

Design and Simulation of a Biofluids Suction System

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Abstract: Biofluid suction is a critical component of medical society management, which is the major leading cause of preventable death. Current commercially available suction systems have not been scientifically validated for key performance measures relevant to prehospital care. Current suction systems devices are not endorsed for health casualty care and are considered too large and heavy to carry onto the health care society. There are commercially available manual and powered suction devices on the market, and several are specifically advertised for use with expensive and complicated devices. However, a review of the health problems information, as a review, and the limited literature on performance, to suggest that no device on the market meets even the most basic requirements of being small, lightweight, rugged, and less cost with a better suction performance. A fresh approach is needed, one that entails evidence-based requirements and specifications combined with engineering design and manufacture specially geared towards prehospital combat use.

Fortunately, existing guidelines, regulations and the literature do inform some aspects of big medical problems in the biofluid suction device systems. This includes parameters for size and weight, suction performance, and robustness to survive environment. The Bio fluid-system designed as a Cad model with solid work design software then set the simulation with the same software. The system design circuit with suitable sensors (Temperature, Flow rate, Level of fluid) to achieve the real-time data and gain the average sets of data that can be analyzed in next chapter.

However, the data also expose significant gaps in knowledge and standards. While measures such (Temperature, rate flow, velocity, level, there are no standards for required vacuum pressures, Recommendations can be inferred from the literature, but the quality of supporting evidence is limited and subject to future research. The improvement of the system will lead to modify the design to contain more fluid and improve the electric system to improve efficiency of the system.

CHAPTER ONE INTRODUCTION

1. Introduction

Biofluid Suction process is a critical procedure in the medical society, which is the Major leading cause of preventable death around the world. Current available portable suction devices systems have not been scientifically validated for key performance measures relevant to medical care in the manufacturing and medical fields [1].

2. Problem statement

Biofluids blockages management often determines survival in both trauma and medical patients. Skilled interventions often make the critical difference in survival for patients with actual or impending airway compromise [2]. Managing airways in the tactical environment presents an additional level of unique and complex challenges for any emergency provider[3]. Hazardous or confined spaces and hostile action inherently limit the ability to intervene with an artificial airway or assisted ventilation.

3. Objectives

To design and simulation a suitable Biofluid suction system as a key requirement to considerations of a suction system that intended for use on surgical and choking medical cases. This project summarizes the modeling and simulation and the future steps toward the development of a portable medical suction system that intended to achieve the requirements- medical literature and industry standards.

4. Scope of the study

1. Collect Data of the Previous study to create and improve the Biofluid suction system.
2. To design a model of the Suction system using CAD design software (Solid work and auto disc fusion 360)
3. Simulation the system using Solidwork Software.

5. Background of the project

In medicine, devices are sometimes necessary to create suction. Suction may be used to clear the airway of blood, saliva, vomit, or other secretions so that a patient may breathe. Suctioning can prevent pulmonary aspiration, which can lead to lung infections. In pulmonary hygiene, suction is used to remove fluids from the airways. to facilitate breathing and prevent growth of microorganisms. Small suction-providing devices are often called aspirators[4].

In surgery suction can be used to remove blood from the area being operated on to allow surgeons to view and work on the area. Suction may also be used to remove blood that has built up within the skull after an intracranial hemorrhage[5].

Suction devices may be mechanical hand pumps or battery or electrically operated mechanisms. In many hospitals and other health facilities, suction is typically provided by suction regulators, connected to a central medical vacuum supply by way of a pipeline system.

6. Summary

This chapter provide a clear knowledge of the introduction as a clear view of the Biofluid field and how it's important to the human Body organs. Show the important major problems and how to make a clear objective of how to design a prorated system that can achieve all the objective by the scope of the study efficiently.

CHAPTER TWO LITERATURE REVIEW

1. Introduction

A literature review is a piece of academic writing demonstrating Background studies and understanding of the academic literature on a specific topic placed in context. A literature review also includes Preview academic material. Usually, a literature review forms a section or part of a dissertation, research project or long essay.

Focusing on different aspects of the literature review can be useful to help plan, develop, refine and write it. To use and adapt the prompt questions in project worksheet below at different points in the process of researching and writing the review.

2. Body Fluids

Body fluids are considered to be the interstitial fluids, saliva, tears, and gastric juices. They moisten the tissues, muscles, body organs and skin. In Chinese medicine, the production of these fluids is influenced by proper gastrointestinal function by the spleen and stomach qi. These vital fluids are formed from the food we eat and the water we drink. The lungs control respiration, which releases moisture and distributes body fluids through full breathing. Body fluids are excreted through the pores as sweat. They are also dispersed throughout the body by the action of lung qi. The qi energy motivates the circulation of lymph and interstitial fluids, which is sent to the kidneys for filtration,

absorption and reabsorption. Fluids are then transformed and sent to the bladder as urine, or collected in the large intestine to assist the discharge of feces[6].

1. Body fluid types

1. Bile

Bile is a fluid that is made and released by the liver and stored in the gallbladder. Bile helps with digestion. It breaks down fats into fatty acids, which can be taken into the body by the digestive tract.

2. Blood and blood products such as plasma and serum

1. Blood

The blood has many different functions, including: transporting oxygen and nutrients to the lungs and tissues. forming blood clots to prevent excess blood loss. carrying cells and antibodies that fight infection[7].

2. Plasma

The main role of plasma is to take nutrients, hormones, and proteins to the parts of the body that need it. Cells also put their waste products into the plasma. The plasma then helps remove this waste from the body. Blood plasma also carries all parts of the blood through your circulatory system[8].

3. Serum

Serum proteins—also known as blood or plasma proteins—are proteins present in blood that serve many different functions, including transport of lipids, hormones, vitamins, and minerals in the circulatory system and the regulation of acellular activity and functioning of the immune system [9].

3. Breast milk

Breast milk provides the ideal nutrition for infants. It has a nearly perfect mix of vitamins, protein, and fat everything baby needs to grow. And it's all provided in a form more easily digested than infant formula. Breast milk contains antibodies that help your baby fight off viruses and bacteria [10].

4. Cerebrospinal fluid

Assists the brain by providing protection, nourishment, and waste removal. CSF provides hydromechanical protection of the neuraxins through two mechanisms. First, CSF acts as a shock absorber, cushioning the brain against the skull [10].

5. Cerumen (earwax)

It protects the skin of the human ear canal, assists in cleaning and lubrication, and provides protection against bacteria, fungi, and water [11] .

6. Endolymph and perilymph

Perilymph and endolymph have unique ionic compositions suited to their functions in regulating electrochemical impulses of hair cells necessary for hearing[12].

7. Female ejaculate:

We hypothesize that female ejaculation has a unique function in producing a secretion into the urethra that provides protection from urinary tract infections (UTIs). We further predict that female ejaculate contains antimicrobial compounds including elements such as zinc Female ejaculation is characterized as an expulsion of fluid from the Skene's gland at the lower end of the urethra during or before an orgasm[13].

8. Gastric juice

Its main function is to inactivate swallowed microorganisms, thereby inhibiting infectious agents from reaching the intestine [14].

9. Mucus (including nasal drainage, phlegm cough droplets):

The major function of mucus is to protect the lung through clearance against foreign particles and chemicals entering the lung[15] .

10. Peritoneal fluid

Peritoneal fluid acts to moisten the outside of the organs and to reduce the friction of organ movement during digestion and movement[16].

11. Pleural fluid

The pleural cavity, with its associated pleurae, aids optimal functioning of the lungs during breathing. The pleural cavity also contains pleural fluid, which acts as a lubricant and allows the pleurae to slide effortlessly against each other during respiratory movements[17].

12. Saliva

Saliva is an aqueous fluid found in the oral cavity playing a fundamental role in the preservation and maintenance of oral health. Saliva acts in relation to taste, mastication, bolus formation, enzymatic digestion, and swallowing[18].

13. Sebum (skin oil)

Sebum is an oily, waxy substance produced by the body's sebaceous glands. It coats, moisturizes, and protects your skin. It's also the main ingredient in what you might think of as your body's natural oils[19].

14. Semen

The secretions in semen are important for the survival and motility of sperm. They provide a medium through which sperm can swim. They also include sperm-sustaining substances, such as high concentrations of the sugar fructose, which is the main source of energy for sperm[20].

15.

Sweat is mainly water, but it also contains some salts. Its main function is to control body temperature. As the water in the sweat evaporates, the surface of the skin cools. An additional function of sweat is to help with gripping, by slightly moistening the palms [21].

16. Tears

Tears prevent dryness by coating the surface of the eye, as well as protecting it from external irritants. There are no blood vessels on the surface of the eye, so oxygen and nutrients are transported to the surface cells by tears. Foreign bodies that enter the eye are washed out by tears[21].

17. Vaginal fluid and secretions

Vaginal discharge serves an important housekeeping function in the female reproductive system. Fluid made by glands inside the vagina and cervix carries away dead cells and bacteria. This keeps the vagina clean and helps prevent infection. Most of the time, vaginal discharge is perfectly normal[22].

18. Vomit

Nausea and vomiting are important as biological systems for drug side effects, disease co-morbidities, and defences against food poisoning. Vomiting can serve the function of emptying a noxious chemical from the gut, and nausea appears to play a role in a conditioned response to avoid ingestion of offending substances.

19. Urine

The urinary system's function is to filter blood and create urine as a waste by-product[23].

2. Lung fluid disease

Lung disease is any problem in the lungs that prevents the lungs from working properly. There are three main types of lung disease:

1. **Airway diseases:** These diseases affect the tubes (airways) that carry oxygen and other gases into and out of the lungs. They usually cause a narrowing or blockage of the airways. Airway diseases include asthma, COPD and bronchiectasis. People with airway diseases often they feel as if they're [24].
2. **Lung tissue diseases:** These diseases affect the structure of the lung tissue. Scarring or inflammation of the tissue makes the lungs unable to expand fully (restrictive lung disease). This makes it hard for the lungs to take in oxygen and release carbon dioxide. People with this type of lung disorder often say they feel as if they are "wearing a too-tight sweater or vest." As a result, they can't breathe deeply. Pulmonary fibrosis and sarcoidosis are examples of lung tissue disease[25].
3. **Lung circulation diseases:** These diseases affect the blood vessels in the lungs. They are caused by clotting, scarring, or inflammation of the blood vessels. They affect the ability of the lungs to take up oxygen and release carbon dioxide. These diseases may also affect heart function. An example of a lung circulation disease is pulmonary hypertension. People with these conditions often feel very short of breath when they exert themselves[26].

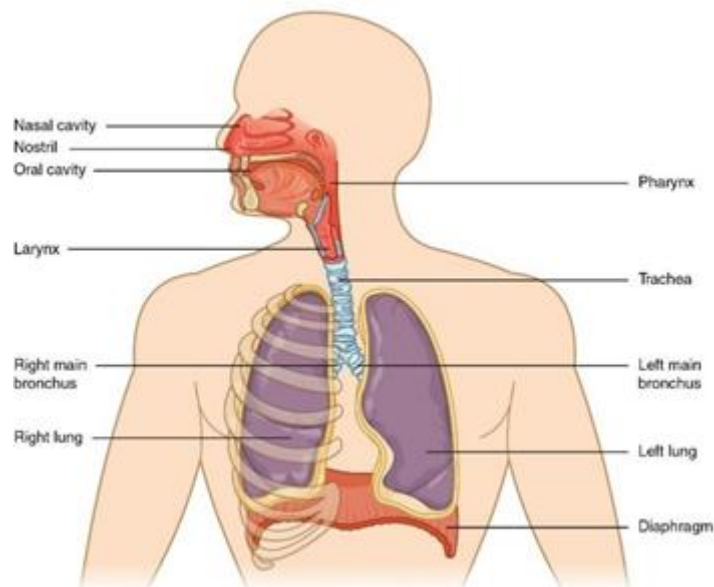


Figure 2.1: Human lung system

1. Pulmonary edema

Pulmonary edema is a condition caused by excess fluid in the lungs. This fluid collects in the numerous air sacs in the lungs, making it difficult to breathe. In most cases, heart problems cause pulmonary edema. But fluid can collect in the lungs for other reasons, including pneumonia, exposure to certain toxins and medications, trauma to the chest wall, and traveling to or exercising at high elevations. Pulmonary edema that develops suddenly (acute pulmonary edema) is a medical emergency requiring immediate care. Pulmonary edema can sometimes cause death. The outlook improves if you get treated quickly. Treatment for pulmonary edema varies depending on the cause but generally includes supplemental oxygen and medications. Pulmonary edema signs and symptoms may appear suddenly or develop over time. The signs and symptoms you have depends on the type of pulmonary edema[27].

Sudden (acute) pulmonary edema signs and symptoms Difficulty breathing (dyspnea) or extreme shortness of breath that worsens with activity or when lying down A feeling of suffocating or drowning that worsens when lying down A cough that produces frothy sputum that may be tinged with blood Wheezing or gasping for breath Cold, clammy skin, Anxiety, restlessness or a sense of apprehension Bluish A rapid, irregular heartbeat (palpitations) . Heart failure and other heart conditions that raise pressure in the heart increase the risk of pulmonary edema. Risk factors for heart failure include. However, some nervous system conditions and lung damage due to near drowning, drug use, smoke inhalation, viral infections and blood clots also raise your risk[28].

People who travel to high-altitude locations above 8,000 feet (about 2,400 meters) are more likely to develop high-altitude pulmonary edema (HAPE). It usually affects those who do not first become acclimated to the elevation (which can take from a few days to a week or so). In general, if pulmonary edema continues, the pressure in the pulmonary artery can go up (pulmonary hypertension). Eventually, the heart becomes weak and begins to fail, and pressures in the heart and lungs go up[29].

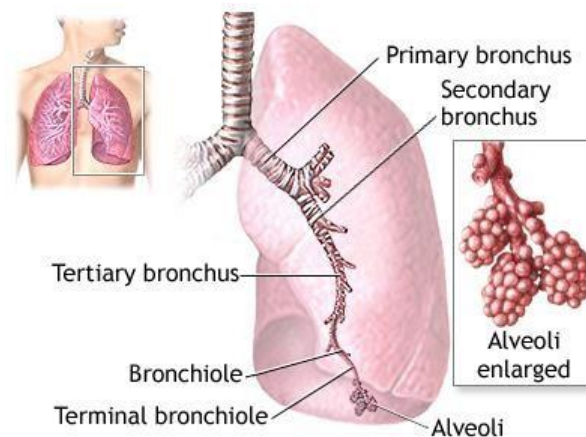


Figure 2.2: Lung physiology

2. Pleural effusion

A pleural effusion is an unusual amount of fluid around the lung. Many medical conditions can lead to it, so even though your pleural effusion may have to be drained, your doctor likely will target the treatment at whatever caused it. The pleura is a thin membrane that lines the surface of your lungs and the inside of your chest wall. When you have a pleural effusion, fluid builds up in the space between the layers of your pleura. Normally, only teaspoons of watery fluid are in the pleural space, which allows your lungs to move smoothly in your chest cavity when you breathe[30].

1. Pulmonary embolism

This is a blockage in an artery in one of your lungs, and it can lead to pleural effusion. Pleural effusion, sometimes referred to as “water on the lungs,” is the build-up of excess fluid between the layers of the pleura outside the lungs. The pleura are thin membranes that line the lungs and the inside of the chest cavity and act to lubricate and facilitate breathing. Normally, a small amount of fluid is present in the pleura.

Some patients with pleural effusion have no symptoms, with the condition discovered on a chest x-ray that is performed for another reason. The patient may have unrelated symptoms due to the disease or condition that has caused the effusion. Symptoms of pleural effusion include: Chest pain Dry, nonproductive cough Dyspnea .shortness of breath, or difficult, labored breathing Orthopnea (the inability to breathe easily unless the person is sitting up straight or standing erect).

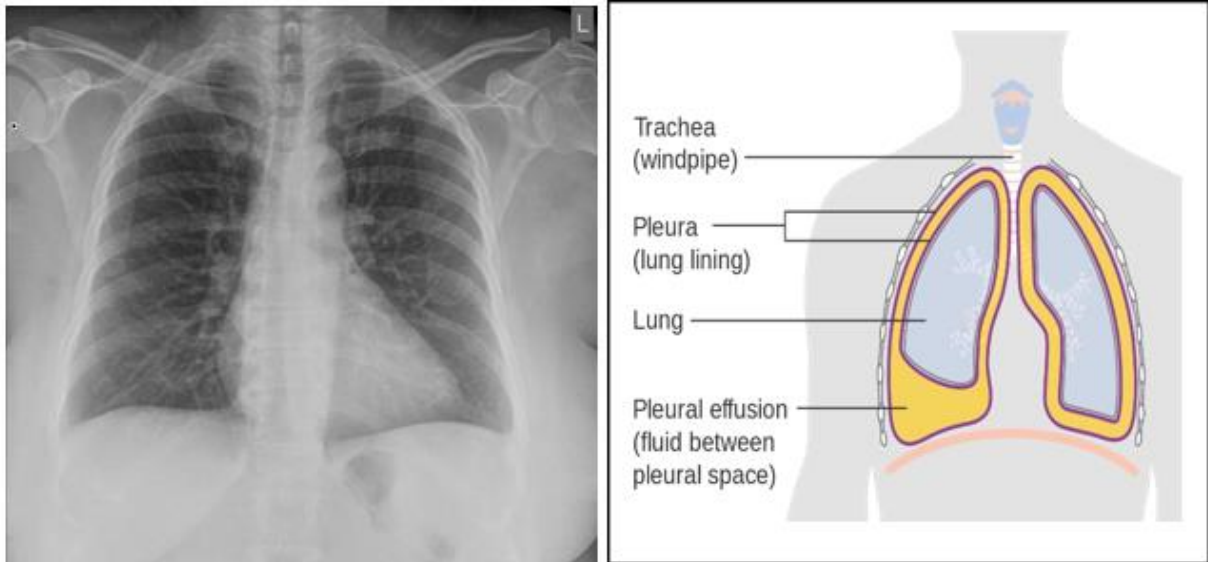


Figure 2.3: Pulmonary embolism

3. COVID-19 Pneumonia

In pneumonia, the lungs become filled with fluid and inflamed, leading to breathing difficulties. For some people, breathing problems can become severe enough to require treatment at the hospital with oxygen or even a ventilator[31].

The pneumonia that COVID-19 causes tends to take hold in both lungs. Air sacs in the lungs fill with fluid, limiting their ability to take in oxygen and causing shortness of breath, cough and other symptoms.

While most people recover from pneumonia without any lasting lung damage, the pneumonia associated with COVID-19 may be severe. Even after the disease has passed, lung injury may result in breathing difficulties that might take months to improve[32].

As COVID-19 pneumonia progresses, more of the air sacs become filled with fluid leaking from the tiny blood vessels in the lungs. Eventually, shortness of breath sets in, and can lead to acute respiratory distress syndrome (ARDS), a form of lung failure. Patients with ARDS are often unable to breath on their own and may require ventilator support to help circulate oxygen in the body[33].

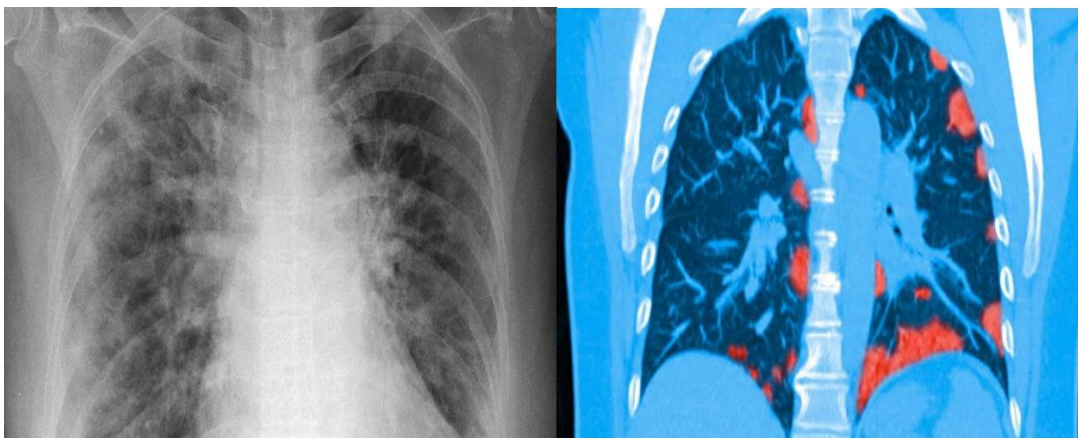


Figure 2.4: COVID-19 Pneumonia

Whether it occurs at home or at the hospital, ARDS can be fatal. People who survive ARDS and recover from COVID-19 may have lasting pulmonary scarring.

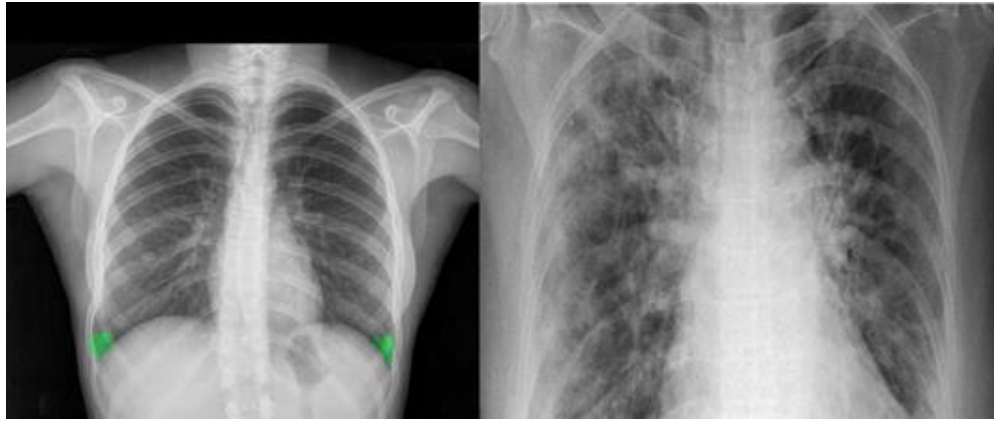


Figure 2.5: COVID-19 fluid Capillary Blockage

3. MEDICAL SUCTION AND FLUID WASTE MANAGEMENT

Suction plays a critical role in numerous medical procedures. It's also a key component of every tactical medical kit. Yet many first responders and other medical professionals are familiar with only one or two suction aspirators. In an emergency or when you collaborate with another agency, your familiarity with a wide range of suction equipment may be the most important factor in patient outcomes. Here are the types of suction aspirators you might encounter.

vacuum for the suction system is generated either by a centrally located vacuum generator (or a pump) or by a free-standing device. The source of the negative pressure is connected to multiple devices to achieve the therapeutic function: a vacuum regulator, suction tube, canister, and suction catheter in a daisy chain. Once vacuum suction is generated, the only device that can control the negative pressure upstream to the patient is the vacuum regulator; therefore, it is the most critical component to optimize the power of a vacuum and ensure safety. The optimal vacuum pressure is selected by occluding the vacuum port on the regulator (or the suction tube as an alternative) to set the optimal pressure.

The type of suctioning equipment used often depends on the type of suctioning you intend to do. There are four basic types:

1. Oropharyngeal suctioning

The most commonly used form of suctioning in emergency medicine, this type of suctioning maintains a patent airway by suctioning the throat via the mouth.



Figure 2.6: Oropharyngeal suctioning

3. Nasopharyngeal suctioning:

An alternative to oropharyngeal suctioning, nasopharyngeal suctioning allows access to the throat through the nose. It can be especially helpful for patients with broken or missing teeth, serious jaw injuries, or any type of physical trauma that makes accessing the mouth difficult[34].



Figure 2.7: Nasopharyngeal suctioning

4. Nasotracheal suctioning

Nasotracheal suctioning, like nasopharyngeal suctioning, accesses the airway through the nose, but is reserved for middle and lower airway issues.

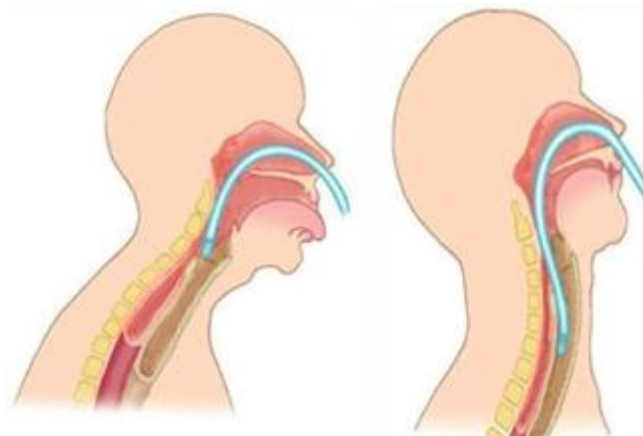


Figure 2.8: Nasotracheal suctioning

5. Suctioning through an artificial airway

Artificial airways must regularly be cleared of secretions, and suctioning supports this goal. Patients with airway obstructions may also require suctioning through an artificial airway[35].

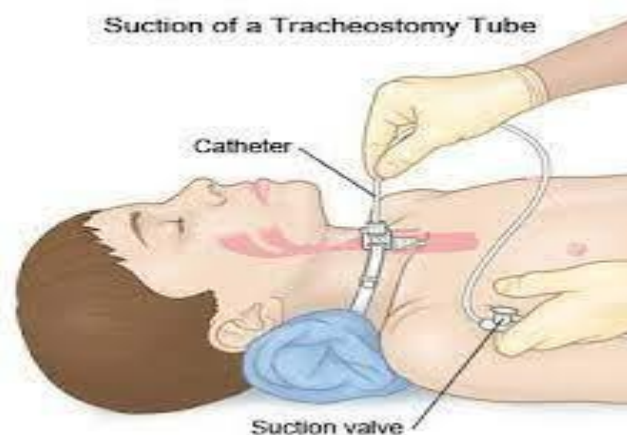


Figure 2.9: Suctioning through an artificial airway

4. Suction Device systems

Suction devices for use in health care can be classified into three types. Manually powered devices system, portable electrically powered devices system and Suction vacuum system unit.

1. Standards of the Suction Devices

A review of the available literature reveals standards, either proposed, validated or accepted for the performance of a portable suction systems for use in healthcare sector. Similarly, there are no accepted standards to guide the performance suction for use in prehospital or emergency care. There are, however some sources that inform the discussion.

1. Manually powered devices system 2.4.1.1.1 Ambu Res-Cue Manual Suction Pump

Table 2.1: Ambu Res-Cue

Weight	0.507 lbs
Dimensions	7.28 x 2.52 x 6.61 in
Flow Rate	>20 LPM
Vacuum Pressure	225 to 450 mmHg
Battery Life	Hand-powered

Consumer reviews for this device were found on Amazon. Reviewers claim this device is compact and easy to assemble. It would not be recommended for dedicated EMS use as the suction power is not guaranteed, but it is recommended for emergencies in which battery- powered devices are not available.



Figure 2.10: Ambu Res-Cue

2. Curaplex Manual Suction Unit

Table 2.2: Curaplex Manual Suction Unit

Weight	0.6 lbs
Dimensions	7.09 x 8.66 x 3.15 in
Flow Rate	>20 LPM
Vacuum Pressure	450 mmHg
Battery Life	Hand-powered

Consumer reviews for this device were found on Amazon. Several reviewers claim the device they received suctions very little, if at all, while other reviewers claim they could use this device in nonemergency settings.



Figure 2.11: Curaplex Manual Suction Unit

3. Emergency Aspirator from Vitalograph

Table 2.3: Aspirator from Vitalograph

Weight	0.882 lbs
Dimensions	6.5 x 6.5 x 3.43 in
Flow Rate	4.56 LPM
Vacuum Pressure	120 to 450 mmHg
Battery Life	Hand-powered

Consumer reviews were not found. The manufacturer claims this hand-powered device is widely used in hospital and military settings. The Emergency Aspirator conforms to EN ISO 10079-2 and is made from tough polycarbonate to withstand serious shocks. It is also easy to disassemble for cleaning and has a unique overflow design. Performance reviews were not available and there is no summary recommendation on the product.



Figure 2.12: Aspirator from vitalograph

2. Portable electrically powered devices system

1. DeVilbiss 7305D Series Homecare Suction Unit

Table 2.4: DeVilbiss 7305D Series Homecare Suction Unit

Weight	3.8 lbs
Dimensions	9 x 7 x 8 in
Flow Rate	27 LPM
Vacuum Pressure	80 to 550 mmHg
Battery Life	60 min, rechargeable

Consumer reviews for this device were found on Vitality Medical. Every single reviewer claims this device is too loud. One reviewer stated that the noise outweighed any of the positive aspects; however, all other reviewers stated it did clear airways despite the loud noise. It follows performance standards stated in ISO 10079-1.



Figure 2.13: DeVilbiss 7305D Series Homecare Suction Unit

2. Eeros Tote-L-Vac Suction Unit

Table 2.5: Eeros Tote-L-Vac Suction Unit

Weight	15.5 lbs
Dimensions	8 x 12 x 9.5 in
Flow Rate	36 LPM
Vacuum Pressure	Up to 550 mmHg
Battery Life	30 minutes, rechargeable

Consumer reviews were not found. The manufacturer claims that this device can provide high enough vacuum pressure and flow rates to perform airway clearance procedures despite its compact size. Due to the battery power and portability, the ToteL-Vac could be used for EMS, home health, hospital patient transport, and wherever battery power is a requirement. Performance reviews were not available and there is no summary recommendation on the product.



Figure 2.14: Eeros Tote-L-Vac Suction Unit

3. Drive Medical VacuMax Suction Machine with Rechargeable Battery

Table 2.6: VacuMax Suction Machine

Weight	5 lbs
Dimensions	12.4 x 9.8 x 8.1 in
Flow Rate	25 LPM
Vacuum Pressure	150 to 530 mmHg
Battery Life	50 min, rechargeable

Consumer reviews for this device were found on Drive Medical. The VacuMax Suction Machine received an average of 3.5/5.0 stars from two reviewers. One reviewer claims the device is poorly designed and does not take into consideration ease of use for wheelchair patients. Both reviewers stated the device has good suction ability and works well



Figure 2.15: VacuMax Suction Machine

4. Drive Medical VacuMax Suction Machine v.II

Table 2.7: VacuMax Suction Machine v.II

Weight	8.82 lbs
Dimensions	15.4 x 8.7 x 8.7 in
Flow Rate	25 LPM
Vacuum Pressure	700 mmHg
Battery Life	110 V on request

Consumer reviews were not found. The manufacturer claims that this device has low maintenance costs and has built in mechanical overflow safety. The INSTAD is used on hospital crash carts, during patient transfers, long-term home care, by tracheostomy, and by EMS. Performance reviews were not available and there is no summary recommendation on the product.



Figure 2.16: VacuMax Suction Machine v.II

3. Suction vacuum system unit.

1. EuroLite Suction Device

Table 2.8: EuroLite Suction Device

Weight	9.92 lbs
Dimensions	11.8 x 5.51 x 13 in
Flow Rate	12 LPM
Vacuum Pressure	600 mmHg
Battery Life	110 V on request

Consumer reviews were not found. The manufacturer claims that this device has low maintenance costs and has built in mechanical overflow safety as well as an electronic acoustic alarm. The EuroLite is used in nursing, obstetrics, and neonatal and pediatrics.

Performance reviews were not available and there is no summary recommendation on the product.



Figure 2.17: EuroLite Suction Device

2. John Bunn Vacutec 800 EV2 Portable Aspirator Suction Unit

Table 2.9: Vacutec 800 EV2

Weight	11.6 lbs
Dimensions	4.9 x 15.3 x 10 in
Flow Rate	0 to 40 LPM
Vacuum Pressure	0 to 560 mmHg
Battery Life	115 VAC

Consumer reviews were found on 4MD Medical. The John Bunn Vacutec 800 EV2 received 5.0/5.0 stars from 8 reviewers. All reviewers claim this product does exactly what it advertises. One reviewer stated that it is dependable and may be a good option for field medical or dental applications. It complies with EN60601 standards.



Figure 2.18: Vacutec 800 EV2

3. Laerdal Suction Unit

Table 2.10: Laerdal Suction Unit

Weight	8.9 lbs
Dimensions	12.4 x 13 x 6.3 in
Flow Rate	>30 LPM
Vacuum Pressure	80 to 500 mmHg
Battery Life	45 minutes, no-tools- necessary field changeable

Consumer reviews were not found. The manufacturer claims the Laerdal Suction Unit is effective at improving patient safety because it is powerful and effective and exceeds international standards. This product is in compliance with the Council Directive 93/42/EEC Medical Device Directive. Performance reviews were not available and there is no summary recommendation on the product.



Figure 2.19: Laerdal Suction Unit

4. Medela Dominant Flex Aspirator

Table 2.11: Medela Dominant

Weight	20.5 lbs
Dimensions	8.3 x 12 x 14.8 in
Flow Rate	40 to 60 LPM
Vacuum Pressure	713 mmHg
Battery Life	Plug into wall

Consumer reviews were not found. The manufacturer claims the Medela Basic Aspirator is built to perform in hospitals, clinics, and medical practices. It cannot operate unless plugged in. Performance reviews were not available and there is no summary recommendation on the product.



Figure 2.20: Medela Dominant

5. Manufacturing Standards for Suction Devices systems

Suction system is FDA class II ISO 10079 provides detailed minimal standards for suction devices intended for use in emergency and prehospital care. They do not address combat casualty care. The evidence supporting minimum performance standards for suction devices is not strong. No standard has been validated clinically or operationally, and may be inadequate for emergency and prehospital care. The standards are not specific to battlefield medicine and are unlikely to be applicable to combat casualty care environments

6. Summary

For purposes of this project, the focus will be on the first two categories, as fixed systems are not relevant to the mobile needs of far-forward combat casualty providers. Suction units can also be subdivided into the following two categories based on the location of intended use. Suction system field that are intended to be carried by the individual prehospital provider. These devices are relatively lightweight and compact. Portable or “luggable” devices that are intended to be carried in a transport vehicle or used a stationary machine in a temporary facility such as an aid station.

CHAPTER THREE

Project Methodology

1. Introduction:

This chapter is about the methodology and the way this project is carried and brought about to achieve the desired results and outcomes. The method and approach used for the investigated of the modelling and simulation strategy of the suction system that will be discussed in this chapter. The following parts of this chapter will further discuss and explain the methodology used in this project.

2. Flow chart Methodology

The flows chart diagram shows the process of the project, starting with the model and experimental model then combined the model as a combination system. After creating the system starting simulating suction system designer shown in the Figure below.

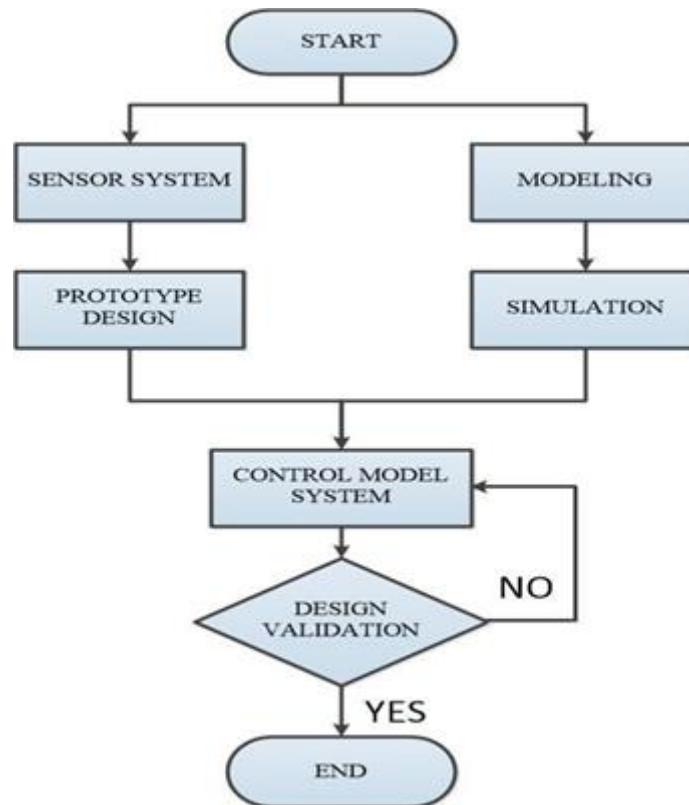


Figure 3.1: Flow Chart

3. Theoretical Pump and Vacuum Concepts

Pump suction devices used to suction, increase pressure or move liquids or gases. Pumps can be configured for vacuum, pressure and vacuum-pressure purposes. Pumps in Series Pressure head doubles when compared to one operating pump. Flow rate remains the same when compared to one operating pump. Pumps in Parallel Flow rate doubles when compared to one operating pump. Pressure head remains the same when compared to one operating pump.

The current concept design is depicted in the figure. This design utilizes a pump as the mechanism to suction obstructions out of a person's airway, an inline hydrophobic filter and a collection canister. The inline hydrophobic filter is intended to protect the pump from any contaminants and also restricts the passage of any fluid to the air pump. Inherently, this makes the pump reusable while the filter, canister and tubing require replacement after usage. The concept design also has an on/off switch, a low battery LED and a potentiometer to regulate the pumping power[36].

The control system of the device is composed of an Arduino Leonardo and a motor shield. Two power sources are used to power the entire device; a 12V battery is solely dedicated for the pump and a 9V battery powers the Arduino board. After examining the design concept, it was determined that the device had the following deficiencies:

- ✓ Low suction; higher suction is desired
- ✓ smaller portable device is desired
- ✓ Requires two separate batteries to operate
- ✓ The prototype that provides a large pressure drop and restricts flowrate

4. Initial condition

Table 3.1: Initial Condition

Description	Unit
Vacuum pump pressure	60Kpa
Liquid viscosity (water)	8.90×10^{-4} Pa·s
System device dimension (cylindrical)	Height =270 mm, Diameter = 130 mm
Flow rate	3.2 L/Min, Voltage = 5 V
Current	0.4 m A

Mathematical Model

The Poiseuille law or Poiseuille equation, is a physical law that gives the pressure drop in an incompressible and Newtonian fluid in laminar flow flowing through a long cylindrical pipe of constant cross section. It can be successfully applied to air flow in lung alveoli, or the flow through a drinking straw or through a needle. The assumptions of the equation are that the fluid is incompressible and Newtonian; the flow is laminar through a pipe of constant circular cross-section that is substantially longer than its diameter; and there is no acceleration of fluid in the pipe. For velocities and pipe diameters above a threshold, actual fluid flow is not laminar but turbulent, leading to larger pressure drops than calculated by the Hagen–Poiseuille equation[37].

$$\Delta p = \frac{8\mu LQ}{\pi R^4} = \frac{8\pi\mu LQ}{A^2}$$

where:

Δp is the pressure difference between the two ends = 60 Kpa = 60000 pa

L is the length of pipe = 1 m

μ is the dynamic viscosity = 8.90×10^{-4} Pa·s

Q is the volumetric flow rate, R is the pipe radius = 4 mm A is the cross section of pipe

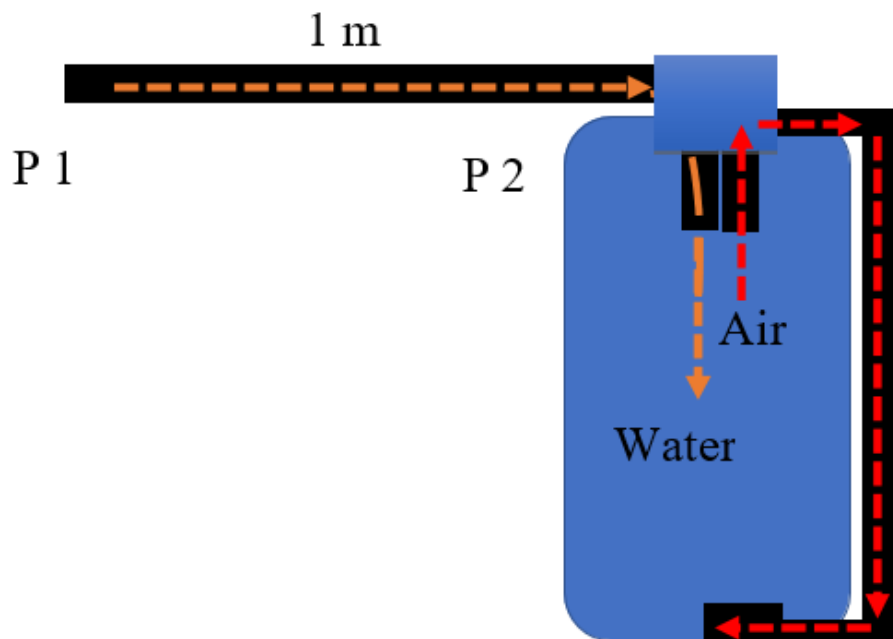


Figure 3.2.1: Mathematical model

The average volume flow rate 0.165 m³.s, the average rate will be according to 4.3 L/min

5. CAD model:

Computer-aided design is a way to digitally create 2D drawings and 3D models of real-world products—before they're ever manufactured.

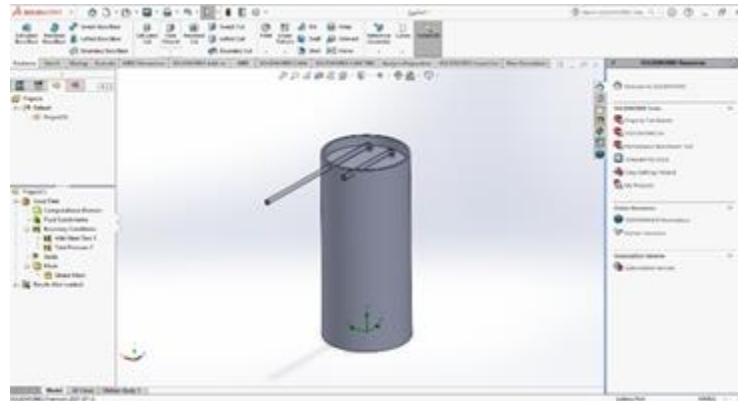


Figure 3.2: CAD Model

With 3D CAD, you can share, review, simulate, and modify designs easily, opening doors to innovative and differentiated products that get to market fast. CAD is used to accomplish preliminary design and layouts, design details and calculations, creating 3-D models, creating and releasing drawings, as well as interfacing with analysis, marketing, manufacturing, and end-user personnel in the figure below .

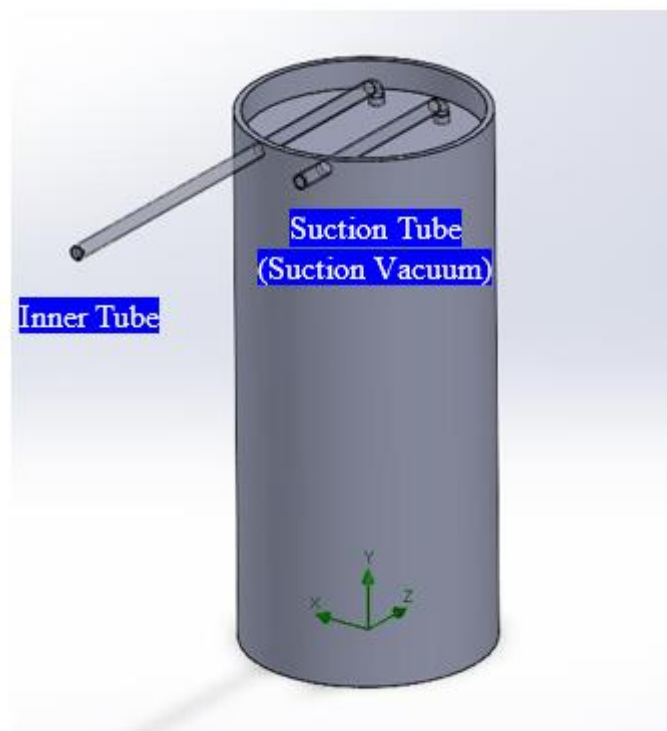


Figure 3.3: Cad model descriptions

SOLIDWORKS is used to develop bio fluid systems from beginning to end. At the initial stage, the software is used for planning, visual ideation, modeling, feasibility assessment, prototyping, and project management. The software is then used for design and building of mechanical, electrical, and software elements. Finally, the software can be used for management, including device management, analytics, data automation, and cloud services.

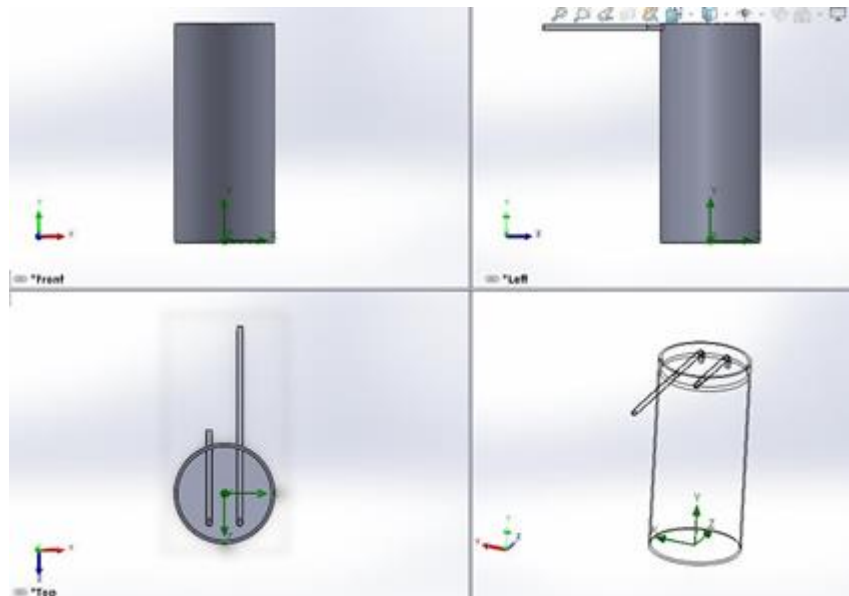


Figure 3.4: Cad model with four perspectives

1. 3D printing of the model

Design and transform the design into STL design. Using 3D printer to achieve the model according to the CAD design as shown in the figures below [38].

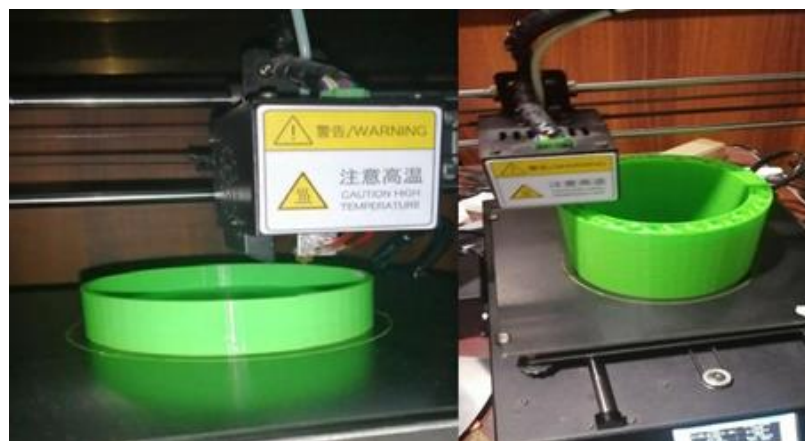


Figure 3.5: 3D printing process (base part)



Figure 3.6: 3D printing process (the cover)

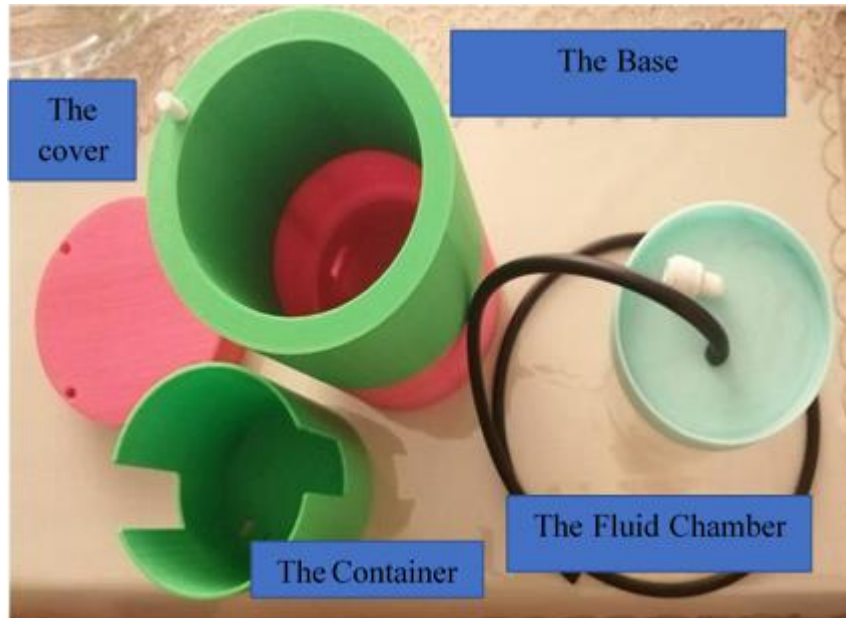


Figure 3.7: The main parts of the Suction units

6. Simulation concept:

1. SOLIDWORKS Simulation

SOLIDWORKS Simulation has been around for years tracing its roots back to 1982 and the Structural Research and Analysis Corporation (SRAC). SOLIDWORKS Simulation used to be called COSMOS Works, and since its early days, the Finite Element Analysis program has strived to be powerful, accurate, and EASY to use. Flow Simulation is an intuitive Computational Fluid Dynamics (CFD) solution embedded within SOLIDWORKS 3D CAD that enables you to quickly and easily simulate liquid and gas flows through and around your designs to calculate product performance and capabilities. Part of SOLIDWORKS Simulation’s ease of use are the simple Six Steps that every Simulation Study shares.

SOLIDWORKS Simulation is a Finite Element Analysis (FEA) program built into the familiar SOLIDWORKS CAD interface. Simulation provides designers and engineers the tools they need to quickly test their designs and intelligently iterate on them. Utilizing NAFEMS validated FEA solvers, SOLIDWORKS Simulation can provide accurate, reliable results for a wide range of study types from basic linear static analysis to more complex nonlinear and dynamic analysis. Speed up the iteration and prototyping phase of your design process with SOLIDWORKS Simulation.

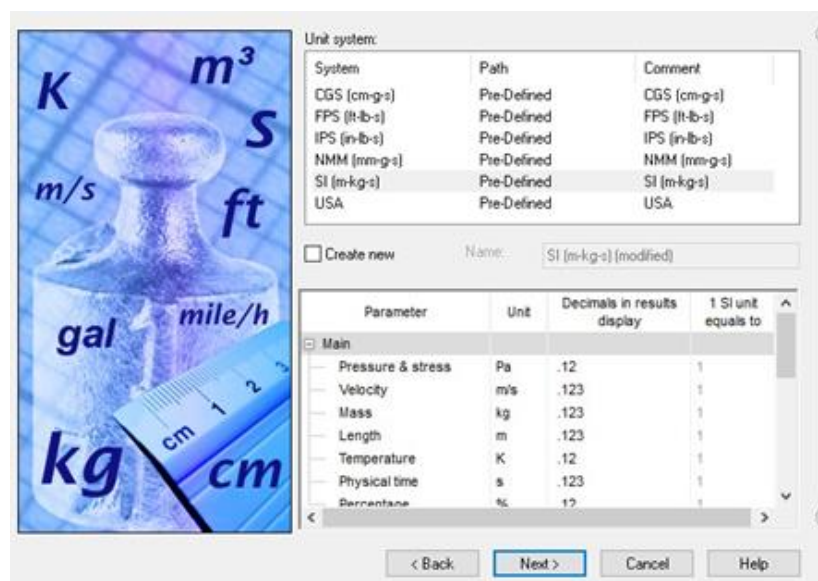


Figure 3.8: Solid work run simulation

Accuracy and reliability is a common question of all Simulation tools. How do we know the results can be trusted? Fortunately, there is an independent group that handles this. The National Agency for Finite Element Methods and Standards (NAFEMS) tests simulation programs against benchmark studies with known results that have been validated mathematically and empirically. All study types available in SOLIDWORKS Simulation have been tested and validated by

NAFEMS. SOLIDWORKS has included setup guides and the NAFEMS benchmark models in the Simulation software so users can run the analysis and compare the results themselves.

2. Steps of the prototype simulation

Step 1: Define your Study. Static, Thermal, Frequency, etc.

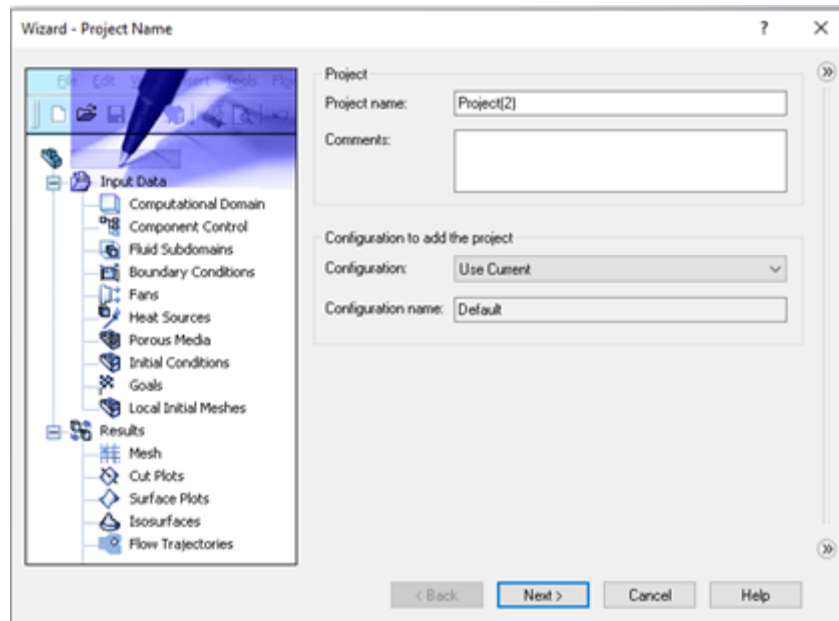


Figure 3.9: Simulation characteristic window

Step 2: Assign the Materials

Step 3: Apply the Boundary Conditions (Free Body Diagram)

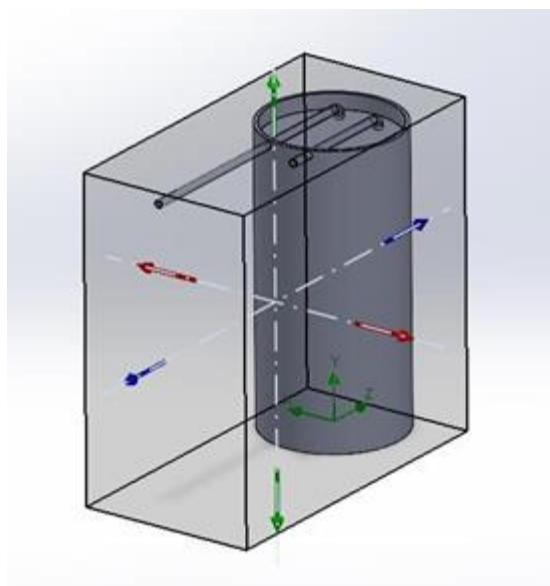


Figure 3.10: Simulation domain

Step 4: Mesh the Model

Step 5: Run the Analysis (Solve)

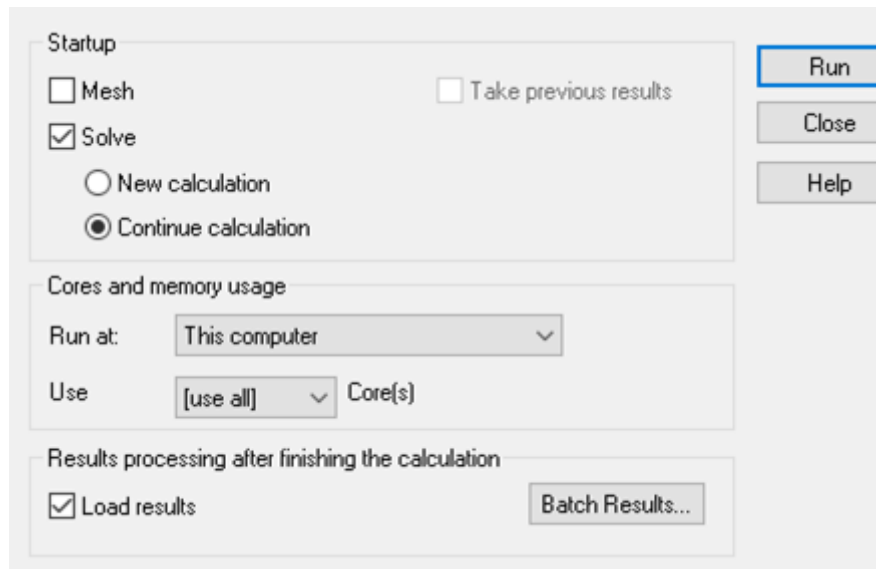


Figure 3.11: Analysis running window

7. Microcontrollers control systems

A microcontroller (MCU for microcontroller unit) is a small computer on a single metal-oxide-semiconductor (MOS) integrated circuit (IC) chip. A microcontroller contains one or more CPUs (processor cores) along with memory and programmable input/output peripherals. Program memory in the form of ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general-purpose applications consisting of various discrete chips[39].

In modern terminology, a microcontroller is similar to, but less sophisticated than, a system on a chip (SoC). An SoC may include a microcontroller as one of its components, but usually integrates it with advanced peripherals like a graphics processing unit (GPU), a Wi-Fi module, or one or more coprocessors.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems. In the context of the internet of things, microcontrollers are an economical and popular means of data collection, sensing and actuating the physical world as edge devices.



Figure 3.12: Microcontrollers

Some microcontrollers may use four-bit words and operate at frequencies as low as 4 kHz for low power consumption (single-digit milliwatts or microwatts). They generally have the ability to retain functionality while waiting for an event such as a button press or other interrupt; power consumption while sleeping (CPU clock and most peripherals off) may be just nanowatts, making many of them well suited for long lasting battery applications.

Other microcontrollers may serve performance-critical roles, where they may need to act more like a digital signal processor (DSP), with higher clock speeds and power consumption.

1. Arduino microcontroller

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics, and for good reason. Unlike most previous programmable circuit boards, the Arduino does not need a separate piece of hardware (called a programmer) in order to load new code onto the board – you can simply use a USB cable. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package. The platform of an Arduino has become very famous with designers or students just starting out with electronics, and for an excellent cause.

2. Arduino Nano

Arduino Nano as a small board based on the microcontrollers The connection of this board is the same as to the Arduino UNO board. This kind of microcontroller board is very small in size, sustainable, flexible, and reliable.

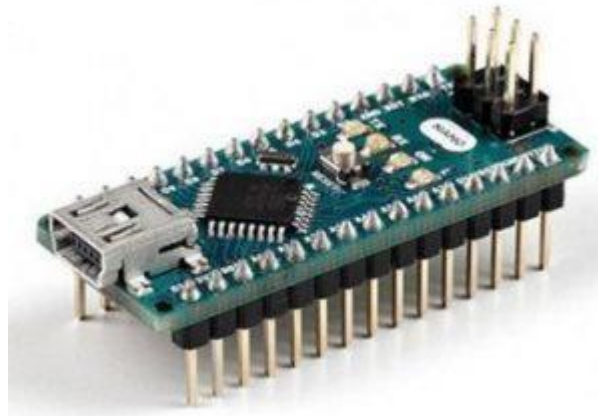


Figure 3.13: Arduino Nano

Table 3.2 Arduino Types

Arduino Board	Processor	Memory	Digital I/O	Analogue I/O
Arduino Uno	16Mhz Atmega328	2KB SRAM, 32KB flash	14	6 input, 0 output
Arduino Due	84MHz AT91SAM3X8E	96KB SRAM, 512KB flash	54	12 input, 2 output
Arduino Mega	16MHz Atmega2560	8KB SRAM, 256KB flash	54	16 input, 0 output
Arduino Leonardo	16MHz Atmega32u4	2.5KB SRAM, 32KB flash	20	12 input, 0 output

As compared with the Arduino Uno board, it is small in size. The devices like mini-USB and Arduino IDE are necessary to build the projects. This board mainly includes analog pins-8, digital pins-14 with the set of an I/O pin, power pins-6 & RST (reset) pins-2. Please refer to this link to know more about Arduino Nano Board.

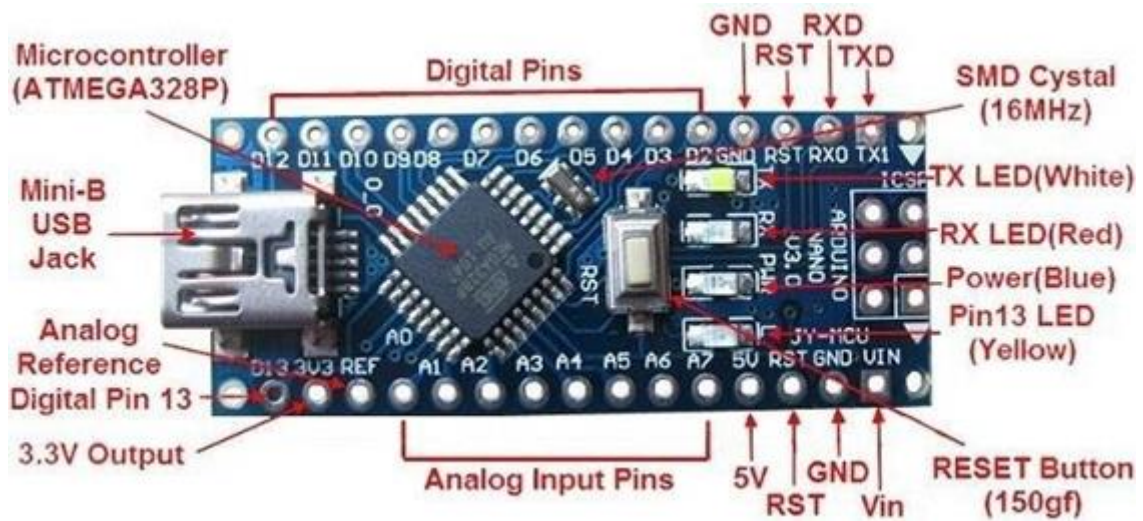


Figure 3.14: Arduino Nano components

8. System Design

Systems design is the process of defining elements of a system like modules, architecture, components and their interfaces and data for a system based on the specified requirements. It is the process of defining, developing and designing systems which satisfies the specific needs and requirements of a business or organization.

1. Electric circuit Diagram

The electronic system contains of major components and Mainor components. The major parts contain of (Arduino Nano microcontroller, power supply unit, volume pump) while the Mainor components consist of (Temperature sensors, mass flow sensor, Relay, Non-contact level sensor, LCD screen).

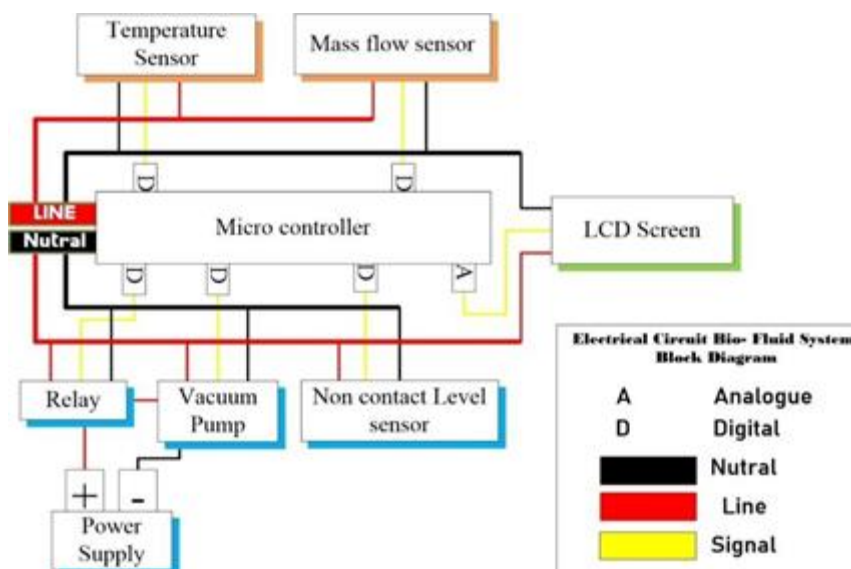






Figure 3.15: Bio fluid electric circuit diagram

Table 3.3: sensor Types that used in the project

Sensor	Figure	Work principle
Temperature sensor		Using to measure the temperature of fluids as Digital signal
Non-contact level sensor		Using to identify the level of fluid without any contact
Relay		Using to contact with motors or fluid pump
Flow rate sensor		Using to measure the mass flow rate of the fluids

The electric circuit system contacts as shown in the figure below that show how the components work as one robust control system that sensing and suck the fluid as a real time then store the data of the temperature, level of the fluid and the mass flow rate in instant time.

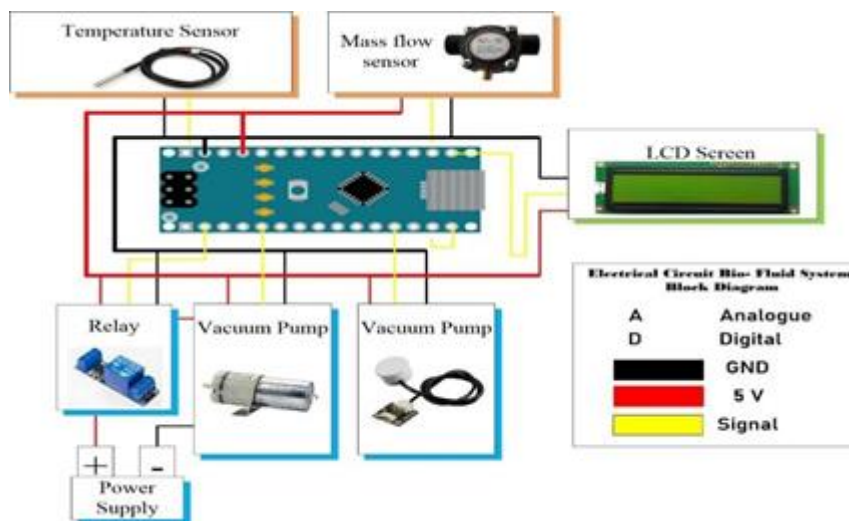


Figure 3.16: Biofluid suction circuit unit diagram

2. Bio fluid units Diagram

The mechanical –fluid components consist of four units that contact and work consequently together as on rigid unit as shown in the figure below. The first unit called suction unit that can be defined as the initial unit that generate a vacuumed pressure. The second unit called the container unit that can be define as a chamber that contain the fluid of the system that had reduce the inner pressure in the container while the outer pressure become tremendous that allow the fluid to come inside due to pressure law then take it to achieved the purpose of this unit.

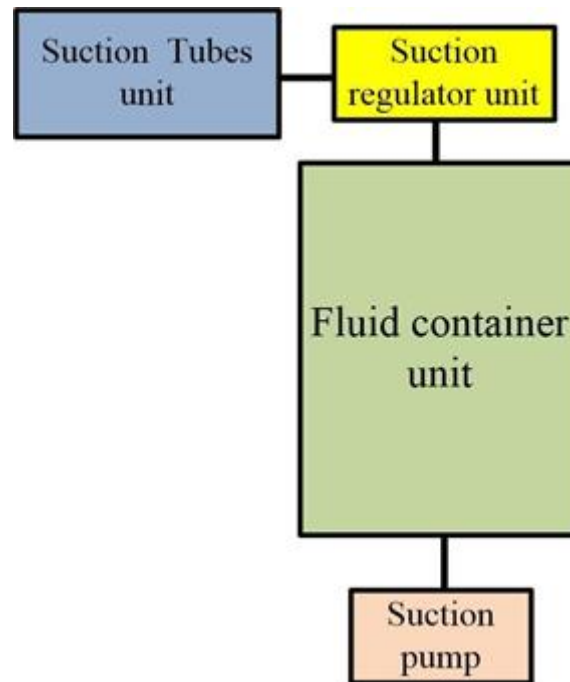


Figure 3.17: Suction system unit

The third unit called suction regulator unit that can be defined as a control unit of the amount of fluid that can be enter the system. The fourth unit called the suction tubes unit that consist of the inner –outer tubes that used between the patient or the Bio-fluid environmental and the system. These four components work as one unit that its responsible to deliver the fluid to the system and contain it with no problems in order to achieved working efficiently and safely requirement[40].



Figure 3.18: Biofluid suction system

9. Summary

The Bio fluid-system designed as a Cad model with solid work design software then set the simulation with the same software. The system design circuit with suitable sensors (Temperature, Flow rate, Level of fluid) to achieve the real –time data and gain the average sets of data that can be analyzed in next chapter.

CHAPTER FOUR RESULT AND DESCUTIONS

1. Introduction

The discussion follows the Results and precedes the Conclusions and Recommendations section. It is here that the project results indicate the significance of the results. The temperature result shows the sever change between the real-time and simulation results due to of the environmental condition.

2. Simulation results

Table 4.1: Average real time data sets

Time (sec)	Counter	Flow rate L/Min	Temperature (K)	Level sensor
0	0	0	0	0
1	1	3.2	315.21 K	0
2	2	3.2	315.21 K	0
3	3	3.2	315.21 K	0
4	4	3.2	315.21 K	0
5	5	3.2	315.21 K	0
6	6	3.2	315.21 K	0
7	7	2	315.21 K	0
8	8	2	315.21 K	0
9	9	2	315.21 K	0
10	10	3.1	315.21 K	0
11	11	3.1	315.21 K	0
12	12	3.1	315.21 K	0
13	13	3.1	315.21 K	0
14	14	3.1	315.21 K	0
15	15	3.1	315.21 K	0
16	16	1.4	315.20 K	0
17	17	1.4	315.20 K	0
18	18	1.4	315.20 K	0
19	19	1.4	315.20 K	0
20	20	1.4	315.20 K	0
21	21	1.4	315.20 K	0
22	22	1.4	315.20 K	0
23	23	2.8	315.20 K	0
24	24	2.8	315.19 K	0
25	25	2.8	300.19 K	0
26	26	2.8	300.19 K	0
27	27	2.8	300.19 K	0
28	28	2.8	300.19 K	0
29	29	2.8	300.19 K	0
30	30	2.8	300.19 K	0
31	31	3	300.19 K	0
32	32	3	300.19 K	0
33	33	2.1	300.19 K	0
34	34	2.1	300.19 K	0
35	35	1.3	300.19 K	0

36	36	2.8	315.18 K	0
37	37	3	315.18 K	0
38	38	3	315.18 K	0
38	38	2.1	315.18 K	0
40	40	2.1	315.18 K	800

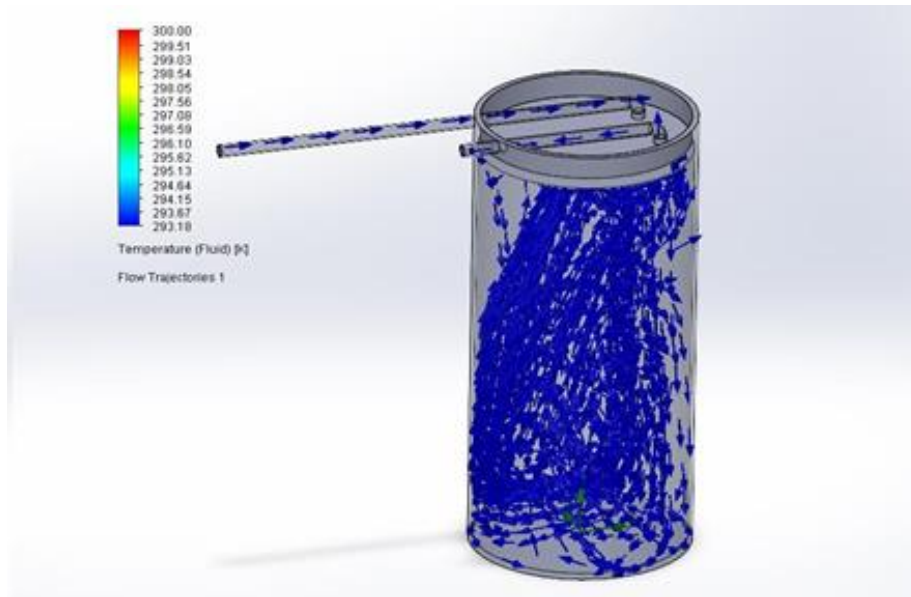


Figure 4.1.1 Temperature simulation

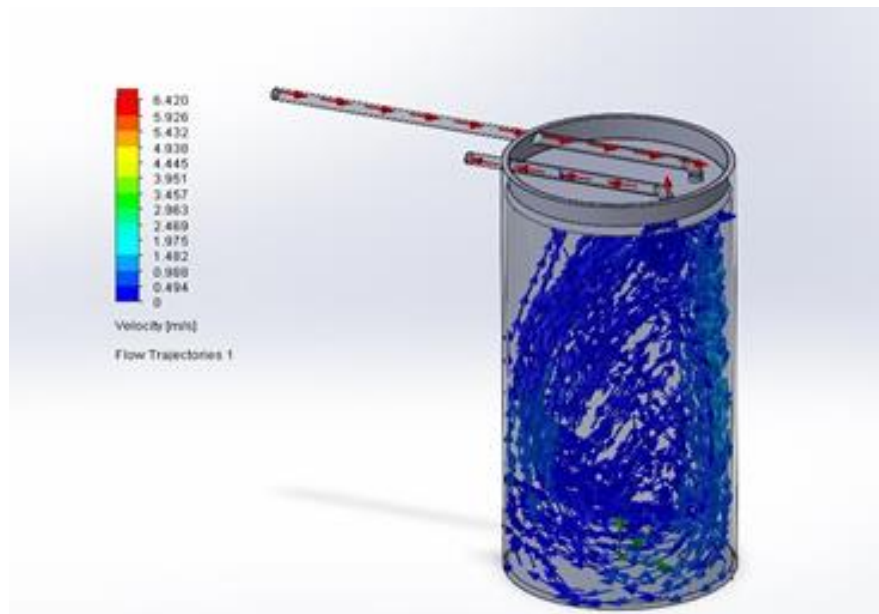


Figure 4.1.1.2 Flow rate simulating

3. Real-time (practical) results

Parallax Data Acquisition tool (PLX-DAQ) software add-in for Microsoft Excel acquires up to 26 channels of data from any Parallax microcontrollers and drops the numbers into columns as they arrive. PLX-DAQ provides easy spreadsheet analysis of data collected in the field, laboratory analysis of sensors and real-time equipment monitoring, using the data set of the rate flow, temperature and level sensor. Using the Real time data set the export from the Arduino – daq tool as average data sets below in tables.

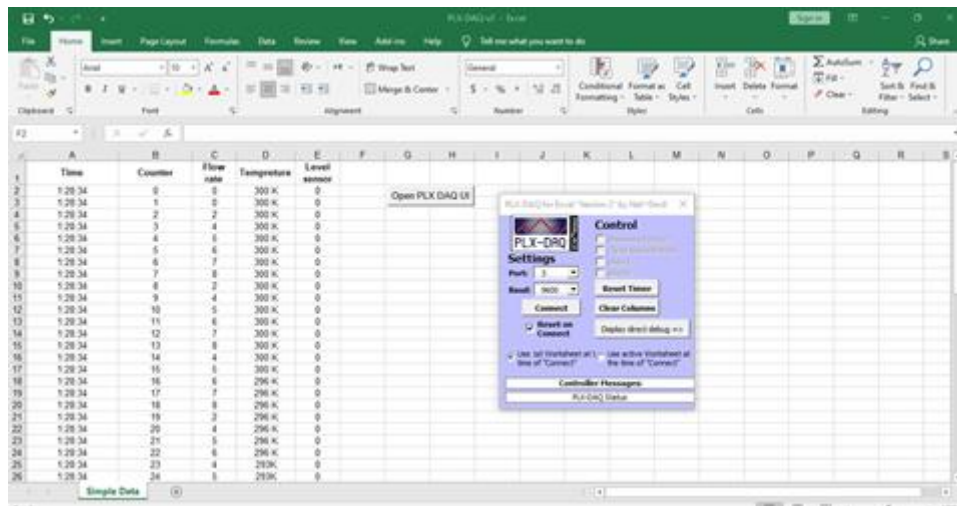


Figure 4.1: PLX-DAQ software

Table 4.2: Average real time data sets

Time (sec)	Counter	Flow rate L/Min	Temperature (K)	Level sensor
0	0	0	0	0
1	1	3	315 K	0
2	2	3	315 K	0
3	3	3	315 K	0
4	4	3	315 K	0
5	5	3	315 K	0
6	6	3	315 K	0
7	7	1.5	315 K	0
8	8	2	315 K	0
9	9	2	315 K	0
10	10	3.1	315 K	0
11	11	3	315 K	0
12	12	3	315 K	0
13	13	3	315 K	0
14	14	3.1	315 K	0
15	15	3.1	315 K	0
16	16	1.2	315 K	0
17	17	1.4	315 K	0
18	18	1.2	315 K	0
19	19	1.2	315 K	0
20	20	1.2	315 K	0
21	21	1.1	315 K	0
22	22	1.2	315 K	0
23	23	2.6	315 K	0
24	24	2.6	315 K	0
25	25	2.6	315 K	0
26	26	2.6	315 K	0
27	27	2.6	315 K	0
28	28	2.6	315 K	0
29	29	2.5	315 K	0
30	30	2.6	315 K	0

31	31	2.8	315 K	0
32	32	2.7	315 K	0
33	33	2	315 K	0
34	34	1.7	315 K	0
35	35	1	315 K	0
36	36	2.6	315 K	0
37	37	2.5	315 K	0
38	38	2.6	315 K	0
38	38	2.8	315 K	0
40	40	2.7	315 K	800

4. Result discussion

The Results dissection follows the Methods and precedes the Discussion section. This can be providing the data collected during working of the project. The Temperature data from simulation result has the same result of the real-time results with error rate proximity to 0.01 in the figure below. The Flow rate data from simulation result has the same result of the real-time results with error rate proximity to 0.1 that caused due to the error pulses with the controller type and the disturbed frequency in the figure below.

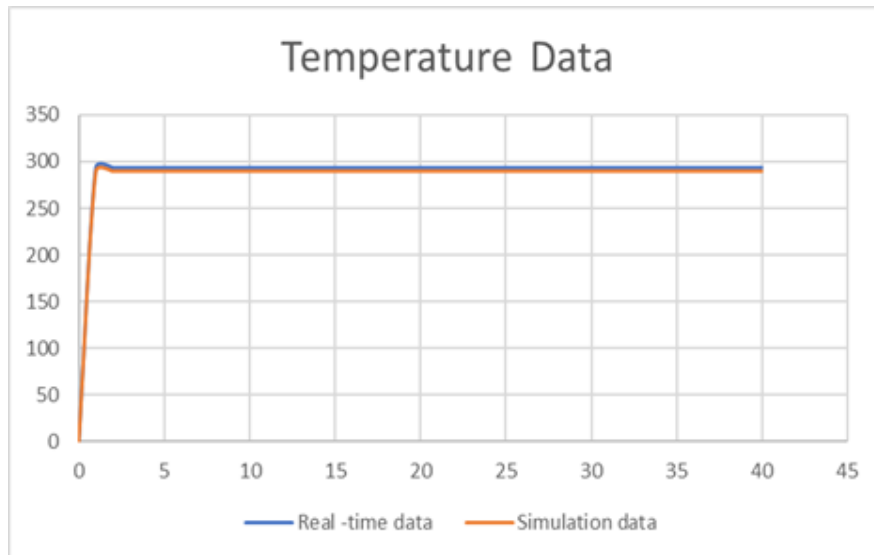


Figure 4.2: Temperature Data



Figure 4.3: Flow rate Data

5. Summary

The design system of suction system shows a sever differences in the Temperature and flow rate domain as an error between real time data set and simulation data sets. the change in data graphs can be reduce due to improvement of electronic components and the biofluids unites that it can make a less disturbed in the comparing between the practical and simulation results.

CHAPTER FIVE FUTURE WORK

Biofluid suction system is required to aid patients with breathing difficulty to breathe more comfortably. This system allows for relieving nurses and other careers from the millions of person-hours spent yearly on tracheal suctioning fluids. In addition, When the system interacts with the medical practical test in healthcare society the result will be huge in cost savings and will be more efficacy in the medical caring society.

The development of the project should be done with a better accurate electronic components like microcontrollers and sensors units. The development of shape of the system can be seen in the with a better design model that it can be more realistic and more practically. The data can generate and deliver online if it's connected to the internet with a better accuracy in the reduction of noise and disturbed. This system can be developed to make it more efficient in the medical and industry field.

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