equipment Manufacturer**
   Industriestrasse
   Switzreland
   www.telsonic.com

9. **Ultrasonics Steckmann GmbH** — **Equipment Manufacturer**
   Germany
   www.ultrasonics.de

U S A

1. **Branson Ultrasonic Corporation** — **Equipment Manufacturer**
   CT 06813-1961
   www.bransonultrasonics.com

2. **Dukane Ultrasonics** — **Equipment Manufacturer**
   IL 60174
   www.dukane.com

3. **Sonics & Materials Inc.** — **Equipment Manufacturer**
   CT 06810
   www.sonics.biz

4. **Sonobond Ultrasonics** — **Equipment Manufacturer**
   PA 19382
   www.sonobondultrasonic.com

5. **Ultra Sonic Seal** — **Equipment Manufacturer**
   PA 19014
   www.ultrasonicseal.com

Chapter 11 - Glossary

TECHNICAL TERM	MEANING
Acoustical Property	Sound energy transmitting property of a material.
Actuator / Thruster	A strong inflexible frame which essentially clamps the ultrasonic stack assembly (the converter, booster and horn) and the device that moves this stack to contact the parts and apply a pre-determined force on them.
Amorphous Plastic	Nomenclature of a plastic that has a random molecular structure.
Amplitude	The peak-to-peak distance moved by the horn/booster face when it vibrates.
Antinode	Any point on a vibrating horn where the amplitude is the maximum. Such points are usually on the longitudinal axis of the horn.
Assembly Stand	A strong inflexible frame that houses and holds the components of an integrated ultrasonic welder, such as the power supply, machine base and air cylinder.
Booster	An element placed between the Converter and Horn to change Horn amplitude in pre-determined jumps. Actually another horn, that functions as a mechanical transformer.
Boss	A projection with a hollow space in which an insert can be located.
Butt Joint	Two flat contacting surfaces.
Colourants	Colouring agents added to resins to obtain desired colours. Used in liquid or powder form.
Catenoidal Horn	A conical shaped horn, having its two outer ends cylinderical shaped, and its inner 1/3rd portion exponential curve shape. It provides medium amplitude and stress, and is often tapped on its front face to accept threaded, replacable tips.

Clamping Force	The force on the part, exerted by the horn, during welding.
Compatibility	Possibility of plastics to weld to each other.
Composite Horn	A combination of several horns, mechanically attached to each other. Usually a large circular or rectangular “mother horn” to which is attached one or more (even as many as 12) smaller horns to weld a large complex part.
Contoured Horn	A horn whose front face is not flat, but is shaped to fit the geometry of the part.
Converter	A device that converts electrical energy to mechanical energy using Piezo-electric ceramic elements.
Coupler	A booster which does not change the amplitude, but acts merely as a coupler.
Dampen	To smother vibrations by mechanical means.
Degating	Separation of injection moulded plastic parts from their runners at the gate.
Diaphragmming	High amplitude of vibration at the centre of a part, in comparison to that at its rim. Leads to high stress and failure of thin parts.
Digital Timer	A timing device, based on digital circuits, that can accurately control time (typically upto 0.005 secs) in a programmed circuit.
Dual Pressure	Two differing pressure values during weld and hold sequences of ultrasonic plastic assembly.
Dwell Time	See Hold Time.
Electro-strictive	See Piezoelectric Principle.
Energy Director	A small triangular-shaped bead of plastic, moulded around its weld perimeter. It focuses ultrasonic energy at its apex, leading to rapid heating and melting.
Exponential Horn	A horn having an exponential curve along its entire longitudinal axis.

Far Field Welding	When the distance between the Horn contact point and the joint interface is more than 6 mm, it is called Far Field Welding.
Filler	Inert materials such as glass, talc, asbestos added to resins to make them more rigid.
Fixture	A device that holds a weld component very rigidly during ultrasonic welding. Also called a nest or jig.
Flame Retardant	A substance added to a resin to change its combustible property.
Flash	The excess molten plastic from a welded joint.
Flash Trap	In-built provision in a joint design to capture and retain flash.
Forming	Changing the shape of a plastic part to a new profile.
Frequency	Number of alternating cycles per second measured in Hertz (Hz).
Friction Welding	Joining parts by rubbing one part relative to another rigidly held part, under pressure, to create heat and melt through surface friction.
Full-Wavelength Horn	A metal section, one wave-length long, that has a specific natural resonant frequency, and transfers sound energy (or mechanical vibrations) at the same frequency to the part, with minimum losses.
Gain	Ratio of output amplitude to input amplitude of a Booster or Horn.
Gate	The point through which molten plastic enters the mould cavity.
Generator	An electronic circuit that takes in mains voltage at 220 V, 50 Hz and converts it to high frequency electrical energy.
Half-Wavelength Horn	A metal bar, having good Acoustical properties, machined to a specific profile, and length, tuned to have a specific natural resonant frequency.
Hand Gun	A portable hand held ultrasonic stack, using a trigger to

	initiate ultrasonics.
Heading	Same as Staking.
Hermetic Seal	A leak tight seal that can withstand pressure.
Hold Time	The time allocated for melted plastic in the weld area to resolidify.
Horn	An Acoustic tool, designed to have a specific longitudinal natural resonant frequency, that enables it transfer sound energy (mechanical vibrations) at that frequency, to the plastic part.
Horn Abrasion	Wear on the horn face.
Horn Amplitude	The total peak-to-peak travel of the horn face, when it is vibrated.
Horn Analyzer	An instrument used to measure and analyse Horn Frequency.
Hygroscopicity	Moisture absorption characteristic of a material.
Insert	A metal bush, usually threaded, designed to be embedded in a plastic part, to accept screws.
Insertion	Firmly embedding a metal insert into a plastic part.
Integrated Welder	A stand-alone one piece welder that houses all components of an ultrasonic welder, such as the power supply, controls, protection circuits, the stand, the actuator base etc.
Interface	The two faces of mating parts to be joined.
Interference Joint	Same as Shear Joint.
Joint Design	The optimum interface design that ensures good welding results. Three basic requirements of good joint design are small initial contact, uniform contact area, and a means of self alignment of the two halves to be welded.
Loading Meter	A meter that indicates the power supply loading during a welding cycle.

Lubricant	An additive to improve the flow characteristics of resins and ease processing. Wax and stearic acid are typical lubricants.
Magnetostrictive Effect	Dimensional change in materials on being magnetised. This effect is used to convert electrical energy into mechanical vibrations.
Marking	Scratches or scruffing on plastic parts caused by the horn or fixture during welding.
Mould Release Agent	A spray that facilitates removal of injection moulded parts from their moulds.
Multiplexer	An electronic device that receives data from several sources and transmits it over a common channel.
Near Field	When the point of horn contact on the part is less than 6 mm away from the weld interface, it is refered to as Near Field welding.
Nodally Mounted Device	A device attached to the horn at its nodal point so it does not vibrate. It could be used to add pressure at selected points to hold an assembly tightly during welding, to dampen undesirable vibrations, over-come part warpage or provide alignment.
Nodal Point	The points in an ultrasonically vibrating body, such as horn or booster, where no movement occurs due to ultrasonic vibration.
Parent Strength	Tensile strength of the parent unwelded material.
Peak-to-Peak Displacement	Total distance — up and down — travelled by a vibrating face.
Piezoelectric Material	A ceramic material that changes dimensions when electric potential is applied across it.
Piezoelectric Principle	Dimensional change in materials when polarized or electrically excited. This is used to convert electrical energy into mechanical energy.
Power Control	An electrical device that controls the output from the power supply and converter. It is used to control horn amplitude.

Power Supply	An electronic device, used in an ultrasonic welder, that accepts conventional 220V, 50Hz mains supply and converts it into high voltage, high frequency electrical output.
Pre-Loading	A predetermined force applied on a part before triggering ultrasonics.
Pre-triggering	Triggerring ultrasonics before the Horn contacts the part.
Plasticizer	An additive to increase the flexibility of resins.
Pneumatic	Operated or controlled by air.
Polymer	A chemical compound of Carbon and one or more of 5 common elements, Hydrogen, Oxygen Nitrogen, Chlorine or Sulphur, in a 1 to 4 ratio. Polymers are also called resins.
Press / Thruster	A pneumatic device to enable linear movement of the ultrasonic stack in a consistent manner.
Programmer	An electronic circuit that controls the sequence of all operations.
Regrind	Plastic material that is recycled and added to the virgin resin.
Replaceable Tip	A threaded, machined tip attached to a tapped horn. Replacable Tips are commonly used in ultrasonic staking, spot welding and insertion applications.
Resin	See Polymer.
Resin Grade	Physical and Chemical properties of a resin.
Resonance	Maximum vibratory motion in response to the applied excitation. Ultrasonic converters, boosters and horns have maximum efficiency when used at their resonance frequencies.
Scan Welding	Continous application of ultrasonics to a flat part travelling under a vibrating horn to progressively weld a large area.
Semi-crystalline Plastic	A plastic that has an orderly molecular structure.
Shear Joint	A design that provides a positive interference in the

	assembly of two parts. The scrubbing action of ultrasonics melts this interference and creates a strong, leak tight weld.
Slotted Horn	A horn that has longitudinal slots cut into it to break up transverse and diagonal vibrations.
Sound	Mechanical vibrations that travel as longitudinal waves in any material medium such as air, water, or metal.
Spot Welding	Welding thin plastic sections or sheets at pots, or localised points, using ultrasonic energy.
Staking	The creation of a locking head by reforming a plastic stud, to assemble plastic to similar or dissimilar plastics, using ultrasonic energy.
Step Horn	A horn having two distinct diameters about its midpoint.
Stud	A cylindrical plastic projection that is eventually reformed into a locking head.
Stud Welding	Welding one or more plastic studs to a plastic part designed to receive such studs.
Swaging	Reforming a ridge of plastic to capture another part.
Thermoplastic	A polymer or resin that can be repeatedly heated, melted and reformed, like ice. Suitable for Ultrasonic Processing.
Thermoset	A plastic or resin that undergoes an irreversible change on heating, like a boiled egg. Unsuitable for Ultrasonic Processing.
Tool	See Horn and Fixture.
Transducer	A device using piezoelectric elements to convert high frequency electrical energy into high frequency mechanical vibration.
Traverse Welding	Scan welding, but the horn and anvil move across a large part, instead of the part moving under the horn.
Tuning the System	Matching the frequency of a power supply output to the

	exact resonant frequency of the ultrasonic stack (converter-booster-horn) it is driving.
Ultrasound or Ultrasonic Sound	Mechanical vibrations having frequencies above the range of human hearing, having the same physical nature as sound.
Ultrasonic Welding	Use of frictional heat created by high frequency vibrations to soften, melt and weld thermoplastic parts.
Vacuum Horn	Creation of low pressure inside a horn by connecting it to a vacumn pump, to enable it hold small light parts during ultrasonic assembly.
Velocity (Horn)	The rate of movement of the horn face.
Weld Time	Time interval the parts to be welded are exposed to ultrasonic energy.

Ultrasonic Plastic Assembly

nevik ultrasonics
101-102, Eshan Plaza, Pipeline Road, Satpur, Nashik - 422 007.
Phone : (0253) 235 1935,
E-mail : nevik.ultrasonics@gmail.com
www.nevik.in

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