

# Ultrasonics: Past, Present & Future

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**Abstract - Ultrasonic technique provides the interaction of high frequency sound wave with matter resulting to generation of information about physico-chemical properties. Ultrasound is a very useful and flexible modality in medical imaging that uses high-frequency sound waves to characterize tissue. Although, during the last decades ultrasonic technology developed new techniques to represent a clean and effective tool to refine classical existing techniques. Some techniques look like to be the case of pertinent sectors such as environment, food industry, pharmaceuticals, machinery mining, chemicals manufacture etc. Many researchers have been studies the application of ultrasonic waves in different areas like medicines, oceanography, aerospace, navy and material science. Nowadays Ultrasonics became a multidimensional area of study due to its different industrial and medical field.**

## INTRODUCTION

Ultrasonics is a branch of physics in which high frequency sound wave is concerned. Usually, people can capable to perceive sounds with a frequency range varies between 16 Hz to 20 KHz (20,000 cycles per second). Modern ultrasonic devices can produce frequencies of as high as several gigahertz by transforming alternating electric current into mechanical vibrations and researchers have produced ultrasound with frequencies up to about 10 GHz. Around 1900, Ultrasonics was very useful and powerful tool for research areas in the field of physics. Later on, from the middle of the 20<sup>th</sup> century, the applications of ultrasonic energy to produce or to amplify a wide variety of methods have been investigated. At industrial level, ultrasound was being using for the study of inspection and characterization of different materials. Ultrasonic technique can not applied only to inspect bulk and surface flaws but also finding the information on material microstructures. Ultrasonic technique provides the interaction of high frequency sound wave with matter resulting to generation of information about physico-chemical properties. Ultrasound is a very useful and flexible modality in medical imaging that uses high-frequency sound waves to characterize tissue. Although, during the last decades ultrasonic technology developed new techniques to represent a clean and effective tool to refine classical existing techniques. Some techniques look like to be the case of pertinent sectors such as environment, food industry, pharmaceuticals, machinery mining, chemicals manufacture etc. Many researchers have been studies the application of ultrasonic waves in different areas like medicines, oceanography, aerospace, navy and material science. Nowadays Ultrasonics became a multidimensional area of study due to its different industrial and medical field. The possibilities and limitations of ultrasonics for these purposes are discussed.

## EARLIER STAGE OF ULTRASONICS

Sound waves have been studies for many different purposes for hundreds of years but the advancement of ultrasonics had its beginning in 1794 with the discovery of echolocation among bats by physiologist Lazzaro Spallanzani. The most notable breakthrough came in 1880 when the piezoelectric effect discovered by French physicist Pierre Curie and his brother Jacques Curie. They found that asymmetric crystals such as quartz and Rochelle salt (potassium sodium tartrate) produce an electric charge when mechanical pressure is applied. On the contrary, mechanical vibrations are obtained by applying electrical oscillations to the same crystals. The ultrasonic technology in more limited sense was given during world war I with Langevin's use of high frequency based electrostatic sound transmitters and quartz resonators for submarine detection in 1917. Since that was an exciting time of discovery and development for ultrasonics in different areas of research, industry and medicine. A sonar device was the first practical application of ultrasound and piezoelectric technology that was developed during World War I. The U.S. Navy utilized sonar on a large scale to detect enemy submarines during World War II. In the beginning of 1929, the use of ultrasonic vibrations in detecting metal device was proposed. In 1931, Malhauser obtained a patent for using ultrasonic transducers to detect flaws in solids. The use of ultrasound in medical diagnosis began during World War II. Neurologist Karl Dussik in 1942 is created with being the first to use sonography for medical diagnosis. From the early time, Japan played an essential role in the field of ultrasonics and it was also the first country to apply Doppler Ultrasound, which detects internal moving objects such as blood flowing through the heart. In the 1950s researchers in the USA and Europe became increasingly aware of the progress that had been made in Japan and they began work on extensive study of ultrasonics in additional medical applications. The first ultrasonic instruments displayed their result with blips on an oscilloscope screen. That was followed by the use of 2-D, gray scale imaging. Now high-resolution, computer-enhanced and color are common.

## PRESENT STATES

In the present years, a large number of studies have published on the uses of high frequency based ultrasonics for various reasons. Recently, the developments of ultrasonic technology have increased in different applications of medical & sciences and work ongoing in these fields. Industrial competitiveness of ultrasonic based technologies are non-destructive testing and better known in its more common applications for flaw detection, thickness gauging and acoustic imaging. Ultrasonic material testing is based

on a simple principle of physics which governs that the high frequency sound waves propagate through the solid materials have been examined to detect any kind of internal defect within the material. This type of ultrasonic testing can also be used to measure thickness of an object. Other special equipment is used to receive these high frequency sound waves. This testing have been used to detect a variety of discontinuities such as hidden cracks, voids, plastic, metal, steel and any alloy; yet these are also significant to composites, ceramics and wood product also. At currently, for accurate and fast location determination of flaws; many advanced flaw detectors are available in the market, which have a trigonometric function with using the ultrasonic techniques. Transducers can be used to set the programme with predetermined instrument settings. Frequencies of 20 KHz to 100 MHz utilizes for ultrasonic testing but most of work performed between 500 KHz to 20 MHz frequency range. For the system of laser-based maintenance, laser ultrasonic testing includes a technology likewise non-destructive testing technique. It is a technique that uses laser beam to generate and detect ultrasonic waves in substances under the surface of the materials. Present applications for laser ultrasonics is water inspection, wall thickness measurement of seamless steel tubes and inspection of composite components in aircraft. Lockheed Martin, was the first scientist who executed a laser ultrasonic test system for composite components inspection.

Modern ultrasonic technology continues to offer astonishing advances in the medical field. Nowadays ultrasound imaging is one of the most valuable tools for development of medical ultrasound and actively used for last 20 years. It has been performed in both diagnostic and therapeutic procedures. In ultrasonic imaging; elastography, super resolution imaging, ultrasound contrast agent imaging and 2D array transducer are remarkable. Recent advances of ultrasound is to improving the image quality and physicians are able to perceive much clearer image quality that are a lot deeper and lot lesser than was formerly possible. Due to the improvement of this image-quality, ultrasound is now used to procedures by magnetic resonance imaging (MRI) and computed tomography (CT). Ultrasonic biomicroscopy (UBM) is one of the most significant advances of present development of ultrasound. It is used for clinically purpose to investigate different kinds of glaucoma, especially these affected by or related with anatomical abnormalities. A new development in ultrasound technology involves three-dimensional ultrasound that formats the data of sound wave into three-dimensional (3D). A study of Doppler ultrasound can be a part of ultrasound examination and also known as Color Doppler Ultrasonography, which is a unique ultrasound technique that permits the doctor to see and analyse blood flow through arteries and veins in various body organs. Other auspicious innovative progress in this field is Power Doppler (PD), which is a new reformation of Doppler. In detecting blood flow, Power Doppler (PD) has 3-times the sensitivity of conventional Color Doppler (CD). At present, ultrasound technology is being developed very rapidly for the use of surgery. With the help of transducer, ultrasonic surgical instruments (USTs) transforms an ultrasonic signal into mechanical vibration, a waveguide then propagates the vibration and amplifies. Ultrasonic surgical instruments can cut bone and other tissue while concurrently tissue, extremely helpful in various medical procedures. This normally decreases the average length of surgery and harmful to tissue, resulting in fewer impediment overall.

## ULTRASONICS FOR HUMAN BEINGS

Ultrasound is a versatile technique that has many advantages for human beings. Ultrasonics are briefly analyzed by the principle of the generation, propagation and detection. Various researchers have described numerous examples of the importance of ultrasound in medicines industry and research. These offers additional exciting opportunities of ultrasonics in flaw detection and navigation processes – for control system in industrial purpose; in medical diagnosis – for the treatment of certain diseases; for cleaning – in the operation of cavitation effect; for chemical effects – in alloying certain metals and various working methods. Some scientific applications of ultrasonics are evolving for new results in physical, chemical and biological processes. There are some important applications are briefly discussed.

1. **Cleaning** – Ultrasonic cleaning method is one of the most important advances of ultrasonics for example removal of dirt, grease, rust and paint from metal ceramics glass and crystal surface of parts which are used in the electronics, aircraft, automotive and precision instruments industries. Normally, Cavitation process can understand the principle of ultrasonic cleaning. Ultrasonic cleaning can be used cavitation bubbles induced by agitate a cleaning solution. The repeated collapsing of the bubbles creates tiny shock wave that scrub of the parts. Water, detergent and organic solvents have used for cleaning solution.
2. **Machining** – At industrial level, ultrasonic machines are the future of machining that is using all over the world for producing hard and brittle forms of materials. The modern technology produces solution that helps in opening up the market opportunities and has made things easier. It is a non-traditional machining process, which is used for cutting the materials that are very hard and highly abrasive because this technique has done the actual cutting. It is a low material removal rate machining process. It is also known as ultrasonic impact grinding which is involves a vibrating tool. The best choice of this method is working with hard materials such as composites, ceramic matrix, ruby, glass piezo-ceramics, quartz, diamond, ferrite, alumina, technical ceramics and many other similar ones.
3. **Soldering and welding** – For joining the substances, Ultrasonics is very beneficial method. Soldering and welding both are applied by this method. Ultrasonic soldering method is a modernized technique that permits solder to bond with glass or non-metallic materials. Ultrasonic soldering exploits cavitation's energy to permit the removal of the oxide layer on aluminum. Hence, it utilizes this procedure, which prevents the need for flux in the soldering process. The most common use of ultrasonic welding method is to be used the thermoplastics; it is used high frequency ultrasonic vibrations to create friction the materials, which are being held together under the pressure to generate the solid-state weld. This is one of the fastest welding method is used today. Ultrasonic welding process is easy to weld a variety of combination of the materials such as silver, copper, gold, aluminum etc.
4. **Non-destructive testing** – Non-destructive testing is one of the most significant techniques that have been employed immensely for industrial work. Ultrasonics is especially familiar with non-destructive testing because it can be used with most type of substances. It has been utilized to examine both their surface and interiors. Ultrasonic testing uses pulse-echo

technique to detect the imperfections in substances and to measure the properties. In this process the sound wave propagate through solid materials have been examined to detect flaws, cracks and other internal discontinuity in metals. Normally, for NDT purpose the range of frequency is used 1 MHz to 15 MHz.

5. **Electronics** – Ultrasonics is extensively used in the electronics industries, the reason is that ultrasonic wave can be generated, detected and explained by electronic device. Ultrasonic technology is used to cleaning, testing and soldering of electronic component. The surface acoustic wave (SAW) device is an electronic component, which is using ultrasonic frequencies indifferent medium such as cellular phone, machinery and high performance TV receiver etc electronics are everywhere.
6. **Agriculture** – In agriculture, ultrasonic method has been applied to germination of seeds, growth rates and yields of crops and use in destroying viruses, bacteria and fungi. It can also be used to improve the quality of homogenized and is used for pest control and for killing the germs and insects.
7. **Oceanography** – Ultrasonic devices are generally used in oceanography application to investigate the ocean and tracking of submarines.
8. **Sonochemistry** – Sonochemistry is the process, which is used to explain a subject that uses sound energy to affect chemical changes. Most effects of Ultrasonics on chemical processes are due to acoustic cavitations: the formation, growth and implosive collapse of bubbles in a liquid. In the sonochemistry, very high intensity ultrasound can be used to cause chemical and physical changes in substances.
9. **Flow metering** – Flow metering is a technique that uses sound wave to fix the velocity of a fluid flowing in a pipe. The ultrasonic flow metering of the liquids is based on the Doppler Effect. Due to the Doppler Effect, frequency of the reflected wave is different under the flowing conditions. The frequency shift increases when the fluid moves faster.
10. **Material science** – Ultrasonic waves can be practiced for multiple purposes; one of them would be synthesis of material science for determination of such properties of the solids as compressibility, elasticity and specific heat ratios. It can be used to produce an “acoustic microscope” which is able to visualize in detail down to one micro level. Ultrasonics has also been used for the determination of fundamental microstructure characteristic such as grain, size and texture.
11. **Medical ultrasonics** – Ultrasound finds so many useful applications in medical field. Medical technology has made a great contribution in imaging continues to propose amazing advances in various specialties such as cardiology, obstetrics and other internal medicines. Currently, Ultrasonics has brought about a reformation in the field of medical sciences. Ultrasound can be divided into two main parts ie diagnostic and therapeutic. Diagnostic ultrasound is also called sonography or ultrasonography. Typical diagnostic sonography operates in the frequency range of 2 to 15 MHz. It is an ultrasound based diagnostic imaging method used to visualize endomorph body structures including blood vessels, tendons, joints, muscles and other internal organs for possible pathology or injuries. It can also be used to estimate and indentify the source of swelling, pain and infections and also detect tumors. Therapeutic ultrasound used sound waves of very high frequency (1 to 3 MHz) to modify or destroy tissue. On your therapeutic needs the procedures are vary depending, it uses breaking up large kidney, stone, gallstone and treatment of tumors and cysts. An example of medical treatment applications is brain surgery, for which a sharply focused, high intensity beam can destroy disease tissue with high precision. Ultrasound is totally secure & pain-free and also does not necessary anesthesia in most cases.

## FUTURE IMAGE OF ULTRASONICS

The future image of ultrasonics looks auspicious; those in the field of non-destructive testing observe an electrifying modern set of opportunities. In the emergency time, non-destructive testing has played an essential role in the field of defence, military and nuclear power industries. Non-destructive testing technique includes visual inspection testing, eddy current testing, ultrasonic testing, liquid penetrant testing, magnetic particle testing and radiography. NDT technique are increasingly utilized by varied industries such as defense, aerospace, nuclear power, oil and gas, automotive and construction among others. Advancements in the field of NDT have further offered gigantic growth potential for technologies such as phase array ultrasonic testing, computed tomography and data management tools, as these techniques are used to drive highly precise outcomes. The NDT testing industry has been examined and its vital techniques as well as future advancement challenges are indentified. Increasing global challenger has led to dramatic changes in product development and business cycle. With the improvement of new composite materials, manufactures keep looking for fresh ways to inspect them. As these techniques get more technical and the apparatus becomes more sophisticated. There will be increasing need of versatile, cost effective and more reliable volumetric NDT techniques. In the field of NDT, this trend will drive the emphasis on standards and the coming year will continue to proceed as a full-fledged engineering speciality. Niche and fior market are other areas of research and development, presents critical information and factual data about ultrasonic industry. The latest research report of 2018 on global contact ultrasonic sensor market survey major consideration after performing numerous different sensible and extensive analysis on ultrasonic sensor industry. Looking to the future, the primary purpose of contact ultrasonic sensors report is to discriminate, explicate and forecast the global market based on various aspects such as service, application, solution, method, region and vertical. The report designedly inspects every sub-segment regarding the individual development trends, offering the market and the future possibility. Another promising technology of ultrasonic processing is food processing and preservation. The increase in the consumers demand for processed food products has led food manufacturers to focus on modern technologies for preservation and food safety. Innovations and research have been increasing in non-thermal technologies, particularly ultrasonication, for multi-functionalities in food processing. There are several areas of food technology such as crystallization, freezing, bleaching, degassing, extraction, drying, filtration, emulsification, sterilization, cutting, etc. The future possibility and the need for studying the ocean on a global scale also provide a major impetus for new partnerships in oceanography. Ocean scientists have made a number of exciting discoveries in past thirty years, which have changes our view of earth. Some important technologies namely high frequency radars, sea glinders, drifters, underwater hydrophone, sonar these are used to study and understand ocean around the world. The future of

ultrasonics will be a highly experienced company in the application of power ultrasound from research and development activities. Ultrasonics will be developed innovative business ideas and reputation with companies, academic universities and government research institutions around the world for the advancement and commercial use of power ultrasound in industries such as pharmaceutical, petrochemistry, petroleum, minerals, plastics, water and waste effluent, acoustic microscopy, piezoelectric sensor, cosmetics, civil engineering etc. There will be broad variety techniques of possible applications for the use of high power ultrasound in all industries. The use of ultrasound for a cleaning industry is expected to promptly escalate in significance throughout the world. Ultrasonic cleaning uses ultrasound and an appropriate cleaning solvent to clean items and this industry is delineate it as a key technology for the future prospects.

The widespread trends and future opportunities are also taken into consideration in medical ultrasound. Ultrasound is a secure, relatively inexpensive, portable and easily accessible imaging modality, making it a beneficial diagnostic and monitoring tool in medicine. The best known approaches in ultrasound imaging such as magnetic resonance imaging (MRI), Doppler ultrasonic imaging, computed tomography (CT), and others, of providing real-time imaging of anatomical structures. The trend toward cost-effective volume imaging, increase computational power and the availability of contrast agents are three main drivers pushing ultrasound-imaging technology towards functional and volume imaging. Ultrasound power is an essential device which is applicable in several measuring techniques including piezoelectric sensor, acoustic microscopy, ultrasonic imaging in medical for diagnostics and therapeutic purpose. The global ultrasound imaging market is considerable research and development effort in other areas, particular for global markets. The comprehensive data related growth aspects and the global ultrasound market-driving factor is lead to strategic business planning. The global ultrasonic imaging market published the latest research report of medical imaging likely cardiology, urology, gynecology, and vascular clinical applications. There are several important technologies such as 2D imaging, 3D imaging, 4D imaging, Doppler imaging and others, which are used for medical imaging. Ultrasonic imaging is a fledged industry. The global ultrasound imaging market will experience a slight increase over the coming year, climbing from \$7.6 billion by 2022 and is forecast to grow at a CAGR of 4.9% from 2017 to 2022. The main operator for the extension of this market are the rising demand for minimal invasive and non-invasive diagnostic approaches, technology development and an increasing number of patients. Future trends that have a direct impact on the dynamics of the ultrasonic imaging industry incorporate technological modernization and advancement, diagnostic Ultrasound in the field of guided therapy and surgery and commercial application of hand-held devices. Medical ultrasound will continue to extend, offering further advancement in portability, image processing, ubiquity, and display.

## CONCLUSION

It has been concluded in this paper that ultrasonics is still important because it adds a new set of opportunities in different areas such as industry, medicine, aerospace, material science, food processing, pharmaceutical, microbiology, minerals, agriculture, chemical, biotechnology, underwater application, optical data processing, engineering, forensic science, etc. The scope of modern ultrasonics industries will have opportunity to involve the possibilities of applying ultrasonic transducers for development of advanced materials particularly piezoelectric materials in electronics and for interpreting and enhancing the results in computers. New and improved ceramic piezoelectric materials are becoming available on the market. The current states and future trends of ultrasonics extends an unlimited area of research and development activity and it opens up great opportunities for their applications.

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