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імені ІГОРЯ СІКОРСЬКОГО»
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“____”_____2021р.

Дипломна робота

на здобуття ступеня бакалавра

зі спеціальності 163 «Біомедична інженерія»
(код і назва)

на тему: Модель звукової високочастотної зубної щітки у програмі Solidwork

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Department of BIOMEDICAL ENGINEERING
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«As a manuscript»
UDC 615.849.19

« Approved for defense»
Head of the Department of BMI
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(signature) (initials, surname)
" ___ " _____2021

Diploma thesis

For a bachelor's degree

in the specialty 163 « Biomedical engineering »
(code and name)

topic: Model sonic toothbrush with high frequency vibration in Solidwork

Completed: 4th year student, group BM-73i
(group code)

Sara Adly _____
(Full Name) (signature)

Supervisor Assoc. dep. BMI, Ph.D., Assoc. prof. L.E. Kalashnikova _____
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" ___ " _____2021

TASK
For student`s bachelor thesis

Sara Adly
(Full Name)

1. topic Model sonic toothbrush with high frequency vibration in Solidwork

scientific supervisor of the dissertation Ph.D., Assoc. prof. L.E. Kalashnikova
(last name, first name, patronymic, academic degree, academic title)

approved by the order of the university No257 / 19-si from 11/18/2021

2. The deadline for students to submit a dissertation 06.06.2021

3. The object of study is sonic toothbrush

4. the subject of research is high frequency vibration

5. List of tasks to be developed create a high frequency sonic toothbrush in the SOLIDWORK software. When using the Fritzing program, create a printed circuit board of the device being developed. Use the Ansys program to calculate the vibration frequency of the sonic toothbrush model.

6. Approximate list of graphic material 1 tables, 22figures

7. Approximate list of publications: the bachelor thesis protection

8. Final deadline 07.06.2021

SCHEDULE

№ з/п	Name of stages of execution diploma thesis	Deadline for stages diploma thesis	Note
1	Analysis of scientific literature and patent databases on a given topic	10.11.2020	
2	Development of the content and structure of bachelor thesis	26.02.2021	
3	Investigation of structures sonic toothbrush	12.03.2021	
4	Development of the program solidwork a to create a model of a sonic toothbrush	26.03.2021	
5	Using the Fritzing program, create a printed circuit board of the device being developed. Use the Ansys program to calculate the vibration frequency of the sonic toothbrush model.	24.04.2021	
6	Safety and precautions	24.05.2021	
7	Registration of bachelor thesis	01.06.2021	
8	Getting a review and feedback	04.06.2021	
9	Passing norm control	07.06.2021	
10	The bachelor thesis protection	16.06. 2021	

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ABSTRACT

The volume of work is 60 pages, the number of illustrations - 23, tables - 1, appendices - 0, sources on the list of links - 30.

Oral hygiene is one of the main factors affecting the health of teeth, oral cavity and diseases of the gastrointestinal tract. Therefore, an important direction in the development of modern dentistry is the development of new personal hygiene products. One of the directions in these developments is the sonic toothbrush. Sonic toothbrushes are used for deep cleaning of teeth and interdental spaces. Easy-to-clean dentures with removable dentures are often recognized as the most powerful and effective toothbrushes on the market. Sonic toothbrushes provide superior cleaning action against surface blemishes and brightens and whitens your teeth with regular use

The relevance of the dissertation lies in the development of a high-frequency sonic toothbrush, in the body of which there is a channel for supplying washer fluid directly to the teeth.

Purpose of the work was to create a model of a sonic high-speed toothbrush in the solidwork program

Objectives of the study were:

1. In the SOLIDWORK program, create the proposed sonic toothbrush.
2. Using the Fritzing program, create a printed circuit board of the device being developed
3. Using the Ansys program, calculate the vibration frequency of the sonic toothbrush model

The article examines the creation of a model of a high-frequency toothbrush in the solidwork program. Frequency-amplitude characteristics of the developed device for personal oral hygiene are investigated. The electronic circuit of such a device has been analyzed in detail.

Key words: sonic toothbrush, plaque removal, toothbrush, dentistry, oral diseases, oral hygiene.

РЕФЕРАТ

Обсяг роботи 60 сторінка, кількість ілюстрацій - 24, таблиць - 1, додатків - 0, джерел в списку посилань - 30.

Погана гігієна порожнини рота є однією з причин ряду стоматологічних захворювань. Також своєчасна і ефективна гігієна може бути як засобом профілактики, так і засобом лікування різних захворювань. Однак існує ряд проблем, пов'язаних із забезпеченням належного очищення поверхонь зубів. Пасти та щітки, що використовуються населенням для чищення зубів, в більшості випадків не здатні забезпечити ефективність видалення патогенного нальоту [17].

Актуальністю є те, що гігієна порожнини рота - один з основних факторів, що впливають на здоров'я зубів, порожнини рота і захворювання шлунково-кишкового тракту. Тому важливим напрямком розвитку сучасної стоматології є розробка нових засобів особистої гігієни. Один з напрямків в цих розробках - звукова зубна щітка. Звукові зубні щітки використовуються для глибокого чищення зубів і міжзубних проміжків. Легко очищувальні зубні протези зі знімними протезами часто вважаються найпотужнішими і ефективними зубними щітками на ринку. Звукові зубні щітки забезпечують чудове очищаючу дію проти поверхневих дефектів, а також освітлюють і відбілюють зуби при регулярному використанні.

Актуальність дисертації полягає в розробці високочастотної звукової зубної щітки, в корпусі якої є канал для подачі безпосередньо до зубам.омивающей рідини

Метою роботи було створення моделі звукової високочастотної зубної щітки в програмі Solidwork.

Завдання дослідження:

1. У програмі SOLIDWORK створіть модель високочастотної звукової зубної щітки.

2. За допомогою програми Fritzing створити друковану плату розроблювального пристрою.

3. За допомогою програми Ansys розрахувати частоту вібрації моделі звукової зубної щітки.

У статті розглядається створення моделі високочастотної зубної щітки в програмі Solidwork. Досліджено частотно-амплітудні характеристики розробленого пристрою для особистої гігієни порожнини рота. Детально проаналізовано електронна схема такого пристрою.

Ключові слова: звукова зубна щітка, видалення нальоту, зубна щітка, стоматологія, захворювання порожнини рота, гігієна порожнини рота.

CONTENT

INTRODUCTION

Personalized care and innovations in the field of oral hygiene are essential in the prevention of dental caries and periodontal disease for adults and children, and especially for patients undergoing treatment with fixed braces. For patients in the period of puberty, this is most relevant, since the processes of mineralization of the enamel of permanent teeth by the time of eruption have not yet been completed, thus the insufficient quality of hygiene procedures can lead to an aggravation of the cariogenic situation, violation of the integrity of the structure and the tightness of the attachment of its elements.

Brushing your teeth is the easiest and most affordable way to avoid dental diseases. To maintain adequate oral hygiene, many assistive devices are offered - dental irrigators, interdental brushes, single-beam brushes, etc. it can be difficult to motivate children to use something other than toothpaste and a brush. One of the most common oral hygiene methods is the use of a toothbrush.

The benefits of sonic toothbrushes have been discussed more and more recently.

Sonic brushes allow for better oral hygiene compared to mechanical hand and electric toothbrushes.

Compared to mechanical toothbrushes, sonic brushes are more effective precisely due to the complex mechanical and vibration effects. Some manufacturers in sonic brushes additionally use the technology of mechanical or rotary action of the head. However, such a function is superfluous for sound products, since the bristles do their job perfectly under the influence of sound waves.

Compared to mechanical or chemical methods of dental surface treatment, this sonic cleaning has the main advantage - the preservation of tooth enamel does not suffer.

With this treatment, the tartar is separated much faster, and the enamel is not damaged. Soft plaque is easily and completely removed. There is a significant

decrease in bacterial activity, and these effects extend to soft tissues, to the pockets of the gums. The sonic effect also prevents microbial growth on the bristles. Sonic teeth cleaning procedure is comfortable for the patient, painless and safe.

Thus, a personal care product such as a sonic toothbrush can be an effective tool for regular manipulations in the oral cavity, and also, with daily use, will help prevent the development of various dental diseases.

There are different models of sonic brushes on the market with different vibration speeds of the cleaning head. Vibration speed is usually in the range of 29,000 to 38,000 vibrations per minute, which can be attributed to medium and low speed vibration vibrations.

Therefore, the purpose of the work was to create a model of a sonic high-speed toothbrush in the Solidworks program

The objectives of the study were:

- in the solidworks program, create the proposed sonic toothbrush;
- using the fritzing program, create a printed circuit board of the device being developed;
- using the ansys program, calculate the vibration frequency of the sonic toothbrush model.

SECTION 1

FUNDAMENTALS OF DENTAL DISEASES PREVENTION

Personalized care and innovations in the field of oral hygiene are essential in the prevention of dental caries and periodontal disease for adults and children, and especially for patients undergoing treatment with fixed braces. For patients in the period of puberty, this is most relevant, since the processes of mineralization of the enamel of permanent teeth by the time of eruption have not yet been completed, thus the insufficient quality of hygiene procedures can lead to an aggravation of the cariogenic situation, violation of the integrity of the structure and the tightness of the attachment of its elements.

1.1. Tooth Anatomy.

This drawing of a healthy tooth, as depicted in figure 1, is cut in half lengthways shows the layers of the tooth and its internal structure, as well as how the tooth relates to the gum and surrounding jaw bone [1].

- The crown is the part of the tooth that is visible above the gum (gingiva).
- The neck is the region of the tooth that is at the gum line, between the root and the crown.
- The root is the region of the tooth that is below the gum. Some teeth have only one root, for example, incisors and canine (‘eye’) teeth, whereas molars and premolars have 4 roots per tooth.

The crown of each tooth has a coating of enamel, which protects the underlying dentine. Enamel is the hardest substance in the human body, harder even than bone. It gains its hardness from tightly packed rows of calcium and phosphorus crystals

within a protein matrix structure. Once the enamel has been formed during tooth development, there is little turnover of its minerals during life (figure 1.1).

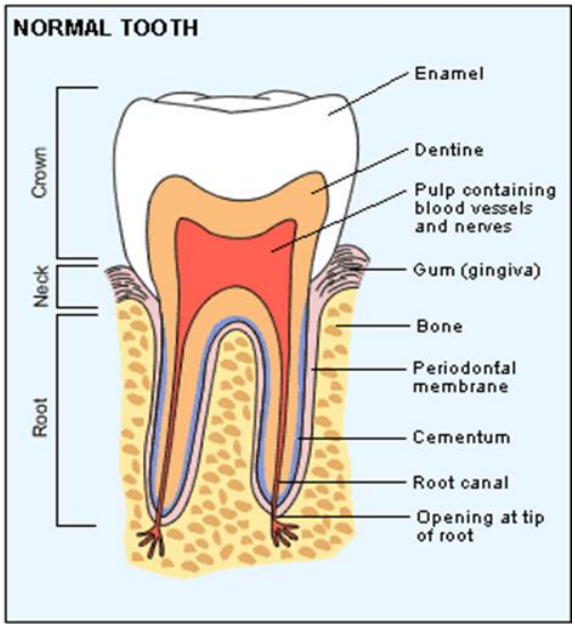


Figure 1.1 – Scheme regarding the Structure of the Tooth

Mature enamel is not considered to be a ‘living’ tissue. The major component of the inside of the tooth is dentine. This substance is slightly softer than enamel, with a structure more like bone. It is elastic and compressible in contrast to the brittle nature of enamel. Dentine is sensitive. It contains tiny tubules throughout its structure that connect with the central nerve of the tooth within the pulp. Dentine is a ‘live’ tissue. Below the gum, the dentine of the root is covered with a thin layer of cementum, rather than enamel. Cementum is a hard bone-like substance onto which the periodontal membrane attaches. This membrane bonds the root of the tooth to the bone of the jaw. It contains elastic fibers to allow some movement of the tooth within its bony socket [2].

The pulp forms the central chamber of the tooth. The pulp is made of soft tissue and contains blood vessels to supply nutrients to the tooth, and nerves to enable the tooth to sense heat and cold. It also contains small lymph vessels which carry white blood cells to the tooth to help fight bacteria.

The extension of the pulp within the root of the tooth is called the root canal. The root canal connects with the surrounding tissue via the opening at the tip of the

root. This is an opening in the cementum through which the tooth's nerve supply and blood supply enter the pulp from the surrounding tissue.

1.2. Anatomy of Oral Cavity and Structure of Teeth

The oral cavity, as shown in figure 2, is the primary part of the digestive tract. The oral cavity is divided into two sections:

- the vestibule of the mouth/buccal cavity;
- the oral cavity itself.

In the oral cavity, the enzymatic breakdown of carbohydrates begins under the action of the amylolytic enzymes of saliva - ptyalin and maltase. Ptyalin breaks down carbohydrates to maltose disaccharide, and maltase breaks down maltose to glucose. In the oral cavity, food is disinfected with the bactericidal substance of saliva - the vestibule of the mouth is limited in front and on the sides by the lips and cheeks, behind and from the inside - by the teeth and mucous membrane of the alveolar processes of the upper and lower jaws. The oral cavity itself is connected to the pharyngeal cavity through the pharynx (figure 1.2) [3].

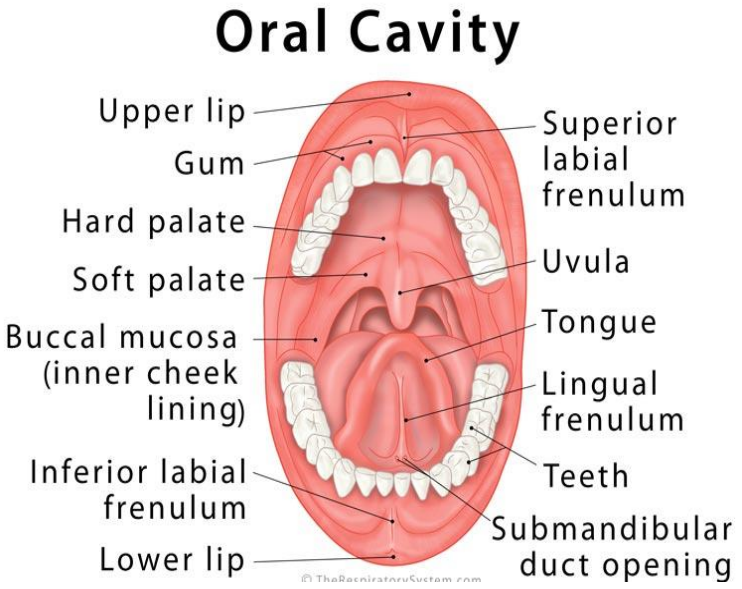


Figure 1.2 – Anatomy of Oral Cavity and Structure of Teeth

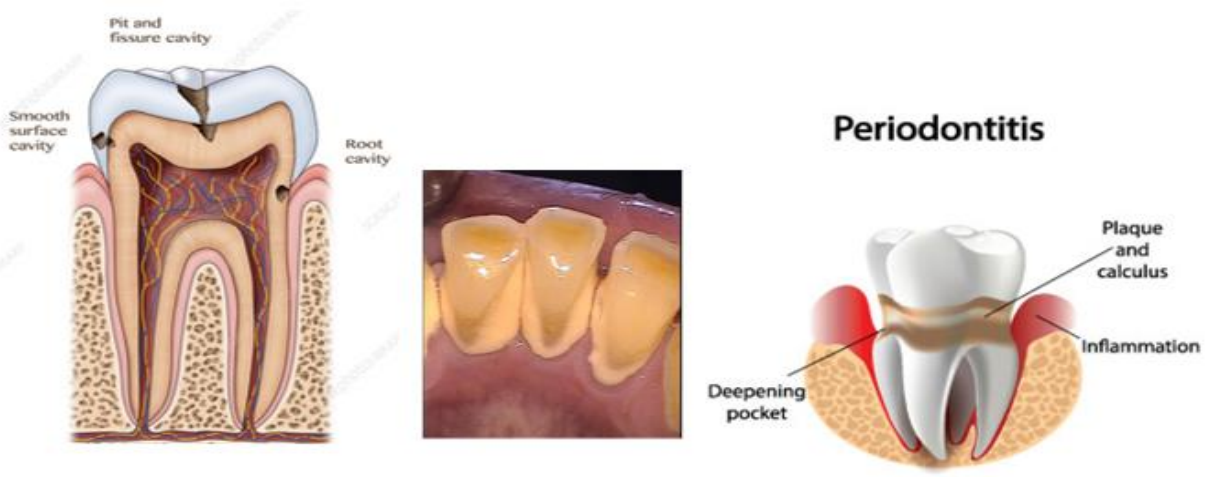
1.3. Diseases of the Oral Cavity and Teeth (Periodontal)

Oral disease is the fourth most costly disease to treat in high-income countries, with the burden of oral disease being reduced through the development of improved oral hygiene systems that primarily provide curative care. Most systems are based on the need for care provided by private dentists, although some high-income countries establish public oral health systems. In most low- and middle-income countries, investment in oral care is low, and resources are mostly dedicated to emergency oral care and pain relief [4].

Periodontal diseases (periodontium is a complex of tissues: tooth, periodontium, alveolar part of the jaw, gums) are among the most common dental diseases and are found in 80% of children and almost the entire adult population. In the occurrence of periodontal diseases, trauma, dental plaque, supragingival and subgingival deposits of tartar, overhanging fillings, defects in prosthetics, and the hygienic state of the oral cavity are important. Common factors include a lack of vitamin A, groups B, C, E, disorders of phosphorus-calcium metabolism, protein, mineral, carbohydrate metabolism, and changes in the digestive, nervous, vascular systems, allergic reactions, and decreased immunity [5].

- Plaque: During the meal, the teeth grind the food, and small residues of it inevitably remain in the mouth. They do not linger on the gums and fall into the interdental spaces, which are very convenient for this, where they are located until the next brushing of the teeth. If, however, tooth brushing is irregular, or ineffective, then food remains in the dental gaps and becomes a habitat for bacteria. Then the microflora of the oral cavity already turns into macroflora, forming plaque on the teeth, which consists of 95% of flora and fauna. As a result, this plaque causes tooth decay and periodontitis. In addition, the surface of plaque is not smooth, but rough, which improves the adhesion of food debris to it. And the further, the more. When plaque lasts a week or more, it gets denser and turns into tartar, which must be removed at the dental clinic [6].

- Dental calculus (Fig. 3b): hardened plaque that forms on the surface of the teeth. Tartar is quite dark, which is explained by the fact that it contains food debris, food debris, dead cells, bacteria, phosphorus, iron and calcium salts [7].
- Tooth caries (fig. 3a): his is an infectious process associated with exposure to microflora, violation of the diet, the composition of trace elements in food, especially fluoride. According to the depth of the defect, initial, middle, and deep caries are distinguished. [8].
- Periodontitis (fig. 3c): This is one of the variants of complicated caries, when the nerve disintegrates and the ligament holding the tooth in the jaw is affected. The tooth becomes mobile, it hurts at the slightest touch. Periodontitis often develops in teeth with poorly healed root canals [9].



(a) (b) (c)

Figure 1.3 – Diseases of the oral cavity and teeth (periodontal):
a - dental caries; b- dental calculus; c - periodontitis

Tartar will prevent you from brushing and flossing as thoroughly as you can. Cavities and tooth decay may result from this. Tartar that forms over the gum line can be harmful to health. This is because the bacteria in it causes gum inflammation and damage. This could result in chronic gum disease [10]. Tartar is a serious oral health issue that must be addressed. Although tartar is not instantly toxic or dangerous, if it is not eliminated, it may trigger a variety of issues in the future [11]:

– tartar increases the surface area to which dental plaque may adhere, giving bacteria a place to flourish;

– the same bacteria that causes cavities and irritates your gums will ultimately contribute to gum disease;

– tartar retains stains quickly because it is porous, like a cotton shirt or a marble countertop; the most prominent odors would be coffee, tea, and tobacco smoke;

– tartar will find it difficult to clean and floss as well as you can. this will result in extra cavities and tooth decay.

Minerals in your saliva bind with plaque to form crystals that solidify into tartar if plaque is not removed routinely and completely. Tartar has a rough surface that makes plaque removal with a toothbrush and floss impossible. Tartar is unsightly, turning yellow or brown as stains build up. It may also lead to tooth decay, poor breath, and severe causes of gum disease because it absorbs plaque and makes brushing at home impossible (figure 1.4) [12].

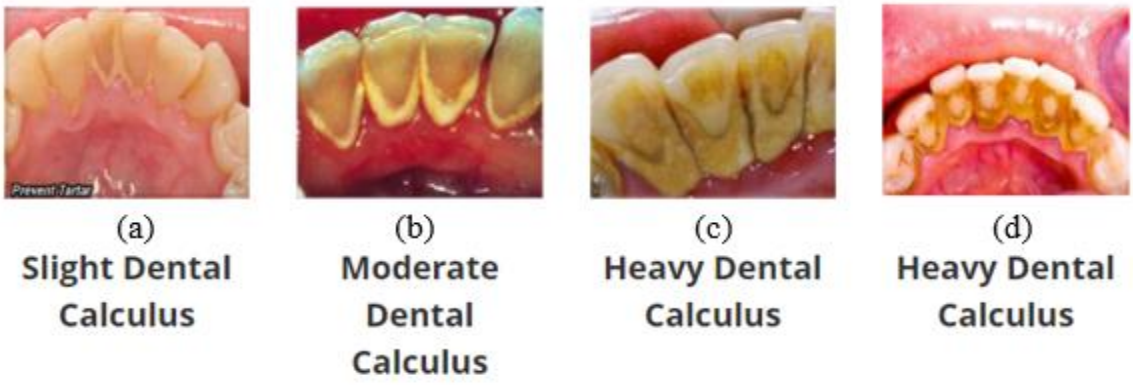


Figure 1.4 – Stages of teeth tartar formation

Calculus removal is important to stop a variety of severe health complications. Calculus buildup, according to studies, can cause gums to swell and bleed. Gingivitis, or gum disease, is the first stage of periodontal disease. Periodontal disease has also been linked to an increased risk of cardiovascular disease and stroke. [12].

1.4. Modern tecnologies of individual oral hygiene

As we saw in the previous section, poor oral hygiene is one of the causes of a number of dental diseases. Also, timely and effective hygiene can be both a means of prevention and a means of treating various diseases. However, there are a number of problems associated with ensuring proper cleaning of tooth surfaces. Pastes and brushes used by the population for cleaning teeth, in most cases, are not able to provide the effectiveness of removing the pathogenic plaque. Despite this, patients still prefer to use traditional methods of cleaning teeth, the use of which, in addition to the formation of tartar, also leads to damage to the neck of the tooth. The possibilities of modern methods of prevention are practically not used in daily dental care [13].

The main cause of diseases of hard tooth tissues (caries) and periodontal tissues (periodontitis) is the formation of bacterial plaque in hard-to-reach areas of the tooth surface. Plaque formation is caused by poor nutrition and ineffectiveness of the teeth cleaning technique used. Immunocompromised patients should pay increased attention to the prevention of plaque formation. The same applies to the removal of dental calculus, which (as we have found out earlier) is hardened plaque [14]. Tartar is the main sign of the need to use more effective methods of preventing diseases of the teeth and gums.

The first generations of electric toothbrushes had a rectangular head, similar to that of a traditional manual toothbrush, and performed reciprocating movements that corresponded to back-and-forth movements of manual toothbrushes, especially in the horizontal direction. The use of such toothbrushes has shown their low efficiency and lack of advantages in comparison with the traditional method of brushing teeth using manual toothbrushes, which led to the disappearance of this product from the market. Technology, which made it possible to create an electric toothbrush with a small round cup-shaped head, which performed high-frequency reciprocating rotational

movements [15]. They operate at an audio frequency of an average of 30,000 strokes per minute or 250 Hz, which allows for deeper and at the same time "gentle" foamy cleaning. This electric toothbrush was already significantly more effective in removing soft plaque and was more convenient to use than its predecessors. However, such a brush has its drawbacks, it is the size of its cleaning head, which has a relatively large dimensions and is not always convenient for use by patients [16].

One of the latest developments is the laser toothbrush. According to the researchers, such a toothbrush is capable of ensuring the sterility of the oral cavity, however, the developers are silent about the effect of this type of toothbrush on the general microflora of the oral cavity, which maintains a healthy state of the oral cavity in general and teeth in particular.

There are also sonic toothbrushes that work with the effect of magnetostriction at sound frequencies (about 250 Hz). In these brushes, sound vibrations are sent to the bristles, thereby providing improved cleaning of teeth from daily plaque, but the sonic brush cannot cope with long-term plaque (for example, smoking plaque). Toothbrush tube. Such a brush has a cleaning hollow head with openings for supplying a dental cleaner and bristles, a hollow neck, a hollow handle with a container for a dental cleaner, and a dispensing device adapted to pressurize the cleaning agent [15].

The presented design allows you to simplify the dosing procedure and maximize the efficiency of using the toothpaste. However, the advantages of this type of toothbrush are not very convincing, and the design becomes much more complicated and the manufacturing cost increases. Therefore, the question arises about the use of this type of toothbrush. A toothbrush with the function of examining the oral cavity differs from conventional toothbrushes in that a light source is mounted in the head of a conventional manual toothbrush, which is powered by batteries mounted in the handle of the toothbrush [15].

Sonic toothbrushes, as shown in figure 6, are less difficult to use than manual toothbrushes and can help you improve your brushing habits. A sonic toothbrush completes the brushing process for you - all you have to do is move the brush around

your mouth, instructing it to reach all of your teeth's surfaces. Sonic toothbrushes vibrate at 50,000 brushes per minute, which is far quicker than traditional toothbrushes. Sonic toothbrushes vibrate at 10 times the rate of an electric toothbrush, so a two-minute brushing session with one will clean your teeth more effectively. It cleans your teeth completely using sonic technology. Brush heads that vibrate at a high rate and move bristles from side to side. Another benefit of sonic toothbrushes is that they provide an extra sort of cleaning based on the fluid dynamics phenomenon. Sonic toothbrushes swirl the fluids in the mouth (water, saliva, and toothpaste), efficiently changing them into cleaning agents that reach crevices that the brush cannot, such as between teeth and below the gum line, due to the substantially faster brush speed [17]. Moreover, sonic toothbrushes are suitable for people with veneers, fillings, braces, chronic inflammation in gums, old plaque, debris, arthritis, carpal tunnel, as well as developmental disabilities. Users of both Sonicare sonic toothbrushes and Oral-B electric toothbrushes improved their overall oral health in a six-month research, but the sonic toothbrush was much more successful in eliminating plaque, lowering gingivitis, and increasing tooth and gum health in adult periodontitis patients [17].

1.4.1. Comparison of Sonic Toothbrush Technologies

A toothbrush is a must-have daily personal hygiene item for everyone's oral cavity. A toothbrush is made up of a handle, a working portion (head), and a neck. The bristles (pile) are reinforced in a variety of ways on the head. Toothbrushes are classified into five types based on the hardness of their bristles: very soft, gentle, medium hard, hard, and very hard. Brushes are classified as manual, electric, ultrasonic, sonic, or ionic based on their cleaning method. Each toothbrush category has its unique set of mechanical and functional properties. People tend to buy brushes based on pricing and style rather than usefulness.

Manual toothbrushes are the simplest to use and hence the most prevalent. When selecting such a brush, you should consider the rigidity of the bristles. There are five levels of hardness, ranging from extremely soft to very hard. Despite the fact that they are substantially more expensive than mechanical toothbrushes, electric mechanical toothbrushes have gained popularity in recent years. Which toothbrush to choose: electric or sonic? Compared to rotary sonic brushes, they are more effective precisely due to the complex mechanical and vibration effects [18]. Some manufacturers in sonic brushes additionally use the technology of mechanical or rotary action of the head. However, this option is superfluous for sound products, since the bristles do their job perfectly under the influence of sound waves

Comparison Sonic and ultrasonic toothbrush has shown the feasibility of using sonic toothbrushes in individual home oral hygiene. Whereas ultrasonic toothbrushes should be used with professional recommendations

Because of the same root in the names, many people confuse ultrasonic and sonic toothbrushes. Aside from the name, what do they have in common?

2. The vibrations in the bristles are caused by the waves. As a result of these changes, when toothpaste is combined with water and saliva, it produces a thick foam [19].
3. The resultant foamed liquid flows in the direction of the gingival grooves and openings between the teeth as a result of brush vibrations. As a result, the cleaning agent reaches the most difficult-to-reach regions and efficiently dissolves plaque.
4. The brush's impulse motions aid to clean the tooth enamel and increase blood circulation in the gum tissue.

Sonic and ultrasonic toothbrushes - the difference:

- frequency of waves - sound waves operate in the range up to 260 hz, and ultrasonic waves - from 20 thousand hz;
- the frequency of vibrations of the bristles is 18-40 thousand / min in sound, and up to 100 million / min in ultrasound [19].

What is the difference between a sonic toothbrush and an ultrasonic one, if we consider their principle of operation? The feature of sound devices is a more intense (double) action, and ultrasound models have a very delicate effect on tissues, but are contraindicated for children, unsafe for fillings, orthopedic structures (veneers, crowns, etc.) [18]

Given the advantages and distinctions described, it is unclear which type of toothbrush is better. Each of them has its own set of attributes and scope. The sonic brush is more effective against tartar, plaque, and pigmentation. Ultrasound is useful in the hygiene of problem gums, in preventing the formation of inflammatory processes, and in preventing relapses in the presence of chronic disorders [19].

1.4.2. Examples and characteristics of toothbrushes - as a Comparative Characteristic

- ✓ **Philips Sonicare Protective Clean 4500 HX6830 / 44**

Ideal for daily use, as it takes very gentle care of teeth and gums.

Has two modes of operation:

- whitening;
- cleaning and polishing.

The device's designers have packed it with a slew of handy features:

- philips sonicare technology - creating a pulsation that allows you to clean enamel even in the interdental space;
- warning in case of too much pressure on the gums;
- complete with a nozzle with brushsync - an option for light and sound notification that it's time to change the thick bristles for whitening;
- attachment;
- quadpacer - time control function for oral cavity care in each zone;
- easy start is an easy start mode with a gradual rise in pulsation intensity, helpful when transitioning from a manual brush or for persons with sensitive teeth.

✓ **Philips Sonicare Diamond Clean HX9352 / 04**

This brush, like a professional master, fights plaque on the teeth and bacteria that provoke the development of caries.

The advantages of the model:

- philips sonicare diamondclean is suitable for travel and frequent business trips with a convenient case and usb travel charger;
- destroys pathogenic bacteria in the most inaccessible areas of the oral cavity;
- has 5 different modes:
- for a gentle massage of the gums;
- for delicate cleaning of sensitive teeth;
- for enamel clarification and polishing;
- intensive for removing stains from enamel;
- for everyday hygiene.

By using this brush, you will forget about gum problems and provide highly effective protection of your teeth from caries.

✓ **EDEL WHITE Sonic Generation (Switzerland) (figure 1.5)**

This brush is for the whole family, including children from the age of seven.

The versatility of the device is provided by 3 different operating modes:

- intensive - for effective but gentle cleaning of sensitive teeth, problem gums, including inflammation, the formation of pockets, exposed tooth necks, for braces and various types of implants;
- whitening - suitable for healthy teeth and gums, designed to remove plaque and gently massage the gum tissue;
- delicate - provides high-quality preventive hygiene.
- the advantages of the model:
- unique erdmann design nominated for the red dot design award;
- double head for simultaneous fast hygiene of the teeth of the upper and lower dentition;

- the thinnest elastic bristles, do not injure the gums, are suitable even for the thin enamel of children's teeth, penetrating into the narrowest spaces between the teeth;
- the presence of a timer to control the duration of cleaning;
- led indicator that signals the need to change the nozzle.

a) b) c)

Figure 1.5 – Examples of sonic toothbrushes: a) Philips Sonicare Protective Clean 4500 HX6830 / 44; b) Philips Sonicare Diamond Clean HX9352 / 04; c) EDEL WHITE Sonic Generation

Knowing the features of the operation of each type of electric brushes, we can highlight the advantages of sound models. So, the sonic electric toothbrush - the pros:

- effective plaque removal, dental calculus prevention;
- smoothness of the enamel after cleaning (the effect of a professional procedure);
- high efficiency of cleaning hard-to-reach areas;
- bristles remove impurities from the depressions at the base of the tooth, narrow gaps between the teeth;
- under the influence of high-frequency vibrations, finely dispersed foam saturated with oxygen is formed from biological fluids and toothpaste, which easily penetrates into the most inaccessible areas, destroys and flushes out soft plaque.

What else is good sonic: there are practically no contraindications to its use. It is suitable for everyone - children, adults with healthy teeth, with dental restorations and prostheses, with gum problems and mobile teeth.

1.4.3. Basic vibration characteristics

Vibration is a type of mechanical vibrations that occur when mechanical energy is transferred to a body from a source of vibrations. Vibration is the movement of a point or a mechanical system, in which there is an alternate increase and decrease in time of the values of at least one coordinate. Just like noise, vibration is one of the factors in the physical environment of a person [20].

The parameters characterizing the simplest type of vibration - sinusoidal (harmonic) vibrations are: frequency / (Hz); amplitude A (m) - the value of the greatest deviation of the oscillating point from the equilibrium position; vibrational speed V (m/s) - the maximum of the values of the speed of the vibrating point; oscillatory acceleration W (m/s^2) - the maximum of the values of the oscillating point accelerations; vibration frequency –f, Hz = 1/s.

Due to the specific properties of the sense organs, the effective values of the above parameters are decisive in assessing the impact of vibration. So, the effective value of the vibration velocity is the root-mean-square of the instantaneous values of the velocity V (t) during the averaging time ty, which is chosen taking into account the nature of the change in the vibration velocity over time

Since the absolute values of speed and acceleration vary over a wide range, like noise, using the Weber-Fechner law, the relative levels of vibration velocity and vibration acceleration, expressed in decibels (DB), are used to assess vibration:
where V0 is the threshold (zero) value of the vibrational speed; WQ is the vibration acceleration threshold.

The use of a logarithmic scale for the hygienic assessment of the impact of vibration is also due to the fact that the sensitivity of the human body to the action of vibration changes in proportion to the logarithm of the impact. The strength of vibration that affects a person is governed by the velocity and acceleration of the vibration, as well as the frequency response. This is due to the fact that the perception of vibration is affected by speed for small amplitudes and acceleration for large amplitudes.

Vibrations occurring in real production conditions are a complex oscillatory process consisting of individual sinusoidal oscillations with different frequencies and amplitudes. To characterize such vibrations, the spectra of the effective values of the parameters characterizing the vibration are used.

By spectrum, vibrations are subdivided into:

- narrow-band, in which the vibration velocity levels at certain frequencies or frequency ranges are more than 15 dB higher than the values in neighboring ranges;
- broadband, which do not have pronounced frequencies or narrow frequency ranges at which the levels of vibration velocity exceed the levels of neighboring frequencies by more than 15 db.

The frequency composition is distinguished:

- low-frequency vibrations (with a predominance of maximum levels in the octave frequency bands of 1-4 Hz for general vibrations, 8-16 Hz for local vibrations);
- medium-frequency vibrations (8-16 Hz - for general vibrations, 31.5-63 Hz for local vibrations);
- high-frequency vibrations (31.5—63 Hz - for general vibrations, 125—1000 Hz for local vibrations).
- vibration parameters, Are the amplitude values of the vibration displacement Xt, the vibrational velocity Vm and the vibrational acceleration at, as well as the period T (s) and the frequency / (Hz) of the vibrations.
- amplitude of vibration displacement can be expressed as the distance between the points with the maximum deviation achieved during movement (the magnitude of the doubled amplitude), or as the distance from a central point to the point of maximum deviation (the maximum value).
- vibration displacement in the case of sinusoidal oscillations, it is determined by the formula:

$$X = X_m \sin(\omega t + \varphi) \qquad (1.1)$$

- in most cases, the initial phase is not taken into account in industrial sanitation calculations.
- vibration frequency, expressed in number of cycles per second (Hz), affects the degree of transmission of vibration to the body (for example, the surface of a chair or the handle of a vibrating instrument), the degree of transmission through the body (for example, from a chair to the head), and the effect of vibration on the body. The frequency is related to the oscillation period by the ratio f = / T.

$$a_m = \omega^2 X_m = \omega V_m \qquad (1.2)$$

- vibration can be defined by one or more frequencies (discrete spectrum) or by a large frequency range (continuous spectrum). The frequency spectrum is separated into bands (octave bands).
- the upper cutoff frequency / in is twice the lower cutoff frequency / n, = 2 in the octave range.
- the octave band has a geometric mean frequency of that/ s = l / LL-
- standard geometric mean frequencies are: 1; 2; four; eight; sixteen; 31.5; 63; 125; 250; 500; 1000 Hz.
- a person is able to sense vibration in the range from fractions of a hertz to 8000 Hz. The threshold for perception of vibration velocity is considered to be 10-4 cm / s, and the threshold for pain is 1 m / s.
- since human organs do not respond to an absolute change in the intensity of the stimulus, but to its relative change (Weber-Fechner law), logarithmic values have been introduced - the levels of vibration velocity and vibration acceleration, measured in decibels (dB):

1.4.4. Modern of Sonic Toothbrush Technologies

Sonic electric brushes are a type of oral hygiene appliance with a main handle and changeable nozzles. The electromagnet-based mechanism sets it apart from typical electric brushes. The accessories function with a sound wave in addition to the amplitude swinging of the head with a cyclic movement of the bristles. It is formed due to the moving elements of the head, where the spring and the resonator create an oscillation frequency of up to 260 Hz, which forms the sound wave [4]. The resulting frequency, together with the movement of the bristles, forms a mixture of water, saliva and cleaning agent in the mouth. Thanks to the cyclic movement, the inner side of the tooth, the interdental space, the palate and tongue, as well as hard-to-reach places near the gingival

groove are washed. The bristles on the head move up and down. With the correct positioning of the sonic brush (an angle of 45 degrees to the gingival line and movement from below to the tooth edge), bacterial plaque is completely swept away. The amplitude of oscillations varies from 20 to 40 thousand oscillations / minute for adult variants. The mode of operation with a suitable sound wave depends on the required function (work with gums, dental structures, and sensitive areas). Slightly less, up to 13 thousand vibrations / minute, offer electric sonic brushes for children. It will turn out to find an option for both the first baby tooth and teenage solutions with a stylish design.

The principle of operation of the sonic brush is as follows. A high-speed motor rotates a metal weight with an offset center of gravity. As a result, the handle of the toothbrush enters into resonance and begins to vibrate at a frequency of 17,000 - 22,000 movements per minute. Some manufacturers of sonic toothbrushes have improved this technology by installing a micromotor directly into the brush head, thereby increasing the vibration power. This can be seen in the already outdated budget Lebond toothbrushes (figure 1.6).

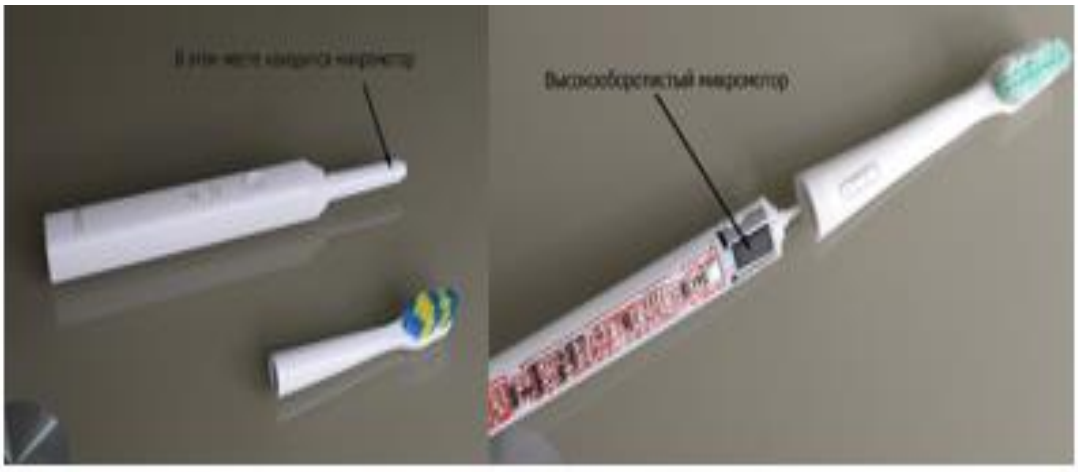


Figure 1.6 – Lebond toothbrushes

Such brushes operate at low frequencies and have specific vibration characteristics. Vibrations are chaotic, low quality of teeth cleaning, heavy load on teeth (up to 300 grams per dentition), low vibration amplitude (up to 1 mm).

The advantages of this technology are the low cost and compact size of the brushes.

It is easy to determine that the product works according to this technology - the pin on which the replaceable nozzle is put on is thick and made of plastic. The second generation of sonic brushes - vibrating sonic toothbrushes. These are the most common toothbrushes and there are many on the market. Such products from different manufacturers have a similar operating technology, but there are also important differences.

Classic electromagnetic brushes contain an electromagnet inside the product, which moves up and down a metal armature (on a spring). Vibrations directed across the teeth at a frequency of up to 31,000 movements per minute, the load on the dentition is low (up to 120 g), the vibration amplitude is high (up to 3 mm) (figure 1.7).

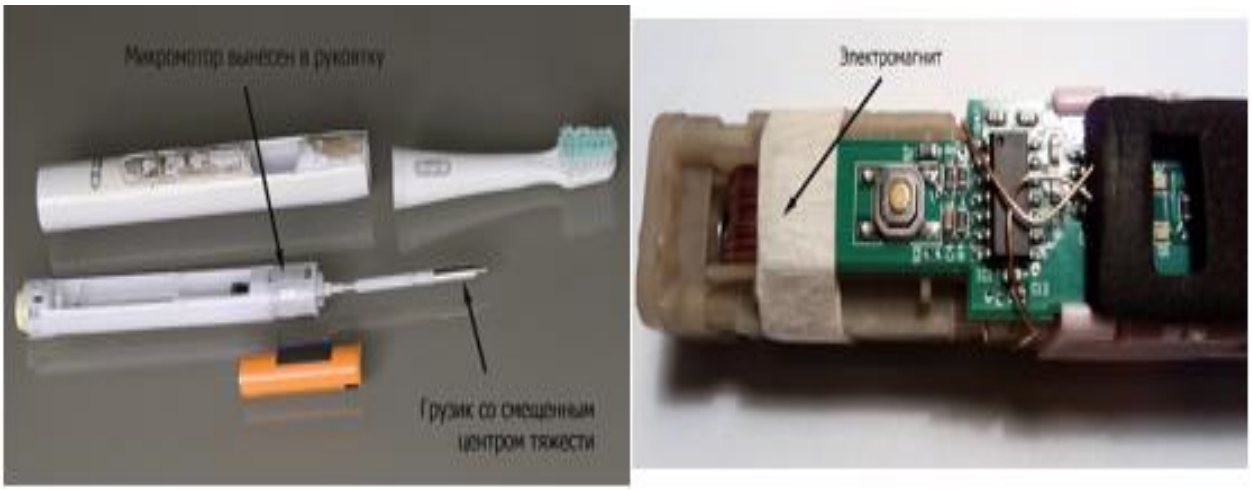


Figure 1.7 – Internal Components of Classic Electromagnetic Brushes

There is also a type of toothbrush with directional vibrations (to the tooth or to the side). In this case, the vibration frequency can be increased to 47,000 movements per minute and the efficiency of plaque removal can be increased. But there are also disadvantages - a low vibration amplitude (up to 0.3 mm) and a high load on the dentition (up to 500 g, which, according to dentists, is unacceptable).

The most popular in this category are Philips Sonicare sonic toothbrushes with advanced technology. There are 2 electromagnets inside the product, which alternately drive the built-in armature. Vibrations directed to the tooth at an angle of 30 degrees. Vibration frequency up to 31,000 movements per minute (figure 1.8). There is a high efficiency of plaque removal with a relatively moderate load on the dentition (250-400 g). Amplitude of vibrations up to 1 mm.

Figure 1.8– Electromagnets inside the product for sound toothbrush

Popular brushes: Philips Sonicare, iPik, Curaprox, Waterpik, CS Medica, Megasmile and most "Chinese" toothbrushes.

The third generation of toothbrushes is based on M.TIC technology (developed by Lebond) - high-frequency micro-rotation

Principle of operation**:** Inside the product there are 2 electromagnets between which the armature performs micro-rotation (placed on bearings). Vibrations directed strictly tangentially to the dentition. The vibration frequency depends on the stiffness of the bristles used (figure 1.9).

Figure 1.9 – The structure of the sonic toothbrush motor

Average vibration amplitude at different frequencies:

- The frequency is 31,000 movements per minute - the amplitude is up to 7 mm.
- Frequency of 33,000 movements per minute - amplitude up to 5 mm.
- Frequency of 37,000 movements per minute - amplitude up to 1 mm.

Vibration characteristics: Movement of the bristles strictly up and down the dentition, low load on the dentition (up to 100 grams), high vibration amplitude (up to 7 mm).

According to dentists, these brushes are priority in use and are absolutely safe for teeth, do not affect dental structures, are delicate for the gums and do not lead to their recession (drooping).

Popular brushes: Lebond, Xiaomi and some toothbrushes introduced since 2017 copy M.TIC technology (figure 1.10).

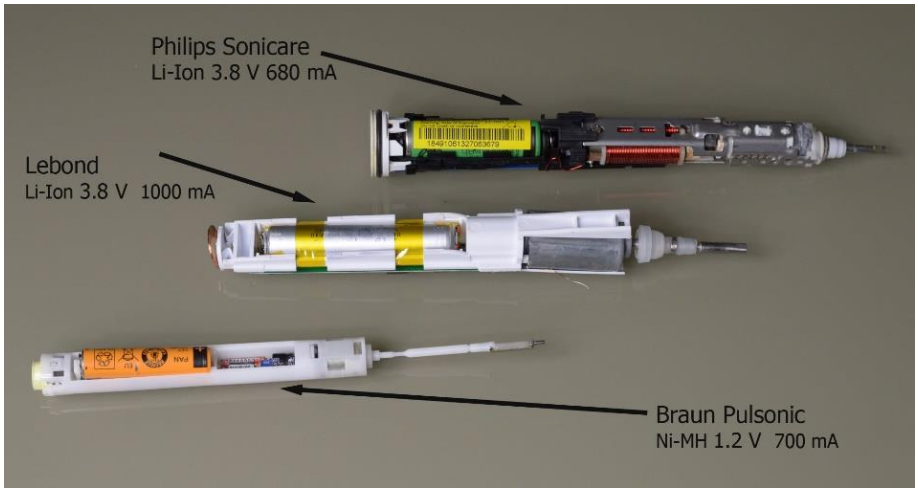


Figure 1.10 –The internal structure of a sonic toothbrush

Conclusions to the section 1

One of the reasons for a number of dental diseases is non-observance of the rules of personal (individual) oral and dental hygiene. In the first place in such violations, it is necessary to consider untimely brushing of teeth with dental,. One of the most convenient and widespread methods of cleaning teeth and oral cavity is a toothbrush. Currently, there are many directions in the development of toothbrush shapes. One of these models is a sonic toothbrush. Sonic toothbrushes are used for deep cleaning of teeth and interdental spaces. Easy-to-clean dentures with removable dentures are often considered the most powerful and effective toothbrushes on the market.

SECTION 2

DEVELOPMENT OF SOFTWARE FOR CREATING A TOOTHBRUSH BASED ON HIGH FREQUENCY VIBRATION

2.1. Proposed sonic toothbrush model implemented in SOLIDWORKS

The quality and features of today's electric toothbrushes do not completely satisfy the expectations of customers in terms of improving dental care. According to my consumer requirement analysis, the most essential characteristics are the durability, and vibratory brushing modes, such as whitening, gums massage, and sensitivity modes, which contribute to the elimination of dental plaque and general dental health [21]. Furthermore, the consumer wishes for an electric toothbrush that lasts for a long time, clean itself automatically, and improve the overall dental health [22]. Therefore, the design should include high-quality materials for both the brush’s head and body. Taking this researched information into consideration, my aim is to develop a user-friendly sonic toothbrush that would further enhance the cleaning quality of the teeth, better performance, longer battery life, and an attached micro-bubbler (water channel).

This sonic toothbrush vibrates at around 10 times the rate of an electric toothbrush, a two-minute brushing session with this sonic toothbrush will give you more cleaning power and better dental hygiene results. The micro-bubbler that I have installed makes it easier for the consumer to brush their teeth effectively without the need to constantly rinse the mouth while brushing. Because of the much higher rate of brush speed, this sonic toothbrush mix the fluids in the mouth (water, saliva, and toothpaste), effectively turning them into cleaning agents that reach into gaps that the brush can’t access, like between teeth and below the gum line.

Therefore, the software I have used to implement the proposed sonic toothbrush model, including its internal functionality, is SOLIDWORKS, as shown in figure 2.1. SOLIDWORKS, a strong modeling computer-aided plan and computer-aided designing program, is one of the foremost well-known computer program alternatives for mechatronics engineers. It is utilized to create mechatronics frameworks from starting to end. At the starting stage, the computer program is utilized for arranging, visual ideation, modeling, achievability evaluation, prototyping, and venture administration. The program is at that point utilized for plan and building of mechanical, electrical, and program components. At long last, the program can be utilized for administration, counting gadget administration, analytics, information computerization, and cloud administrations. Mechanical, electrical, and electronics engineers use SOLIDWORKS software solutions to create a connected design. (figure 2.1) The application of programs is intended to keep all engineers in communication and capable of responding to design needs or changes [23].

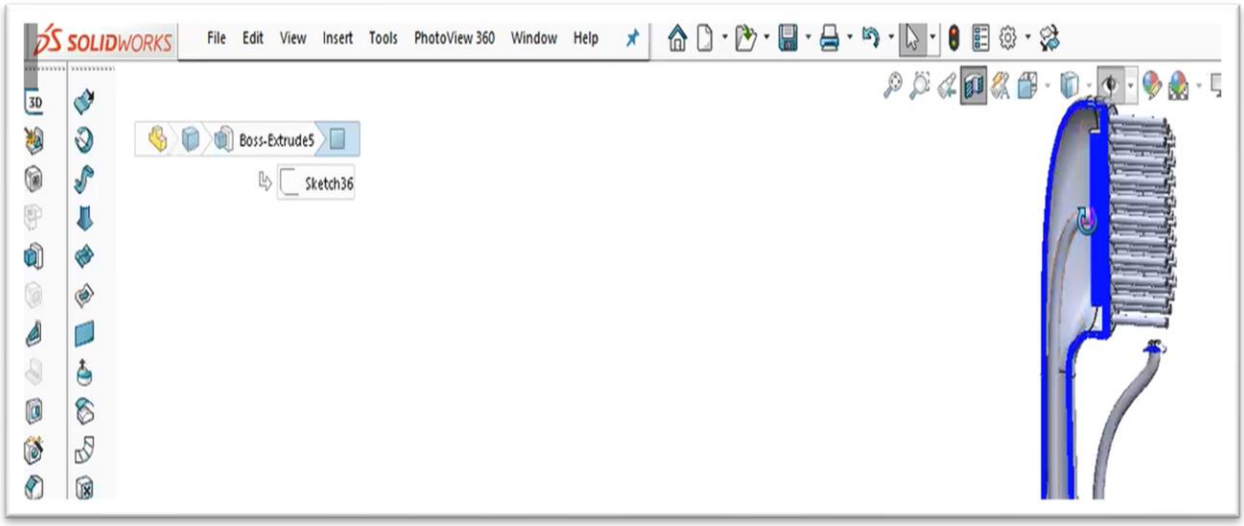


Figure 2.1 – Screenshot of the proposed model designed in SOLIDWORKS

- Vibrational Toothbrush Bristles

The bristles of this sonic toothbrush ensure proper cleaning action is achieved by the vibration of the toothbrush bristles, due to the attachment of the DC motor that is connected through a transducer till the head of the brush.

- Flexible Micro-bubbler

The motor connected to the micro-bubbler to produced bubbles and it is targeted at a position to ensure proper cleaning action. In addition, it has a flexible arm in order to allow the user to adjust it according to their own comfort position.

- Silicone Grip Coating

This sonic toothbrush has a soft touch silicone rubber coating to help ensure that a proper grip has been made by the user.

- Toggle Switch

This brush can be utilized as an electrical brush or a manual toothbrush. A toggle switch has been placed on the brush, which gives the user option on whether they would like the brush to just function the vibrational tooth bristles or just the micro-bubbler or use both the functionalities simultaneously.

- Water Tank

The water tank is connected to the reservoir tank that is installed inside the toothbrush for easy handling. A centrifugal motor is installed inside the brush to pump the water from the main tank into the reservoir tank. A non-return valve is installed with the reservoir tank to avoid the stored water in the toothbrush to flow back into the main reservoir (figure 2.2).

Figure 2.2 – Labelled diagram of the Proposed Sonic Toothbrush

2.2 Internal Functionality of the Proposed Sonic Toothbrush

The system of the brush has a printed circuit board, or PCB attached inside and it is used to mechanically support and electrically connect electronic components using conductive pathways, tracks or signal traces etched from copper sheets laminated onto a non-conductive substrate. The circuit used is a small round printed circuit board powered by the 700 mAH batteries (figure 2.3).

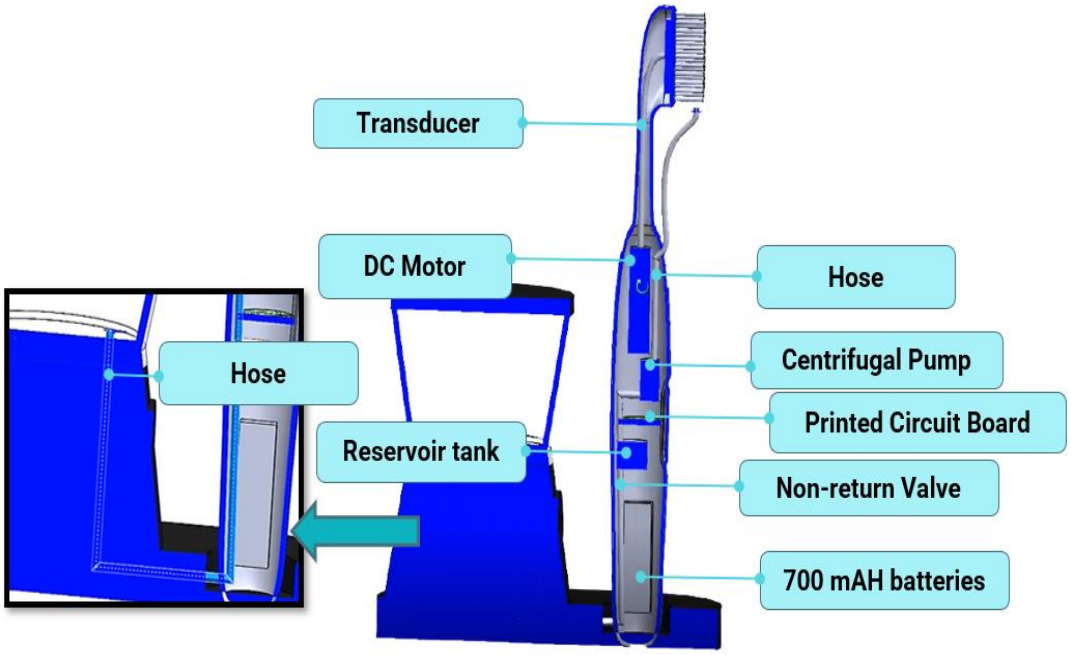


Figure 2.3 – Labelled diagram of the internal components used in this sonic toothbrush model

These batteries can ensure 30 minutes of working time for this brush, and it can be charged up to 2 hours. Further, I have installed a DC motor that is connected through a transducer till the tip of the tooth bristles. The DC motor receives electrical signal from the circuit and transforms it into mechanical, hence, the motor rotates and the transducers which is connected to the motor makes the bristles move back and forth. Due to the vibrations produced in the toothbrush bristles, this would enable the user to achieve better cleaning action for their teeth.

Moreover, the water tank as shown from the picture above, is connected to the reservoir that is mounted inside the toothbrush. The centrifugal motor installed inside the brush pumps the water from the main tank into the reservoir tank, in order to

produce bubbles into the micro-bubbler. In addition, a non-return value is installed below the reservoir tank to avoid the stored water in the toothbrush to flow back into the main reservoir tank. A hose is connected between the Centrifugal Motor and the micro-bubbler. The micro-bubbler rotates in such a way that it pushes out the water in the form of bubbles. These bubbles implode with the sonic vibrations and remove impurities such as food remnants, tartar, bacteria, staining etc. The tip of the micro-bubbler is a geometrical shape and it is designed in such a way by taking calculations into consideration, which will confirm the formation of bubbles by leaking a very small amount of the water. The micro-bubbler is targeted at a position to ensure better dental cleaning action.

2.1.General Description of How the Modal Works

The sonic toothbrush usually has a transducer attached to the puff face that vibrates at a particular frequency and this vibration generally causes the cleaning action. I have modelled this toothbrush with simple bristles attached to a body, which can be seen by the isolator. It is a single head body so that it can move back and forth motion and side by side motion, but this motion is not enough to clean your teeth, hence, you will have to move it to the desired location. It will just provide the high frequency oscillations that can help cleaning of the fine particles or other debris stuck in your teeth. Further, a transducer is generally attached to the oscillating head and this transducer is generally attached to a DC motor, these are generally the crystals which are electronically powered and these crystals are tamed to produce a particular frequency. Based on various studies, an electrical toothbrush generally uses 32000 strokes per minute, this will be the general frequency that the crystals will be producing. The frequency can go higher or lower depending on the product you will be making.

A Printed Circuit Board (PCB) is installed inside the toothbrush, and it is basically a circuit that ensures everything is tuned electrically as well as everything performed in the optical function, and they can be controlled using an external switch by a human intervention. PCB have a control unit that sends signals to other electronic components to perform certain tasks or what functionality the user wants. Moving on towards the battery section, I have installed a 700 mAH battery that powers the PCB control unit with an operational time of 30 minutes when fully charged and it generally takes 2 hours for the brush to be charged completely.

Moreover, I have mounted a micro-bubbler that produces bubbles and it is placed at a position that enables better cleaning action to be achieved. The micro-bubbler has a flexible host that made out of a braided steel so that a person can adjust it according to their own preferences and the area they are targeting. It can also be made rigid depending upon how the user would want it to function. The geometrical shape on top of the flexible micro-bubbler will have a system which will ensure the formation of bubbles by leaking a very small amount of the water.

Moreover, this sonic toothbrush is a wireless toothbrush as it needs to be handheld, and not used when connected to the main charging unit. The charging unit is mounted at the bottom so that essentially when the toothbrush is not being used, you can just place this toothbrush on the base and it will get charged. The brush has to contain some amount of water or soapy water so that the bubble formation will take place while brushing the teeth. A non-return valve is mounted below the reservoir tank to ensure the water that is pumped into the brush will not go back into the main reservoir unit. As per the water tank, the jar will contain 414 ml of water that will act as a main source of water for the brush and it is connected to the reservoir tank with the aid of a hose which is then connected to a centrifugal motor that allows the micro-bubbler to produce water bubbles. The reservoir tank pumps and stores 75ml of water from the main water tank. A toggle button has been installed on the outer section of the brush that can be made as a rocker button with a toggled position to ensure different parts can be turned on and off independently, in order to send signals to the

PCB circuit. The toothbrush is coated with a soft grip silicone rubber surface that can be removed and placed back.

2.2. Modal Analysis for the Sonic Toothbrush implemented in Ansys Software

A modal analysis has been conducted with the aid of Ansys software, as shown in figure 2.4, in order to check whether issues will be encountered with the input vibrational frequencies. Ansys offers a comprehensive software suite that spans the entire range of physics, accurately simulating the structural, fluid, thermal and electromagnetic performance of any product or process. Ansys Mechanical finite element simulation software is used to simulate computational models of systems, electronics, or device components in order to evaluate stability, durability, elasticity, temperature distribution, electromagnetism, fluid flow, and other properties [13]. ANSYS utilizes certain data sources and assesses the item conduct to the physical science that you are trying it in. It is a broadly useful programming used to recreate the communications between different physical science like elements, statics, liquids, electromagnetic, warm, and vibrations. ANSYS normally sets out the client a freedom to establish a virtual climate to reenact the tests or working states of the items prior to assembling the models. This would absolutely diminish the expense of creating models and mostly the time. In this aggressive world the exactness and time are the most main consideration for the organization or the association to support. ANSYS helps in expanding the exactness and diminishing the hour of result of the eventual outcome.

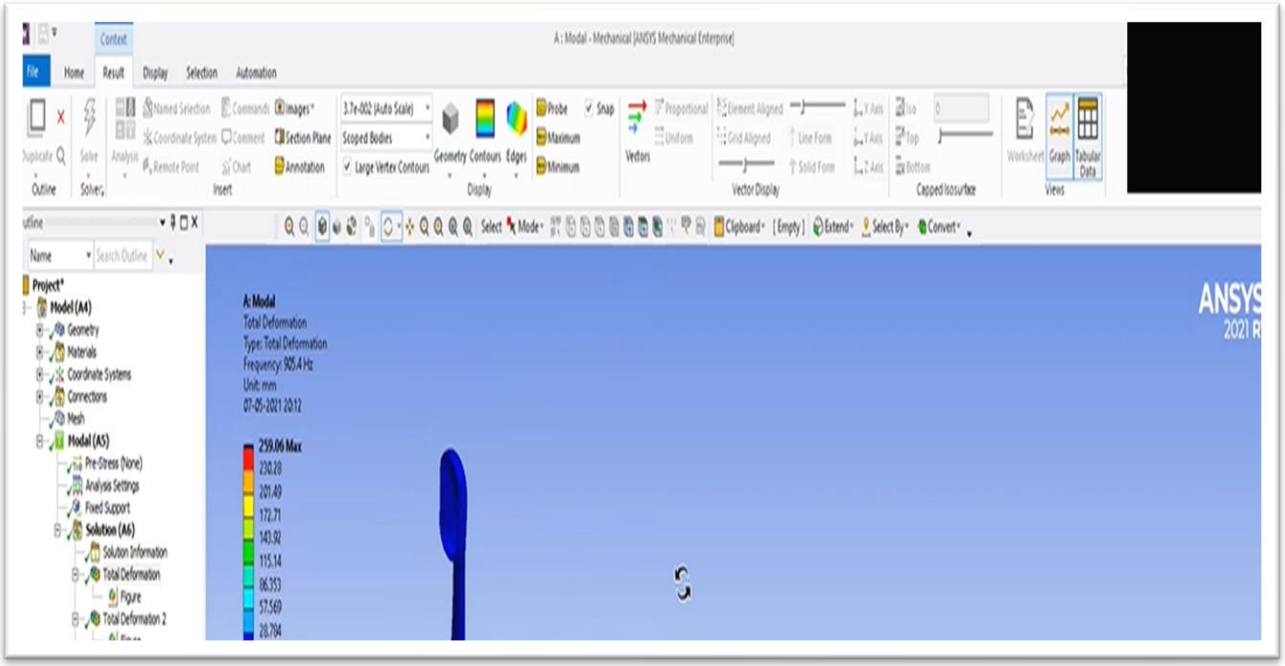


Figure 2.4 – Screenshot of the modal analysis developed in Ansys program

The main purpose of implementing this proposed project in Ansys software, is to investigate the vibration characteristics of the sonic toothbrush. In order to conduct this investigation, different frequencies were used on the modal analyses to determine the durability and efficiecy of the proposed sonic toothbrush. Therefore, it is have used two different frequency samples, in order to compare their vibrational analysis. The figure 2.5 (a and b) shows the comparison between two sample frequencies. Sample 1 (a) depicts resonance in 905 Hz, this enables brush to handle 55000 strokes per minute without causing any damage to the structure. This ensures that this Sonic Toothbrush is safe to use while in vibrational motion. Sample 2 (b) depicts resonance in 1224.2 Hz, which is equivalent to 73000 strokes per minute. However, the structure of this sonic toothbrush will not be able to handle this amount of vibrational frequency. Therefore, damaging the entire structure of the toothbrush.

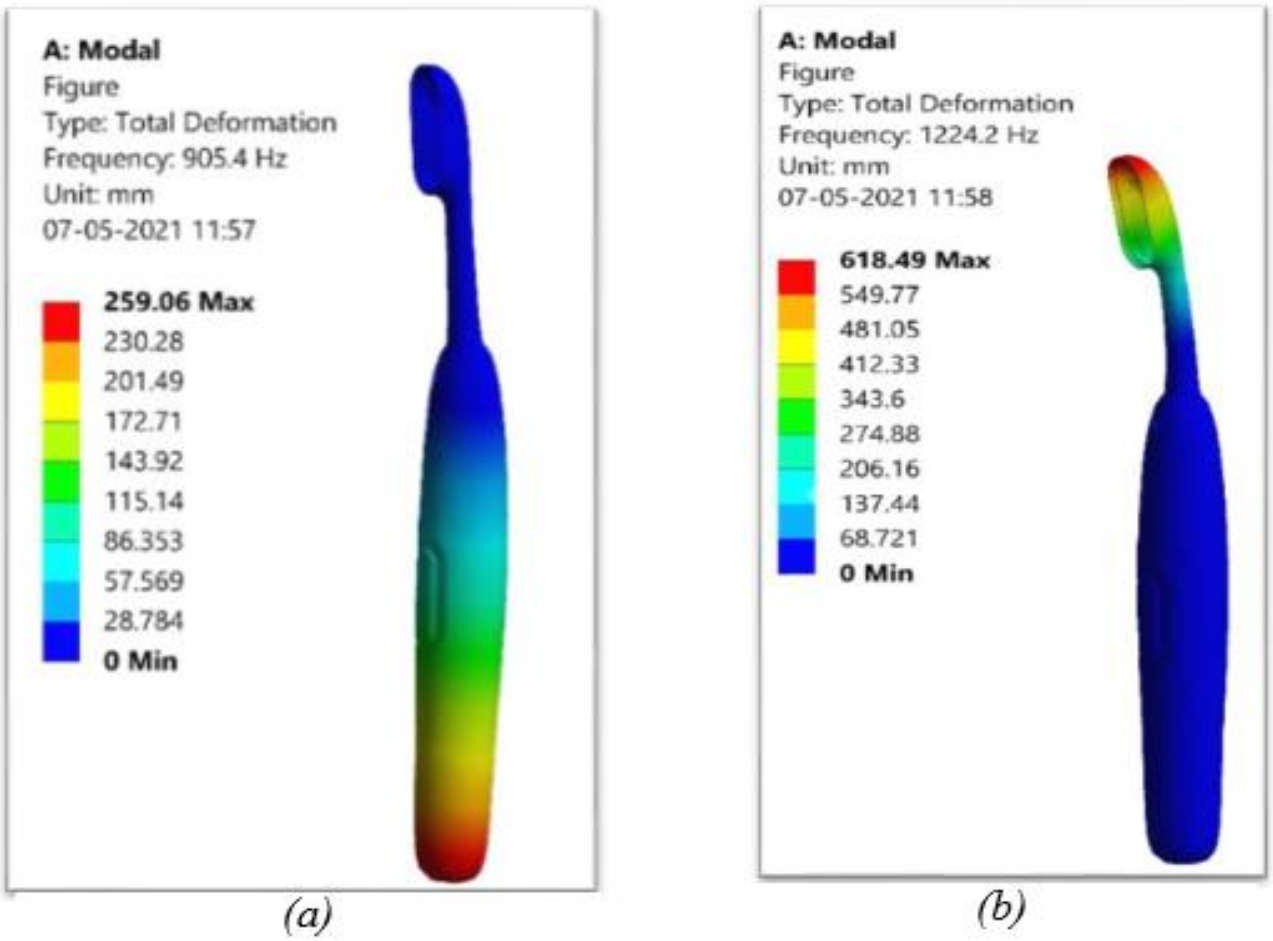


Figure 2.5 – Modal Analysis for the Sonic Toothbrush

a) depicts resonance in 905 Hz, this enables brush to handle 55000 strokes per minute without causing any damage to the structure
b) depicts resonance in 1224.2 Hz, which is equivalent to 73000 strokes per minute

2.3.Circuit Model of the Sonic Toothbrush implemented in Fritzing Software

The following are circuit models that I have implemented with the aid of a software called Fritzing. Fritzing is an open-source hardware project that allows us to use electronics as an artistic medium. In the spirit of Processing and Arduino, we have a coding tool, a community forum, and resources that promote an innovative environment that enables users to record their designs, share them with others, teach electronics in the classroom, and layout and produce professional PCBs [24].

Moreover, these circuit models that I have designed would provide an in-depth understanding of what components I have used in order to build this proposed sonic toothbrush with a performance that provides better dental cleaning quality.

- **Breadboard**

Figure 2.6 is a breadboard, often known as a proto board, is a building platform for electronics prototyping. It was originally just a bread board, a polished piece of wood used for slicing bread. "Prototype" is also a synonym for "Breadboard." The solderless breadboard is reusable since it does not require soldering. A breadboard is a broadly utilized device to plan and test circuit[25]. You don't have to bind wires and parts to make a circuit while utilizing a bread board. Attachment strips are utilized to hold the vast majority of the parts in a circuit. By and large it comprises of two areas each with 5 lines and 64 segments. This makes it simple to use for making temporary prototypes and circuit design experiments. This was not a feature of older breadboard models. Breadboards may be used to prototype a wide range of electronic systems, from simple analog and digital circuitry to entire central processing units (CPUs).

The components on the circuit board's back are depicted in the diagram below. A mid-range 8-bit microprocessor controls the toothbrush. Because the microcontroller is not a bespoke chip, it must be configured with the appropriate software. The huge gold rings and triangle toward the end of the toothbrush are used to accomplish this during manufacture. The clock signal for the microcontroller's timing is provided by the resonator. Moreover, an electromagnetic coil moves a magnet, which drives the toothbrush head. The coil is divided into two halves, each connected in the opposing way, resulting in magnetic fields on opposing sides. The coil is pulsed in one direction to rotate the magnet, then pulsed in the opposite direction to rotate the magnet in the other direction. The high-speed brushing vibration is the outcome. The driving mechanism is dissected in the diagram below. The coil is continually switching polarity, causing the north pole to move from top to bottom (the yellow and blue poles of the coil). Because the magnet has poles on the front and rear edges (perpendicular to the coils), it will try to spin back and forth along the toothbrush's long axis to line

up with the coil. The mechanism restricts rotation to a few degrees, resulting in a back-and-forth rotating vibration rather than a motor-like motion. The torsion bar transmits this rotational vibration to the toothbrush head, causing the head and bristles to vibrate.

Moving on towards the charging section of the sonic toothbrush, instead of being plugged in, the toothbrush is placed on a stand and charged inductively. The coil of the toothbrush is magnetically attached to the stand's coil, allowing power to be sent wirelessly. At the bottom of the toothbrush, you can see the coil. When the coil is put on the stand, it generates about 12 volts, which is used to charge the battery. For efficiency, the electricity is carried at a high frequency of 80 kHz. A diode bridge connects the coil to a diode bridge, which converts the electricity to DC. Then, as commanded by the Arduino microcontroller, it passes via a transistor circuit that regulates the charging. The toothbrush's battery is a 700 mAH rechargeable battery with a 1.2 volts rating.

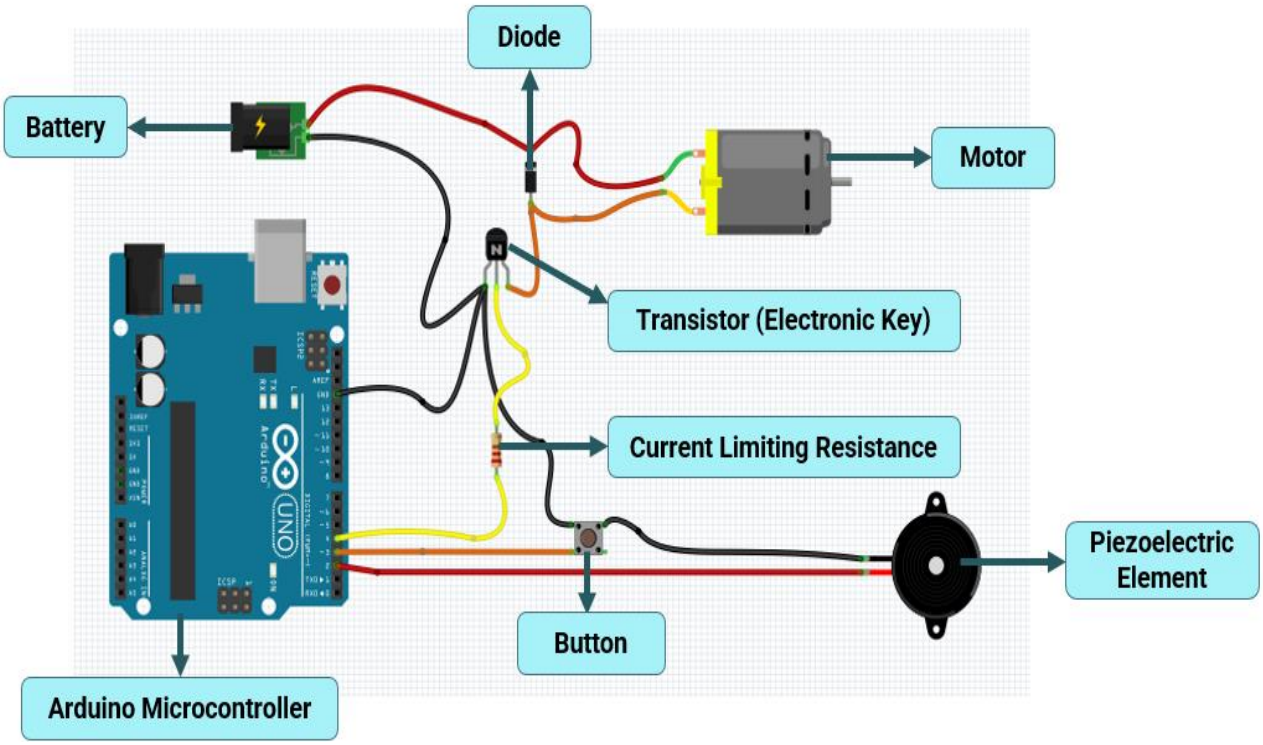


Figure 2.6 – Labelled diagram of the Breadboard Circuit Model

A circuit is the way that an electric flow goes on, and a basic circuit contains three parts important to have a working electric circuit, specifically, a wellspring of voltage, a conductive way, and a resistor. Circuits are driven by streams. A circuit is a current-flowing loop. The circuit's energy is supplied by a power source, such as a battery. Electrons travel from the power source's negative side via the circuit and back to the source's positive side. The circuit is complete when the electrons have returned to the power source. Figure 2.7 is a labelled diagram of the schematic circuit model utilized in the proposed sonic toothbrush.

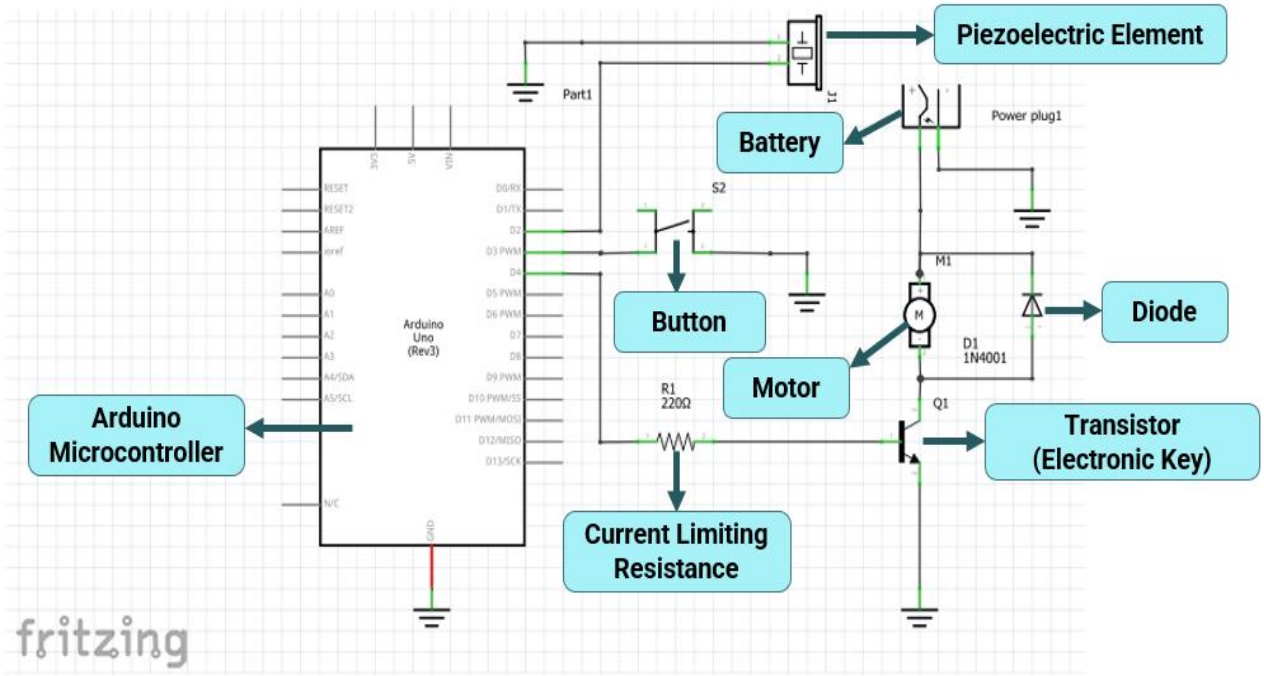
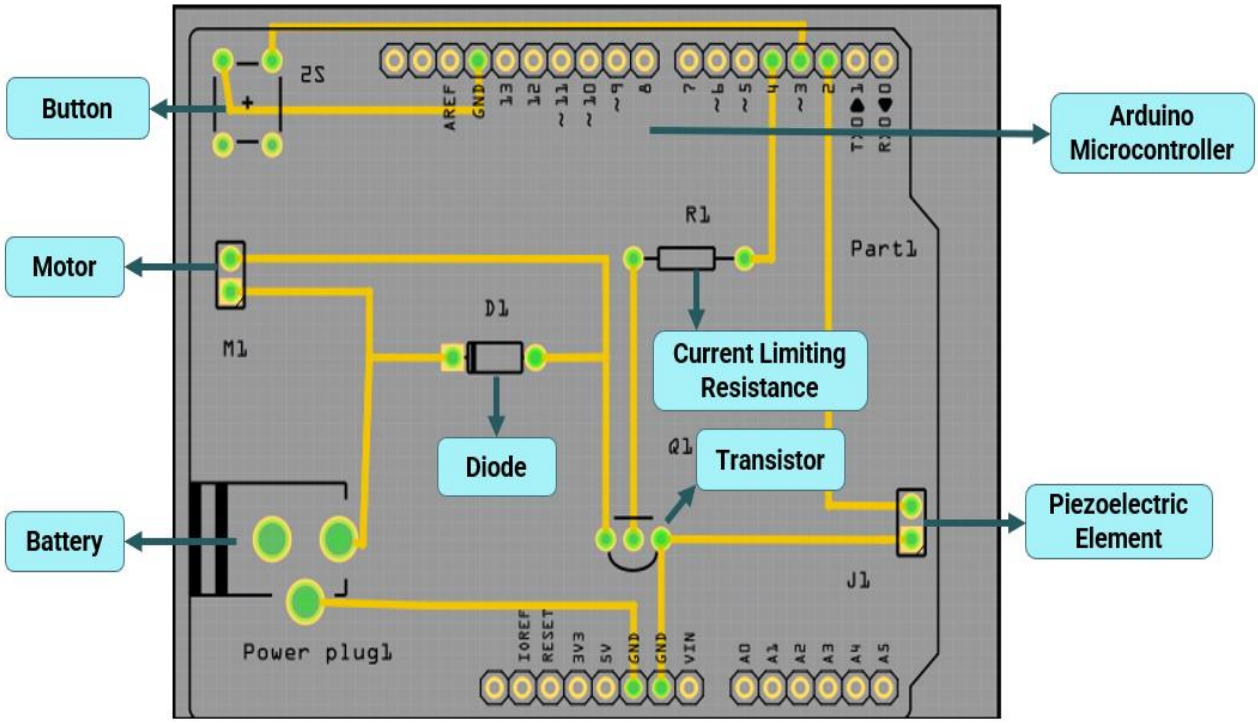


Figure 2.7 – Labelled diagram of the Schematic Circuit Model

- **Printed circuit board (PCB)**

Using conductive paths, tracks, or sign lines cut from copper sheets coated onto a non-conductive substrate, PCB is used to precisely maintain and electrically interconnect electronic devices. It is a circuit board if it has just copper rails and wires, and no circuit components such as capacitors, resistors, or dynamic devices have been included into the actual substrate of the board it is also more accurately alluded to as printed wiring board

(PWB) or carved wiring board. Semiconductors, connectors, resistors, diodes, capacitors and radio gadgets are mounted to, and "talk" to each other through the PCB. Figure 2.8 is a PCB Circuit model used in Fritzing as you can see in the diagram



below.

Figure 2.8 – Labelled diagram of the PCB Circuit Model

The following are the description of every component used in the circuit models depicted previously:

- The Motor

A motor is a machine that changes electrical energy over to mechanical energy." In another words, the electrical energy is a "battery" and the mechanical energy is the "turn." To clarify an engine genuinely, the notable "Fleming's left hand rule" is a decent methodology. At the point when electric flow courses through an electrical wire put between two magnets looking with one another, it creates power. Electric flow, attractive field and movement individually applies opposite headings each other similarly as when you open the center finger (electric flow), the pointer (attractive field) and the thumb (power) of your left hand separately to commonly symmetrical tomahawks (figure 2.9).

- ✓ It is used to supply water.
- ✓ It is located in the water pump housing.

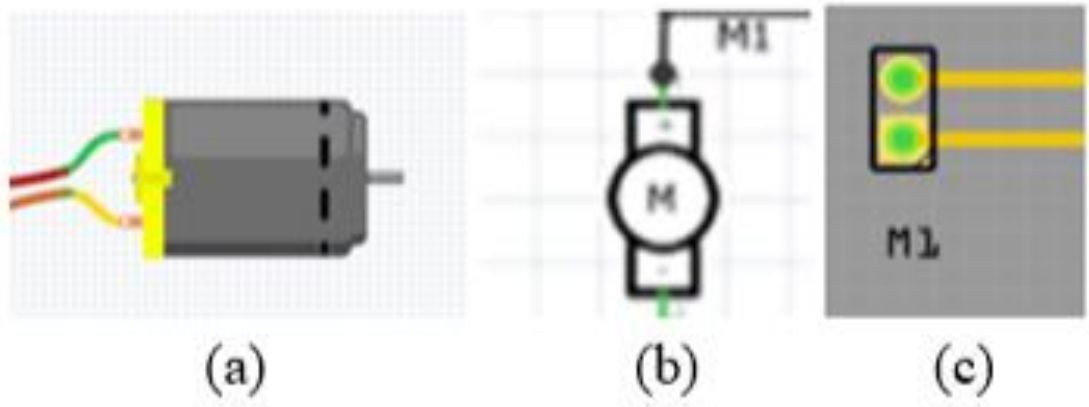


Figure2.9 – Different Models of Motor

- The Transistor

A transistor is a kind of a semiconductor gadget that can be utilized to both direct and protect electric flow or voltage. A semiconductor essentially goes about as a switch and an enhancer. In straightforward words, we can say that a semiconductor is a small gadget that is utilized to control or direct the progression of electronic signs

- ✓ It is used when the motor needs to turn on and off.

Below is the diagram used in Fritzing program to show different forms of button in breadboard, circuit and PCB model (figure 2.10).

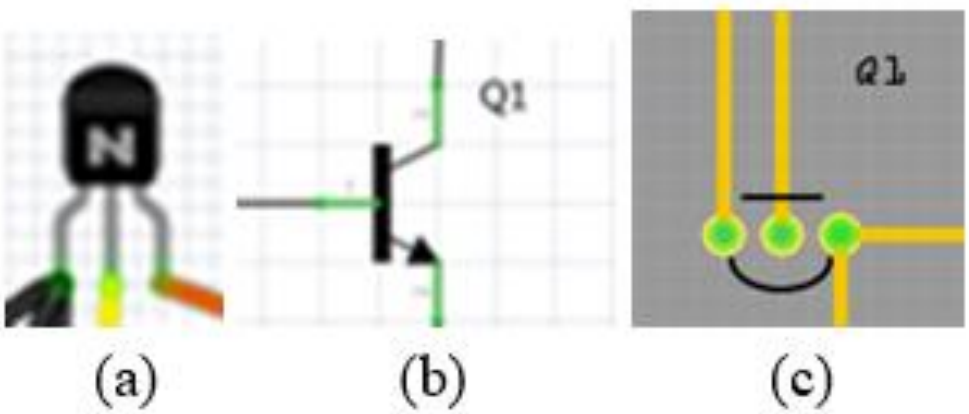


Figure 2.10 – Different Models of Transistor

- Resistance

A resistor is an aloof electrical part that makes obstruction in the section of power. They might be found in for all intents and purposes every single electrical organization and electronic circuits. In ohms, opposition is estimated. At the point when one ampere of current goes through a resistor with a one volt drop between its terminals, the opposition is estimated in ohms.

✓ It helps to turn the motor on and off when needed.

Below is the diagram used in Fritzing program to show different forms of button in breadboard, circuit and PCB model (figure 2.11).

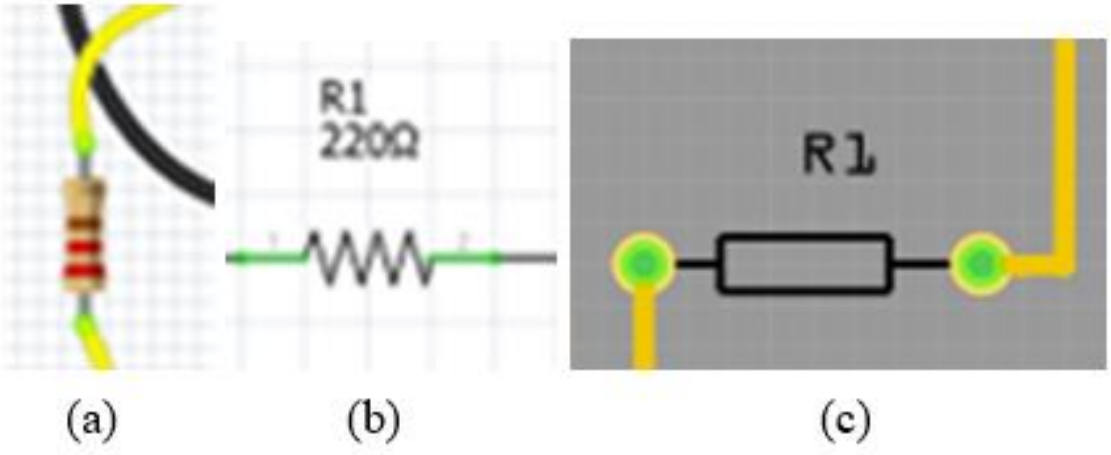


Figure 1.11 –Different Models of Resistance

- Diode

A diode is a semiconductor device that operates as a one-way current switch. It permits current to flow smoothly in one direction but substantially limits current flow in the opposing direction.

✓ It helps to turn the motor on and off when necessary.

Below is the diagram used in Fritzing program to show different forms of button in breadboard, circuit and PCB model (figure 2.12).

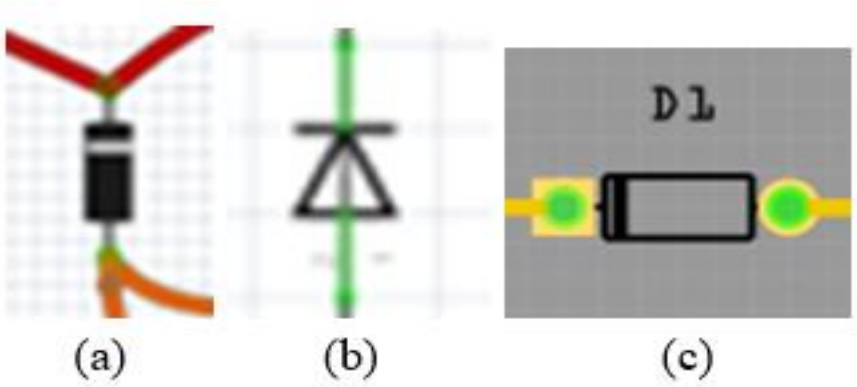


Figure 2.12 – Different Models of Diode

- The button

The button is required to turn on your device when you start using it.

Below is the diagram used in Fritzing program to show different forms of button in breadboard, circuit and PCB model (2.13).

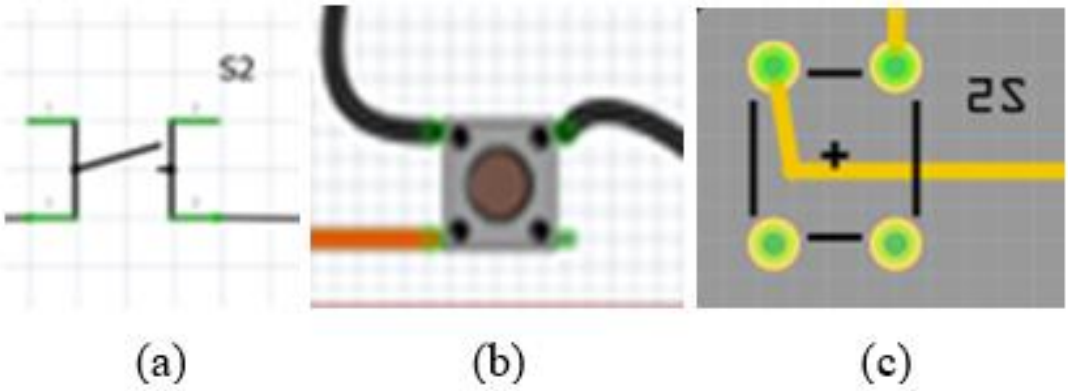


Figure 2.13 – Different Models of the button

- The Microcontroller

Arduino microcontroller is made up of a hardware programmable circuit board (also known as a microcontroller) and software called an IDE (Integrated Development Environment) that runs on your computer and is used to create and upload computer code to the physical board.

- it controls all the devices in the circuit;
- it receives a signal from the button to start the work;
- it includes a piezoelectric element in the circuit;

Below is the Arduino microcontroller used in Fritzing program to show the breadboard, circuit and PCB model (figure 2.14).

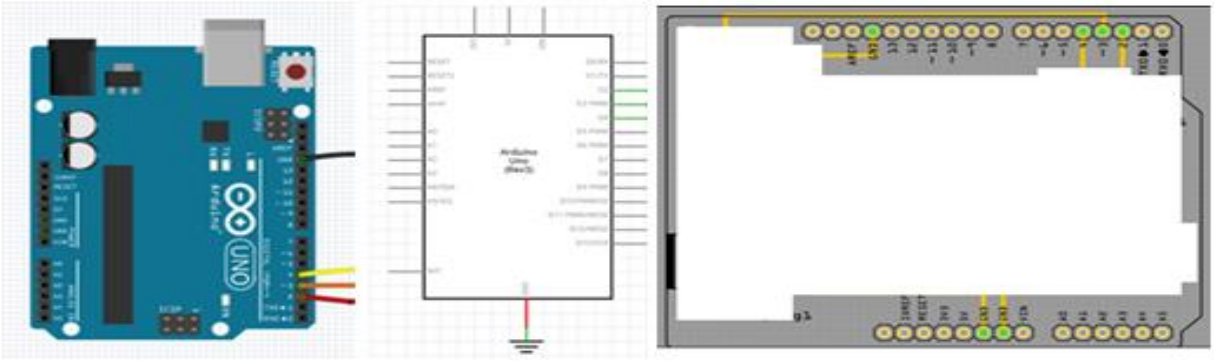


Figure 2.14 – Different Models of the Microcontroller

- Piezoelectric Element

Piezoelectric elements have a unique property in that when an external voltage is provided, the element elongates or vibrates, similar to how it generates electricity when external pressure is applied (figure 2.14).

- When necessary, it helps to turn on and turn off the water pump in the circuit (motor);
- Once we are done using by the end of the program, it turns everything off.

Figure 2.14 –Model of Piezoelectric Element

Conclusions to the section 2

The scheme works as follows:

1) Pressing the button turns on the piezo element and it gives signal to the microcontroller to start for a few minutes (brushing your teeth).
2) Then the water supply is automatically turned on if you want to use it for 60 seconds (rinsing the teeth).
3) At the end of the process, the following are automatically switched off: piezo element and the water supply.

Technical characteristics of the proposed sonic toothbrush:

- Sound vibration 55,000 times / minute
- Suitable for adults and children
- Inductive charging (wireless)
- (Lithium battery) 700mAh full charge in 2 hours
- IPX7 Waterproof
- Bristles: DuPont (unique polyester based material used to create structured surface)
- Noise: less than 40 dB (A)
- Dimensions (HxWxD) - 18 x 2.7 x 2.7 cm
- Weight - 0.2 kg

SECTION 3

SAFETY AND PRECAUTIONS

3.1. Protection against negative factors arising from the operation of an sonic toothbrush

Within this section, harmful and dangerous factors that affect the human body during the operation of an ultrasonic toothbrush will be considered. Means and warnings to avoid this negative impact will also be discussed.

Factors that analyze the working conditions, the workplace of the device operator (doctor, nurse) was chosen, which is located in the dentist's office.

Negative factors that can affect the operator and the patient: noise, improper lighting, disturbance of the microclimate, the influence of ultrasound. Let's analyze the effect of ultrasound on the operator and the patient. Ultrasound has been used in medicine for more than 30 years, and the most controversial and controversial issue was the safety of the use of ultrasonic waves for the operator and the patient [26].

Many reputable international organizations have been involved in the biological effects of ultrasound and its safe use in recent years: the World Health Organization, the World Federation for the Application of Ultrasound in Medicine and Biology, the International Electro technical Commission, and individual national communities.

All of these organizations came to the same conclusion in their reporting documents that to date no effects have been found that could prevent the widespread use of sonic waves for therapeutic purposes. At the same time, the most significant and definite conclusion for both developers and users is the conclusion made in December 1987 by the American Institute for the Application of Ultrasound in Medicine organization: When exposed to tissues in vivo (directly on the body) with unfocused ultrasound intensities below 100 mW/cm^2, there has been no evidence of significant biological effects in the range of ultrasonic frequencies utilized for diagnostic and therapeutic applications.

This conclusion was confirmed several times in subsequent years. Thus, over the past decade, it has been generally accepted to consider ultrasonic exposure to be completely safe if the radiation intensity is less than 100 mW / cm2. At the same time, in a number of publications it was noted that this threshold is conditional and adopted for definiteness as a temporary reference point. In the future, as additional experiments and research are carried out, its value can be revised.

The above conclusion of the AIUM can be represented as a graph of the dependence of the intensity on the time of exposure to sound on the human body (Fig. 3.1).

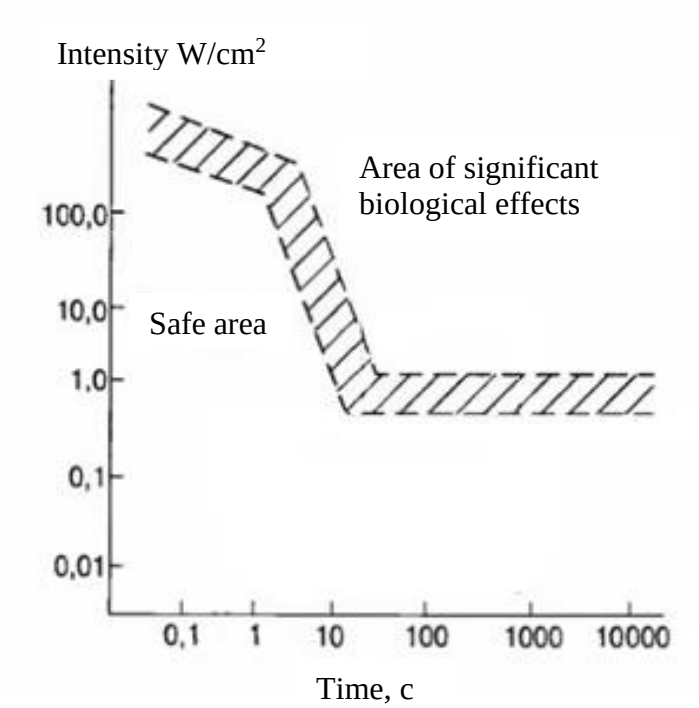


Fig. 3.1. Safe operation area of ultrasonic equipment

In the graph, the solid line indicates the area where the intensity levels of most of the sonic devices in use today fall.

To regulate the issue of the spread of the intensity values of the spread of the intensity values, the Food and Drug Administration in the United States adopted a document (Table 3.1) regulating the threshold intensity levels depending on the field of clinical application.

Table 3.1.The level of the threshold sound intensity depending on the area of clinical application

Application area	I, mW / cm^2
Cardiology	430
Peripheral vessels	720
Ophthalmology	17
Fetal imaging	94
Other applications	94

The intensity levels can surpass the given threshold numerous times, as seen in the table above. In this scenario, the last sentence of the Application of Sound in Medicine conclusion should be used as a guide: similar effects were not proven at greater intensities, when the product of intensity and exposure duration was less than 50 J/cm^2).

Organization of the Operator's (Dentist's) Workplace

The place of the dental filling operation is the dentist's office. The lighting in this cabinet should be both natural and artificial [27]. The intensity of the artificial illumination of the operator's workplace should be 300 lux (lux). The light coefficient of natural lightening should be 1: 5-1: 6, the light coefficient at the farthest point from the windows should be at least 1.0-1.5%.

3.2. Electrical Safety

Since the device for sonic oral hygiene is powered by alkaline batteries with a nominal voltage of 1.5 V, the exposure current is constant [28]. Touch voltages and currents flowing through the human body during normal (non-emergency) operation of the electrical installation should not exceed the values specified in (Table 3.2.)

Table 3.2 Thresholds for the safe impact of electricity on the human body

Current type	*U*, В	*I*, мА
	no more	
Alternating current ,50 Гц	2,0	0,3
Alternating current , 400 Гц	3,0	0,4
D.C.	8,0	1,0

Notes:

1. Touch voltages and currents are given for a duration of exposure of no more than 10 minutes per day and are set based on the reaction of sensation.
2. Touch voltages and currents for persons performing work in conditions of high temperatures (above 25 ° C) and humidity (relative humidity above 75%) should be reduced by three times.

To protect the patient from influencing currents and voltages in the event of device malfunctions, it is necessary to ensure proper isolation from water ingress on the batteries.

3.3. Fire Safety

The dental office, like any other department of therapeutic institutions, is a place where a large number of people are concentrated [29]. There are medical devices in the office that work from the power supply, therefore there is a danger of fire and such an office must be assigned category B fire safety. Therefore, it is necessary to follow the standard fire safety measures in medical institutions. Electrical appliances must be in good working order and grounded. The cabinet must be equipped with a powder or carbon dioxide fire extinguisher (carbon dioxide and refrigerant types of fire extinguishers are also applicable), since it is forbidden to use

air-foam to extinguish electrical installations [30]. Do not store oxygen or other gas cylinders indoors. Household items should not obstruct emergency exits.

Conclusion by section 3

An sonic toothbrush does not have negative effects on the human body, since the intensity used does not exceed 100 mW/cm^2, and the exposure time according to the standard is no more than 3 minutes (180 s), which absolutely meets the safety requirements. Exposure to electric current, even in emergency mode, does not exceed the permissible limits of exposure to the human body, but in order to minimize such an effect, as well as to ensure uninterrupted operation of the sonic apparatus, it is necessary to provide for high-quality isolation from water ingress on the batteries and toothbrush mechanisms.

CONCLUSION

1. An enlarged comfortable sonic toothbrush that will further improve the quality of brushing your teeth, better performance, longer battery life and an attached micro-bubbler (water channel).

2. Developed a user-friendly sonic toothbrush that further enhances the cleaning performance of the teeth with an attached micro-bubbler (water channel).

3 .According to the Modal Analysis that I have conducted,

- The proposed sonic toothbrush is safe to use while in vibrational motion;
- Shows resonance in 905 Hz which is equivalent to 55,000 strokes per minute.

4. High efficiency and low power consumption of the piezoelectric element allow:

Use lithium batteries of the type as batteries, which affects the ease of use, and also increases the service life:

The cost of using such a toothbrush is reduced (batteries wear out over time and require expensive replacement, which directly affects the life of the brush);

5. A sonic toothbrush has significant advantages over other personal oral hygiene products:

- Sound effect is most effective mechanically plaque.
- possible gentle cleaning of the tooth surface without damaging the hard tissues of the tooth. Sound effect makes it possible to avoid negative abrasive effects on the tooth enamel.
- can be used by children and adults, people with artificial prostheses, implants, braces systems.

REFERENCES

1. Tooth Anatomy - Gosford, Experienced Dentists: VC Dental. Retrieved 7 June 2021, from https://www.vcdental.com.au/tooth-anatomy-education/
2. What Are the Different Types of Teeth?. Retrieved 7 June 2021, from https://www.medicinenet.com/teeth_types/article.htm
3. Otukoya R, Shepherd E (2018) Principles of effective oral and denture care in adults. Nursing Times [online]: 114: 11, 22-24.
4. Richards D. (2018). The effectiveness of interproximal oral hygiene aids. Evidence-based dentistry, 19(4), 107–108. https://doi.org/10.1038/sj.ebd.6401341
5. A Manual of Paediatric Dentistry./ R.J.Andlaw, W.P.Rock.-4th ed., 1996 Copyright, P. 29-55
6. Sreenivasan, P. K., & Prasad, K. V. (2017). Distribution of dental plaque and gingivitis within the dental arches. Journal of International Medical Research, 1585-1596. https://doi.org/10.1177/0300060517705476
7. Sreenivasan, P. K., & Prasad, K. V. (2017). Distribution of dental plaque and gingivitis within the dental arches. Journal of International Medical Research, 1585-1596. https://doi.org/10.1177/0300060517705476
8. Mathur, V. P., & Dhillon, J. K. (2018). Dental Caries: A Disease Which Needs Attention. Indian journal of pediatrics, 85(3), 202–206. https://doi.org/10.1007/s12098-017-2381-6
9. Sanz, M., Marco Del Castillo, A., Jepsen, S., Gonzalez-Juanatey, J. R., D'Aiuto, F., Bouchard, P., Chapple, I., Dietrich, T., Gotsman, I., Graziani, F., Herrera, D., Loos, B., Madianos, P., Michel, J. B., Perel, P., Pieske, B., Shapira, L., Shechter, M., Tonetti, M., Vlachopoulos, C., … Wimmer, G. (2020). Periodontitis and cardiovascular diseases: Consensus report. Journal of clinical periodontology, 47(3), 268–288. https://doi.org/10.1111/jcpe.13189

10. Chauhan, Y., Jain, S., Ratre, M. S., Khetarpal, S., & Varma, M. (2020). Giant Dental Calculus: A Rare Case Report and Review. International journal of applied & basic medical research, 10(2), 134–136. https://doi.org/10.4103/ijabmr.IJABMR_84_19
11.11. Sanz, M., Marco Del Castillo, A., Jepsen, S., Gonzalez-Juanatey, J. R., D'Aiuto, F., Bouchard, P., Chapple, I., Dietrich, T., Gotsman, I., Graziani, F., Herrera, D., Loos, B., Madianos, P., Michel, J. B., Perel, P., Pieske, B., Shapira, L., Shechter, M., Tonetti, M., Vlachopoulos, C., … Wimmer, G. (2020). Periodontitis and cardiovascular diseases: Consensus report. Journal of clinical periodontology, 47(3), 268–288. https://doi.org/10.1111/jcpe.13189
12. Kamath, D. G., & Umesh Nayak, S. (2014). Detection, removal and prevention of calculus: Literature Review. The Saudi dental journal, 26(1), 7–13. https://doi.org/10.1016/j.sdentj.2013.12.003
13. Pizanis, V. G., & Pizanis, C. (2019). Effective and Ineffective Clinical Teaching in Dental Hygiene Education: A Qualitative Study. Journal of dental education, 83(8), 904–913. https://doi.org/10.21815/JDE.019.087
14. Partido, B. B., Webb, C. A., & Carr, M. P. (2019). Comparison of calculus detection among dental hygienists using an explorer and ultrasonic insert. International journal of dental hygiene, 17(2), 192–198. https://doi.org/10.1111/idh.12388
15. Yaghini, J., Mogharehabed, A., Safavi, N., Mohamadi, M., & Ashtiju, F. (2015). Evaluation of the effect of low level laser therapy toothbrush in treatment of dentin hypersensitivity. Journal of lasers in medical sciences, 6(2), 85–91.
16. Chicalé-Ferreira, A. B., Palma-Dibb, R. G., Faraoni, J. J., Gatón-Hernández, P., Silva, L., Silva, R., de Queiroz, A. M., Lucisano, M. P., & Nelson-Filho, P. (2020). Effect of manual and electrical brushing on the enamel of sound primary teeth and teeth with induced white spot lesions. American journal of dentistry, 33(1), 25–28.

17. Pitchika, V., Pink, C., Völzke, H., Welk, A., Kocher, T., & Holtfreter, B. Long-term impact of powered toothbrush on oral health: 11-year cohort study. Journal of Clinical Periodontology. 2019 713-722. https://doi: ttps://doi.org/10.1111/jcpe.13126
18. Ccahuana-Vasquez, R. A., Conde, E. L., Cunningham, P., Grender, J. M., Goyal, C. R., & Qaqish, J. (2018). An 8-Week Clinical Comparison of an Oscillating-Rotating Electric Rechargeable Toothbrush and a Sonic Toothbrush in the Reduction of Gingivitis and Plaque. The Journal of clinical dentistry, 29(1), 27–32.
19. Hernandé-Gatón, P., Palma-Dibb, R. G., Silva, L., Faraoni, J. J., de Queiroz, A. M., Lucisano, M. P., Silva, R., & Nelson Filho, P. (2018). Effect of ultrasonic, sonic and rotating-oscillating powered toothbrushing systems on surface roughness and wear of white spot lesions and sound enamel: An in vitro study. American journal of dentistry, 31(2), 76–80.
20. Mirovich Leonard (2001). Fundamentals of vibration, - 826 p. https://www.slideshare.net/yanpain2/fundamentals-of-vibrations-leonard-meirovitch
21. Deinzer, R., Ebel, S., Blättermann, H., Weik, U., & Margraf-Stiksrud, J. (2018). Toothbrushing: to the best of one's abilities is possibly not good enough. BMC oral health, 18(1), 167. https://doi.org/10.1186/s12903-018-0633-0
22. Singh, G., Mehta, D. S., Chopra, S., & Khatri, M. (2011). Comparison of sonic and ionic toothbrush in reduction in plaque and gingivitis. Journal of Indian Society of Periodontology, 15(3), 210–214. https://doi.org/10.4103/0972-124X.85662
23. Tanasiewicz, M., Hildebrandt, T., & Obersztyn, I. (2016). Xerostomia of Various Etiologies: A Review of the Literature. Advances in clinical and experimental medicine : official organ Wroclaw Medical University, 25(1), 199–206. https://doi.org/10.17219/acem/29375

24. Lugović-Mihić, L., Pilipović, K., Crnarić, I., Šitum, M., & Duvančić, T. (2018). Differential Diagnosis of Cheilitis - How to Classify Cheilitis?. Acta clinica Croatica, 57(2), 342–351. https://doi.org/10.20471/acc.2018.57.02.16
25. Definition of breadboard. Retrieved 7 June 2021, from https://www.pcmag.com/encyclopedia/term/breadboard
26. Ng, C., Tsoi, J., Lo, E., & Matinlinna, A. (2020). Safety and Design Aspects of Powered Toothbrush-A Narrative Review. Dentistry journal, 8(1), 15. https://doi.org/10.3390/dj8010015
27. Lance, LDA, K., Reil, LDA, E., & Norsted, DDS, J. (2011). Office Organization Systems. Inside Dental Assisting, 7(5). Retrieved from https://www.aegisdentalnetwork.com/ida/2011/10/office-organization-systems
28. P.J. Schram, Guidelines for Electrical Safety in the Dental Office, The Journal of the American Dental Association, Volume 85, Issue 2, 1972, Pages 365-371, ISSN 0002-8177, https://doi.org/10.1016/S0002-8177(72)52050-0. (https://www.sciencedirect.com/science/article/pii/S0002817772520500)
29. Pentapati KC, Kukkamalla MA, Purayil TP. Fire safety in dental clinics: Basics for dentists and dental students. J Dent Res Rev [serial online] 2015 [cited 2021 Jun 7];2:102-3. Available from: https://www.jdrr.org/text.asp?2015/2/2/102/161217
30. Pentapati, Kalyana & Purayil, Tina & Kukkamalla, MeenaAnand. (2015). Fire safety in dental clinics: Basics for dentists and dental students. Journal of Dental Research and Review. 2. 102. 10.4103/2348-2915.161217.