College of Engineering

Department of Mechanical Engineering

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Senior Design Project Report

Design of an Ultrasonic Cleaner

In partial fulfillment of the requirements for the Degree of Bachelor of Science in

Mechanical Engineering Team Members

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Abstract

Ultrasonic cleaning is used to clean submerged items (into water or special solvent) restore the items back into their original state by using ultrasound. The frequency used in ultrasound varies between 20 to 400 kHz. The duration of the cleaning process is usually between three and six minutes but could take up to 20 minutes depending on the item to be cleaned. This ultrasonic method can be used to clean in various items like tools, jewelry and industrial parts such as pipes, heat exchangers, valves and filters or even in dental cleaning. The estimated components needed for the project should be power source, signal generator (possible with amplifier), transducer and mechanical set-up. In ultrasonic cleaning there is no need to disassemble the part to be cleaned. Ultrasonic cleaning uses cavitation bubbles induced by high frequency pressure (sound) waves to agitate a liquid. It can remove dust, dirt, oil, pigments, rust, grease, algae, fungus, bacteria, polishing compounds, fingerprints, soot wax and mold release agents, and so on.

The practical goal of this project is the design and the manufacture of a working prototype of an ultrasonic cleaner. Also, the project envisage the testing of the prototype for different tasks such as cleaning of car parts, jewelry and corrosion.

Chapter 1: Introduction

1.1 Project Definition

Ultrasonic cleaning is used to clean submerged items (into water or special solvent) restore the items back into their original state by using ultrasound. The frequency used in ultrasound varies between 20 to 400 kHz. The duration of the cleaning process is usually between three and six minutes but could take up to 20 minutes depending on the item to be cleaned. This ultrasonic method can be used to clean in various items like tools, jewelry and industrial parts such as pipes, heat exchangers, valves and filters or even in dental cleaning.

The estimated components needed for the project should be power source, signal generator (possible with amplifier), transducer and mechanical set-up. In ultrasonic cleaning there is no need to disassemble the part to be cleaned. Ultrasonic cleaning uses cavitations bubbles induced by high frequency pressure (sound) waves to agitate a liquid. It can remove dust, dirt, oil, pigments, rust, grease, algae, fungus, bacteria, polishing compounds, fingerprints, soot wax and mold release agents, and so on.

Ultrasonic cleaners are used in the automotive, sports, printing, marine, medical, pharmaceutical, electroplating, hard drive components, engineering, and weapons industries. Experimental ultrasonography is also used to determine the elastic constants of many differentiated materials. Ultrasonic waves are usually sent only through materials at an angle located on the surface of the material (orthogonal). However, in the water an angle can be determined for a longitudinal wave, Materials. Then by measuring the flight time for each of the waves, the elastic constants of the material can be determined.

In ultrasonic cleaner use "Cavitation" and it is the rapid formation and collapse of millions of tiny bubbles (or cavities) in a liquid. Cavitation is produced by high and low pressure waves generated by high frequency which is sound. in the the low pressure phase, these bubbles grow from microscopic size until, during the high pressure phase, they are compressed and implode. When they implode, it creates kinetic energy, and over a small distance, very rapid water movement. This is what does the actual cleaning in an ultrasonic tank also figure 1.1 shows the growth and collapse of a cavitation bubble[1].

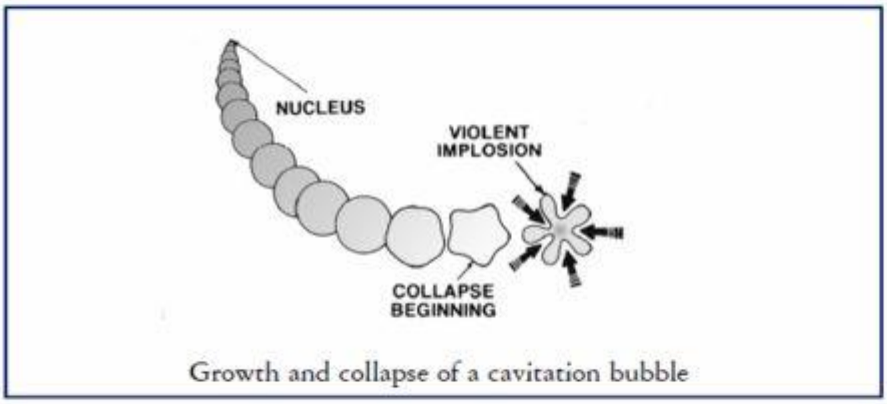


Figure 1.1: Growth and collapse of a cavitation bubble[1].

1.2 Project Objective

The objective of this ultrasonic cleaner project are to learn and apply how to design a prototype that can clean items in good and in efficient way. The machine can save time because it's depending of the properties of ultrasonic cleaner which can clean in short term of time. Also, ultrasonic clean design can save money because the value parts of the design are cheap. In the last the design will be small size that one man can lift and also easy to move and carry.

Objective

1. Design an ultrasonic cleaning machine that can clean items in an efficient way.
2. Design a prototype ultrasonic cleaner.
3. The machine can save time and money also easy to move and carry.

1.3 Project Specifications

The project consists of different components in order to make this ultrasonic cleaner work properly. These components are transducer, controller, generator, solvent and tank . The components will be discussed in section 3.1.

1.4 <u>Applications</u>

Ultrasonic cleaners are used in the automotive, sports, printing, marine, medical, pharmaceutical, electroplating, hard drive components, engineering, and weapons industries also ultrasonic cleaner are used in jewelry industrial also figure 1.2 shows ultrasonic cleaner before and after.

Figure 1.2 : ultrasonic cleaner before and after

Chapter 2: Literature Review

This section describes the project background, previous work is presented and a comparative study with the literature is performed.

2.1 Project Background

Bouncing sound waves off of underwater objects was first used during World War I for submarine detection. The energy levels and frequencies are considerably different than those of an ultrasonic parts cleaners but the principle is the same: electricity is used to stimulate a disk, which generates mechanical waves. As we moved into the new millennium, we brought with us the technology of cleaning, the details of which could fill a book. In order to keep this discussion to a manageable size, we are going to confine the discussion to ultrasonics and follow its path through the 20th century, showing some of the twists and turns that have brought us to the present day's technology.

The history of ultrasonic cleaning dates back almost 70 years to the early 1930s. One of the laboratories at the Radio Corporation of America (RCA), located in New Jersey, discovered the use of ultrasonics for cleaning quite by accident. While using freon to cool the internal components of a radio, they noticed a wave action surrounding a crystal that was operating at 300 kHz. Although this phenomenon had interesting characteristics, it was not actively pursued as a cleaning mechanism for years. Ultrasound was primarily only used for image processing, which was discovered by John Wild who is considered the father of modern ultrasound. He identified transducers that can be used to give off sound waves that reflect back and project pictures of different organs.

Figure 2.1: Submarine.

The majority of ultrasonic cleaning systems, which were developed later in the 1950s, were operated at 18 to 40 kHz.; 18 kHz is the lowest frequency, which is still used routinely in industry today, however, a 6 kHz system was developed in Russia but was short lived. Up until the late 1980s most of the commercially available systems operated at 25 to 40 kHz.

The use of ultrasonics in this frequency range provided cleaning for thousands of applications where no other means of agitation was effective. The energy imparted to a component by ultrasonics is fairly aggressive. This is extremely beneficial in the case of soil that effectively adheres to the substrate. However, it is detrimental to a substrate that is delicate and can be damaged by the robust activity of ultrasonics. In the past seven years, a number of advances in the field of ultrasonics have had a positive impact on the ability to utilize this mode of soil removal on sensitive components. It is during this period that new developments in higher mid-range ultrasonic frequencies become an area of focus.

Every ultrasonic cleaning system consists of three components.

1. Ultrasonic Generator.
2. Transducer.
3. Tank or Vessel.

2.1.2 Ultrasonic Generator

The function of the ultrasonic generator is to utilize the available electrical power, usually 120 or 240 volt 60/50 Hertz, and convert it into a higher voltage and faster cycle to activate the transducer, usually 2000 volts at 40,000 Hertz for a 40KHz cleaning system [2]. This can clearly be seen in figure 2.2 which gives a visual illustration of the process of converting electricity into ultrasound mechanical energy also figure 2.3 show real generator..

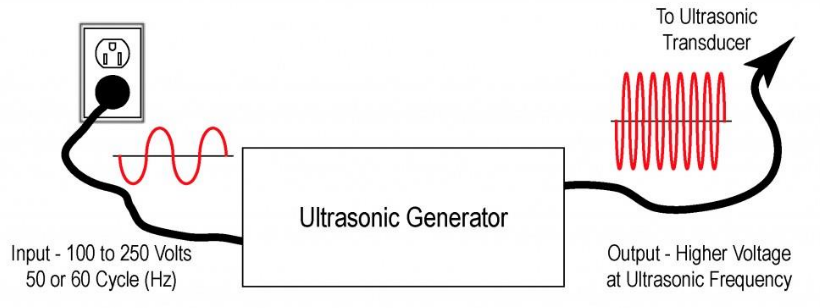


Figure 2.2: Ultrasonic Generator system [3].

Figure 2.3: Real Ultrasonic Generator [4].

2.1.3 Transducer

The function of the transducer is to take a signal in one form (electrical) and convert it into a signal of another form (a sound wave, which also may be expressed as a acoustics pulse or pressure wave). A good example would be a microphone and speaker. We speak into a microphone and produce a sound wave or acoustic pulse that is then converted by the microphone transducer into an electrical signal. This electrical signal is transmitted to a speaker transducer that converts this electrical signal back into a sound wave. The function of the transducer used in ultrasonic cleaning is to convert the electrical pulses from the generator into a sound wave or pressure wave. When this sound wave/pressure wave is driven through a liquid with appropriate amplitude it will cause the formation of a cavitation vapor/vacuum cavity,

which is the scrubbing force found in ultrasonic cleaning systems [2].figure 2.4 shows the details of transducer and figure 2.5 shows real one.

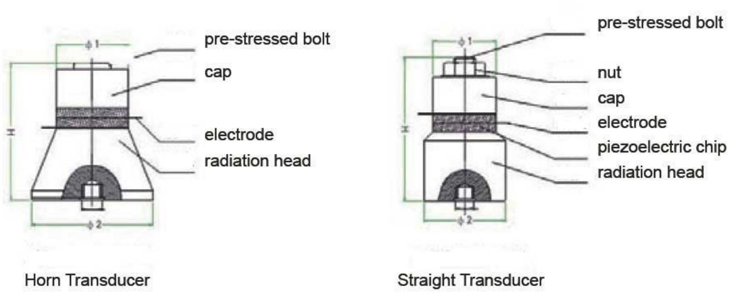


Figure 2.4: Transducer in details [5].

Figure 2.5: Real Transducer.

2.1.4 Tank or Vessel

The transducer must be bonded to the sides or bottom or immersed into (using an immersible Transducer) a tank or vessel filled with a liquid to remove the high intensity pressure wave from the Transducer. Ultrasonic cleaning transducers cannot be operated dry or series damage may result to both the generator and the transducer [2]. Figure 2.6 shows real Ultrasonic cleaner tank.

Figure 2.6: Real Ultrasonic cleaner tank [6].

2.1.5 Ultrasonic cleaner solution

Figure 2.7: Ultrasonic cleaner solution.

2.1.5.1 Alkaline Solutions

Alkaline solutions have a pH of 10 or higher, with the higher pH solutions being more aggressive. They may or may not contain caustic soda, depending on the strength of the cleaner. Moderately alkaline solutions (pH 11.0 to 12.5) are great for almost all metals, including cast iron, steel, stainless steel, aluminum, zinc, copper, brass, and tin. They also work well when cleaning glass, ceramics, and most plastic materials [7]. High caustic solutions are a special case of alkaline solutions. They can be used if needed; however, we should always try more moderate alkaline ultrasonic cleaning solutions first. High caustic cleaners contain hydroxides and usually silicates as well, and are good for removing heavy grease, oils, and waxes from cast iron, steel, and stainless steel. When placing magnesium in our ultrasonic cleaners, a low caustic solution must be used if we are to avoid damaging the part [7].

2.1.5.3 Acidic Solutions

Acid-based solutions have a pH of around 5.0 or lower, with lower pH cleaners being the more aggressive versions. The use of acid solutions is usually material-specific, since some acids will destroy the base material while others will not. They are great for removing oxides from most metals, as long as the solution has inhibitors to protect the base metal [7].

2.1.5.4 Enzymatic Solutions

Enzymatic ultrasonic cleaning solutions are designed to remove protein-based contaminants from parts typically found in the medical and food industries. As such, they are typically used on stainless steel, titanium, brass, and aluminum, but can also be used on glass and most plastics found in laboratories [7].

2.1.5.5 De-ionized Water

DI water is safe to use on any material that can safely be placed in water, which means it will work on nearly every material. Metals, fabrics, glass, plastics, epoxies, and hard rubber materials are all acceptable. The type of part should be considered when DI water is used as an ultrasonic cleaning solution, since many parts will oxide quickly when removed from the solution unless they are subsequently placed in a wetting solution and immediately dried. Frictionless bearings, small servo motors, switches, and printed circuit boards are some examples of the parts requiring special post-cleaning treatment [7].

2.1.6 Frequency

• The lower the operating frequency the larger the implosion bubble.

• The higher the operating frequency the smaller the implosion bubble.

As we lower the operating frequency the implosion bubble becomes larger and releases more energy when they implode but we also lower the number or amount of events. As we increase the operating frequency we reduce the size of the implosion bubble releasing less energy when they implode but we also increase the number or amount of events. The maximum size of the cavitation event is proportional to the applied frequency. At equal power inputs to a 25 KHz tank, a 40 KHz tank, and a 68 KHz tank the 40 KHz tank will have 60% higher number of events than the 25KHz tank, and the 68 KHz tank will have 70% higher number of events than the 40 KHz tank. As we increase the frequency we increase the amount of cleaning events and cleaning is more homogeneous but less power is released in each event so cleaning ability may be reduced [2]. Table 2.1 shows the different frequency for different part.

Part or Component	Cleaning Time Range (min)	Temperature (Degrees F)	Ultrasonic Cleaner Frequency (kHz)
Engine Block	45-60	150-165	25
Cylinder Head	30-45	150	40
Fuel Injectors	8-10	150	40
Carburetors	10-20	145	40
Alternator Brush Holder	5-8	130	25
Musical Instrument (Brass Trumpet)	2-5	100	40
Printed Circuit Board with components	3-10	120-135	40 or 68
Surgical Instruments	10-15	Ambient	170

Table 2.1: Ultrasonic cleaner frequency for part [8].

2.2 Previous Work

Taking a look at the means in which washing occurs using the ultrasound principle paves the way for various different researches. One such research conducted by Seda Ersus Bilka and Fulya Turantasb titled "Decontamination efficiency of high power ultrasound in the fruit and vegetable industry" discusses how ultrasound cleaning was used in the food market, and more specifically the food and vegetable industry. They first state by stating "In recent years, there has been an increasing demand for safe antimicrobial substances and sanitizers for the food industry" (Lopez-Gomez et al., 2009). This initially sets up the scene on the form of cleaning that would be used, decontamination, and measuring the relative efficiency of this means of decontaminating through ultrasound waves. Considering the means in which vegetables are washed normally, the authors first bring up how normally the vegetables are washed in water that doesn't contain in chlorine, more specifically, 0 to 30 ppm. However due to the toxic concerns these types of cleaning compounds bring, the research aimed to mediate this problem through the use of Ultrasound in the cleaning processes. The authors state "The application of ultrasound is a non-thermal technology which contributes to the increa

se of microbial safety and prolongs shelf-life, especially in food with heat-sensitive, nutritional, sensory, and functional characteristics" (Alegria et al., 2009; Cao et al., 2010; O'Donnell et al., 2010; Wang et al., 2011; Bhat et al., 2011). These means of mediating such concerns works through cavitation's that occur when using "power ultrasound" (Piyasena et al., 2003). The results found can be seen in table 2.2.

Product	Ultrasound (US) parameters	Treatments	Microbial reductions[a] ($\log_{10}$ CFU/g sample)
Strawberry	350 W/L, 40 kHz, 20 °C, 10 min	US alone	TVC: 0.6 YMC: 0.5
Lettuce	280 W/L, 20 kHz, 53 min	US alone	*E. coli* O157:H7: 4.4 in wash water
Strawberry	120 W, 35 kHz, 15 °C Sample/water: 1/25	US alone	TVC: 0.6 YMC: 1.4
Red bell pepper	120 W, 35 kHz, 15 °C Sample/water: 1/25	US alone	*L. innocua*: 1.98
Iceberg lettuce	10 W/L, 32–40 kHz, 10 min Sample/water:1/20	US alone	*S. typhimurium*: 1.5

Table 2.2: Products used in study with ultrasound parameter analysis [9].

Taking the iceberg lettuce as a sample result, we can see reductions that exist at ($P < 0.05$) from the water control in the decontamination of fresh produce. It is stated in the research that " in the washing of iceberg lettuce, the average reductions for 25, 32–40, and 62–70 kHz treatments were 1.4, 1.3, and 1.3 log10 CFU/g respectively" Which when using the ultrasound application in water significantly reduced the numbers of S. Typhimurium at around 97.9%. (Fulya, 2013)

Another such research conducted on the means in which ultrasound waves can be used for cleaning was in a more specific setting, optics. The research titled Research on ultrasonic cleaning technology of optical components conducted by Lingyan Jiao, Tianjin Jinhang,Tianjin Key Lab and Yi Tong, Tianjin Jinhang. The state in the research that "Along with the higher demand of super smooth optical surface, the cleaning technique that is the critical process to obtain super smooth surface has to meet even higher standards." (Yang,

2014) The continue by discussing how ultrasound cleaning technology is the more effective mean of achieving higher efficiency when cleaning optical lenses. They continue elaborating on this point through the discussion of the mechanism that was the foundation of the research. They discuss how the complex frequency present in ultrasound generates a chemical process correlating the megasonic boundary layer and the particles removed. (Yang, 2014). Upon completion of the research, their results showed that than that of single frequency ultrasound for the particles removal effect, the new complex frequency which include both ultrasonic and megasonic cleaning technologies are very necessary for cleaning optical components [9]. Figure 2.8 shows real ultrasonic cleaner for vegetables.

Figure 2.8: Ultrasonic cleaner vegetables [11].

2.3 Comparative Study

2.3.1 First study

A comparative study of the cleaning effect of various ultrasonic cleaners on new, unused endodontic instruments[10].

Background and aim:

This study was carried out to compare three different ultrasonic cleaner devices in the cleaning process of endodontic instruments by scanning electron microscope (SEM).

Methods:

In this study, 120 unused brand new hand and rotary instruments were examined after removing from the sealed package. The instruments were randomly divided into six groups of 20 rotary or hand files each and observed by SEM before ultra-sonication. Then, every pair of hand and rotary instruments was cleaned using one of the ultrasonic cleaner brands. Again the instruments were examined by SEM and assessed in three different parts, tip, middle and distance 16 (D16). SEM data were analyzed by Kurskal–Wallis and Mann–Whitney tests. figure 2.9 shows hand instrument before and after cleaning.

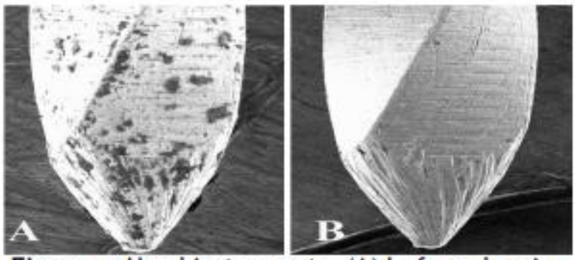


Figure 2.9 Hand instruments, (A) before cleaning and (B) after ultrasonic cleaning (× 150)

Results

The tip of the endodontic instruments was the most contaminated area before ultrasonic cleaning. Statistical analysis showed that all of the tested ultrasonic devices were significantly effective machines for debris removal from endodontic instruments. The hand and rotary instruments cleaned by one of the devices were significantly cleaner than the others ($P < 0.050$). There was a significant difference in cleaning of the separate parts of the instruments during ultra-sonication among ultrasonic cleaners. The tips of the instruments were significantly cleaner than the D16 parts ($P < 0.050$).

Conclusion

Various ultrasonic devices have different ability for cleaning of endodontic instruments. KEYWORDS: Endodontic Instruments, Scanning Electron Microscope, Ultrasonic Cleaner

2.3.2 Second study

Comparison of ultrasonic cleaning schemes: a pilot study [12].

Objective

Ultrasonic cleaning is an effective method for cleaning dental instruments prior to sterilisation. However, there are few studies that directly compare precleaning and ultrasonic cleaning solutions. This study evaluated the efficacy of different ultrasonic cleaning schemes.

Method and materials:

Twenty representative dental instruments, five of which were soiled with a mixture of blood and hydroxyapatite, were used in a series of cleaning runs. Cleaning employed a presoaking agent, ultrasonic cleaning, or a combination of both. Two presoaking agents (Non-ionic Ultrasonic Cleaning Solution and ProEZ Foaming Enzymatic Spray) plus five ultrasonic cleaners (UltraDose, General Purpose Cleaner, Co-enzyme Concentrate, Enzol Enzymatic Detergent, and Non-ionic Ultrasonic Cleaning Solution) were compared, with tap water serving as a control. There were two cleaning times: seven and 15 minutes. After rinsing, the working ends of the instruments underwent scrubbing for 20 seconds using a dental polishing brush held in a haemostat. After scrubbing, the brush and instrument were placed in a tube containing sterile saline. Vortexing of the tube lasted 30 seconds. Testing for the post-cleaning presence of blood involved Hemastix dipsticks. These sticks measure minute amounts of blood in urine and can detect as few as 35 red blood cells per ml. Comparisons of colour change were made to a standard scale followed by assignment of numeric values.

Result:

Tap water was the poorest cleaning solution, while UltraDose was the most effective. Blood removal improved when cleaning time was increased from seven to 15 minutes. The combined effect of a presoak immersion followed by ultrasonic cleaning was the most effective cleaning scheme overall. Cleaning by either ultrasound or presoaking only was less effective. Some instruments were more difficult to clean than others.

Conclusion

Within the constraints of the small number of test runs performed, it was concluded that application of a presoak agent before ultrasonic cleaning produced the most effective instrument-cleaning regimen.

2.3.3 Third study

The effect of pre-soaking and time in the ultrasonic cleaner on the cleanliness of sterilized endodontic files [13].

Aims

To assess whether pre-soaking files in an enzymatic cleaner prior to ultrasonic cleaning had any effect on cleanliness and also to assess the effect of the time that endodontic files spend in an ultrasonic bath prior to sterilization on their overall cleanliness.

Methodology

Twenty root canals in a total of ten patients were cleaned and shaped using conventional techniques. After use, some of the files were pre-soaked and then ultrasonically cleaned for either 5, 10, 30 or 60 min. Other files had no pre-soaking and were then ultrasonically cleaned. There were two control groups, one where the files were pre-soaked and not ultrasonically cleaned and the other where the files were previously pre-soaked nor ultrasonically cleaned. All files were then subjected to a standard packing and autoclaving process. Following autoclaving, the files were examined using a light microscope at a magnification of 40 ×. The cutting section of each file was divided into two parts, the tip and the shaft, for visualization under the microscope. Any debris or cement on the files was measured using a modification of the scale used by Smith et al. (Journal of Hospital Infection, 51, 2002, 233). The data were analyzed using one-way analysis of variance.

Results

Pre-soaking had no significant effect on the cleanliness of the files (P = 0.18 at the tip, P = 0.93 at the shaft). Ultrasonic cleaning had a significant effect on the cleanliness of the files (P <0.00) but there was not a linear relationship between cleanliness and the ultrasonic cleaning time. There was little benefit in extending the ultrasonic cleaning time beyond 5 min. Calcium hydroxide deposits on two files were resistant to ultrasonic cleaning.

Conclusions

There is no benefit in pre-soaking endodontic files prior to ultrasonic cleaning. The optimum time for ultrasonic cleaning was between 5 and 10 min. Further ultrasonic exposure, up to 60 min, did not improve cleanliness. Although a majority of files were free from debris following ultrasonic cleaning, a substantial minority still retained debris. This supports the case for endodontic files being single-use only.

All the study are about endodontic instruments, cleaning schemes and the effect of pre-soaking and time in the ultrasonic cleaner on the cleanliness of sterilized endodontic files some of them Ultrasonic cleaner were good and other not much. Our project study will be focus about cleaning the small industrial items. It will clean the rust and other bad effect into the items. Also our project can clean jewelry. All of that we can escape the study of human body because all the part of our items it's for industrial and for jewelry.

Chapter 3: System Design

3.1 Design Methodology and Design Constraints

3.1.1 Design Methodology

There are some important factors to concentrate on before and while we build our project to keep them in mind to help our project to be as efficient as possible and as effective as it can get. The following are our important points that we focused on:

- Functionality
- Economical.
- Easy to manufacture.
- Practical.
- Applicable.
- User Friendly
- Cheap

These points are important for us to build and manufacture our project. The project should be functional to do its job effectively with any extra intervention by an outside mean. And it should be economical for us and for the possible future users if it is decided to mass produce this idea as it should be easy to manufacture. Ultrasonic cleaning machine should be practical and applicable in its usage in the industrial workplace to clean component that requires cleaning without any issues facing the user as it should be user friendly without any complication in its usage. Finally, we are designing this project to be as cheap as possible compared to other means of cleaning not only to use it in big companies but also in some domestic use. After we took these points into consideration we start build and manufacture the project.

3.1.1.1. Transducers

The transducers job is to create the ultrasonic waves that in return create the cavitations in the solvent which cleans the component from the contaminates. The electrical energy it receives will be subsequently transformed into ultrasound energy. The horn transducer has a cylindrical geometry at its surface area, with the angle reduction reaching 90 degrees when reaching the surface. This shape will help it to release the ultrasonic in a broad direction to cover as much space as possible as seen in Figure 3.1.

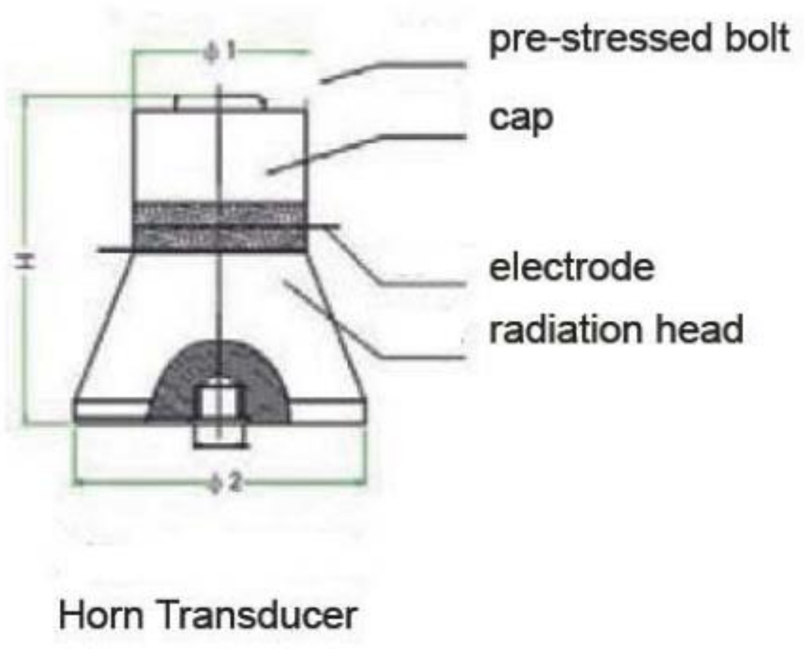


Figure 3.1 Schematic of a horn transducer

Figure 3.1 shows a visual representation of the transducer with the components within it. The dimensions of the transducer are as follows.

- Length= 55mm
- Weight= 350g

3.1.1.2: Ultrasound Generator

The ultrasound generator is what will give the energy to the transducers for it to produce the ultrasonic waves. The generator used in this project was chosen to be 1500W in power to produce enough energy for the 15 transducer. The generator will be located outside of the actual tank that hold the solvan and the component to be cleaned, connecting it to the transducer using wires.

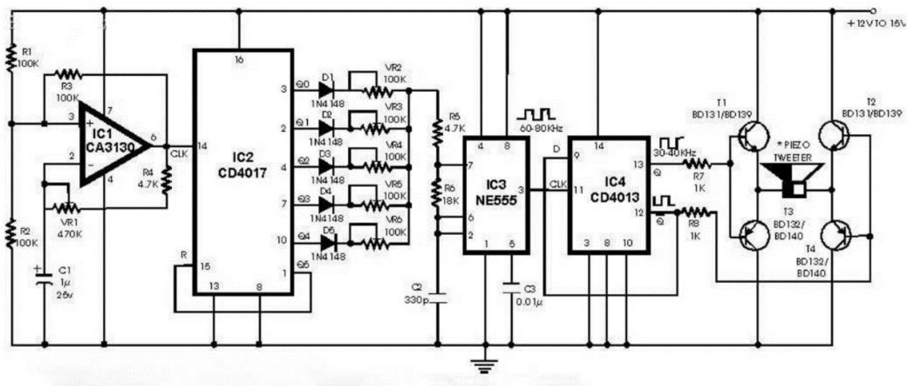


Figure 3.2: Electric Schematic of Ultrasound Generator

The manner in which the device operates can be understood from the schematic of the generator in figure 3.2. The IC amplifier through the input would then allow for the amplification of the energy and movement of it to the alignment of resistors. This will allow for different varying input of different ultrasound energies, up to 1500W, to cater to the number of transducers that are to be included within the final casing through an analog control found on the casing of the generator. The inclusion of a Piezo Tweeter within will lead to the energy supplied to be transformed into high audio frequencies; ultrasound.

The dimensions & Specifications

- Length = 300mm
- Width = 360mm
- Height = 160mm
- Working current: 5.5A
- Working voltage: 200V-240V/50HZ, 100V-120V./60HZ
- Frequency: from 20khz to 40khz (such as 20khz, 25khz, 28khz,30khz,33khz 40khz)

3.1.1.3. Circuit Board

The circuit board will be the bed in which the transducers will be wired on to. The circuit board will allow for the wiring to be done in order to connect the transducers with the ultrasound generator. The circuit board used in the prototype will be located within the actual tank because of its direct attachment with the transducers.

Table 3.1 The Specifications of the Circuit Board

Frequency	40 KHz.28khz.25khz
Power	120w
Drive transducer	One 50w transducer, one 60w transducer, one 100 transducer, two 50w transducers, two 60w transducers
Power Supply	Input: 200V~230V AC
Weight	300g/pcs

3.1.1.3. Tank

It is a box in shape metal or glass that will hold within it the solvent and the component to be cleaned. Also it is attached to its bottom the transducers and the board circuit. And it is important to make sure that the tank can hold the ultrasonic vibration that is generated from the transducer so it won't break or leak during the cleaning.

Table 3. 2Contains details of each part of the prototype

Part	Information	Functionality	Dimension	Cost
28KHz 100W Ultrasonic Cleaning Transducer PZT-4 Type: BJC-28100T-68HS 15 pieces	The component possesses a frequency of 28Khz, a power of 100W, and a resistance factor of 10-22 Ohms.	This component will serve as the primary transformer for the conversion of electricity into ultrasound waves.	66mm length, 700g per piece.	Each piece costs $10 = 37.5 SAR Total: SAR

2400 W Ultrasonic Generator 1 piece	The ultrasound generator is the basis of the project, functioning at a working current of 5.5A and a working voltage of 200V-240V and possessing a frequency of up to 40Khz.	Generating the ultrasound required to be induced by the transducer for the operation.	300 mm long, 360mm wide, and 160mm high.	$300 = 1125 SAR

120 W 220V Ultrasonic Generator Circuit	The circuit possesses a frequency of 40Khz, operating with transducers that work up to 60W.	The generator will serve as the lifeline of the other components since it will provide functionality.	300g per piece	$56 = 210 SAR
Tank	A good quality fish tank aquarium that can hold the solvent without cracking or leaking.	The tank will hold the solvent and the component to be cleaned in it.		$150 = 563 SAR

3.1.2 Design Constraints

In designing this project we faced many limitations regarding our prototype parts. Ranging from material, economical, geometrical constraints, and social which we will discuss all belew.

3.1.2.1. Material

Although the project looks simple in its material selection to choose whatever suites the application, we are constrained to a very limited number of material due to the lack of such component in Saudi Arabia. For example, we are limited in choosing they type of tank and the shape and size of it, and will it handle the vibration from the transducers or not.

3.1.2.2. Economical

In designing this project we faced the general limitations regarding our prototype parts. They are hard to come by in Saudi Arabia. So we had to resort to other means of getting these parts by purchasing them from the internet and ship the parts from overseas to our homes. This process took a long time and more money to provide the parts we need for the prototype to be completed. And it is important to get these parts right the first time when we order it such as the right type and amount of parts and the required power produced by the generator and the right frequency of the transducer. This is why it is important to research and calculate the required parameters before ordering such things from abroad.

3.1.2.3. Geometrical constraints

Other constraints we had deal with is the size of our prototype. Although the project can clean massive parts in the industries such as pipes and heat exchanger we had to limit our self to smaller tools and equipments. As we said before it is hard to find the perfect size for every part of the prototype. We are limited to a specific suppliers of every part, and some of the tank are not built for the specific job of ultrasonic cleaning. So it is not in our hands to choose how big and how much component we can clan in one go as it is predetermined by the builders of the tank.

3.1.2.4. Social

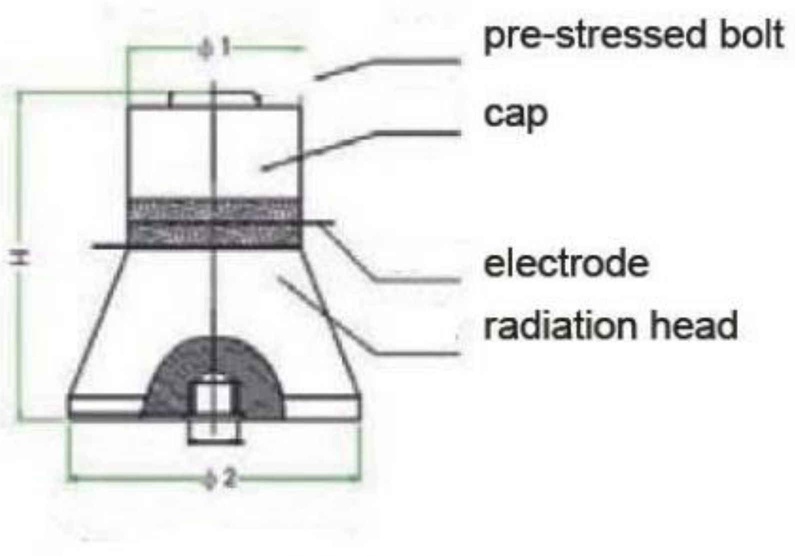
Comfortability breeds contempt, meaning that new concepts that challenge what people are used to are usually met with criticism. Social constraints include a lack of trust and acceptance for the new technology, however due to the innovative revolution that has become more apparent in today's time will allow for people to be more inclined to understand and apply the concept.

Chapter 4: System Testing and Analysis

4.1 Experimental Setup

4.1.1 Transducer

The transducers job is to create the ultrasonic waves that in return create the cavitations in the solvent which cleans the component from the contaminates. The electrical energy it receives will be subsequently transformed into ultrasound energy. The horn transducer has a cylindrical geometry at its surface area, with the angle reduction reaching 90 degrees when reaching the surface. This shape will help it to release the ultrasonic in a broad direction to cover as much space as possible as seen in Figure 4.1.



Horn Transducer

The dimensions & Specifications

- Frequency: 28Khz
- Power: 100W
- Capacity: 5200pf (pzt8)
- Radiating surface: 68mm
- Resonance Resistance: 10-22 Ohms.
- Piezoceramics size: 45*15*5
- Power Supply: Input: 220V~240V AC
- Length: 66mm
- Weight:700g

Main feature

- High efficiency: high mechanical parameter Q, the transduction efficient between electricity and sound above 95%.
- High amplitude: the transducer strength is improved by fixing the high speed vibrator directly on the base of washing groove with bolt. Compare with a magnetic expansion vibrator, its amplitude can be improved above 50%.
- Good heat resistance: a large range of working temperature,low resonance impedance and heat productivity.
- Good construction: fastened by bolt, easy for assembling, high reliability.

4.1.2 Power generator

The ultrasound generator is what will give the energy to the transducers for it to produce the ultrasonic waves. The generator used in this project was chosen to be 2400W in power to produce enough energy for the 24 transducer. The generator will be located outside of the actual tank that hold the solvent and the component to be cleaned, connecting it to the transducer using wires.

The dimensions & Specifications

- size :300mm*360mm*160mm(L*W*H)
- Working current: 7.5A
- Working voltage: 200V-240V/50HZ, 100V-120V./60HZ
- Frequency :from 20khz to 40khz (such as 20khz, 25khz, 28khz,30khz,33khz 40khz)

Typical characteristics of such Ultrasonic Generator

- Push-button programming control with digital display of settings, we can see the working condition on the display panel(such as the working frequency,working current).
- Adopting digital control technology,Perfect circuit design, stability of power output.
- Over current protection, overheating protection, over-voltage protection.
- High and low voltage circuit is completely separated,operational safety.
- The Ultrasonic Power,Timer and Frequency can be adjust as required to meet with different products cleaning.

  (Time control: 0-59’59”)

  (Range of Power Control:0-100%)
- The efficient cooling system.
- Sweep frequency function.

4.1.3 Tank

We use in this project Stainless steel box to hold inside the transducer and water. it is important to make sure that the tank can hold the ultrasonic vibration that is generated from the transducer so it won’t break or leak during the cleaning.

The dimensions & Specifications

- size :130mm*130mm*123mm(L*W*H)
- type of steel: 416.

4.2 Results, Analysis and Discussion

4.2.1 Goals

In this experiment, the major thing that needs to be considered is to clean items by waves. Our goal in this project is clean with small period of time.

4.2.2Experimental methodology

1. Tank to hold the transducer and water.
2. Transducer to generate waves.
3. Powers generate to produce power.

4..2.3System testing

1. Procedure

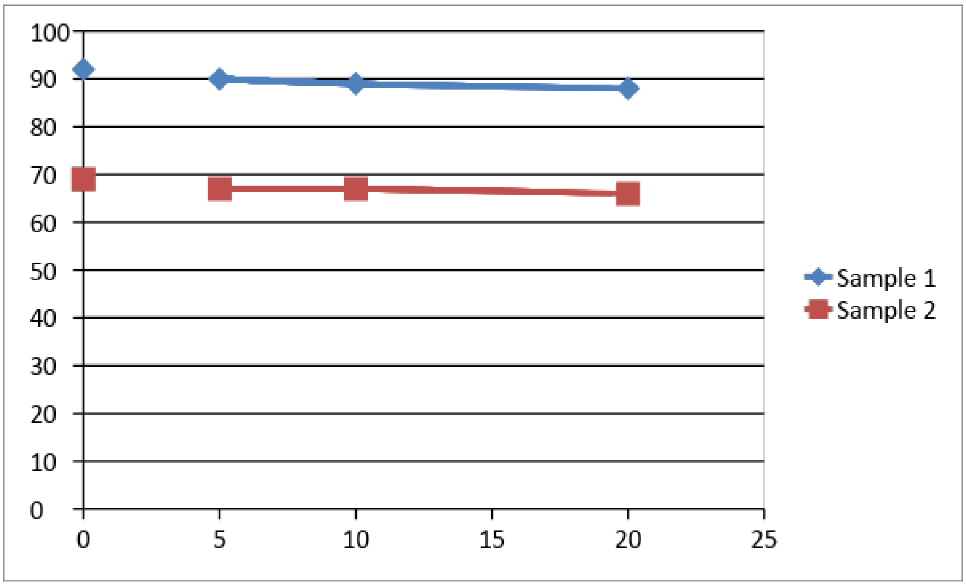
First of all connect the wire for transducer and generator after that put the sample in the tank filled with water and solution. In the last switch on power then start and choose sweep.

As you can see in the table 4.1 it shows tow samples and the different in weight with time.

Time	Sample 1	Sample 2	Power
0 min	92 g 	69 g 	0 A
5 min	90 g	67 g	1.5-1.9 A
10 min	90 g	67 g	1.5-1.9 A
20 min	88 g	66 g	1.5-1.9 A

Table 4.2 Shows the before and after picture.

Sample	Before	After
1		
2		



Chapter 5: Project Management

5.1 Project plan

Here in project plan we will shear a limited time duration to each task, even tho that we have a very limited time to finish the project. Table 5.1 shows duration of each task

Table 5. 1Duration of the tasks

No	Tasks	Start Date	Finish Date	Duration
1	Gantt chart	20/2/2018	20/2/2018	1 Day
2	Introduction	21/2/2018	1/3/2018	9 Days
3	Literature review Project Background Ultrasonic Generator Transducer Tank Ultrasonic cleaner solution Frequency Find suppliers	21/2/2018	1/3/2018	9 Days

4	System Design Design Methodology Transducers Ultrasound Generator Circuit Board Tank Design Constraints	1/3/2018	15/3/2018	15 Days
5	Midterm Presentation	15/3/2018	29/3/2018	14 Days
6	Project management Project Plan Contribution of Team Members Project Execution Monitoring Challenges and Decision Making	1/4/2018	5/4/2018	4 Days

	Project Bill of Materials and Budget			
7	Project analysis Life-long Learning Impact of Engineering Solutions Contemporary Issues Addressed	5/4/2018	12/4/2018	7 Days
8	Conclusions and Future Recommendations	14/4/2018	20/4/2018	6 Days
9	System Testing and analysis	14/4/2018	20/4/2018	6 Days
10	Prepare for final draft report	21/4/2018	25/4/2018	4 Days

5.2 Contribution of Team

In this project we give to one or more than one task to do and the leader also advisor are responsible to assign each task to the group members. Table 5.2 shows contribution for each members.

Table 5.2 Task distribution

No.	Task	Assigned	contribution
1	Gantt chart	Othman Bassam	60% 40%
2	Introduction	Othman Saad Abdullah	10% 45% 45%
3	Literature review	Othman	60%

	Project Background	Bassam	20%
	Ultrasonic Generator	Abdulaziz	20%
	Transducer		
	Tank		
	Ultrasonic cleaner solution		
	Frequency		
	Find suppliers		
4	System Design	Bassam	100%
	Design Methodology		
	Transducers		
	Ultrasound Generator		
	Circuit Board		
	Tank		
	Design Constraints		

5	Midterm Presentation	Abdulaziz Othman Saad Bassam Abdullah	60% 10% 10% 10% 10%
6	Buying Equipment	Othman Abdulaziz	50% 50%
7	Project management Project Plan Contribution of Team Members	Othman	100%

	Project Execution Monitoring Challenges and Decision Making Project Bill of Materials and Budget		
8	Project analysis Life-long Learning Impact of Engineering Solutions Contemporary Issues Addressed	Abdulaziz Saad Abdullah	30% 30% 30%
9	Conclusions and Future Recommendations	All	100%
10	System Testing and analysis	All	100%
11	Prepare for final draft report	All	100%

5.3 Project Execution Monitoring

There are many activities during the semester. Table 5.3 Shows meeting time for each activities.

Table 5.3 Table of activities

Time	*Activities*
One time a month	Assessment class
Weekly meeting	With group members
Weekly meeting	With advisor
Sun, Mar 25	Midterm presentation
Tba	Test the system
May 3	Final presentation

5.4 Challenging and Decision Making

Throughout our senior project period we faced many difficulties and challenges such as:

1. Material and equipment resourcing (purchasing).

2. Design problems.

5.4.1 Material and equipment resourcing (purchasing)

In this project we face a big problem related to the equipment that there are not too many store you can buy from them. The problem we face also time because every time the seller told us that the goods will come in this week and this not happen.

5.4.2 Design problems

We face problem in the design because we didn’t know the dimension of the goods so we can design the actual tank.

5.5 Project Bill of Materials and Budget

Table 5.5 Show the cost of each material and equipment purchased

Table 5.5 List of material and cost

Equipment	Cost (SR)
Power Generator	1600
Transducer	960
Circuits board	0
Shipment	1600
Tank	2000
Total	6160

Chapter 6: Project Analysis

Chapter 6: Project Analysis

6.1 Life Long Learning

We have improved many skills and gained new ones during our project development. Through the project's life cycle, many skills have been added to us. There are several ways that helped us in gaining such profits, group work, deadlines and the need for communication. Each of them participated in us gaining knowledge and experience. The most significant four learning areas will be illustrated next.

6.1.1 Improve our Skills in Some Software Tool

We used several software tools, such as Microsoft Word, Solidswork, and Microsoft PowerPoint. The previously mentioned tools are considered a new gained knowledge since they are new to us. We intended to use these tools professionally. A lot was learned after dealing with these tools that have not been learned before.

6.1.2 Time Management Skill

An important skill that was gained through working with the project, is the management skill. After setting the objectives, we tried our best to meet the goals within a restricted time. The time-management was a struggle but we came over it through disturbing the tasks within our group members. The different tasks that we faced during working on our project made it more difficult but with each challenge, we gained a new skill and more control over time-management. GANTTS chart was built to manage our time. It included all the tasks alongside with subtasks that were a must to be done for the sake of the project. GANTTS chart is a very useful tool that assists us in knowing the start and end dates and time of tasks.

6.1.3 Problem Solving

Going on the project totes a lot about how to brainstorm solutions for the problems we faced. There were problems with the design, there were problems with choosing of the materials and many other steps during the process. we had first to analyze the problem, Learn causes and see how our changes may affect the outcome of the work

6.2 Impact of Engineering Solutions

Our project revolves about Ultrasonic cleaning is an environmentally friendly alternative to cleaning continuous materials, such as wires, cables, tape or pipes. The effect of the cavity generated by the ultrasonic energy removes lubricant residues such as oil or grease, soap, stearate or dust. Ultrasonic cleaning has become easy to use. As in the past, every member of the society can get it at home. Previously, it was only famous for its factories and major companies. It has also become used in hospitals and clinics. The ultrasound cleaning is a necessary tool for getting rid of for all syringes, it is not economically feasible to get rid of all the tools Ultrasonic cleaning also helps factories and companies reduce material losses.

Chapter 7: Conclusion

7.1 Conclusion

In this project, efforts have been made to describe the unique cleaning capabilities of the ultrasonic process. When they are properly employed, ultrasonic cleaning methods can provide a highly effective means of removing insoluble particulates from hard substrate surfaces. As you can see in this project our machine work and as result in chapter 4 you can see the difference before and after clean it's take about 40 min.

We get a lot of experience in this project like for example how to connect the wire for transducer in parallel or series and we study the difference between the two. Also, we get experience in design and build the tank and finally to connect everything to power generator and make the project work.

Our challenges were time consume and it work or not the main problem that the part came late so we afraid that the project will not finish but finally it came and work. Also, from the challenge was the budget we set target that the project must be under 6000 SR and we kept under the target.

In this project we leaner a lot for example how to handle budget and how to stick with it. Also, we learn how to build tank and best design for it. Also, we learn and study a lot about ultrasonic waves.

7.2 Future Recommendations

Our recommendation to improves this project for others team are

1. Build more powerful device by increase the number of transducer.
2. Choose proper stainless steel for tank to make sure that the tank will not affect by chemical.
3. Do other shape for tank other than rectangular and see what the difference is.
4. Use other solution and study the time and difference.

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