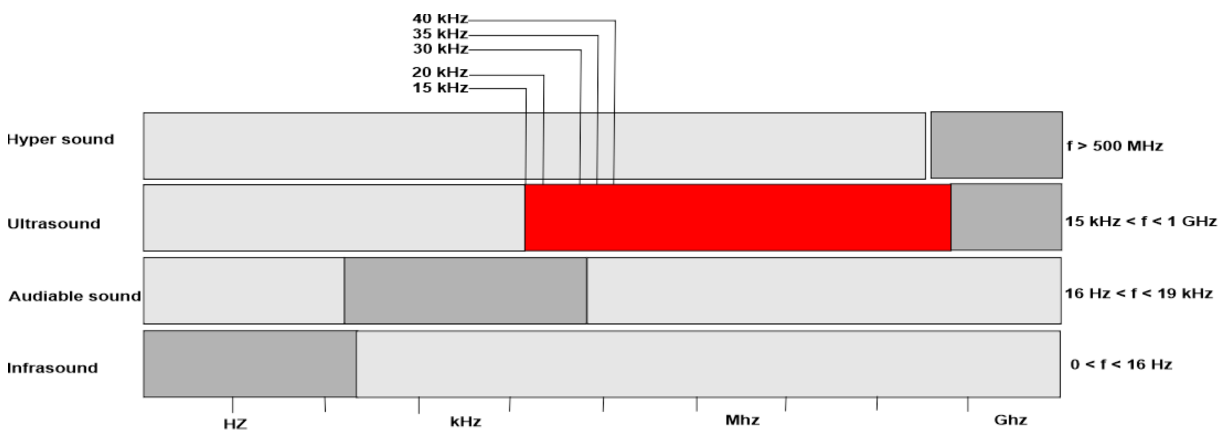
What is Power ultrasonic?

- Sound is the propagation of smallest pressure and density variations in an elastic medium (gas, liquid, solid-state body). For example, a noise is generated when the air in a specific spot is compressed more than in the surrounding area. Subsequently, the layer with changed pressure propagates remarkably fast in all directions at speed of sound of 343 m/s**.**

  Acoustic frequencies between 16 (15) kHz and 1 GHz are referred to as ultrasound; in industrial settings we call it "ultrasonics". To clarify: people are able to hear frequencies between 16 Hz and 20 kHz; i.e., the lower frequencies of industrial ultrasonics are audible, especially if secondary frequencies are generated since ultrasonic is in 1/3 octaves, the first sound you hear is 2/3 octave namely around 13kHz (this gives the high pitching sound one often connects with ultrasonic). And what is more, the ultrasonics can be felt when touching the weld tool. For ultrasonic welding, the frequency range is between 15 kHz and 80 kHz.

  Additional fields of application: Imaging ultrasound in the field of medical diagnostics ranges between 1 and 40 MHz It is not audible or cannot be felt. In the field of industrial material testing, ultrasonics is used at frequencies from 0.25 to 10 MHz

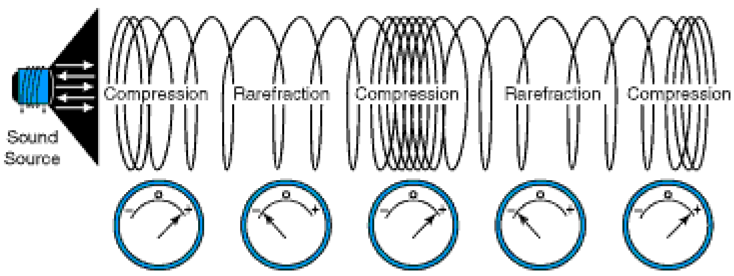


- Classification of ultrasonic frequency ranges – the range audible to the human ear only makes up a fraction of the entire span

The Theory of Sound Waves

In order to understand the mechanics of ultrasonics, it is necessary to first have a basic understanding of sound waves, how they are generated and how they travel through a conducting medium. The dictionary defines sound as the transmission of vibration through an elastic medium which may be a solid, liquid, or a gas. Sound Wave Generation - A sound wave is produced when a solitary or repeating displacement is generated in a sound conducting medium, such as by a "shock" event or "vibratory" movement. The displacement of air by the cone of a radio speaker is a good example of "vibratory" sound waves generated by mechanical movement. As the speaker cone moves back and forth, the air in front of the cone is alternately compressed and rarefied to produce sound waves, which travel through the air until they are finally dissipated. We are probably most familiar with sound waves generated by alternating mechanical motion. There are also sound waves which are created by a single "shock" event. An example is thunder which is generated as air instantaneously changes volume as a result of an electrical discharge (lightning). Another example of a shock event might be the sound created as a wooden board falls with its face against a cement floor. Shock events are sources of a single compression wave which radiates from the source.

The Nature of Sound Waves



The diagram above uses the coils of a spring similar to a Slinky toy to represent individual molecules of a sound conducting medium. The molecules in the medium are influenced by adjacent molecules in much the same way that the coils of the spring influence one another. The source of the sound in the model is at the left. The compression generated by the sound source as it moves propagates down the length of the spring as each adjacent coil of the spring pushes against its neighbor. It is important to note that, although the wave travels from one end of the spring to the other, the individual coils remain in their same relative positions, being displaced first one way and then the other as the sound wave passes. As a result, each coil is first part of a compression as it is pushed toward the next coil and then part of a rarefaction as it recedes from the adjacent coil. In much the same way, any point in a sound conducting medium is alternately subjected to compression and then rarefaction. At a point in the area of a compression, the pressure in the medium is positive. At a point in the area of a rarefaction, the pressure in the medium is negative.

How does ultrasonics vibrations work?

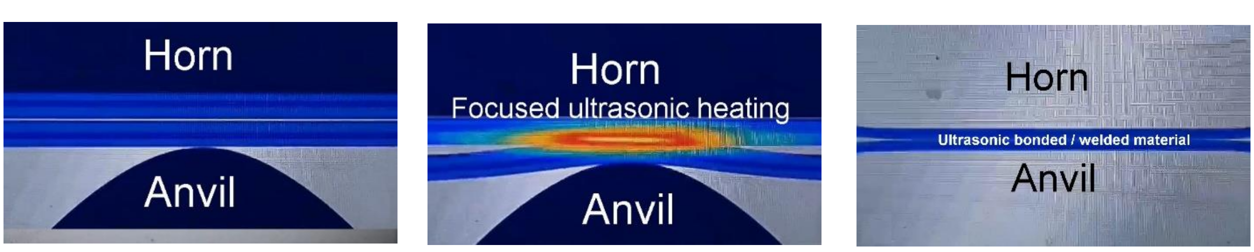
Ultrasonic vibrations are mechanical longitudinal waves that

- Achieve deformation in plastic materials
- Cause friction between molecules

The resulting friction heat generates a melt that bonds the joining partners within the molecules.

Friction occurs due to impedances in the material, absorption and reflection of the mechanical vibration:

- Internal friction in the molecule bond = dissipative work
- External friction between joining materials = surface friction

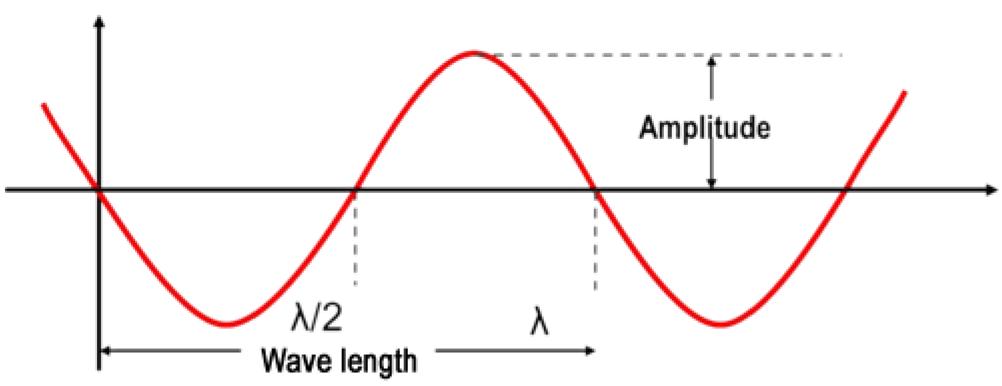


Thermographic illustration of temperature increases during welding

Vibration – amplitude – frequency

During the ultrasonic welding process mechanical vibrations with defined amplitude, force and duration are applied to the materials to be welded. Due to intermolecular and surface friction heat is generated and melts the material.

The core of the ultrasonic welding system is the stack. It is made up of the piezoelectric converter, the booster (amplitude transformer) and the sonotrode. The stack contracts and expands with the ultrasonic frequency. The resulting vibrations are longitudinal waves. The travel of the weld tool, meaning the distance between the peak position and the zero position, is referred to as amplitude - in ultrasonic welding the amplitude is between 5 and 50 µm.



Amplitude-frequency-wave length-definition

$$\lambda = \frac{c}{f}$$

The wave length λ is calculated from the sound velocity, which is a material characteristic, and the frequency.

- **Definition of amplitude**

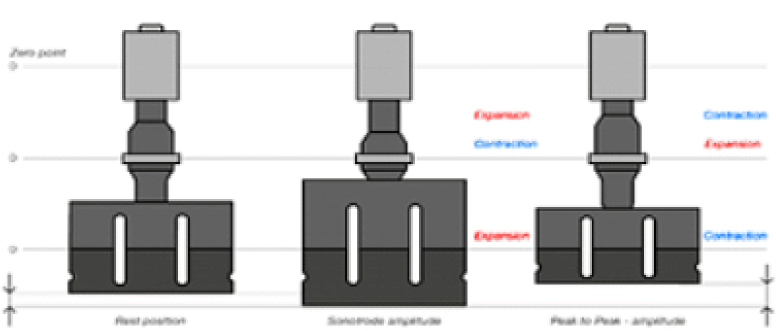
  The amplitude a is defined as half the oscillation amplitude, i.e. from zero to peak value. Unit: Micrometer [µm]

- **Definition of frequency**

  The frequency f is the number of cycles per unit of time
  Unit: Hertz [Hz] is 1 electrical wave length per second.

- **Definition of wave length**

  The wave length l (Lambda) is the distance between two equal states along a wave.



Schematic diagram of the sonotrode movement

What is ultrasonic welding?

Ultrasonic welding of thermoplastic materials is a weld technology utilizing mechanical vibrations to generate heat due to molecular friction. These vibrations excite the molecules in the plastic so that they start moving. The plastic becomes soft and starts melting. The components are bonded by cohesive or form-fit joints After a short hold time under pressure, they are firmly joined molecularly.

Ultrasonic plastic welding technology

Ultrasonic joining technology has been established as joining method for technical thermoplastic materials in a large variety of applications throughout the plastic-processing industry, since 1961.

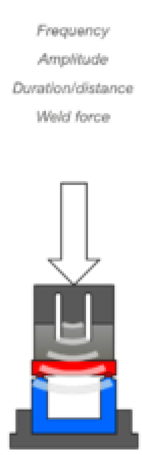
Due to:

- high process speeds
- repeatable weld results

the technology is preferred for high-volume production in the **automotive**, **electrical**, **medical**, **packaging**, **hygiene**, and **filter industry**.

Good bonding quality in terms of strength, tightness and visual appearance are particularly achieved if the part material and design is suited for the ultrasonic process. This means that from the beginning they must be designed such that ultrasonic waves are focused in the weld zone.

- **The factors below control the weld process:**



Component and ultrasonic weld factors

The ultrasonic welding system

The complete ultrasonic welding system is composed of active and passive components. The active components generate the vibrations, transfer them, and apply them into the weld parts the passive components absorb the resulting forces, maintain the parts in position, and particularly support the weld joint.

The converter, booster, and sonotrode are combined to form what is referred to as stack.

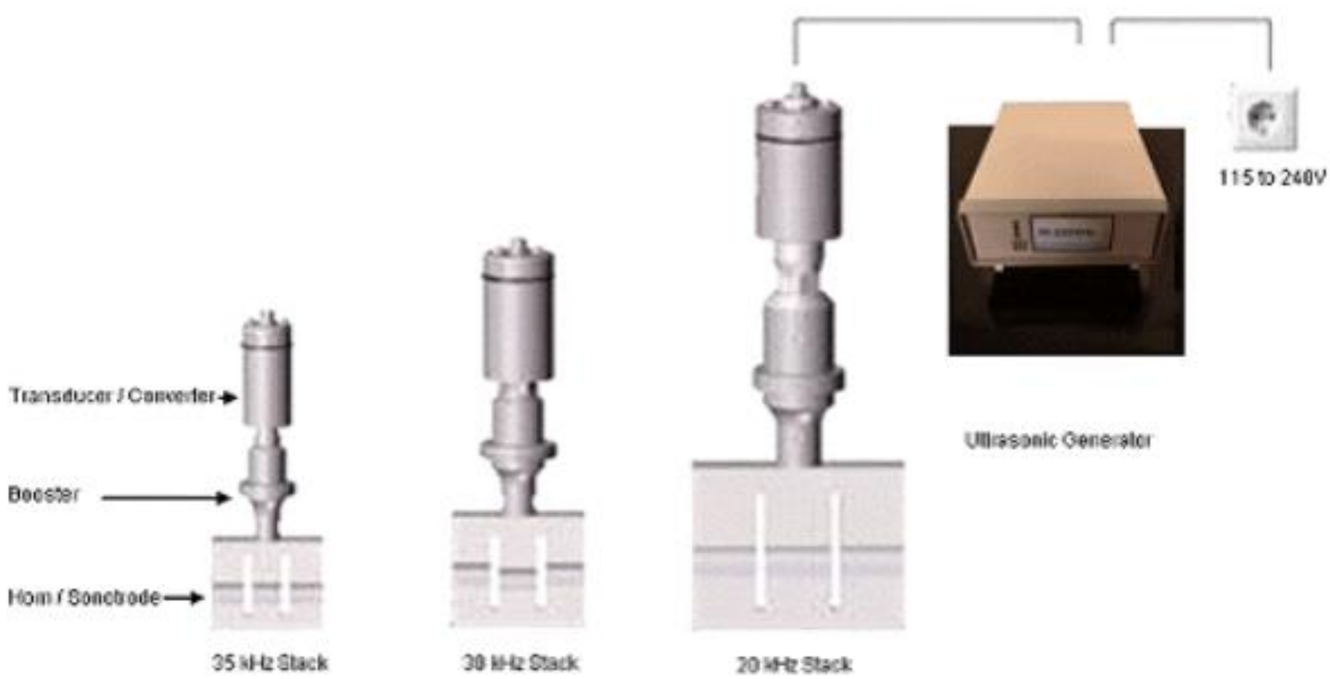
The fully digital ultrasonic generator uses the supply voltage to generate high voltage in the respectively required ultrasonic frequency. All data relevant for the weld process are precisely measured and analyzed. The generator protects the vibrating system from overload, keeps the amplitude (tool movement) at a constant level, and compensates for the changing vibrating behavior of different weld tools.
The converter represents the interface between the electrical and the mechanical area. Utilizing the inverse piezoelectric effect, it converts the electrical oscillation to mechanical longitudinal vibration and transfers it to the booster or the sonotrode.

The amplitude transformer, often referred to as booster, increases or reduces the amplitude coming from the converter. Being suspended at nodal plain, the booster can also be used for vibration-free support of the stack in the ultrasonic welding machine and for transmission of forces.

The sonotrode being the actual active weld tool, transmits the mechanical vibrations into the part; i.e. it launches the ultrasonic vibration. Depending on its design geometry, the sonotrode can either increase or reduce the amplitude.

The stack is always adapted and optimized with regard to the plastic material and the geometry of the part’s contact.

Stack, comprising the converter, booster and sonotrode / horn

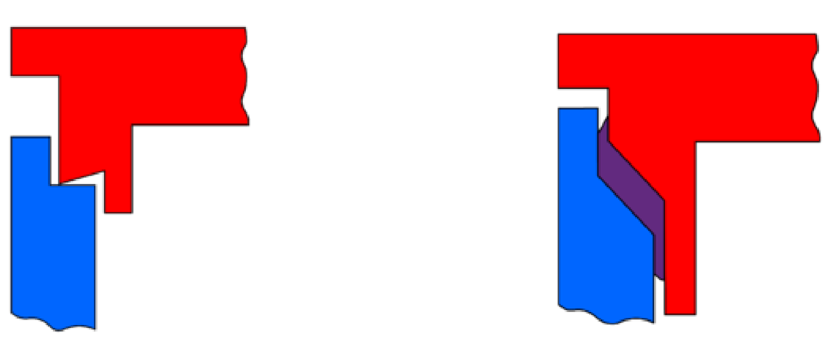


Ultrasonic plastic welding

The secret of ultrasonic plastic welding is focusing the ultrasound with an energy director. In this way, it is possible to generate heat and subsequently melt, restricted to a locally defined area, while using only little energy. Large-area contact surfaces are counterproductive; they require high power and only achieve undefined joining areas with poor strength.

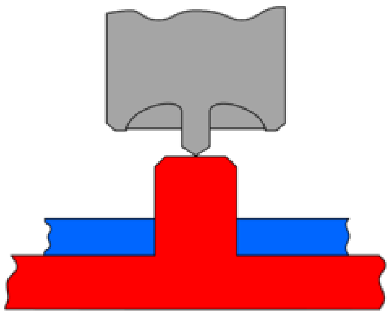
Energy focusing is achieved by:

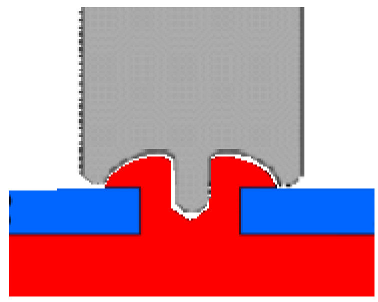
- the energy director (ED)
- sonotrode / horn design
- contouring of the anvil or sonotrode / horn profile
- part before and after welding



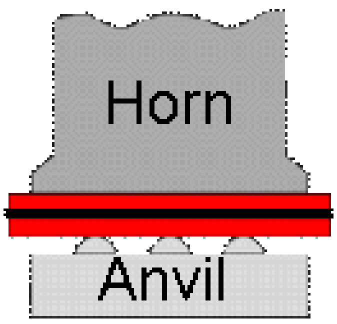
Possibilities of energy focusing due to variations in the joint design / spot welding

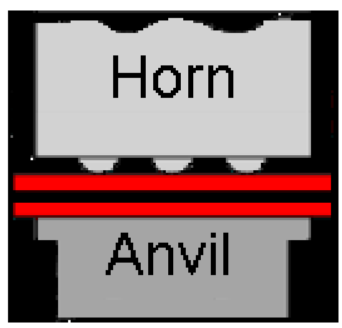
Possibilities of energy focusing due to variations in sonotrode / horn design / staking





Focusing by the **sonotrode / horn shape** (weld tool); e.g. during the ultrasonic staking process, the sonotrode assumes the task of energy concentration.
The centering tip serves as melting initiation aid.

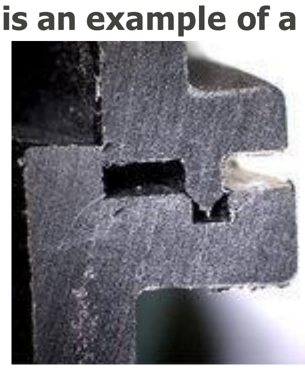




Possibilities of energy focusing due to variations in anvil structures or in the sonotrode / horn

Focusing by means of **contouring of the anvil or in sonotrode / horn structure** for web materials such as film, cardboard, and nonwovens. Local deformation is achieved by anvil or sonotrode / horn contours.

This is an example of a tongue -and- groove weld:

o 

o Unwelded condition Welded condition

Ultrasonic welding was original by luck invented by Robert Soloff in 1961, where he was working in a bio lab, and by accident he came to melt a plastic welding cup with the horn.

Ultrasonic Metal welding

Ultrasonic welding has been used to join metal materials for decades.

Ultrasonic metal welding is a solid-state bonding process in which ultrasonic vibrations create friction-like motion between two surfaces, causing deformation and shearing of asperities to bring metal-to-metal contact and bonding.

In ultrasonic metal welding, dissimilar materials are joined together without the use of applied heat or electric current passing through components.

Ultrasonic energy can weld through contaminates to create a clean seal while providing increased quality and control. To achieve a high-quality seal, one part is held stationary while the second part is compressed beneath a vibrating sonotrode / horn.
The material reaches a plastic state where molecules mix between the two parts, bonding the materials.

Applications include the electrical/electronic, automotive, aerospace, and medical products industries.

While most metals and many dissimilar combinations can be ultrasonically welded, the widest uses involve the softer alloys of copper, aluminum, and nickel.

Ultrasonic Metal welding systems are composed of the same basic elements:
A Ultrasonic press to put the two parts to be ultrasonic assembled under pressure, the press can be:
to be able to have a controlled moment for the ultrasonic process, like Ultrasonic Metal Welding, Ultrasonic Metal Cutting, Solar panel welder ultrasonic rotating metal welder ect. and are in 98% of the times used direct Horizontal on the part.

A ultrasonic nest or ultrasonic anvil where the parts are placed and allowing the high frequency ultrasonic vibration to be directed to the interfaces.

An ultrasonic stack composed of a ultrasonic converter or ultrasonic piezoelectric transducer, an optional ultrasonic booster and a ultrasonic sonotrode / Horn.

All three elements of the ultrasonic stack are specifically tuned to resonate at the same exact ultrasonic frequency (Typically 15, 20, 25, 30, 35 or 40 kHz)

Converter: Converts the electrical signal into a mechanical ultrasonic vibration.

Ultrasonic Booster: Modifies the amplitude of the vibration. It is also used in standard systems to clamp the ultrasonic stack in the ultrasonic press.

Ultrasonic Sonotrode / Horn: Applies the mechanical vibration to the parts to be welded.

An electronic ultrasonic generator (US: Power supply) delivering a high-power AC signal with frequency matching the ultrasonic resonance frequency of the stack.A controller controlling the movement of the press and the delivery of the ultrasonic energy.

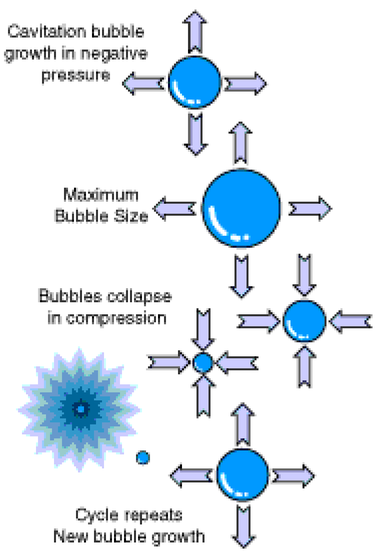
Ultrasonic Cleaning / Cavitation

What is Ultrasonic cleaning

The frequencies used for ultrasonic cleaning range from 20,000 cycles per second or kilohertz (kHz) to over 100,000 KHz. The most commonly used frequencies for industrial cleaning are those between 20 kHz and 50KHz.

Frequencies above 50KHz are more commonly used in small tabletop ultrasonic cleaners such as those found in jewelry stores and dental offices.

Cavitation and Implosion



UITRASONIC ROD

Cavitation is a phenomenon in which the static pressure of the liquid reduces to below the liquid's vapour pressure, leading to the formation of small vapor-filled cavities in the liquid. When subjected to higher pressure, these cavities, called "bubbles" or "voids", collapse and can generate shock waves that may damage machinery. These shock waves are strong when they are very close to the imploded bubble, but rapidly weaken as they propagate away from the implosion.

Cavitation is the rapid formation and collapse of millions of tiny bubbles (or cavities) in a liquid. Cavitation is produced by the alternating high- and low-pressure waves generated by high frequency (ultrasonic) sound. During the low-pressure phase, these bubbles grow from microscopic size until, during the high-pressure phase, they are compressed and implode.

Cavitation is a significant cause of wear in some engineering contexts. Collapsing voids that implode near to a metal surface cause cyclic stress through repeated implosion. This results in surface fatigue of the metal causing a type of wear also called "cavitation". The most common examples of this kind of wear are to pump impellers, and bends where a sudden change in the direction of liquid occurs. Cavitation is usually divided into two classes of behavior: inertial (or transient) cavitation and non-inertial cavitation.

The process in which a void or bubble in a liquid rapidly collapses, producing a shock wave, is called inertial cavitation. Inertial cavitation occurs in nature in the strikes of mantis shrimps and pistol shrimps, as well as in the vascular tissues of plants. In man-made objects, it can occur in control valves, pumps, propellers and impellers.

Non-inertial cavitation is the process in which a bubble in a fluid is forced to oscillate in size or shape due to some form of energy input, such as an acoustic field. Such cavitation is often employed in ultrasonic cleaning baths and can also be observed in pumps, propellers, etc.

Since the shock waves formed by collapse of the voids are strong enough to cause significant damage to parts, cavitation is typically an undesirable phenomenon in machinery (although desirable if intentionally used, for example, to sterilize contaminated surgical instruments, break down pollutants in water purification systems, emulsify tissue for cataract surgery or kidney stone lithotripsy, or homogenize fluids). It is very often specifically avoided in the design of machines such as turbines or propellers, and eliminating cavitation is a major field in the study of fluid dynamics. However, it is sometimes useful and does not cause damage when the bubbles collapse away from machinery, such as in super cavitation.

In elastic media such as air and most solids, there is a continuous transition as a sound wave is transmitted. In non-elastic media such as water and most liquids, there is continuous transition as long as the amplitude or "loudness" of the sound is relatively low. As amplitude is increased, however, the magnitude of the negative pressure in the areas of rarefaction eventually becomes sufficient to cause the liquid to fracture because of the negative pressure, causing a phenomenon known as cavitation. Cavitation "bubbles" are created at sites of rarefaction as the liquid fractures or tears because of the negative pressure of the sound wave in the liquid. As the wave fronts pass, the cavitation "bubbles" oscillate under the influence of positive pressure, eventually growing to an unstable size. Finally, the violent collapse of the cavitation "bubbles" results in implosions, which cause shock waves to be radiated from the sites of the collapse. The collapse and implosion of myriad cavitation "bubbles" throughout an ultrasonically activated liquid result in the effect commonly associated with ultrasonics. It has been calculated that temperatures in excess of 10,000°F and pressures in excess of 10,000 PSI are generated at the implosion sites of cavitation bubbles.

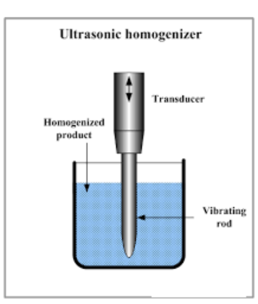
Benefits of Ultrasonics in the Cleaning and Rinsing Processes Cleaning in most instances requires that a contaminant be dissolved (as in the case of a soluble soil), displaced (as in the case of a non-soluble soil) or both dissolved and displaced (as in the case of insoluble particles being held by a soluble binder such as oil or grease). The mechanical effect of ultrasonic energy can be helpful in both speeding dissolution and displacing particles. Just as it is beneficial in cleaning, ultrasonics is also beneficial in the rinsing process. Residual cleaning chemicals are removed quickly and completely by ultrasonic rinsing. In removing a contaminant by dissolution, it is necessary for the solvent to come into contact with and dissolve the contaminant. The cleaning activity takes place only at the interface between the cleaning chemistry and the contaminant.

Ultrasonic cavitation and implosion effectively displace the saturated layer to allow fresh chemistry to come into contact with the contaminant remaining to be removed. This is especially beneficial when irregular surfaces or internal passageways are to be cleaned.

What is "degassing", and why should it be done?

"Degassing" is the initial removal of gases present in the solution. Useful cavitation occurs after gasses have been removed from the cleaning solution, (here you after hear a load noise when the ultrasonic batch stats) leaving a vacuum in the formed bubble. When the high-pressure wave hits the bubble wall, the bubble collapses; it is the energy released by this collapse that will assist a detergent in breaking the bonds between parts and their soils.

Cavitation / Homogenizing



Ultrasonic Cavitation in Liquids Ultrasonic waves of high intensity ultrasound generate cavitation in liquids. Cavitation causes extreme effects locally, such as liquid jets of up to 1000km/hour, pressures of up to 2000atm and temperatures of up to 5000 Kelvin. About ultrasonic cavitation Ultrasonic waves of high intensity ultrasound generate cavitation in liquids. When sonicating liquids at high intensities, the sound waves that propagate into the liquid media result in alternating high-pressure (compression) and low-pressure (rarefaction) cycles, with rates depending on the frequency. During the low-pressure cycle, high-intensity ultrasonic waves create small vacuum bubbles or voids in the liquid. When the bubbles attain a volume at which they can no longer absorb energy, they collapse violently during a high-pressure cycle. This phenomenon is termed cavitation. During the implosion very high temperatures (approx. 5,000K) and pressures (approx. 2,000atm) are reached locally. The implosion of the cavitation bubble also results in liquid jets of up to 280m/s velocity.

Homogenizing

In industry, cavitation is often used to homogenize, or mix and break down, suspended particles in a colloidal liquid compound such as paint mixtures or milk. Many industrial mixing machines are based upon this design principle. It is usually achieved through impeller design or by forcing the mixture through an annular opening that has a narrow entrance orifice with a much larger exit orifice. In the latter case, the drastic decrease in pressure as the liquid accelerates into a larger volume induces cavitation. This method can be controlled with hydraulic devices that control inlet orifice size, allowing for dynamic adjustment during the process, or modification for different substances. The surface of this type of mixing valve, against which surface the cavitation bubbles are driven causing their implosion, undergoes tremendous mechanical and thermal localized stress; they are therefore often constructed of super-hard or tough materials such as stainless steel, Stellite, or even polycrystalline diamond (PCD).

Cavitating water purification devices have also been designed, in which the extreme conditions of cavitation can break down pollutants and organic molecules. Spectral analysis of light emitted in sonochemical reactions reveal chemical and plasma-based mechanisms of energy transfer. The light emitted from cavitation bubbles is termed sonoluminescence.

Use of this technology has been tried successfully in alkali refining of vegetable oils.

Hydrophobic chemicals are attracted underwater by cavitation as the pressure difference between the bubbles and the liquid water forces them to join together. This effect may assist in protein folding.

Ultrasonic sieving

Ultrasonic sieving frame

Ultrasonic sieve deblending system has revolutionized the way difficult powders are screened on sieve meshes, increasing throughput and allowing accurate separation down to 20 microns. Enabling you to sieve your powders on finer meshes with more accuracy than ever before, and up to 10 times higher output rate.

Using an acoustically developed transducer, the ultrasonic transducer assists a high-frequency vibration to the sieve mesh. The frequency of the vibration breaks the surface tension, making the stainless-steel mesh effectively friction-free and preventing oversized and undersized articles from blinding or blocking the mesh screen. The ultrasonic components could be connected to almost every sieving screen in operation. For new sieving designs there's a simple coupling needed for the transfer of ultrasonic energy.

Features

- **Improve product quality –** Screen powders on meshes as fine as 20 microns without blinding or blocking
- **Increase throughput capacity –** Ultrasonic screening can increase sieving capacity tenfold by enabling powders to pass through faster.
- **Reduce production downtime –** Prevent blockages and reduce the frequency with which meshes need to be cleaned.
- **Minimize running costs** – Frictionless system eliminates damage caused by mechanical deblending systems.
- **Upgrade existing systems –** Simple retrofit solution for new and existing vibrating sieves and screeners.
- **Ensure consistent quality**. The ultrasonic sifters enable the manufacturer to accurately screen powders on meshes as fine as 20 microns without blinding or blocking.

Ultrasonic Atomizing

An ultrasonic atomizer is a device that converts a normal stream of liquid into a very fine mist. It consists of a generator and a probe. The generator creates vibrations and focuses them at the tip of the sonotrode / horn

As the liquid flows through the sonotrode / horn or is dropped on the face of the sonotrode / horn, it is converted into fine particles (the higher the ultrasonic frequency the finer the particles become).

The ultrasonic atomizer is often used in manufacturing applications, such as coating fabrics, adding moisture to a gas stream and injecting small amounts of a liquid into a reactor.

The ultrasonic atomizer has a power supply that converts low-frequency electrical energy to high-frequency electrical energy. This electrical energy is then converted into mechanical vibrations by a piezoelectric transducer, which is typically made of ceramic. The vibration is sent back to the piezoelectric transducer after it has bounced off the tip of the sonotrode / horn. This increases the strength of the vibration and creates a pumping action that draws liquid toward the center of the sonotrode / horn.

Liquid is introduced to the sonotrode / horn through an inlet on the side, usually by gravity or a low pressure pump. There are different probes for different applications. A flat tip sonotrode / horn, for example, can focus particles at a specific location. A wide dispersion sonotrode / horn has an extended spray range, making it ideal for coating applications, and a radial sonotrode / horn is typically used to spray the interior walls of bores.

As liquid travels through the sonotrode / horn, it spreads out and becomes flat. The vibrations divide the liquid into individual droplets. The size of the droplet is dependent on the frequency of the electrical energy. The greater the electrical energy frequency is, the stronger the vibrations produced by the piezoelectric transducer are.

When the droplets reach the tip of the sonotrode / horn, they are sprayed out. The flow rate of the spray is dependent on the viscosity of the liquid and the electrical energy frequency. The higher the frequency and viscosity, the lower the flow rate.

The ultrasonic atomizer has several advantages over traditional methods used to disintegrate liquids. Since the ultrasonic atomizer can precisely deliver a uniform spray, manufacturers can efficiently use raw materials and reduce pollution. The sonotrode / horn typically doesn't clog and is easily cleaned. This allows for the atomizing of several types of liquids, without the risk of contamination or erosion of the sonotrode / horn. Liquids containing long chain polymers, however, are difficult to atomize because of their strong cohesive properties.

HOWEVER, due to the atomizing is also a cavitation, the sonotrode / horn will over time be warning down due to the cavitation as explained earlier in this document.

Ultrasonic Food Cutting.

Ultrasonic food cutting is a process utilizing ultrasonic *titanium* knives that vibrate at frequencies from 20 to 40 kHz. Applying ultrasonic vibration to a cutting tool creates a nearly frictionless cutting surface which provides many benefits.

This low friction cutting surface can slice a multitude of food products cleanly and without smearing. Very thin slices are also possible due to the reduced resistance.

Foods containing items such as vegetables, meats, nuts, berries and fruits can be cut without deformation or displacement of the internal product. The low friction condition also reduces the tendency of products like nougat and other soft candies from sticking to the cutting tools, resulting in more consistent cuts and less down time for cleaning.

Because of the advanced process control that is available in ultrasonic generators, cutting performance can be easily manipulated by simply adjusting the equipment parameters.

Bakery products containing cream or sugary layers, as well as other dough or fat-containing foods, like deep frozen fish can be cut or trimmed in a controlled way by ultrasound to produce a quality that is visually appealing.

The cutting geometries of the tools for longitudinal or cross cuts are individually tailored to product requirements.

As a result of ultrasonic vibrations, only slight product residues remain adhered to the sonotrode so that to a certain extent, it demonstrates a self-cleaning action.

Because of the ultrasonic vibrations, cutting sonotrodes work with a lower initial pressure than conventional cutters. At the same time, sonotrode wear is less and the cutting quality is considerably better. In addition, the use of ultrasonic cutting systems has a positive effect on the maintenance and down times of the equipment.

Ultrasonic Cutting.

Ultrasonic cutter vibrates its blade 20,000 - 40,000 times per second (20 - 40 kHz). Because of this movement, the ultrasonic cutter can easily cut resin, rubber (tires), nonwoven fabric and composite materials (wind mill wings production).

Besides being excellent in maintainability, the products are environment-friendly as they do not substantially discharge any crumbs, waste water, noise, or smoke.

Depending on application, cutting can be performed vertically, horizontally or continuously (roll seam sonotrodes) with the appropriate sonotrode design. Sonotrodes / horns used as cutting tools suffer comparatively low wear. Because they are cold, as in the case of ultrasonic cutting and punching, a wide variety of materials can be efficiently processed.

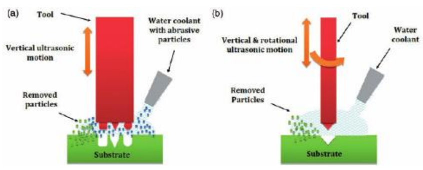
In the textile sector, ultrasonic cutting is distinguished by the fact that the cut edges of the non-woven or fabric do not fray. Instead, they are sealed or fused by ultrasonic technology. Besides which, during cutting desirable material embossing occurs along the cut edges.

The sonotrodes / horns can be flat with a knife below of they can be roller sonotrodes / horns or the can have a “tip” that has a wolfram blade for hard to cut materials.

How does ultrasonic cutter work?

Each object has its special frequency, by which the object is stable and easy to oscillate. By adding an external force that corresponds to that special frequency, a small force can obtain a large oscillation. This phenomenon is called resonance. The cutting edge is oscillated greatly with the use of resonance.

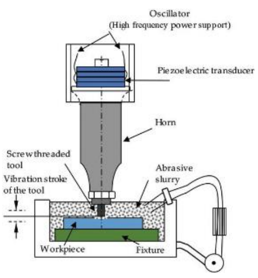
Ultrasonic Machining



Take your machining capabilities to the next level, along with your bottom line, with ultrasonic assisted tool. The latest in ultrasonic machining technology. Experience unprecedented machining efficiency with high performance ultrasonic milling, grinding, core drilling and light weighting of optical glasses and ceramics. Ultrasonic oscillation of the tool promotes free cutting of material, greatly reducing the force applied to the tool as well as the workpiece during processing. This reduction in force allows for rapid material removal and faster cycle times as well as reduced tool wear and longer tool life.

Ultrasonic machining is a subtractive manufacturing process that removes material from the surface of a part through high frequency, low amplitude vibrations of a tool against the material surface in the presence of fine abrasive particles. The tool travels vertically or orthogonal to the surface of the part at amplitudes of 0.05 to 0.125 mm (0.002 to 0.005 in.). The fine abrasive grains are mixed with water to form a slurry that is distributed across the part and the tip of the tool. Typical grain sizes of the abrasive material range from 100 to 1000, where smaller grains (higher grain number) produce smoother surface finishes.

Ultrasonic vibration machining is typically used on brittle materials as well as materials with a high hardness due to the microcracking mechanics.



Ultrasonic vibration machining physically operates by the mechanism of microchipping or erosion on the work piece's surface. Since the abrasive slurry is kept in motion by high frequency, low amplitude vibrations, the impact forces of the slurry are significant, causing high contact stresses. These high contact stresses are achieved by the small contact area between the slurry's particles and the work piece's surface. Brittle materials fail by cracking mechanics and these high stresses are sufficient to cause micro-scale chips to be removed from its surface. The material as a whole does not fail due to the extremely localized stress regions. The average force imparted by a particle of the slurry impacting the work piece's surface and rebounding can be characterized by the following equal Rotary ultrasonic vibration machining

In **rotary ultrasonic vibration machining (CNC)**, the vertically oscillating tool is able to revolve about the vertical center line of the tool. Instead of using an abrasive slurry to remove material, the surface of the tool can be *but not a must* impregnated with diamonds that grind down the surface of the part. Rotary ultrasonic machines are specialized in machining advanced ceramics and alloys such as glass, quartz, structural ceramics, titanium alloys, alumina, and silicon carbide. Rotary ultrasonic machines are used to produce deep holes with a high level of precision.

Rotary ultrasonic vibration machining is a relatively new manufacturing process that is still being extensively researched. Currently, researchers are trying to adapt this process to the micro level and to allow the machine to operate in a milling machine.

Chemical-assisted ultrasonic vibration machining

C**hemical-assisted ultrasonic machining,** a chemically reactive abrasive fluid is used to ensure greater machining of glass and ceramic materials. Using an acidic solution, such as hydrofluoric acid, machining characteristics such as material removal rate and surface quality can be improved greatly compared to traditional ultrasonic machining. While time spent machining and surface roughness decrease with CUSM, the entrance profile diameter is slightly larger than normal due to the additional chemical reactivity of the new slurry choice. In order to limit the extent of this enlargement, the acid content of the slurry must be carefully selected as to ensure user safety and a quality product.

Applications

Since ultrasonic vibration machining does not use subtractive methods that may alter the physical properties of a workpiece, such as thermal, chemical, or electrical processes, it has many useful applications for materials that are more brittle and sensitive than traditional machining metals. Materials that are commonly machined using ultrasonic methods include ceramics, carbides, glass, precious stones and hardened steels. These materials are used in optical and electrical applications where more precise machining methods are required to ensure dimensional accuracy and quality performance of hard and brittle materials. Ultrasonic machining is precise enough to be used in the creation of microelectromechanical system components such as micro-structured glass wafers.

In addition to small-scale components, ultrasonic vibration machining is used for structural components because of the required precision and surface quality provided by the method. The process can safely and effectively create shapes out of high-quality single crystal materials that are often necessary but difficult to generate during normal crystal growth. As advanced ceramics become a greater part of the structural engineering realm, ultrasonic machining will continue to provide precise and effective methods of ensuring proper physical dimensions while maintaining crystallographic properties.

Advantages

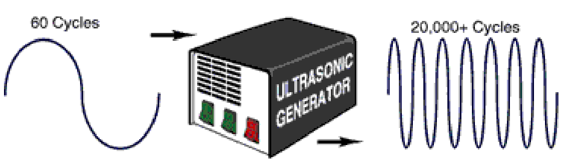
Ultrasonic vibration machining is a unique non-traditional manufacturing process because it can produce parts with high precision that are made of hard and brittle materials which are often difficult to machine. Additionally, ultrasonic machining is capable of manufacturing fragile materials such as glass and non-conductive metals that cannot be machined by alternative methods such as electrical discharge machining and electrochemical machining. Ultrasonic machining is able to produce high-tolerance parts because there is no distortion of the worked material. The absence of distortion is due to no heat generation from the sonotrode against the work piece and is beneficial because the physical properties of the part will remain uniform throughout. Furthermore, no burrs are created in the process, thus fewer operations are required to produce a finished part.

Ultrasonic Generators

The ultrasonic generator converts electrical energy from the line which is typically alternating current at 50 or 60Hz to electrical energy at the ultrasonic frequency. This is accomplished in a number of ways by various equipment manufacturers.

Current ultrasonic generators mostly used for broad band frequencies, (serial generator) like cleaning generators.

Voltage generators mostly used for narrow band frequencies (parallel generators) mostly used for welding generators.



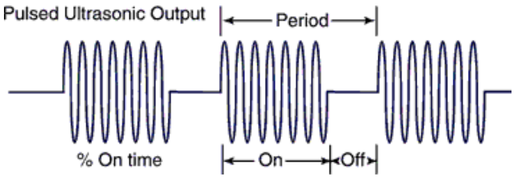
There have been several relatively recent innovations in ultrasonic generator technology which may enhance the effectiveness of ultrasonic cleaning equipment. These include square wave outputs, slowly or rapidly pulsing the ultrasonic energy on and off and modulating or "sweeping" the frequency of the generator output around the central operating frequency. The most advanced ultrasonic generators have provisions for adjusting a variety of output parameters to customize the ultrasonic energy output for the task.

Square Wave Output

Applying a square wave signal to an ultrasonic transducer results in an acoustic output rich in harmonics. The result is a multi-frequency cleaning system which vibrates simultaneously at several frequencies which are harmonics of the fundamental frequency. Multi-frequency operation offers the benefits of all frequencies combined in a single ultrasonic cleaning tank.

Pulse

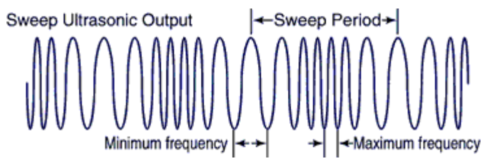
In pulse operation, the ultrasonic energy is turned on and off at a rate which may vary from once every several seconds to several hundred times per second.



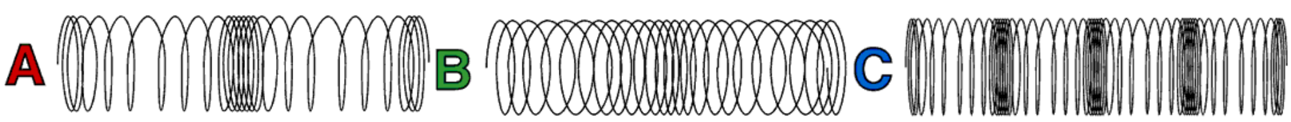
The percentage of time that the ultrasonic energy is on may also be changed to produce varied results. At slower pulse rates, more rapid degassing of liquids occurs as coalescing bubbles of air are given an opportunity to rise to the surface of the liquid during the time the ultrasonic energy is off. At more rapid pulse rates, the cleaning process may be enhanced as repeated high energy "bursts" of ultrasonic energy occur each time the energy source is turned on.

Frequency Sweep

In sweep operation, the frequency of the output of the ultrasonic generator is modulated around a central frequency which may itself be adjustable.



Various effects are produced by changing the speed and magnitude of the frequency modulation. The frequency may be modulated from once every several seconds to several hundred times per second with the magnitude of variation ranging from several hertz to several kilohertz. Sweep may be used to prevent damage to extremely delicate parts or to reduce the effects of standing waves in cleaning tanks. Sweep operation may also be found especially useful in facilitating the cavitation of terpenes and petroleum-based chemistries. A combination of Pulse and sweep operation may provide even better results when the cavitation of terpenes and petroleum-based chemistries is required. **Frequency and Amplitude** Frequency and amplitude are properties of sound waves. The illustrations below demonstrate frequency and amplitude using the spring model introduced earlier. In the diagram, if A is the base sound wave, B with less displacement of the media (less intense compression and rarefaction) as the wave front passes, represents a sound wave of less amplitude or "loudness." C represents a sound wave of higher frequency indicated by more wave fronts passing a given point within a given period of time.

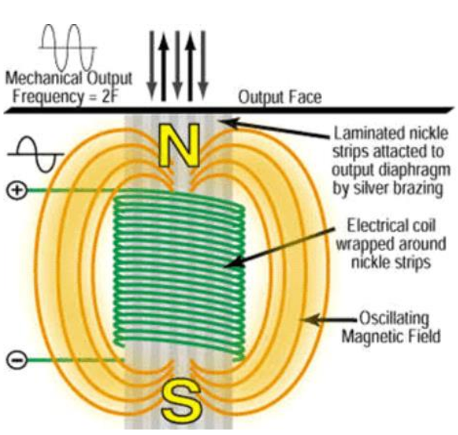


Ultrasonic Transducers

There are two general types of ultrasonic transducers in use today: Magnetostrictive and piezoelectric. Both accomplish the same task of converting alternating electrical energy to vibratory mechanical energy but do it through the use of different means.

Magnetostrictive

Magnetostrictive transducers utilize the principle of magnetostriction in which certain materials expand and contract when placed in an alternating magnetic field.

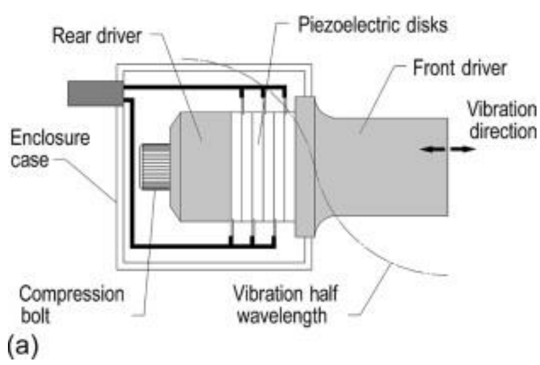


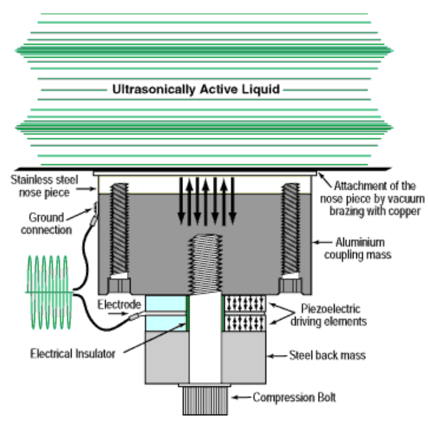
Alternating electrical energy from the ultrasonic generator is first converted into an alternating magnetic field through the use of a coil of wire. The alternating magnetic field is then used to induce mechanical vibrations at the ultrasonic frequency in resonant strips of nickel or other magnetostrictive material which are attached to the surface to be vibrated. Because magnetostrictive materials behave identically to a magnetic field of either polarity, the frequency of the electrical energy applied to the transducer is 1/2 of the desired output frequency. Magnetostrictive transducers were first to supply a robust source of ultra-sonic vibrations for high power applications such as ultrasonic cleaning. Because of inherent mechanical constraints on the physical size of the hardware as well as electrical and magnetic complications, high power magnetostrictive transducers seldom operate at frequencies much above 20 kHz. Piezoelectric transducers, on the other hand, can easily operate well into the megahertz range. Magnetostrictive transducers are generally less efficient than their piezoelectric counterparts.

This is due primarily to the fact that the magnetostrictive transducer requires a dual energy conversion from electrical to magnetic and then from magnetic to mechanical. Some efficiency is lost in each conversion. Magnetic hysteresis effects also detract from the efficiency of the magnetostrictive transducer.

Piezoelectric

Piezoelectric transducers convert alternating electrical energy directly to mechanical energy through use of the piezoelectric effect in which certain materials change dimension when an electrical charge is applied to them.





Above ultrasonic welding transducer   Above ultrasonic cleaning transducer

Electrical energy at the ultrasonic frequency is supplied to the transducer by the ultrasonic generator. This electrical energy is applied to piezoelectric element(s) in the transducer which vibrate. These vibrations are amplified by the resonant masses of the transducer and directed into the liquid through the radiating plate.

Early piezoelectric transducers utilized such piezoelectric materials as naturally occurring quartz crystals and barium titanate which were fragile and unstable. Early piezoelectric transducers were, therefore, unreliable. Today's transducers incorporate stronger, more efficient and highly stable ceramic piezoelectric materials which were develops as a result of the efforts of the US Navy and its research to develop advanced sonar transponders in the 1940's. The vast majority of transducers used today for ultrasonic power applications like cleaning, homogenizing, welding utilizes the piezoelectric effect.

Ultrasonic piezo transducers were original invented by Paul Langevin making what we today call a sandwich transducer. This development was based on the development done by Marie & Pierre Curie done in 1887, and Paul Langevin was studying under Marie Curie.