SMART & PORTABLE THERMOELECTRIC HEATING/COOLING DERIVED FOODWARE

A Project Report

Submitted

In Partial Fulfillment of the Requirements

for the Degree of

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By

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ABSTRACT

In this automation scenario when everyone is serious about glaciers melting & ozone layer depletion so it's important to do which helps in overcoming this problem. Many type of refrigerator are made using refrigerant which to extent affect our environment. Then it strikes to make a refrigerating system in which there is no use of refrigerant so there is an option of vapor absorption system. Now the problem occurs about its shape refrigeration system with absorption system is heavy & bulky.

The idea generation for the project had come in order to face and tackle the food and beverage storage's problem of inefficiency and inability of keeping the preferred temperatures (Adiabatic nature).

Most of the storage container and devices in the market are largely unable to comply with their statement stated-'Adiabatic nature' or 'keeping the temperature same', which is also reasonable. We know 'Adiabatic' state is only a theoretical approach to understand and study the nature of Thermodynamics and heat transfer, hence it is not possible in practical world.

That's where the principle of internal heat generation and manipulation comes to save the day. If the subject is heated or cooled just before the required time, it will subsequently decrease the energy losses and produce the required temperature at the right time. But despite using high energy consuming resistance coils to produce heat and refrigeration system to produce cooling. We use Peltier effect to produce either heating/cooling as per the user's requirement.

The JIT (just in time) philosophy of our product increases accountability to meet the user's needs efficiently while reducing the heat loss/gain incurred during the process of pre-heating/pre-cooling of food.

There have been a lot of advancements made to cups over the years, but no one's made anything for the "modern man," until the **Smart & Portable Thermoelectric Heating/Cooling Derived Foodware E2O** an app-controlled, temperature adjustable Foodware period, carrying medicines and making the temp of the food stuff stable at what they were kept. Without causing any harm to our environment.

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LIST OF SYMBOLS, ABBREVIATIONS & NOMENCLATURE

COP	Coefficient of performance I Current
K	Thermal conductivity
Q	heating and cooling rate
Q_H	heat rejection
Q_L	heat absorption
Q	Electric Resistance
T	Temperature
Tc	cold side temperature
Th	hot side temperature
T	Temperature Difference
TEC	Thermoelectric cooler

CHAPTER 1

INTRODUCTION

World demand for food containers is forecast to rise **4.5** percent annually to **$139 billion** in **2017**. While the US remains by far the world's largest user of food containers, the most significant growth will occur in **India and China**.

This shows the growth factor in this industry and the future necessity as food production rate is declining as many farmers and producers boycotting the agriculture industry due to less economic benefits, so decreasing the food wastage is also one of major emerging concern.

We've come across the idea of building a small, lightweight and portable product offering real time food temperature modulation just before consumption which also helps in decreasing heat losses of hot food after cooking and prevents food spoilage.

India's First Most Advanced Smart Temperature-Adjustable Foodware. There have been a lot of advancements made to cups over the years, but no one's made anything for the "modern man," until the **Smart & Portable Thermoelectric Heating/Cooling Derived Foodware**: an **app-controlled**, **temperature adjustable** Foodware.

You can take the Foodware **(Smart Foodware)** with you absolutely anywhere you go: to the gym, college or park! With the smart Foodware, your cold beverages can stay cold, and you can heat up your warm beverages on the go. The smart foodware itself can be charged, using a micro-USB, or using an AC adapter for fast charge. The cup is connected to the mobile App which cools down and heats your beverage on the go, **sends notifications** as soon as your drink is ready your Foodware.

The **Smart & Portable Thermoelectric Heating/Cooling Derived Foodware** stylish design features a logo that lights up according to the temperature of the water within: it's red when it's hot and blue when it's cold.

The engineering data of Idea is supported by **HEAT & MASS TRANSFER** subject studied during B.tech study, so we are using the heat transfer technology (**TEC**) Thermoelectric cell.

Smart & Portable Thermoelectric Heating/Cooling Derived Foodware: Provides best suitable fluid temperature according to the surroundings for shear human comfort

1.1 PROJECT OBJECTIVE:

The objectives of doing this project are
I. To design a Smart & Portable Thermoelectric Heating/Cooling Derived Foodware.
ii. Develop a Smart Foodware, You can take the Food with you absolutely anywhere you go: to the gym, college or park.

1.2 TECHNOLOGY REVIEW

The theories behind the operation of thermoelectric cooling first appeared in the early 1800s.

- Jean Peltier discovered a heating/cooling effect when passing electric current through the junction of two conductors.

- Alessandro Volta and Thomas Seebeck found that holding the junctions of two dissimilar conductors at different temperatures creates an electromotive force or voltage.

- William Thomson (Lord Kelvin) showed that over a temperature gradient, a single conductor with current flowing in it has reversible heating and cooling.

With these principles developed and the introduction of semiconductor materials in the late 1950s, thermoelectric cooling became a viable technology for small cooling applications. A thermoelectric cooler (TEC), sometimes called a thermoelectric module or Peltier module, is a semiconductor-based electronic component that functions as a small heat pump.

By applying a low-voltage DC power source to a TEC, heat flows via the semiconductor elements from one face to the other. The electric current cools one faces and simultaneously heats the opposite face. Consequently, a given face of the device can be used for heating or cooling by reversing the polarity of the applied current.

The characteristics of TECs make them highly suitable for precise temperature control applications and where space limitations and reliability are paramount or refrigerants are not desired. A typical single-stage cooler consists of two ceramic plates with “elements” of p-type and n-type semiconductor materials (bismuth telluride alloys) between the plates.

The elements of semiconductor materials are connected electrically in series and thermally in parallel. When a positive DC voltage is applied as shown, electrons pass from the p-type to the n-type element, and the cold-side temperature decreases as the electron current absorbs heat, until equilibrium is reached. The heat absorption (cooling) is proportional to the current and the number of thermoelectric couples. This heat is transferred to the hot side of the cooler, where it is dissipated into the heat sink and surrounding environment.

1.2.1 Thermoelectric effect:

The thermoelectric effect is the direct conversion of temperature differences to electric voltage and vice versa. A thermoelectric device creates voltage when there is a different temperature on each side. Conversely, when a voltage is applied to it, it creates a temperature difference. At the atomic scale, an applied temperature gradient causes charge carriers in the material to diffuse from the hot side to the cold side. The term "thermoelectric effect" encompasses three separately identified effects: the **Seebeck** effect, **Peltier** effect, and **Thomson** effect.

1.2.2 The Seebeck effect:

The Seebeck effect is the conversion of heat directly into electricity at the junction of dissimilar electrical conductors. It is named for the Baltic German physicist Thomas Johann Seebeck.

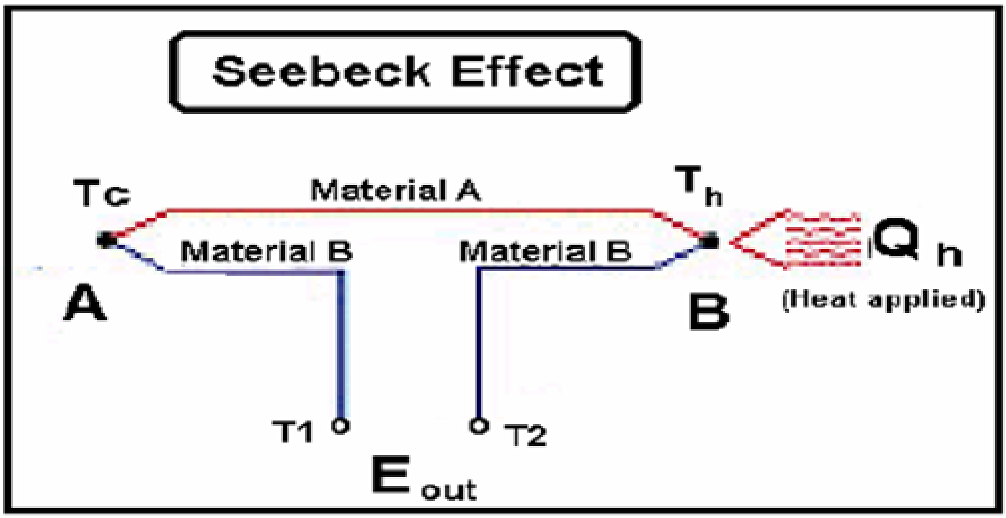


Fig 1.2.2 The Seebeck effect

As shown in Figure 1, the conductors are two dissimilar metals denoted as material A and material B. The junction temperature at A is used as a reference and is maintained at a relatively cool temperature (TC). The junction temperature at B is used as temperature higher than temperature TC. With heat applied to junction B, a voltage (Eout) will appear across terminals T1 and T2 and hence an electric current would flow continuously in this closed circuit. This voltage is known as the Seebeck EMF, can be expressed as

$$E_{out} = \alpha(T_H - T_C)$$

Where:

- $\alpha = dE / dT = \alpha A - \alpha B$
- α is the differential Seebeck coefficient or (thermoelectric power coefficient) between the two materials, A and B, positive when the direction of electric current is same as the direction of thermal current, unit is V/K.
- Eout is the output voltage in volts.

1.2.3 The Peltier effect

Peltier found there was an opposite phenomenon to the Seebeck Effect, whereby thermal energy could be absorbed at one dissimilar metal junction and discharged at the other junction when an electric current flowed within the closed circuit.

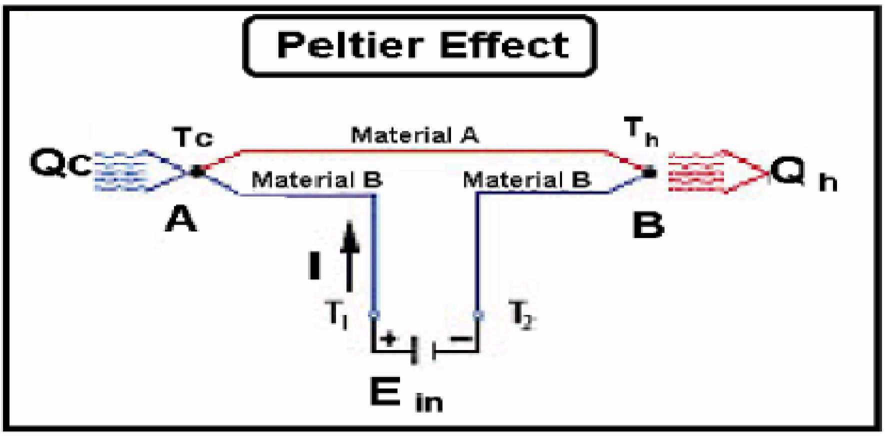


Figure 1.2.3: Peltier effect

In Figure 2, the circuit is modified to obtain a different configuration that illustrates the Peltier Effect, a phenomenon opposite that of the Seebeck Effect. If a voltage (Ein) is applied to terminals T1 and T2, an electrical current (I) will flow in the circuit. As a result of the current flow, a slight cooling effect (QC) will occur at thermocouple junction A (where heat is absorbed), and a heating effect (QH) will occur at junction B (where heat is expelled). Note that this effect may be reversed whereby a change in the direction of electric current flow will reverse the direction of heat flow.

Joule heating, having a magnitude of I^2 x R (where R is the electrical resistance), also occurs in the conductors as a result of current flow. This Joule heating effect acts in opposition to the Peltier Effect and causes a net reduction of the available cooling. The Peltier effect can be expressed mathematically as:

$$Q_c \; or \; Q_H = \beta \times I = (\alpha T) \times I$$

Where:

- β is the differential Peltier coefficient between the two materials A and B in volts.

- I is the electric current flow in amperes.
- QC and QH are the rates of cooling and heating, respectively, in watts.

1.2.4 The Thomson effect

As per the Thomson effect, when an electric current is passed through a conductor having a temperature gradient over its length, heat will be either absorbed by or expelled from the conductor. Whether heat is absorbed or expelled depends on the direction of both the electric current and temperature gradient. This phenomenon is known as the Thomson Effect.

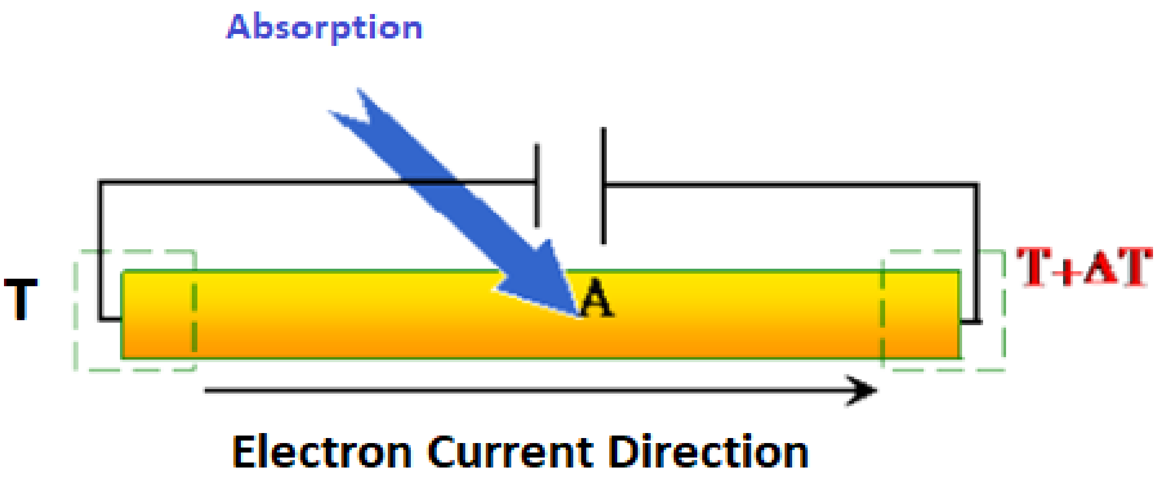


Figure 1.2.4: The Thomson effect

CHAPTER 2

LITERATURE REVIEW

2.1 PELTIER MODULE:

Peltier Module is the component which works on Peltier effect and Seeback effect. At and electrified junction of two different types of materials which act as pure conductor, then presence of heating and cooling is called Peltier Effect. If we are considering two different conductors A & B, when current is to flow through the junction of these conductors, the few amount of heat may be generated at the point of junction. This generated heat is called Peltier Heat and it is said to heat generated per unit time Q, and equal to

$$Q = (\Pi_A + \Pi_B)$$

Where,

Q = *Total Heat at junction of Conductors*

πA = Peltier coefficient of conductor A

πB = Peltier coefficient of conductor A

I =Current flowing through A & B

The heating & cooling through Peltier Module is completely depends upon the point of contact and the material you are using. In our experiment we are using copper metal because copper has very good thermal conductivity. Peltier heating or cooling are the work of build-in contact electric and valence forces on moving charges and the generation (or recombination) in space charge region. The device which works on this principle is some time called thermoelectric module also. Due to the Peltier effect it called Peltier Module. The main problem in this module is the difference of temperature created on the layers of module. The junction temperature is different and layer temperature is slightly difference. We cannot evaluate the exact temperature of the layer. It depends upon the ΔT.

$$\Delta T = T1 - T2$$

Where, T1 is temperature of one side and T2 is temperature of other side. Experimentally it is depend upon the Heat Sink which is connected to the hot side plate. If Heat Sink is keep cool then the lowest temperature will be achieve is -2°C and if we keep hot plate open then the temperature achieve in the hot side is 85°C. But there is problem during heating. If we give power supply more than this temperature then it will burn and device will be damage. So for heating we can use it till 85°C.

It has two types of semiconductors mounted. P type semiconductor branch has positive Seebeck coefficient "α" and in N type semiconductor has negative coefficient of "α". These two branches of semiconductors are joined by a good conductor like metal. On supplying D.C. current, the junction between n and p junction will be cooled and if a body touch with it then **t** will get cooled. In fig.1 Tc and To if the temperature of cold side and hot side respectively. Tc will be always less than To.

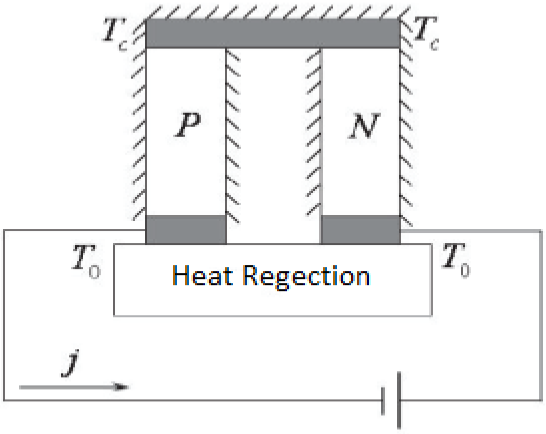


Figure2.1 the schematic diagram of thermoelectric module is shown.

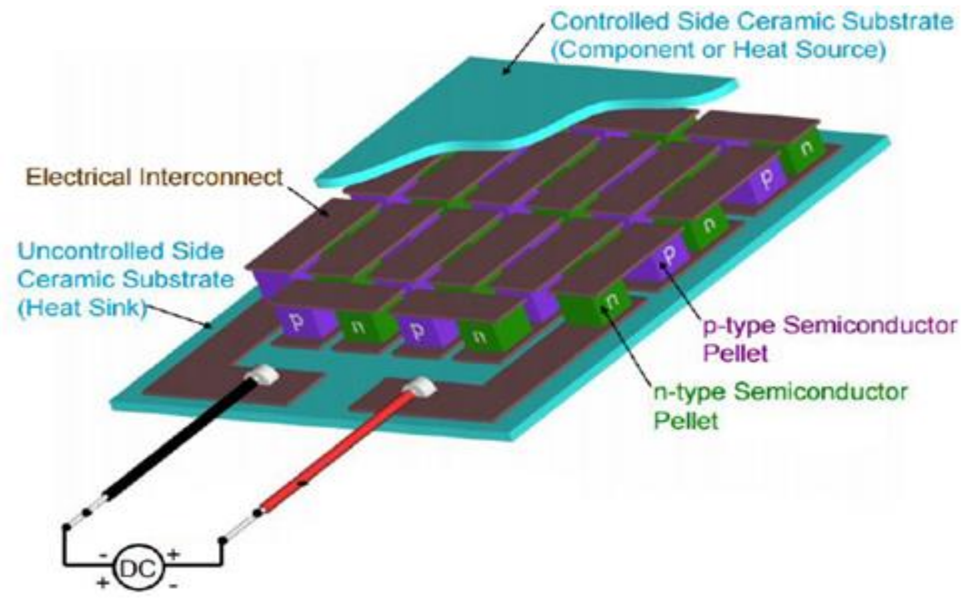


Figure2.1A Fabrication of Peltier

Thermoelectric Cooling or Peltier cooling is one of the best cooling techniques for local use like chillers, Printed Circuit Boards, DC Machines, Power Plant, etc. It has no any movable part and it is completely gases free. It does not need any type of coolant gases or any type of compressors. The heat balance equation considered from equation

$$div\vec{q} = \frac{j^2}{\sigma} + \alpha\vec{j}\Delta T$$

We can calculate the maximum temperature difference which can be gain in special adiabatic process

$$\Delta T_{max} = T_o - T_{min}(x = 0) = T_o\left(1 + \frac{1-\sqrt{1+2ZT_o}}{ZT_o}\right)$$

2.2 TYPES OF PELTIER

2.2A SINGLE-stage thermoelectric cooler

Single-stage thermoelectric designed for medium to low heat pumping capacity requirements. The CM, RC, NL, PL, and SP product lines are the most versatile product lines that II-VI Marlow offers. These product lines cover a vast array of industry needs as they come in many shapes and sizes while offering different levels of heat pumping capabilities.

Benefits

- ROHS EU Compliant
- Solid state reliability
- Localized, spot cooling & precision temperature control
- Operation in any orientation, zero gravity, and/or high G levels
- High resistance to shock and/or vibration
- No acoustical or electrical noise

Used for

- Automotive
- Industrial
- Telecommunications
- Medical
- Consumer
- Aerospace & Defence
- Oil, Gas, & Mining

2.2B Thermocyclers

Thermoelectric that are ideal for use in PCR and other thermal cycling applications. Two thermo cycling product lines, the Extended Life Tec (XLT) series and Life Cycling Cooler

(LCC) series, are built with materials designed to withstand the stresses of thermal cycling. Thermo cyclers have been proven to last for 500,000+ cycles.

Used for

- Life Science – Research and Development
- Clinical Diagnostics – Patient Diagnosis & Treatment
- Pharmaceutical Development
- Physical Therapy Temperature Controlled Pads
- Cosmetic Surgery
- Forensic Science
- Bio-Security
- Chemical Analysis
- Food, Agriculture & Environment

2.2C Multi-stage thermoelectric coolers

Multi-stage thermoelectric coolers (TECs) are designed for medium to high heat pumping capacity requirements. Single-stage coolers can only obtain a ΔTmax of around +70°C. II-VI Marlow builds multi-stage thermoelectrics with as many as five additional levels or "stages". Each additional stage allows for higher heat pumping capability and allows the thermoelectric to achieve a higher ΔT. The multistage cooler line offers superior cooling capabilities over single stage coolers while maintaining their solid-state benefits.

Used for

- Automotive
- Industrial
- Telecommunications
- Medical
- Consumer
- Aerospace & Defence
- Oil, Gas, & Mining

2.3 BATTERY

A battery, which is actually an electric cell, is a device that produces electricity from a chemical reaction. Strictly speaking, a battery consists of two or more cells connected in series or parallel, but the term is generally used for a single cell. A cell consists of a negative electrode; an electrolyte, which conducts ions; a separator, also an ion conductor; and a positive electrode. The electrolyte may be aqueous (composed of water) or non-aqueous (not composed of water), in liquid, paste, or solid form. When the cell is connected to an external load, or device to be powered, the negative electrode supplies a current of electrons that flow through the load and are accepted by the positive electrode. When the external load is removed the reaction ceases. A primary battery is one that can convert its chemicals into electricity only once and then must be discarded. A secondary battery has electrodes that can be reconstituted by passing electricity back through it; also called a storage or rechargeable battery, it can be reused many times.

2.4 IOT TECHNOLOGY

The **Internet of things** (**IoT**) is a system of interrelated computing devices, mechanical and digital machines provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction.

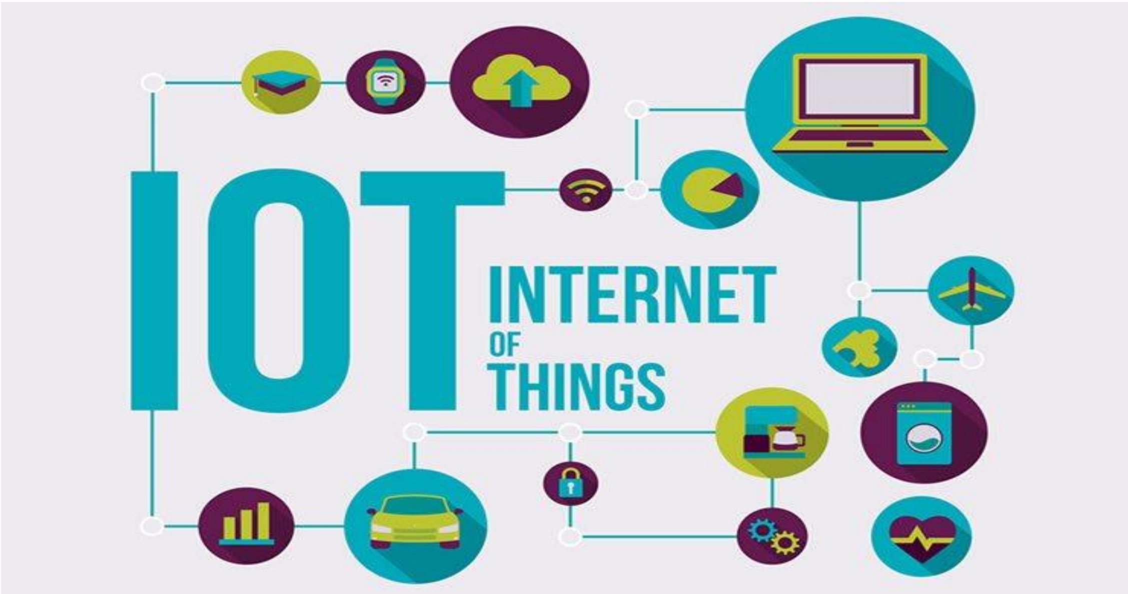


Figure2.4 Internet of things

The definition of the Internet of things has evolved due to the convergence of multiple technologies, real-time analytics, machine learning, commodity sensors, and embedded systems.Traditional fields of embedded systems, wireless sensor networks, control systems, automation (including home and building automation), and others all contribute to enabling the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", including devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smart phones and smart speakers. There are a number of serious concerns about dangers in the growth of IoT, especially in the areas of privacy and security, and consequently industry and governmental moves to address these concerns have begun.

2.4.1 Application

A growing portion of IoT devices are created for consumer use, including connected vehicles, home automation, wearable technology, connected health, and appliances with remote monitoring capabilities.

Product digitization

There are several applications of smart or active packaging in which a QR code or NFC tag is affixed on a product or its packaging. The tag itself is passive, however it contains a unique identifier which enables a user to access digital content about the product via a smart phone. Strictly speaking, such passive items are not part of the Internet of Thing but they can be seen as enablers of digital interactions. The term "Internet of Packaging" has been coined to describe applications in which unique identifiers are used, to automate supply chains, and are scanned on large scale by consumers to access digital content. Authentication of the unique identifiers, and thereby of the product itself, is possible via a copy-sensitive digital watermark or copy detection pattern for scanning when scanning a QR Code, while NFC tags can encrypt communication

2.5 HEAT SINK

A **heat sink** is a passive heat exchanger that transfers the heat generated by an electronic or a mechanical device to a fluid medium, often air or a liquid coolant, where it is dissipated away from the device, thereby allowing regulation of the device's temperature. In computers, heat sinks are used to cool CPUs, GPUs, and some chipsets and RAM modules. Heat sinks are used with high-power semiconductor devices such as power transistors and optoelectronics such as lasers and light emitting diodes (LEDs), where the heat dissipation ability of the component itself is insufficient to moderate its temperature.

A heat sink is designed to maximize its surface area in contact with the cooling medium surrounding it, such as the air. Air velocity, choice of material, protrusion design and surface treatment are factors that affect the performance of a heat sink. Heat sink attachment methods and thermal interface materials also affect the die temperature of the integrated circuit. Thermal adhesive or thermal grease improve the heat sink's performance by filling air gaps between the heat sink and the heat spreader on the device. A heat sink is usually made out of aluminum or copper.

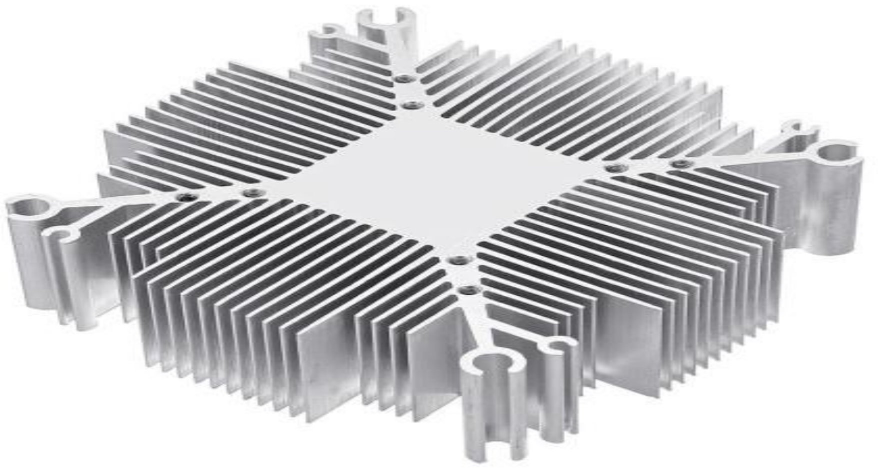


Figure2.5 heat sink

2.5.1 Heat transfer principal

A heat sink transfers thermal energy from a higher temperature device to a lower temperature fluid medium. The fluid medium is frequently air, but can also be water refrigerants or oil

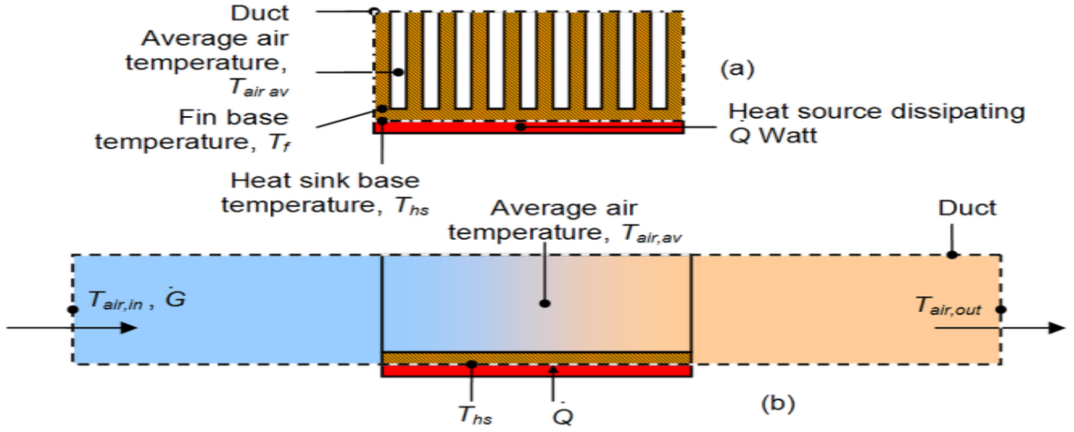


Figure2.5.1 Heat transfer principal with heat sink

If the fluid medium is water, the heat sink is frequently called a cold plate. In thermodynamics a heat sink is a heat reservoir that can absorb an arbitrary amount of heat without significantly changing temperature. Practical heat sinks for electronic devices must have a temperature higher than the surroundings to transfer heat by convection, radiation, and conduction

The power supplies of electronics are not 100% efficient, so extra heat is produced that may be detrimental to the function of the device. As such, a heat sink is included in the design to disperse heat. To understand the principle of a heat sink, consider Fourier's law of heat conduction. Fourier's law of heat conduction, simplified to a one-dimensional form in the x-direction, shows that when there is a temperature gradient in a body, heat will be transferred from the higher temperature region to the lower temperature region. The rate at which heat is transferred by conduction, is proportional to the product of the temperature gradient and the cross-sectional area through which heat is transferred.

2.6 FAN

In E2O project generate Forced convection mechanism, or type of transport in which fluid motion is generated by an external source (like a pump, fan, suction device, etc.).

Figure2.6 forced convection through fan

Alongside natural convection, thermal radiation and thermal conduction it is one of the methods of heat transfer and allows significant amounts of heat energy to be transported very efficiently.

2.7 RESEARCH METHODOLOGY

5.1.1 Thermoelectric Cooler Selection Procedure

Outlined below is a simplified selection procedure devised to allow the user to obtain initial designs and estimates of performance for single- and two-stage thermoelectric coolers. Because of the non-linear behaviour of TECs and the number of variables involved in analyzing them, they can be designed and modelled more accurately by our experienced engineers using IIVI Marlow’s' internally developed computer software. For selection of coolers with more than two stages, or if more precision is required, please consult one of our application engineers. Once the decision to use a thermoelectric cooler has been made, the actual selection of suitable modules is relatively simple. The following pages outline a systematic procedure that will take you through determining your heat load, required DT and the number of stages required tomeet the DT.
Once you have completed the analysis, you will have narrowed the field of suitable TECs to two or three. You may then proceed to Steps 5 through 10 to determine the performance of the selected TECs within your application requirements.

2.7.1.A. Estimating high loads

Before the cooler or heat sink can be selected, the cooling requirements must be defend. This includes determining the amount of heat to be pumped. Minimizing the heat load allows the cooler to achieve colder temperatures or reduces the power required to reach the defend cooling level. The following describes the techniques used to estimate active and passive heat loads and applies only to steady state heat loads. If the heat load is of a transient nature, or involves more complex factors such as air or fluid flow, we suggest that you call one of our applications engineers for assistance.

2.7.1.A1. Heat Load

The heat load may consist of two types: active or passive, or a combination of the two. An active load is the heat dissipated by the device being cooled. It generally equals the input power to the device. Passive heat loads are parasitic in nature and may consist of radiation, convection or conduction. within your application requirements.

2.7.1.A2. Active Heat Load

The general equation for active heat load dissipation is:

Qactive = V2/R = VI = I2R

Where:
Qactive = active heat load (W)
V = applied to the device being cooled (V)
R = device resistance (W)
I = current through the device (A)

For example, a typical lead solenoid (PbSe) infrared detector is operated at a bias voltage of 50 volts and a resistance of 0.5 meg ohms. Therefore, the active load is 0.005 watts.

2.7.1.A3. Radiation

When two objects at different temperatures come within proximity of each other, heat is exchanged. This occurs through electromagnetic radiation emitted from one object and absorbed by the other. The hot object will experience a net heat loss and the cold object a net heat gain because of the temperature difference. This is called thermal radiation. Radiation heat loads are usually considered insignificant when the system is operated in a gaseous environment, since the other passive heat loads are typically much greater in magnitude. Radiation loading is usually significant in systems with small active loads and large temperature differences, especially when operating in a vacuum environment. The fundamental equation for radiation loading is:

Qrad = F e s A (Tamb4 - Tc4)

Where:
Qrad = radiation heat load (W)
F = shape factor (worst case value = 1)
e = emissivity (worst case value = 1)
s = Stefan-Boltzmann constant (5.667 X 10-8W/m2K4)
A = area of cooled surface (m2)
Tamb = Ambient temperature (K)
Tc = TEC cold ceramic temperature (K)

Example calculation:

A Charge Coupled Device is being cooled from an ambient temperature of 27°C (300 K) to -50°C (223 K).

The detector surface area (includes 4 edges + top surface) is 8.54 X 10 -4 m2 and has an emissivity of 1. Assume the shape factor = 1

From the equation above:

Qrad = (1)(1) (5.66X10-8 W/m2K4) (8.54 X 10-4 m2)[(300 K)4 - (223 K)4] = **0.272 W**

2.7.1.A4. Convection

When the temperature of a fluid (in this case, a gas) flowing over an object differs from that of the object, heat transfer occurs. The amount of heat transfer varies, depending on the fluid flow rate. Convective heat loads on TECs are generally a result of natural (or free) convection. This is the case when gas flow is not artificially induced as with a fan or pump, but rather occurs naturally from the varying density in the gas caused by the temperature difference between the object being cooled and the gas. The convective loading on a system is a function of the exposed area and the difference in temperature
between this area and the surrounding gas. Convective loading is usually most significant in systems operating in a gaseous environment with small active loads or large temperature differences. The fundamental equation that describes convective loading is:

Qconv = h A (Tair - Tc)

Where:

Qconv = convective heat load (W)
h = convective heat transfer coefficient (W/m2 °C)
(typical value for a fat, horizontal plate in air at 1 atm)
= 21.7 W/m2 °C
A = exposed surface area (m2)
Tair = temperature of surrounding air (°C)
Tc = temperature of cold surface (°C)

Example calculation:
A square plate is being cooled from 25°C to 5°C. The top and four sides are exposed surfaces. The plate is 0.006 meters thick and each side is 0.1 meters long. From the convection equation: Qconv = (21.7 W/m2°C) (0.0124 m2)(25°C - 5°C) = 5.4 W
It is very important to avoid allowing condensation to form when cooling below the dew point. This problem may be avoided by enclosing the cooling system in a dry gas or a vacuum environment.

2.7.1.A5. Conduction

Conductive heat transfer occurs when energy exchange takes place by direct impact of molecules moving from a high temperature region to a low temperature region. Conductive heat loading on a system may occur through lead wires, mounting screws, etc., which form a thermal path from the device being cooled to the heat sink or ambient environment. The fundamental equation that describes conductive loading is:

Qcond =k*A* DT/DL

Where:
Qcond = conductive heat load (W)
k = thermal conductivity of the material (W/m °C)
A = cross-sectional area of the material (m2)
L = length of the heat path (m)
DT = temperature difference across the heat path (°C)
(usually ambient or heat sink temperature minus cold side temperature).

2.8 HEAT SINK SELECTION

When selecting a heat sink, it is necessary to classify the air flow as natural, low flow mixed, or high flow forced convection. Natural convection occurs when there is no externally induced flow and heat transfer relies solely on the free buoyant flow of air surrounding the heat sink.

2.8.1 Selecting the Heat Sink

The final thermal impedance required is "sink-to-ambient" denoted by the symbol R_{as} This is a measure of how easily heat can be transferred from the base of the heat sink to the ambient air. Heat sink vendors like CUI Devices will typically provide graphs like the one below or data points to illustrate how easily heat can be transferred from the heat sink to the ambient air under various airflow conditions and loads.

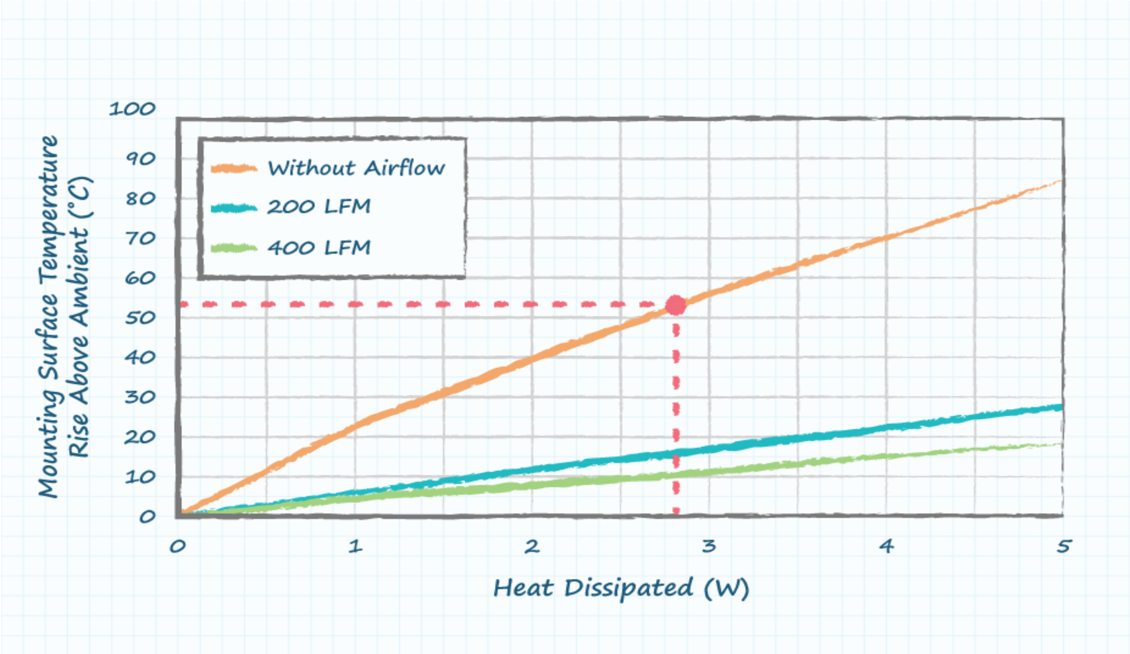


Figure2.8 HEAT SINK SELECTION

For this example it is assumed that the application is operating under natural convection conditions without any airflow. The graph above can be used to calculate the final thermal impedance (sink-to-ambient) for this particular heat sink. The surface temperature rise above ambient divided by the heat dissipated provides thermal impedance at that specific operating condition. In this example the heat dissipated is 2.78 W, which results in a surface temperature rise above ambient of 53°C. Dividing 53°C by 2.78 W produces a sink-to-ambient thermal impedance of 19.1°C/W (calculated as 53°C ÷ 2.78 W).

In prior calculations, the maximum impedance allowed between the junction and ambient air was 27°C/W. Subtracting the impedance of the junction-to-case (0.5°C/W) and the impedance of the case-to-sink (0.45°C/W), the maximum allowance left over for the heat sink is 26.05°C/W (calculated as 27°C/W - 0.5°C/W - 0.45°C/W).

The thermal impedance of 19.1°C/W for this heat sink under the assumed conditions is well below the previously-calculated allowance of 26.05°C/W. This translates to a cooler silicon junction temperature inside the TO-220 package and more thermal margin in the design. The maximum temperature of the junction can be estimated by adding up all the thermal impedances, multiplying them by the number of Watts dissipated in the junction, and adding the result to the maximum ambient temperature:

Estimated Junction Temp. = $T_{Ambient}$ + Watts x ($R_{\theta J\text{-}C}$ + $R_{\theta\ C\text{-}S}$ + $R_{\theta\ S\text{-}A}$)

Estimated Junction Temp. = 50 + 2.78 x (0.5 + 0.45 + 19.1)

Estimated Junction Temp. = 105.7°C

2.9 SELECTION OF BATTERY

Lithium Ion (Li-ion)

Lithium Ion (Li-ion) are the new standard for portable power. Li-ion batteries produce the same energy as NiMH but weighs approximately 20%-35% less. They do not suffer significantly from the memory effect unlike their NiMH and Ni-Cd counterparts. Their substances are non-hazardous to the 0. Because lithium ignites very easily, they require special handling. Unfortunately, few consumer recycling programs have been established for Li-ion batteries at this point in time

Figure2.9 Lithium Ion (Li-ion)

CHAPTER 3

MATHEMATICAL FORMULATON

3.1 FORMULATON

To find the maximum cooling power, differentiating Q1, with respect to I and equating it to 0

$$\frac{dQ_1}{dI} = 0$$

By, solving above equation, we can get current required for maximum cooling power,

$$I_{max} = \frac{(\alpha_p - \alpha_n) * T_1}{R_p + R_n}$$

Value of maximum cooling power, corresponding to I*max*

$$Q_{max} = \frac{\alpha^2 * T_1^2}{2 * R} - K * (T_2 - T_1)$$

$$Here, \quad \alpha = \alpha_p - \alpha_n$$

$$K = K_p + K_n$$

$$R = R_p + R_n$$

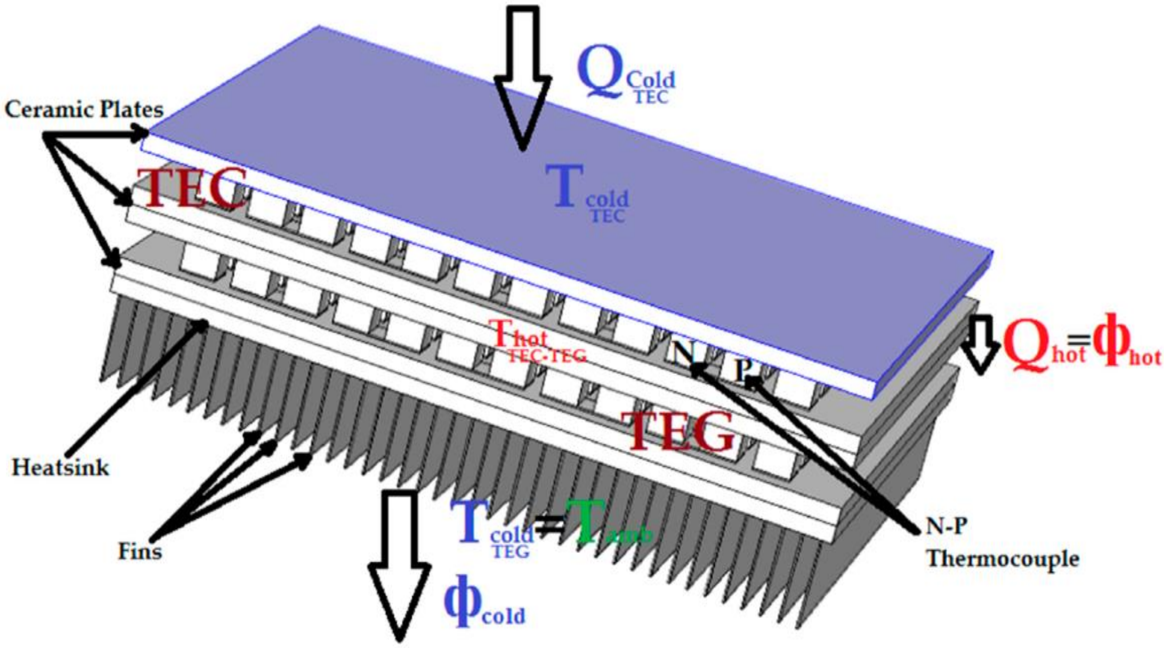
We can calculate the maximum temperature difference which can be gain in special adiabatic process.

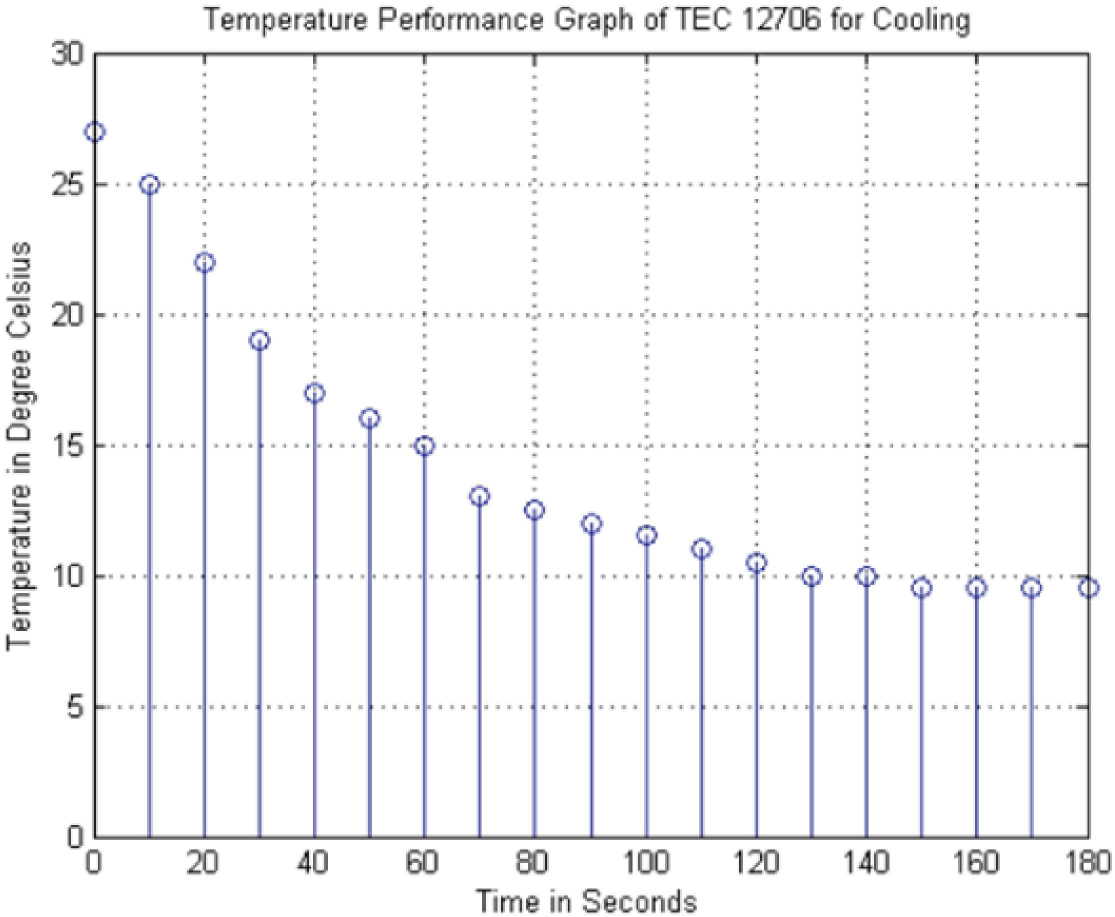
$$\Delta T_{max} = T_o - T_{min}(x = 0) = T_o\left(1 + \frac{1 - \sqrt{1 + 2ZT_o}}{ZT_o}\right)$$

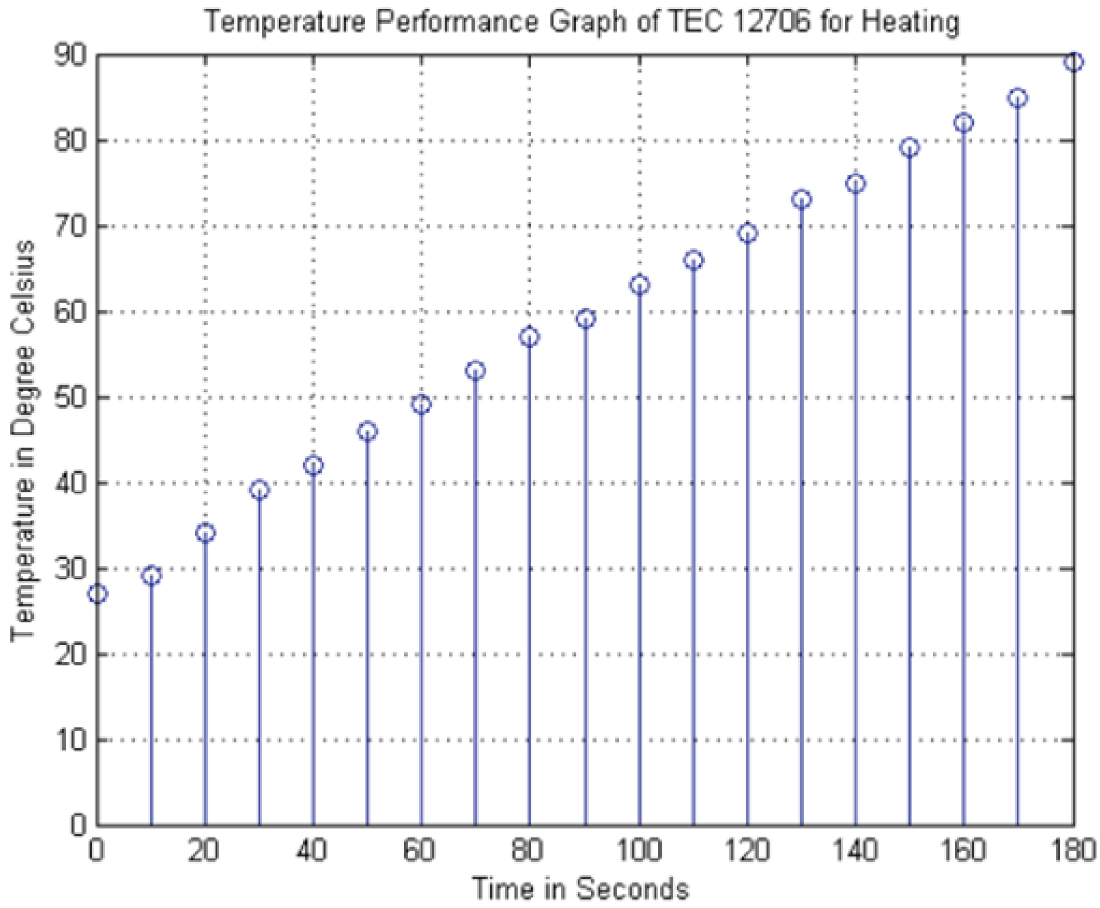
The coefficient of performance COP is the ratio between the cooling capacity Q1 and the electrical power consumption W

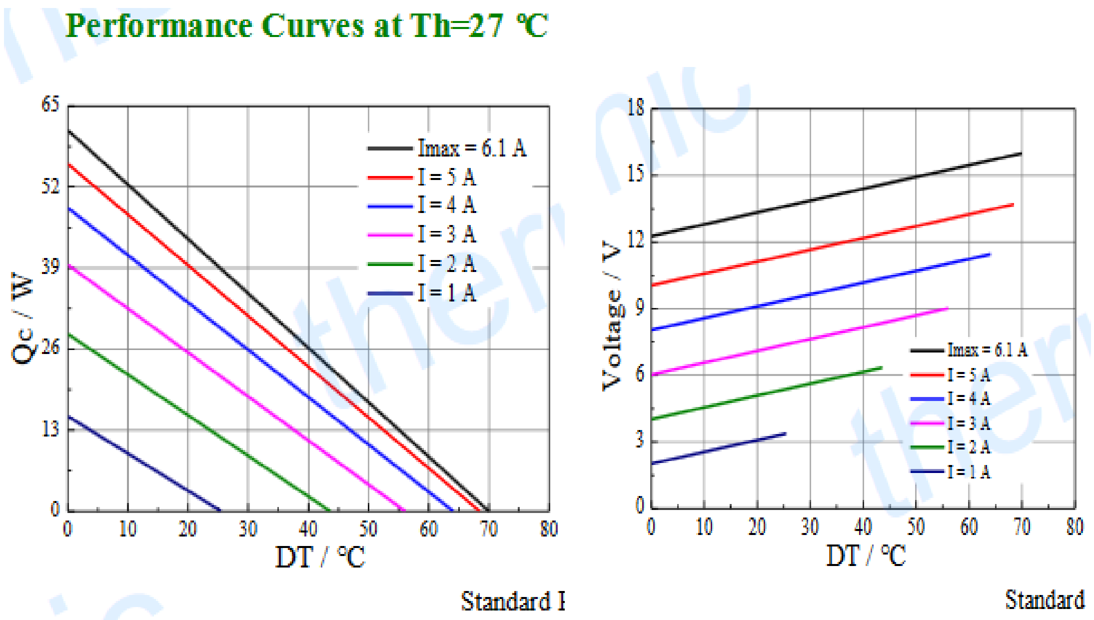
$$COP = \frac{Q_1}{W}$$

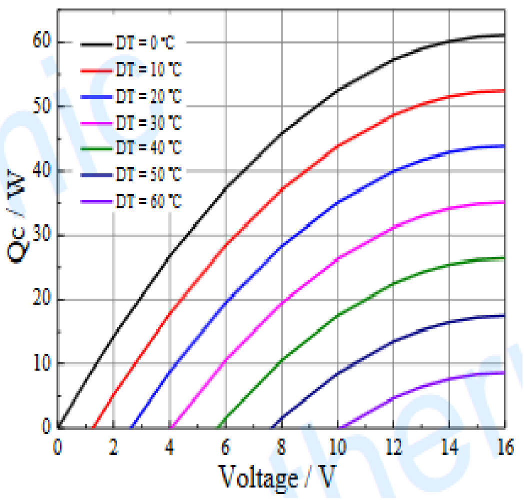
$$\therefore COP = \frac{\left((\alpha_p - \alpha_n)IT_1 - (T_2 - T_1) * (K_p + K_n) - \frac{I^2(R_p + R_n)}{2}\right)}{\left((\alpha_p - \alpha_n).I.(T_2 - T_1) + I^2.(R_p + R_n)\right)}$$

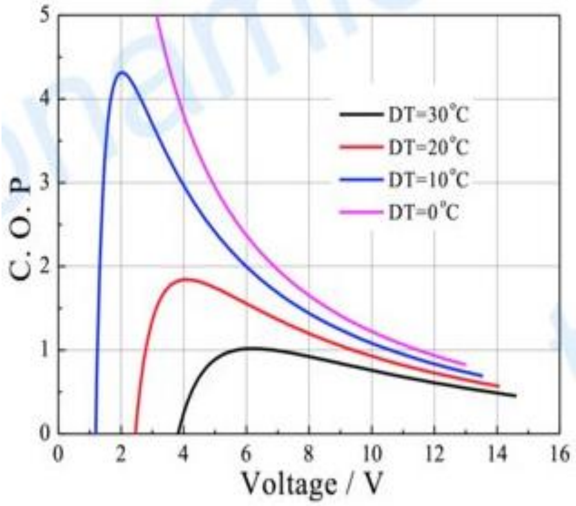

Ceramic Plates
TEC
TEG
Heatsink
Fins
N
P
N-P
Thermocouple

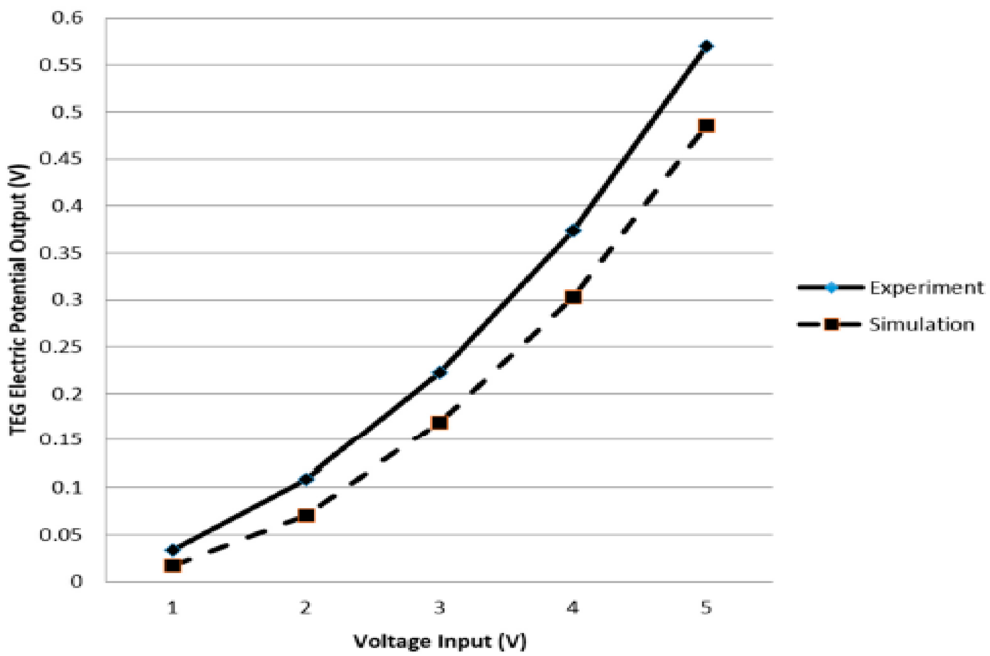

Temperature Performance Graph of TEC 12706 for Cooling
Temperature in Degree Celsius
Time in Seconds


Temperature Performance Graph of TEC 12706 for Heating
Temperature in Degree Celsius
Time in Seconds
0
10
20
30
40
50
60
70
80
90
0
20
40
60
80
100
120
140
160
180

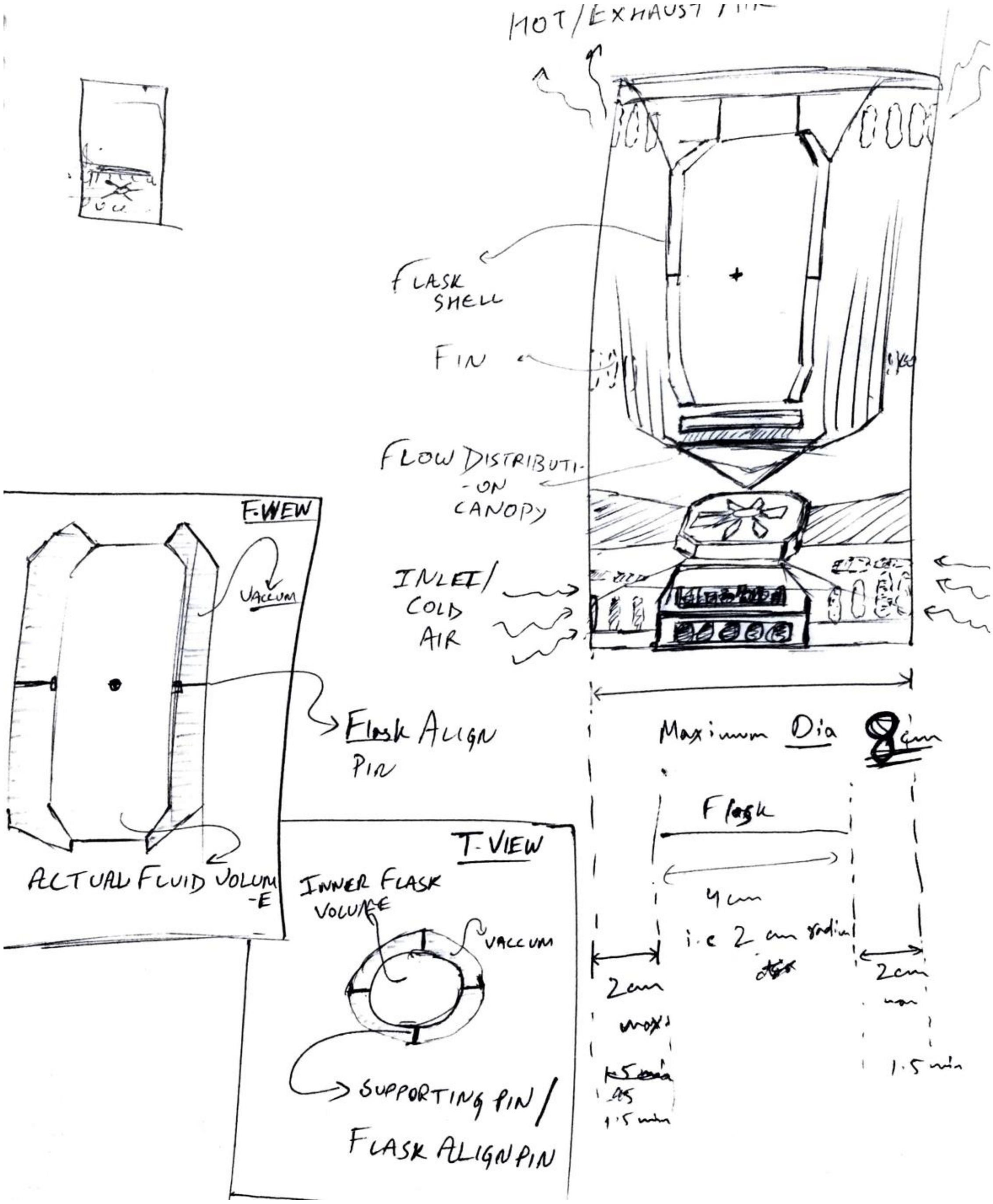

Performance Curves at Th=27 ℃
Qc / W
DT / °C
Imax = 6.1 A
I = 5 A
I = 4 A
I = 3 A
I = 2 A
I = 1 A
65
52
39
26
13
0
0
10
20
30
40
50
60
70
80
Standard I
Voltage / V
DT / °C
18
15
12
9
6
3
0
Imax = 6.1 A
I = 5 A
I = 4 A
I = 3 A
I = 2 A
I = 1 A
Standard


DT = 0 ℃
DT = 10 ℃
DT = 20 ℃
DT = 30 ℃
DT = 40 ℃
DT = 50 ℃
DT = 60 ℃
Qc / W
Voltage / V


DT=30°C
DT=20°C
DT=10°C
DT=0°C
C. O. P.
Voltage / V


Experiment
Simulation
TEG Electric Potential Output (V)
Voltage Input (V)

3.2 CALCULATION



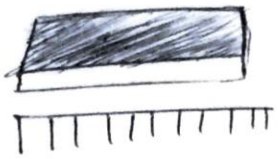
$K \simeq 2.80$

$R \simeq 2.5$

$H = 20.300375$ cm

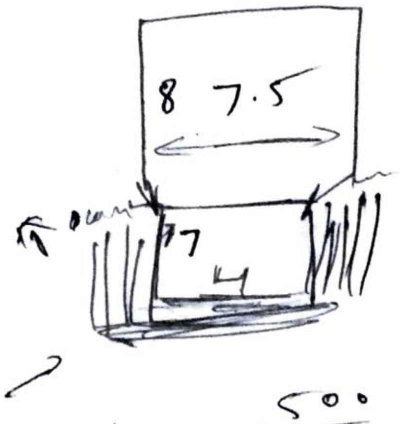
$H = 25.464790$ cm

① $V_{max} = \underline{580 \text{ mL}}$



② Area of Contact

$= 4 \times 4$ cm $= 16$ cm^2



$\dfrac{500}{\pi(r_1^2 h_1 + r_2^2 h_2)}$

$\pi(2^2 \times 7 + 3.75^2 \times 8$

$\underline{441.39 \text{ cm}^3}$

$\boxed{\text{I}}$ Heat Liberated from H_2O of volume 580 ml from 40°C to 15°C

$\boxed{\text{II}}$ Time taken by Peltier – Flask contact to Actually cool the water 580 ml to 15°C.

$\boxed{\text{III}}$ Heat transferred from Hot Side Peltier to Heat Sink. (Conduction)

$\boxed{\text{IV}}$ Rate of Heat dissipation from Heat Sink by forced Convection.

$\boxed{\text{V}}$ Power needed to drive Peltier + Fan + Controller for the operation.

$\boxed{11}$ Amount of Heat Removed from ~~...~~ 35° to 15°C ~~35 to~~

$$Q = m C_p \Delta T$$

$$= 0.580^{m} \times 4.18 \times \cancel{20}\ 20$$

~~= 242440 kJ~~

$$Q = 48.488\ kJ$$

580
418
4640
580x
2320xx
2,42,440

4848800

48.488 kJ

Q = 48.

Always keep module current less than I_{max} for better efficiency and longevity

$$P_{max} = V_{max} \times I_{max} = 12V \times 6A$$

P_{max} of Peltier = 72 W

$$DT = 24°C \quad T_C = T_H - 24 = 50° - 24 = 26°C$$

$$V = 12 \quad I = 5.5 = 66 W \quad Q_c = 48 W$$

$P + Q = 114 W$ on Hot Side of Cooler

- **Heat liberated for bringing down the temperature for 580ml volume :**

$$Qc = m * Cp * \Delta T$$

Therefore:

Qc = 0.580kg * 4.184 kj/kg°C * (20°C)

= **48.53 KJ**

- **Time taken by the apparatus to cools down the Peltier-flask contact :**

Optimal Power required for TEC module = 12V * 5.5A = **66 W**

Power = work / Time

Therefore: **Time = work/Power**

Time = 48.53KJ / 66 Js^{-1}

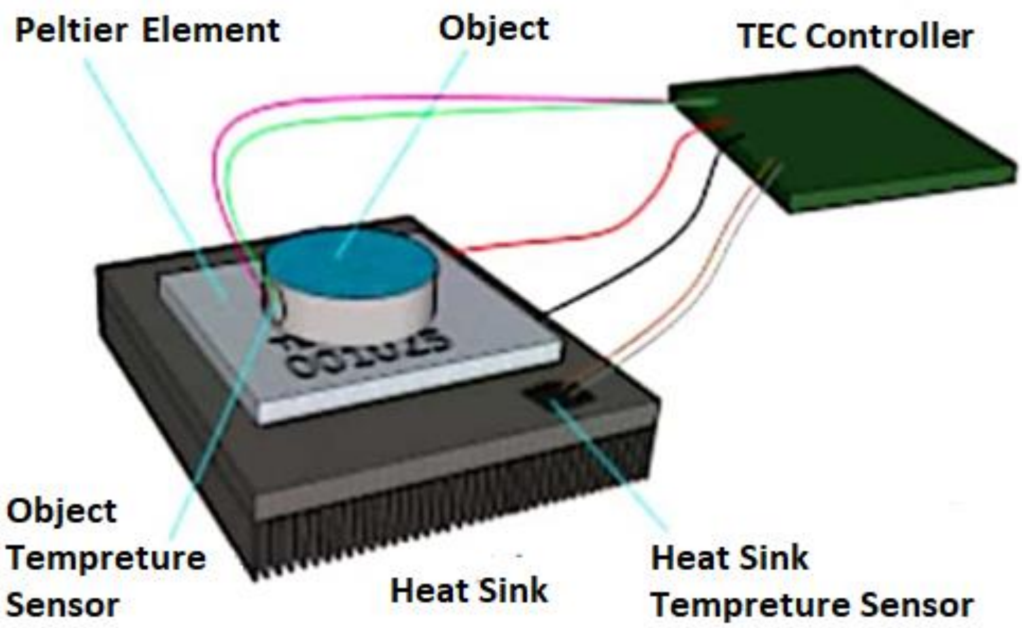
= **12.255 Minutes** (At best conditions i.e. ~ DT=0°C)

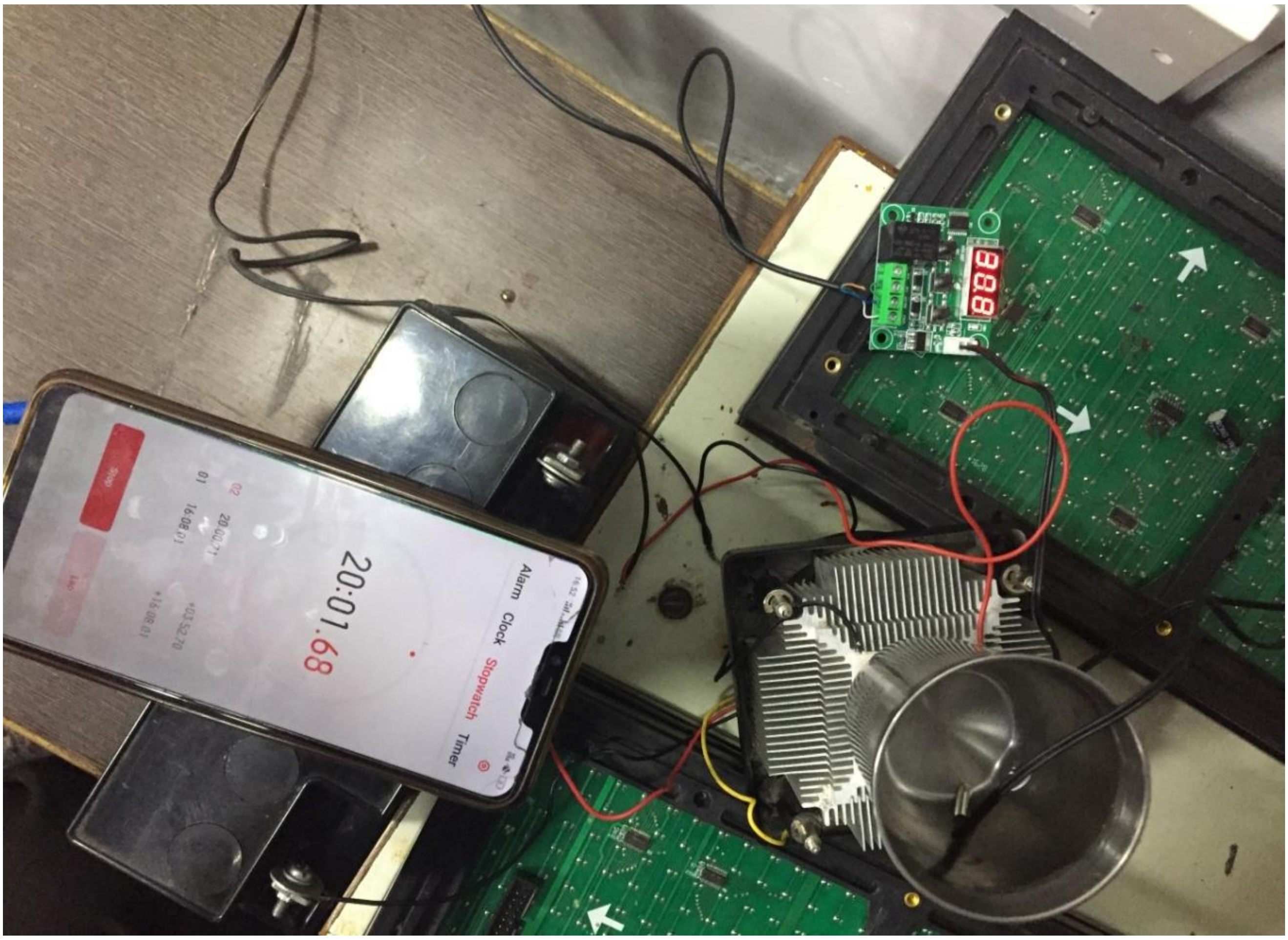
- **Total power needed for the Apparatus for the job:**

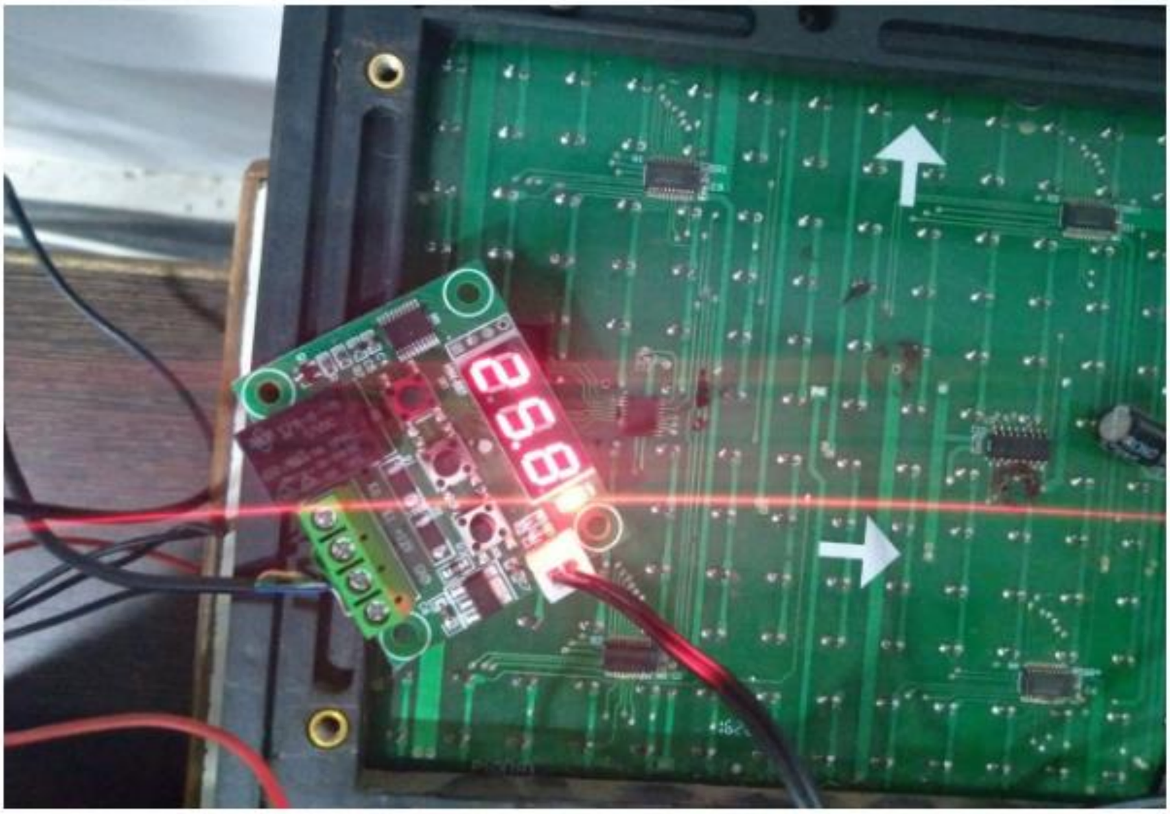
Power = 0.2W (Arduino UNO and Wi-Fi shield) +114W (Peltier-module) +1.08 W (fan)

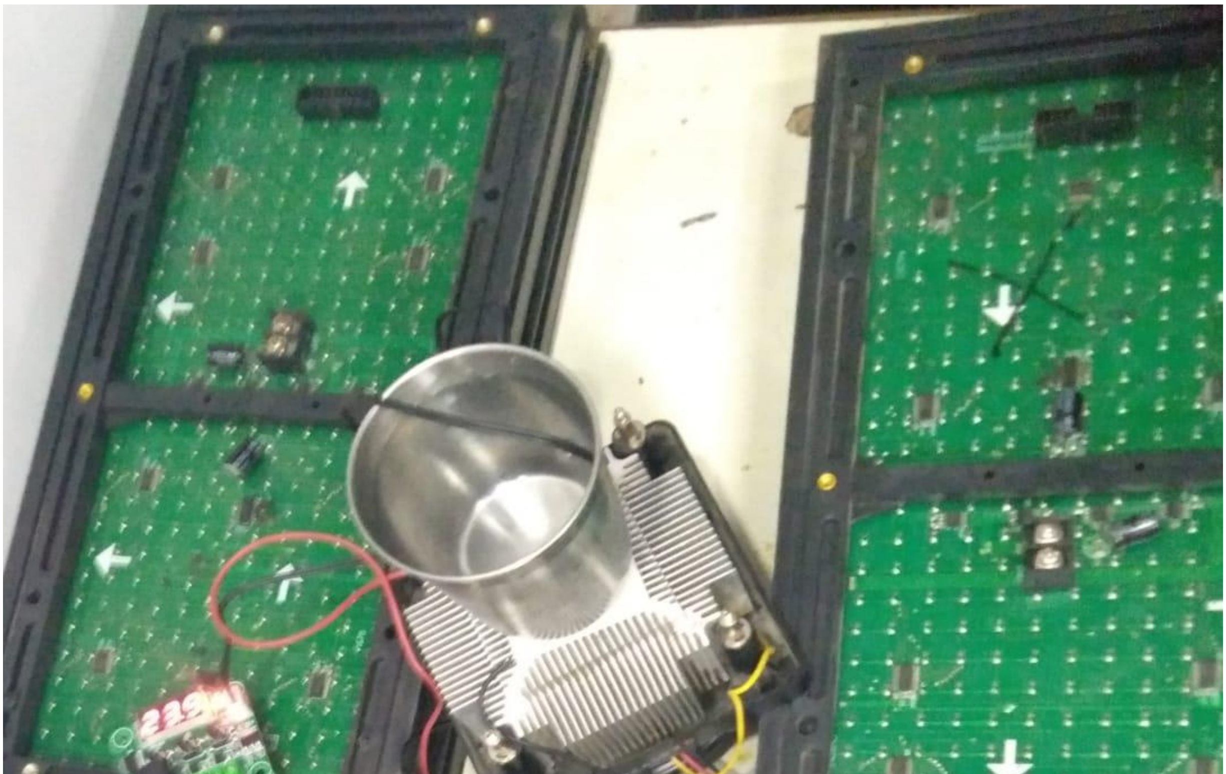
Power = 115.28 W

3.3 EXPERIMENTAL SHOWCASE





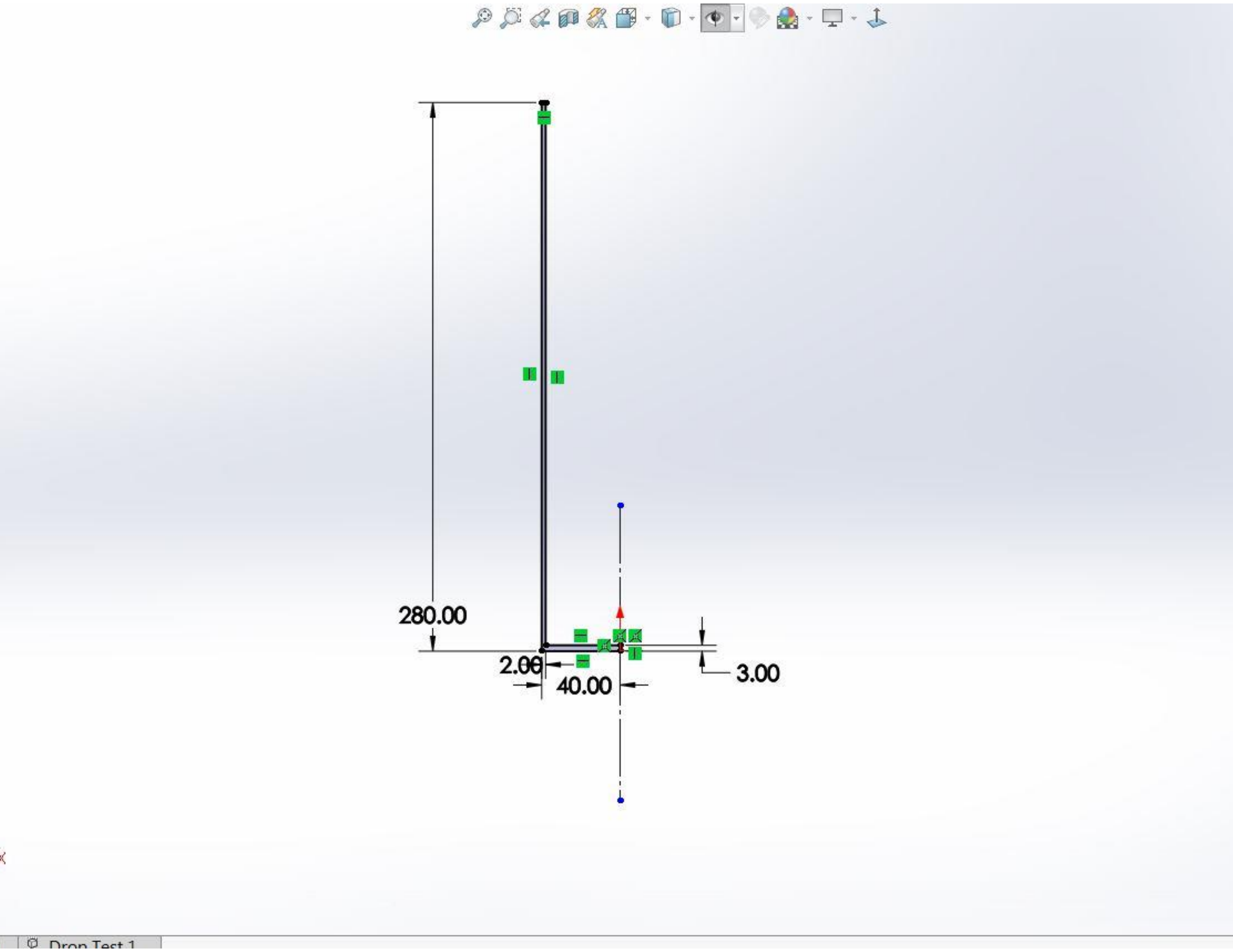


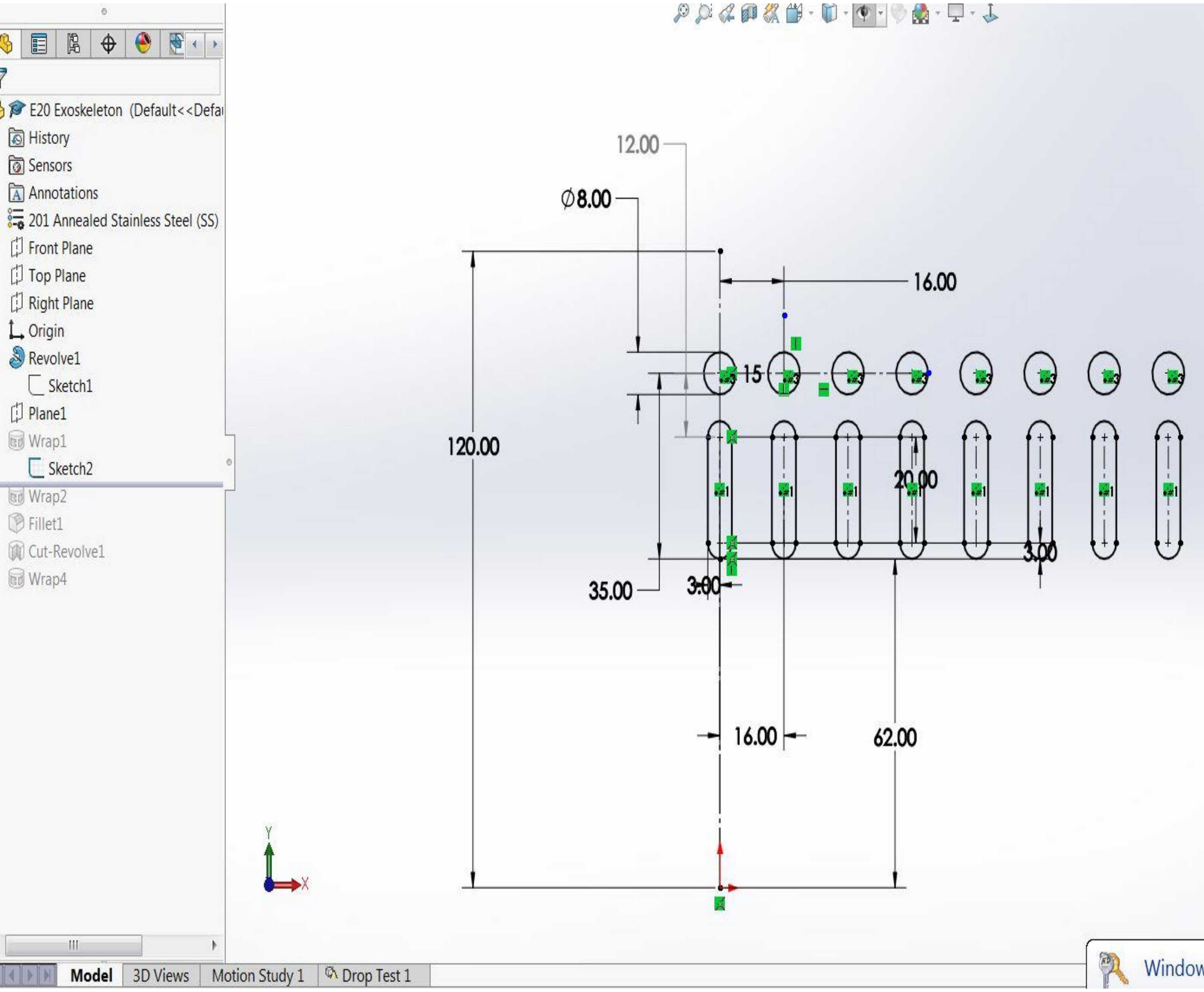


CHAPTER 4

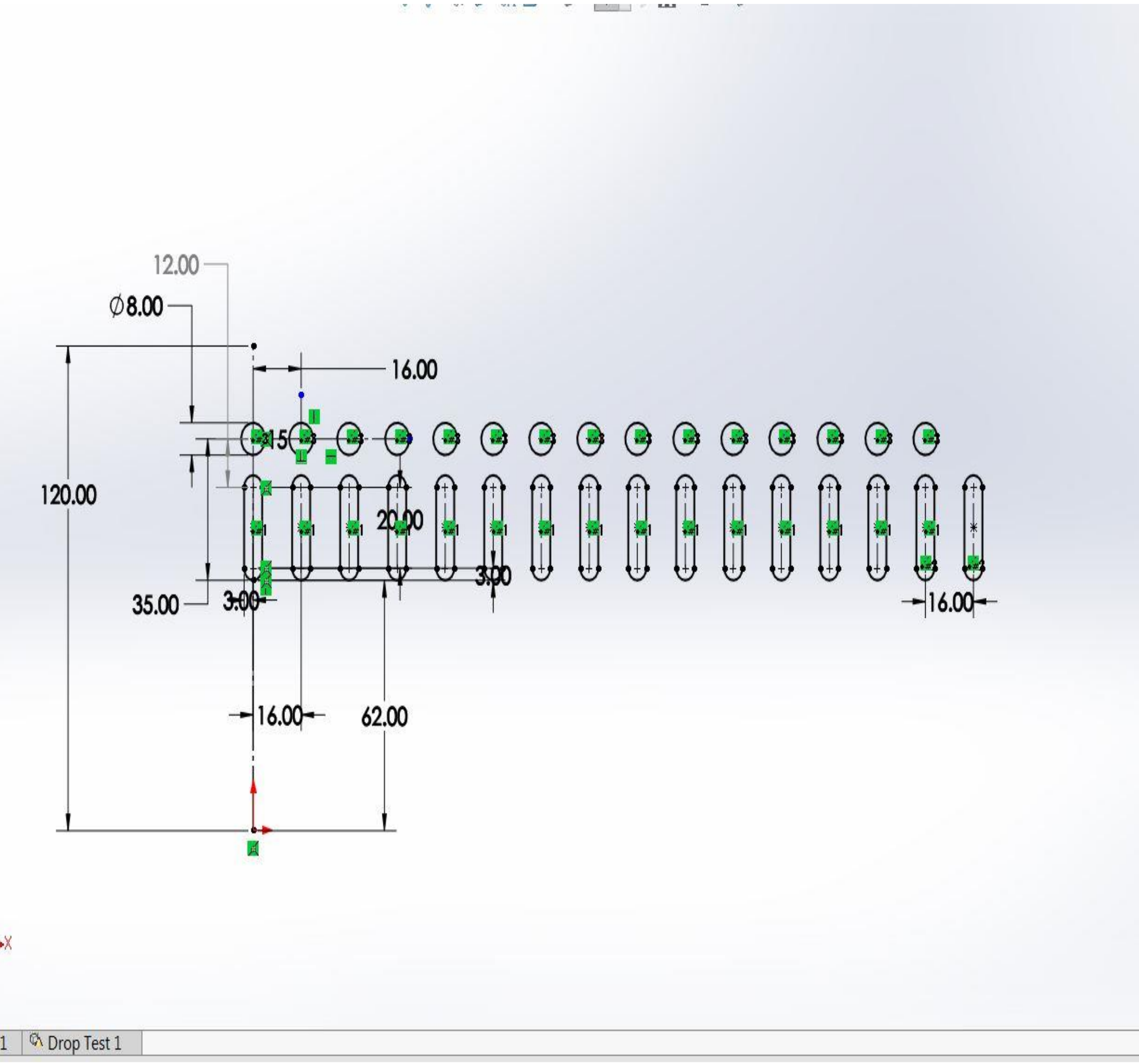
BASE SKETCH

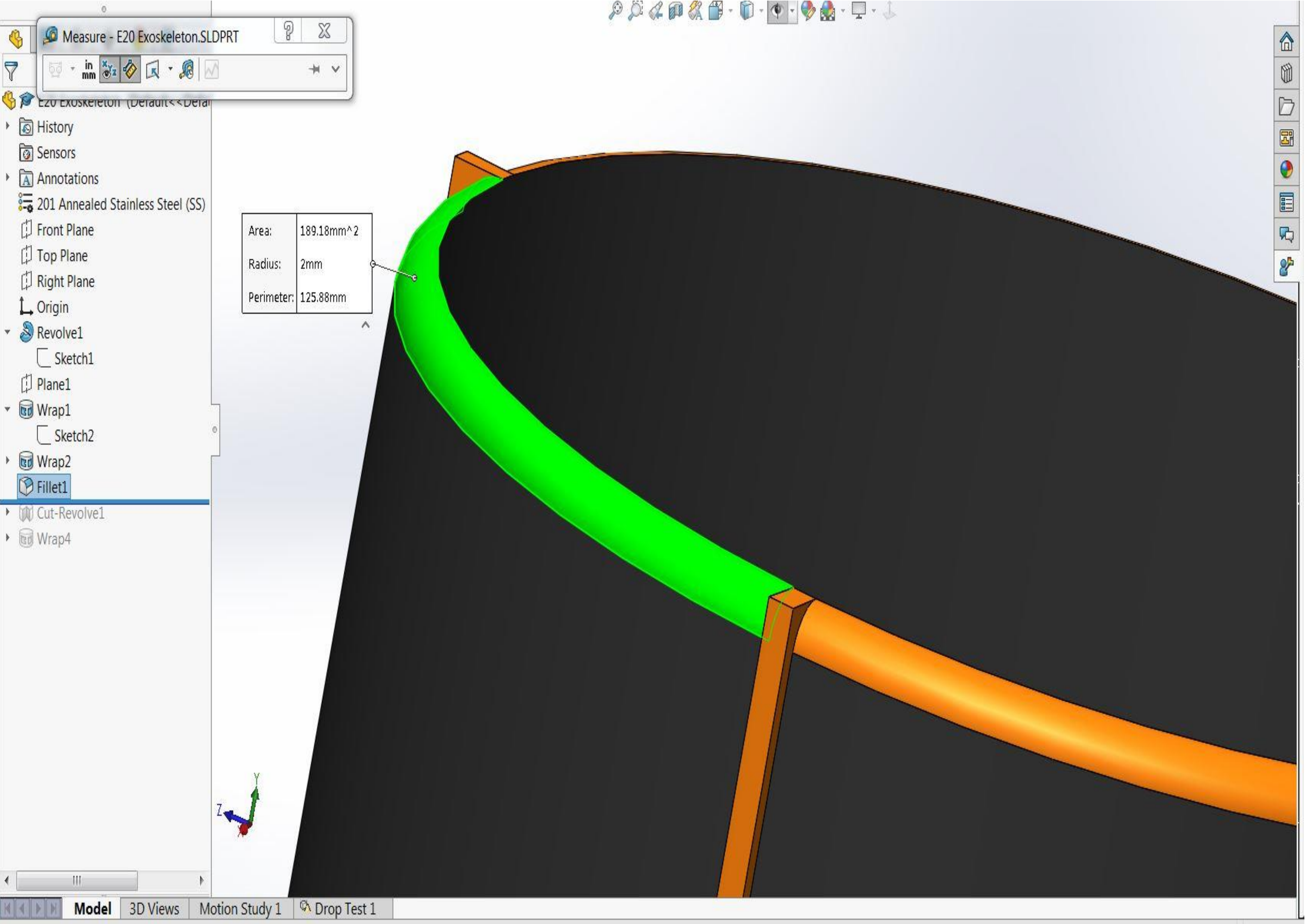
4.1 FRAME



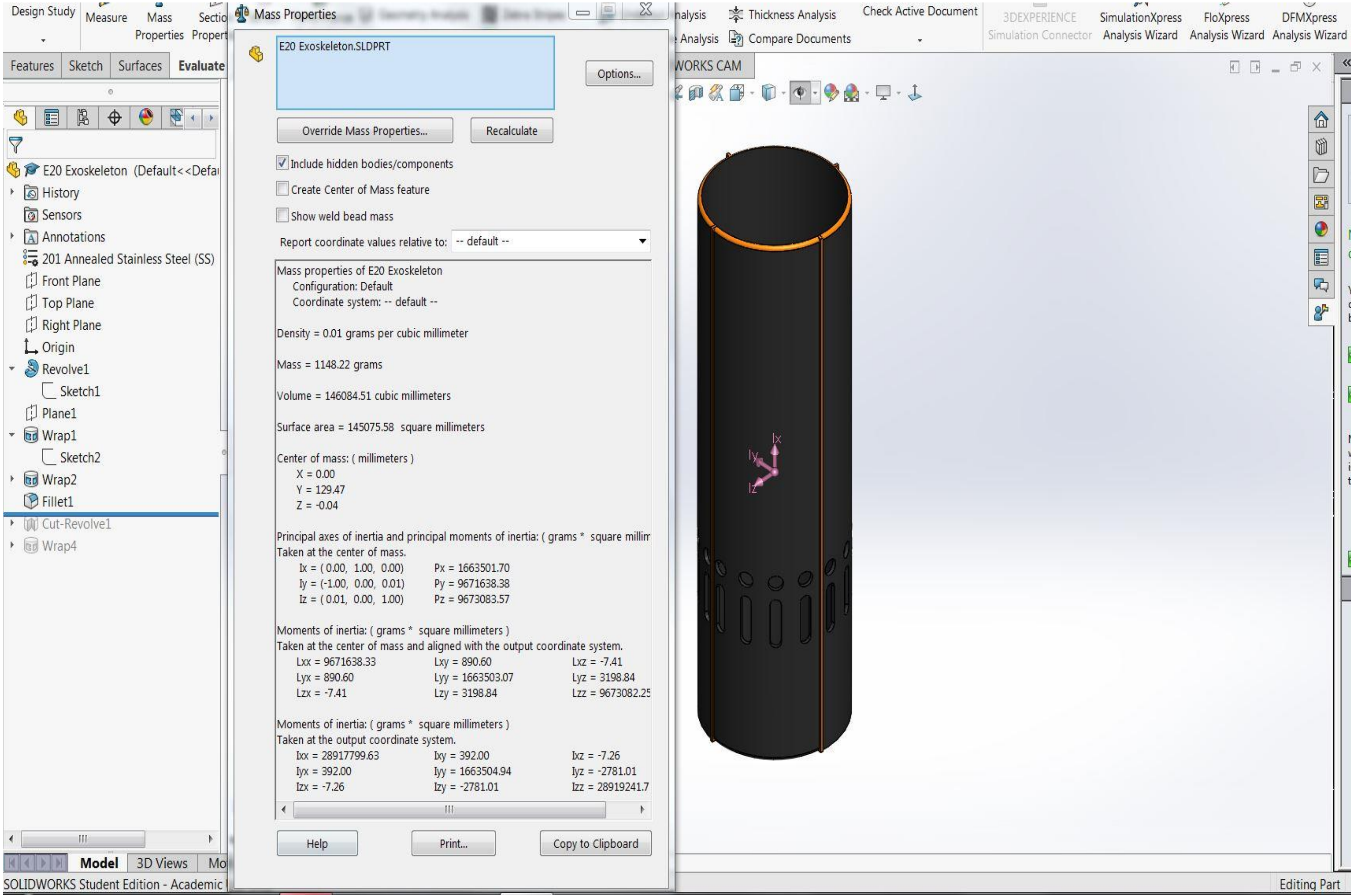


E20 Exoskeleton (Default<<Defa
History
Sensors
Annotations
201 Annealed Stainless Steel (SS)
Front Plane
Top Plane
Right Plane
Origin
Revolve1
Sketch1
Plane1
Wrap1
Sketch2
Wrap2
Fillet1
Cut-Revolve1
Wrap4
12.00
∅8.00
16.00
15
120.00
20.00
3.00
35.00
3.00
16.00
62.00
Model
3D Views
Motion Study 1
Drop Test 1


12.00
Ø8.00
16.00
120.00
20.00
3.00
35.00
3.00
16.00
16.00
62.00
Drop Test 1



Measure - E20 Exoskeleton.SLDPRT
History
Sensors
Annotations
201 Annealed Stainless Steel (SS)
Front Plane
Top Plane
Right Plane
Origin
Revolve1
Sketch1
Plane1
Wrap1
Sketch2
Wrap2
Fillet1
Cut-Revolve1
Wrap4
Area: 189.18mm^2
Radius: 2mm
Perimeter: 125.88mm
Model
3D Views
Motion Study 1
Drop Test 1


Mass Properties
E20 Exoskeleton.SLDPRT
Options...
Override Mass Properties...
Recalculate
Include hidden bodies/components
Create Center of Mass feature
Show weld bead mass
Report coordinate values relative to: -- default --
Mass properties of E20 Exoskeleton
Configuration: Default
Coordinate system: -- default --
Density = 0.01 grams per cubic millimeter
Mass = 1148.22 grams
Volume = 146084.51 cubic millimeters
Surface area = 145075.58 square millimeters
Center of mass: (millimeters)
X = 0.00
Y = 129.47
Z = -0.04
Principal axes of inertia and principal moments of inertia: (grams * square millir
Taken at the center of mass.
Ix = (0.00, 1.00, 0.00) Px = 1663501.70
Iy = (-1.00, 0.00, 0.01) Py = 9671638.38
Iz = (0.01, 0.00, 1.00) Pz = 9673083.57
Moments of inertia: (grams * square millimeters)
Taken at the center of mass and aligned with the output coordinate system.
Lxx = 9671638.33 Lxy = 890.60 Lxz = -7.41
Lyx = 890.60 Lyy = 1663503.07 Lyz = 3198.84
Lzx = -7.41 Lzy = 3198.84 Lzz = 9673082.25
Moments of inertia: (grams * square millimeters)
Taken at the output coordinate system.
Ixx = 28917799.63 Ixy = 392.00 Ixz = -7.26
Iyx = 392.00 Iyy = 1663504.94 Iyz = -2781.01
Izx = -7.26 Izy = -2781.01 Izz = 28919241.7
Help
Print...
Copy to Clipboard
Design Study
Measure
Mass Properties
Features
Sketch
Surfaces
Evaluate
E20 Exoskeleton (Default<<Defa
History
Sensors
Annotations
201 Annealed Stainless Steel (SS)
Front Plane
Top Plane
Right Plane
Origin
Revolve1
Sketch1
Plane1
Wrap1
Sketch2
Wrap2
Fillet1
Cut-Revolve1
Wrap4
Model
3D Views
Thickness Analysis
Compare Documents
Check Active Document
3DEXPERIENCE Simulation Connector
SimulationXpress Analysis Wizard
FloXpress Analysis Wizard
DFMXpress Analysis Wizard
SOLIDWORKS Student Edition - Academic
Editing Part

CHAPTER 5

SOFTWARE MODEL & ANALYSIS

5.1 STATIC STUDY

A

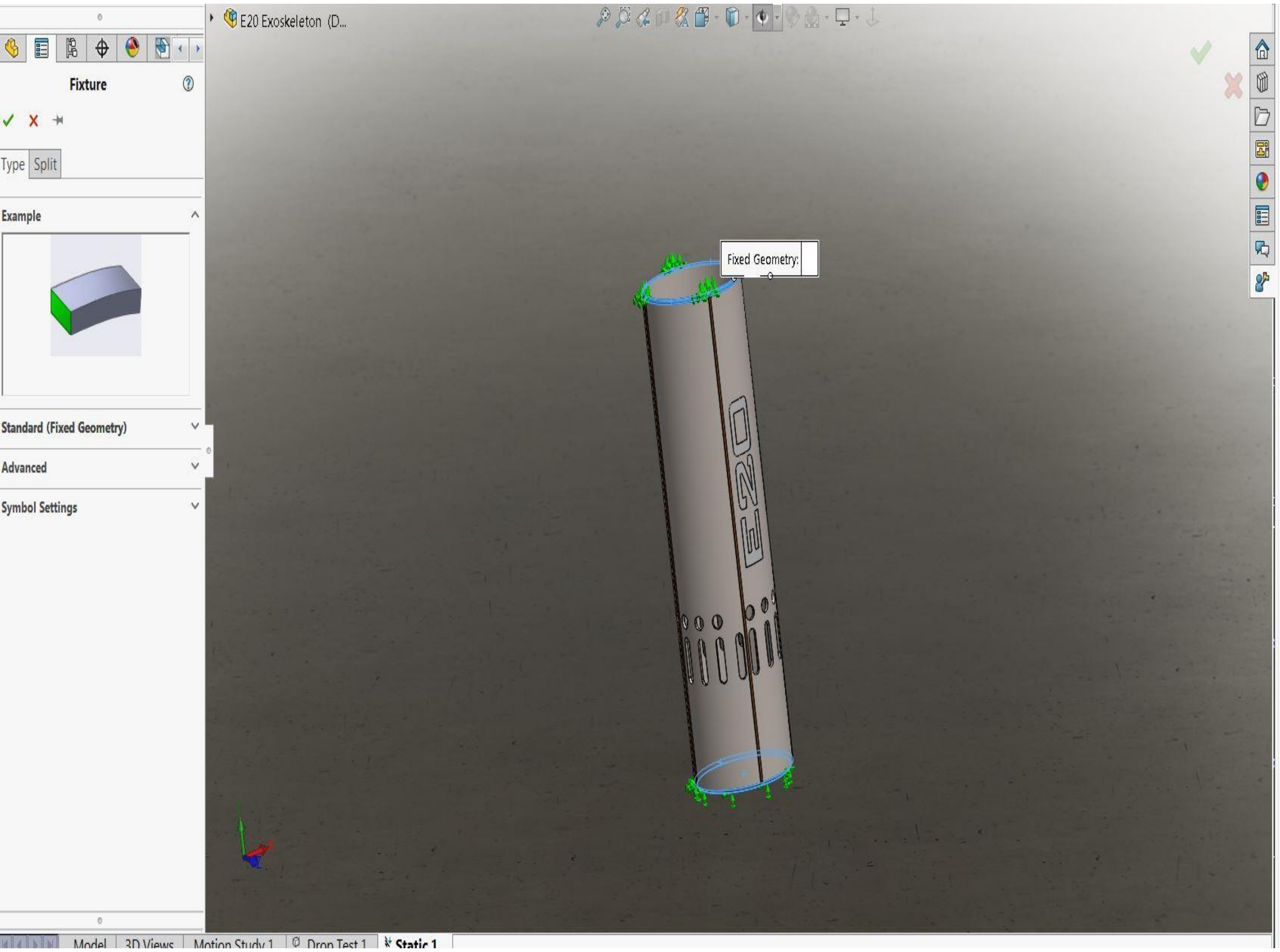


Fig 5.A (Fixed Geometry)

B

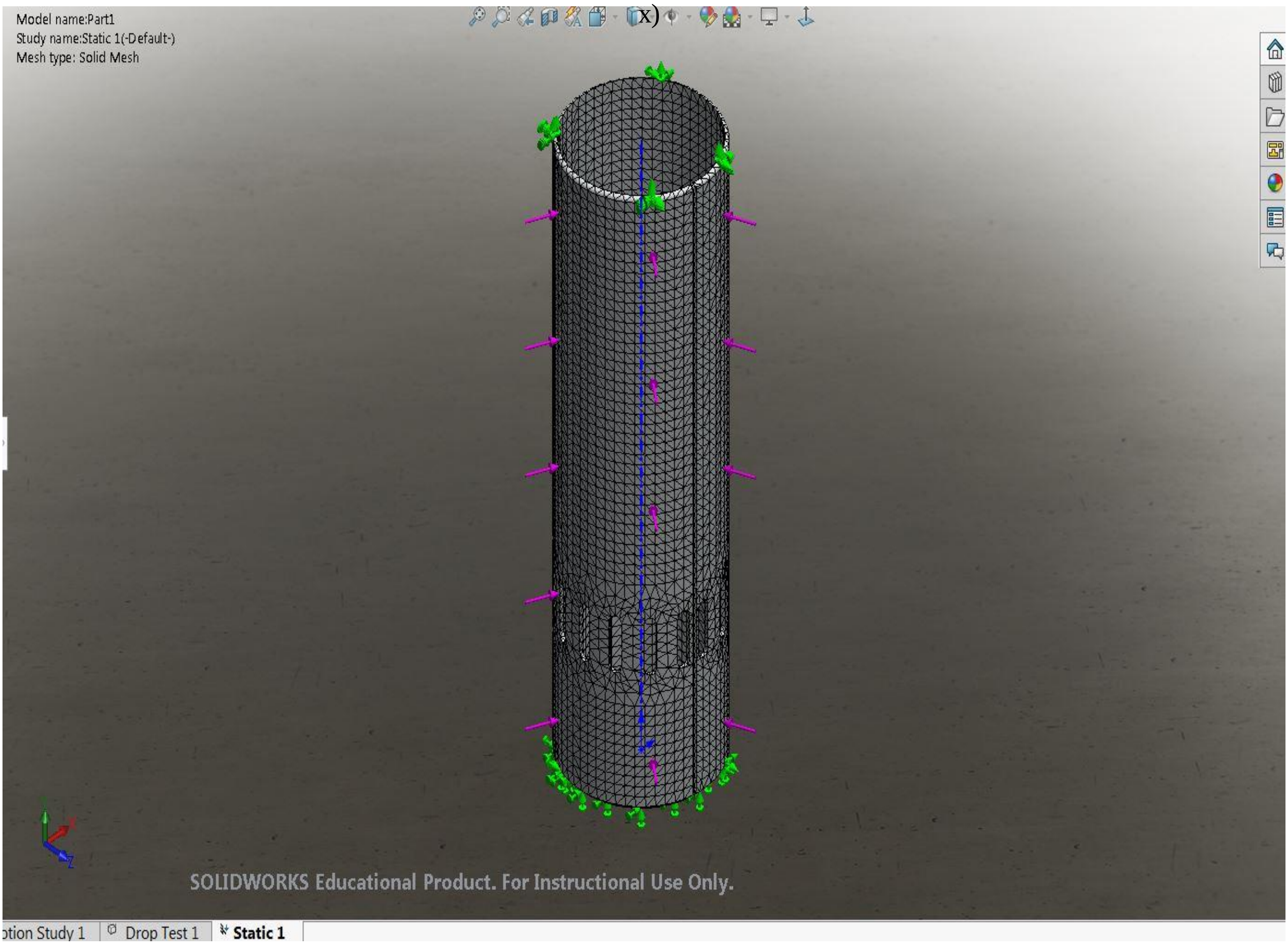
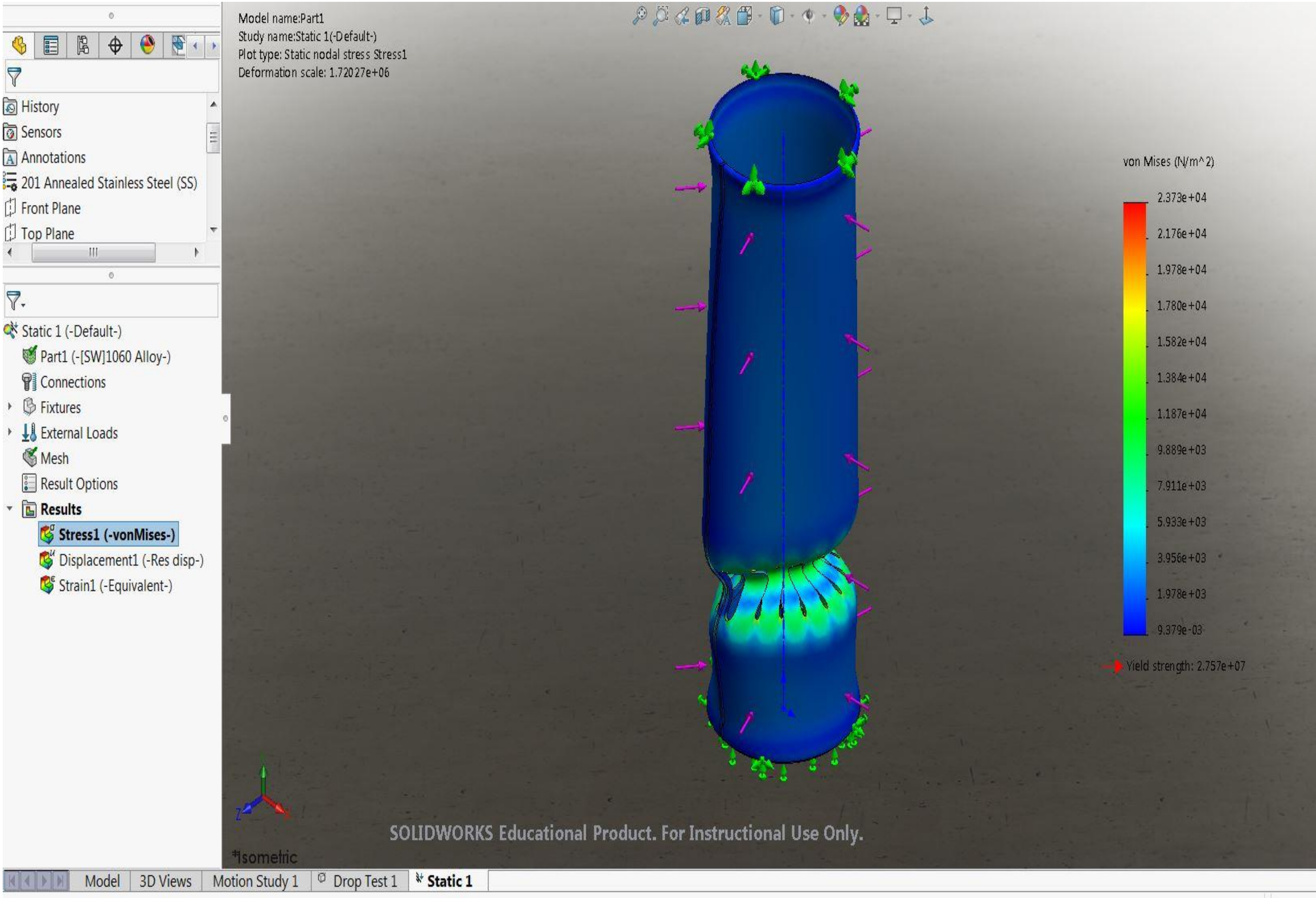


Fig 5.1B (Solid Mesh)

C Fig 5.1C (Nodal Stress Analysis)



History
Sensors
Annotations
201 Annealed Stainless Steel (SS)
Front Plane
Top Plane
Static 1 (-Default-)
Part1 (-[SW]1060 Alloy-)
Connections
Fixtures
External Loads
Mesh
Result Options
Results
Stress1 (-vonMises-)
Displacement1 (-Res disp-)
Strain1 (-Equivalent-)
Model name:Part1
Study name:Static 1(-Default-)
Plot type: Static nodal stress Stress1
Deformation scale: 1.72027e+06
von Mises (N/m^2)
2.373e+04
2.176e+04
1.978e+04
1.780e+04
1.582e+04
1.384e+04
1.187e+04
9.889e+03
7.911e+03
5.933e+03
3.956e+03
1.978e+03
9.379e-03
Yield strength: 2.757e+07
SOLIDWORKS Educational Product. For Instructional Use Only.
*Isometric
Model
3D Views
Motion Study 1
Drop Test 1
Static 1

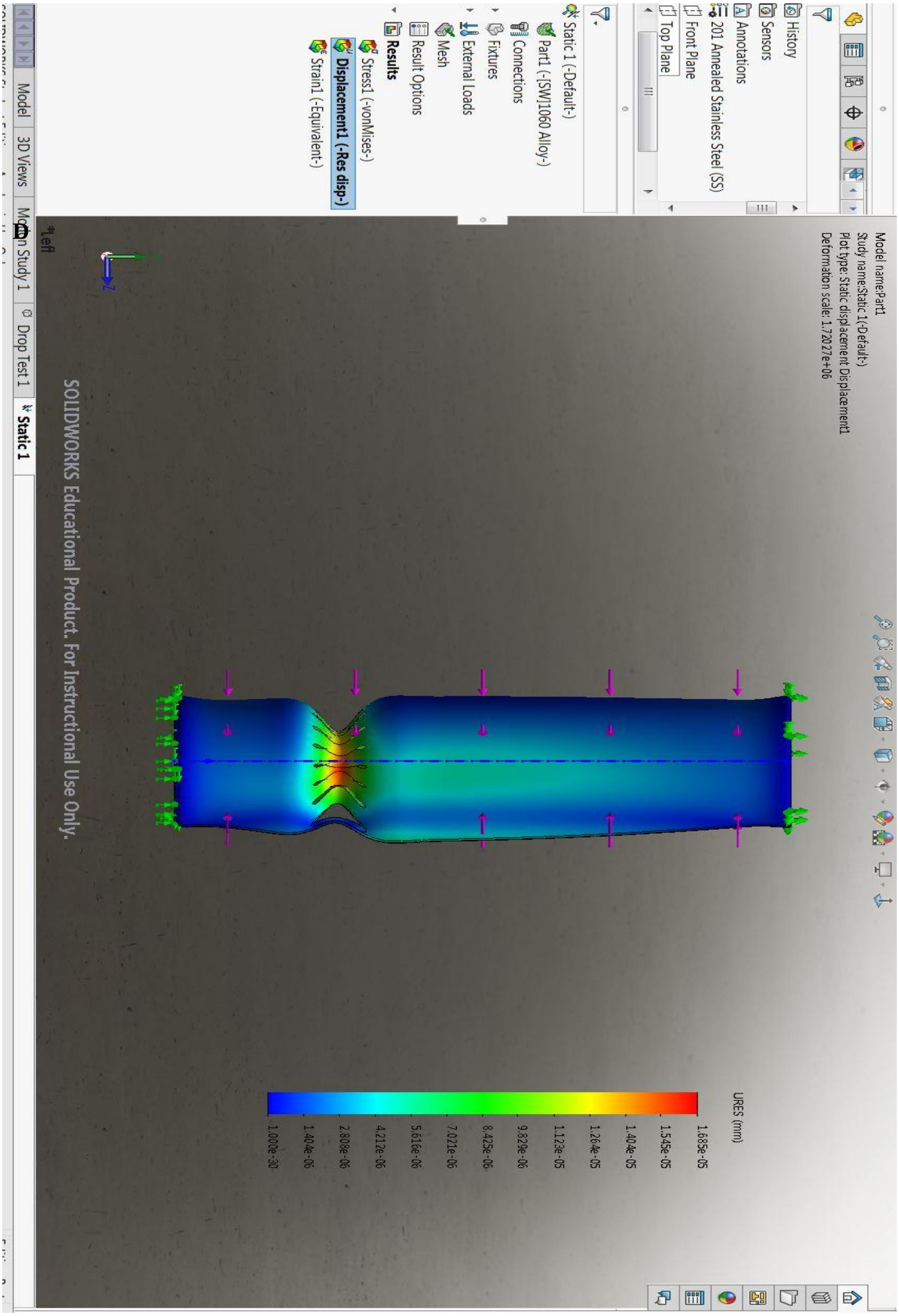
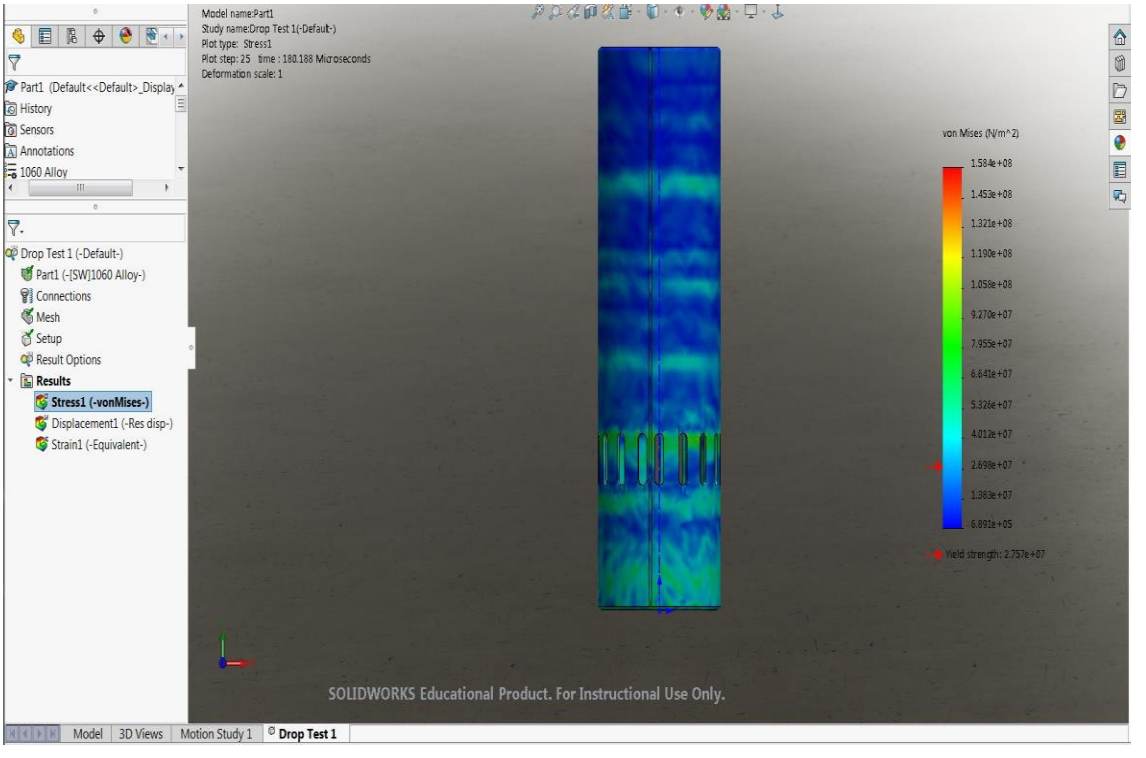


Fig 5.1D (Nodal Displacement Analysis)

5.2 DROP TEST from 2m (material – Annealed Stainless Steel)

A



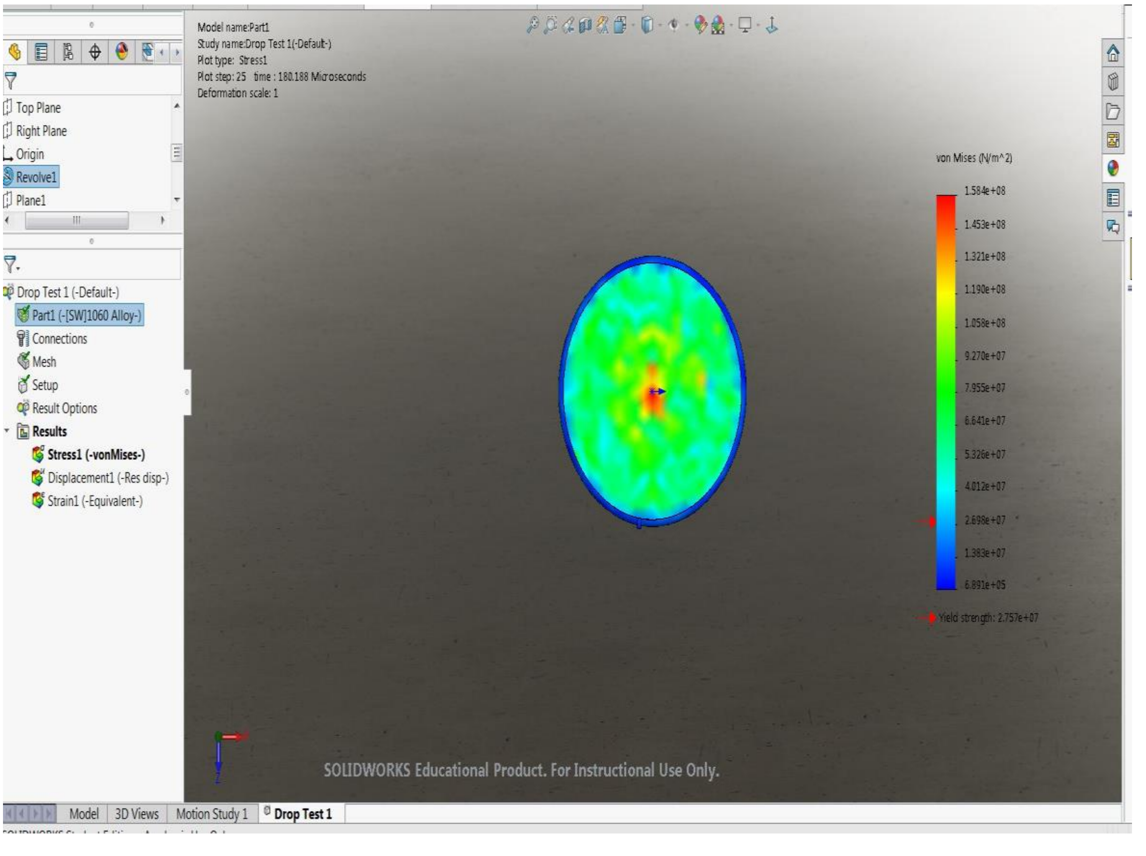


Fig 5.2A (Stress Analysis)

B. Strain Anaysis

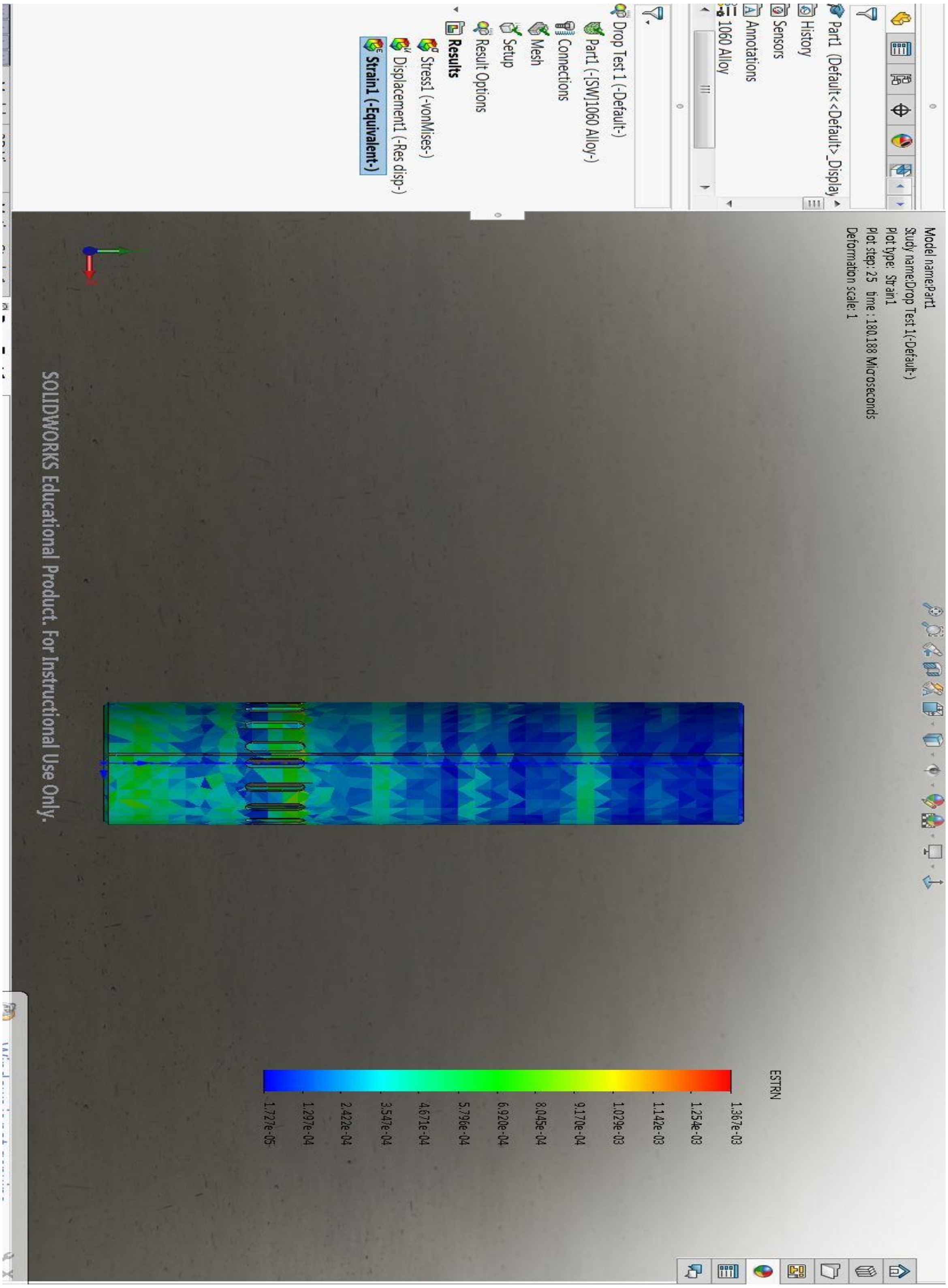
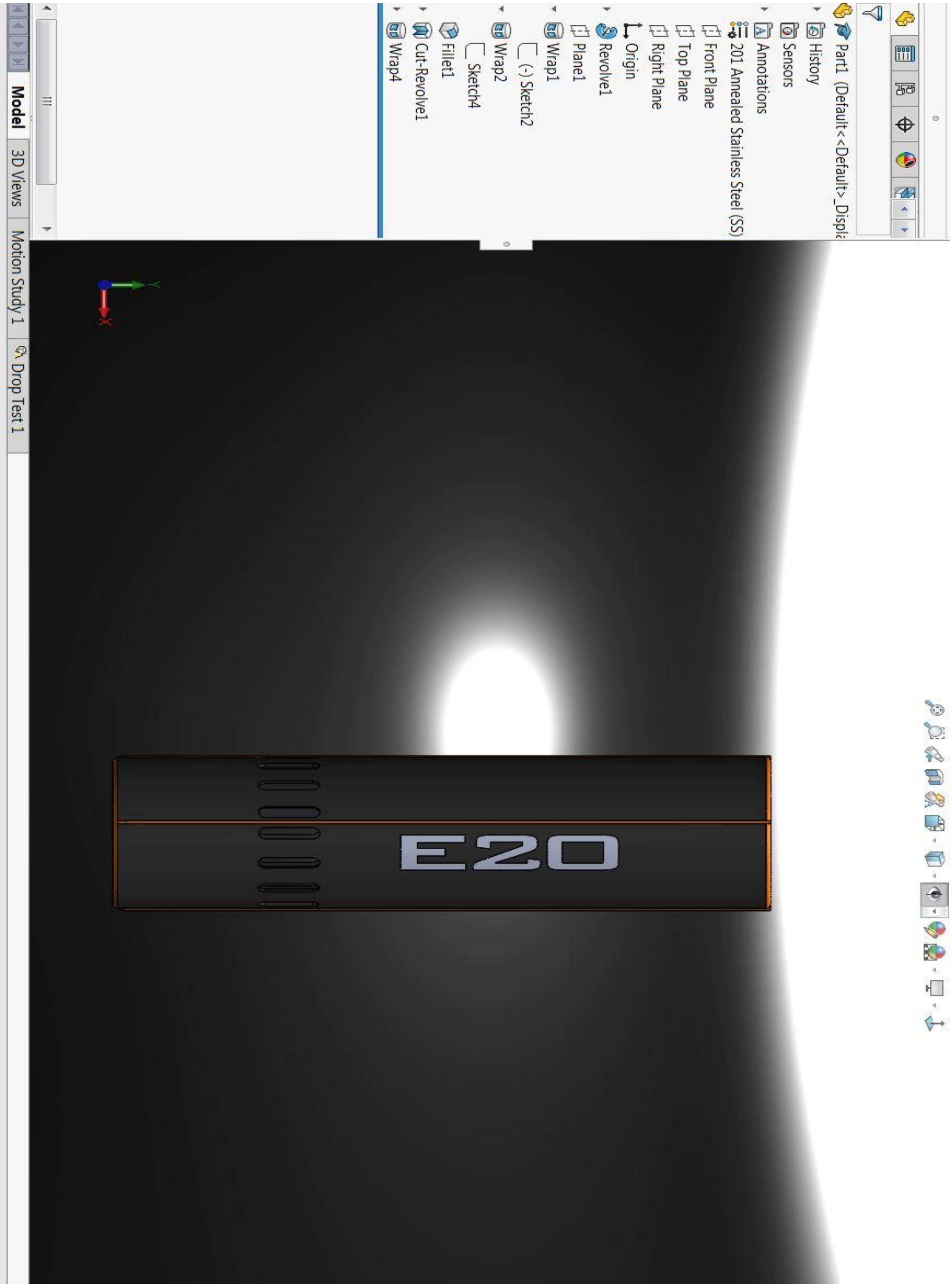
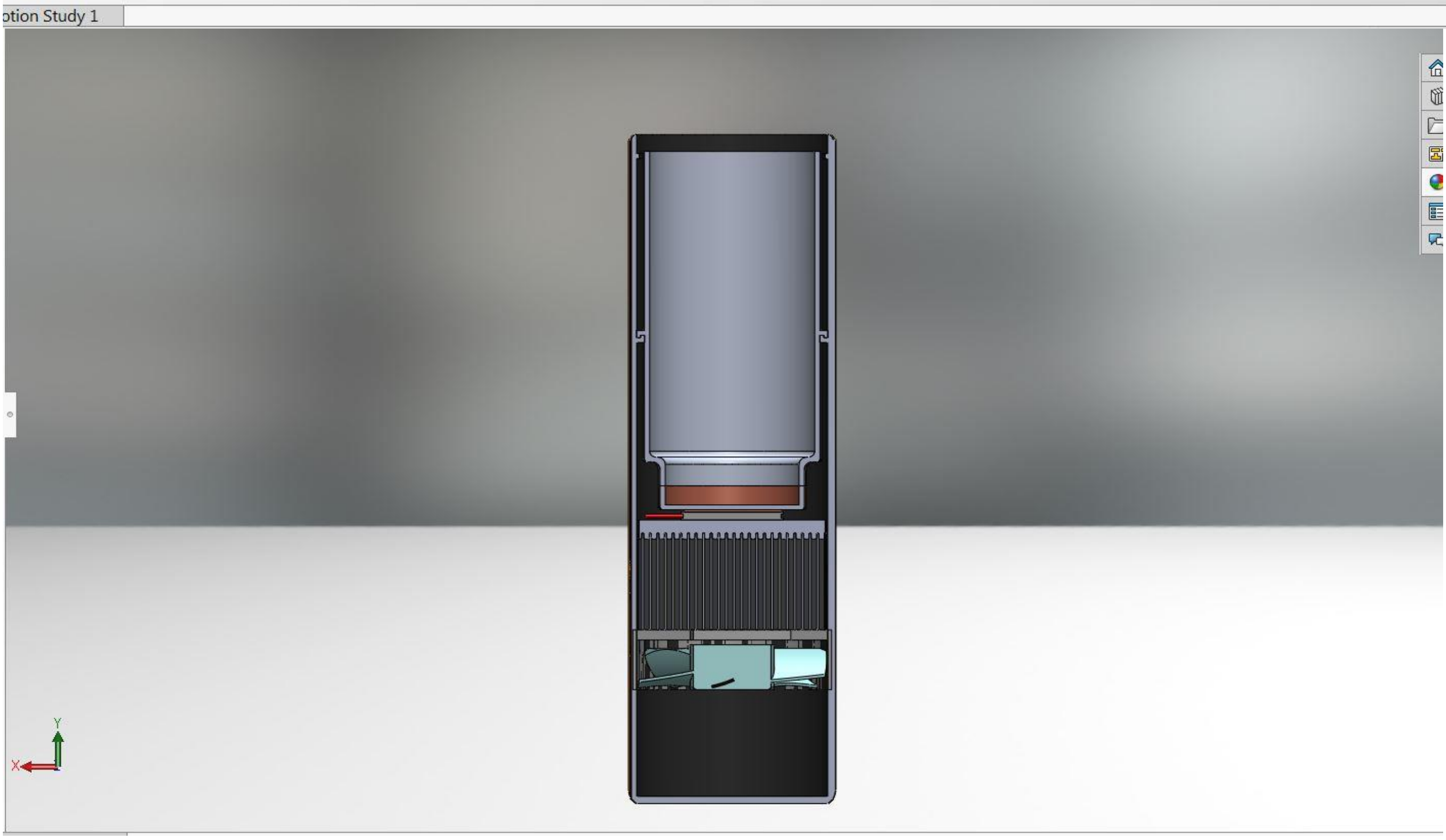


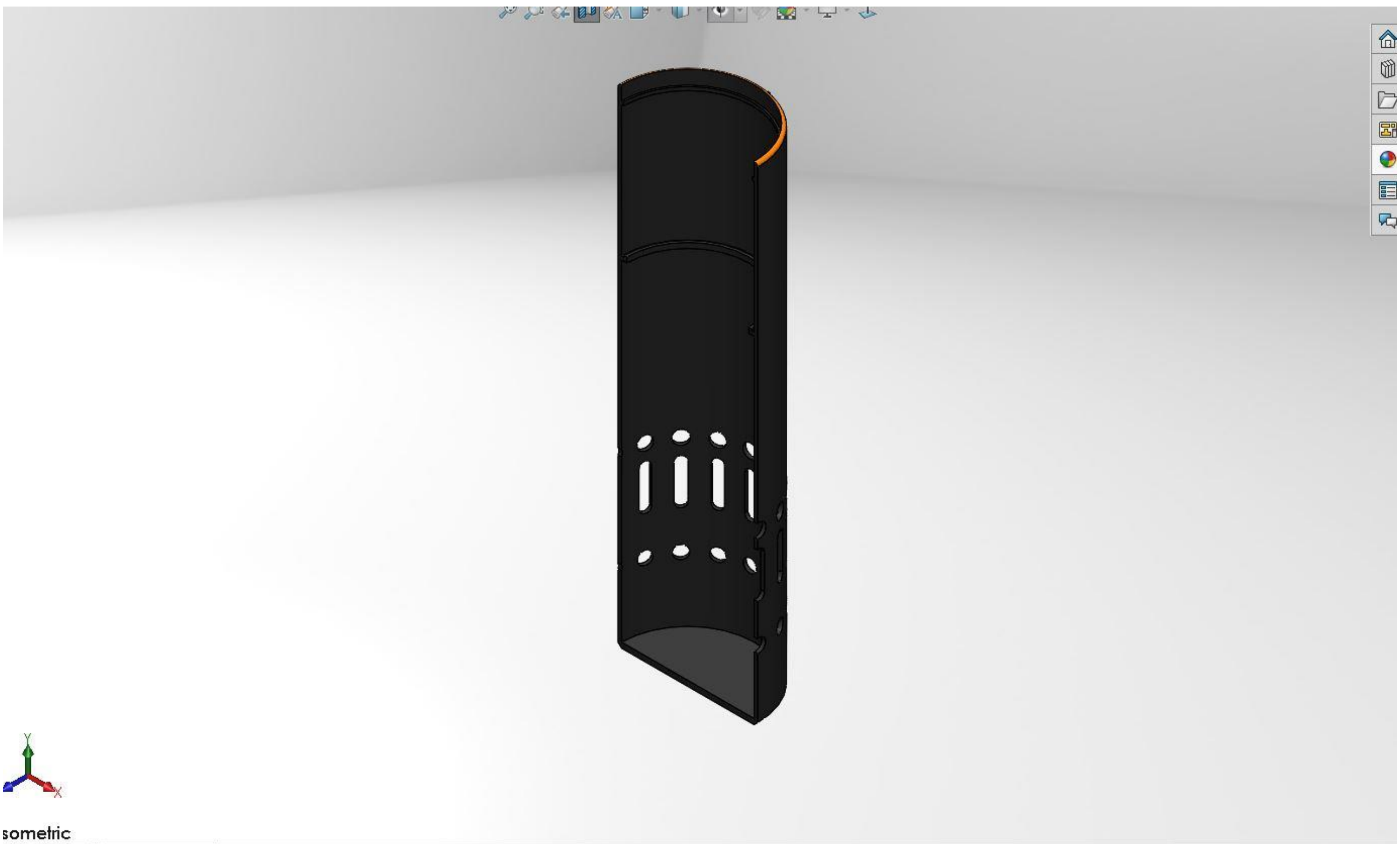
Fig 5.2B (Strain Analysis)

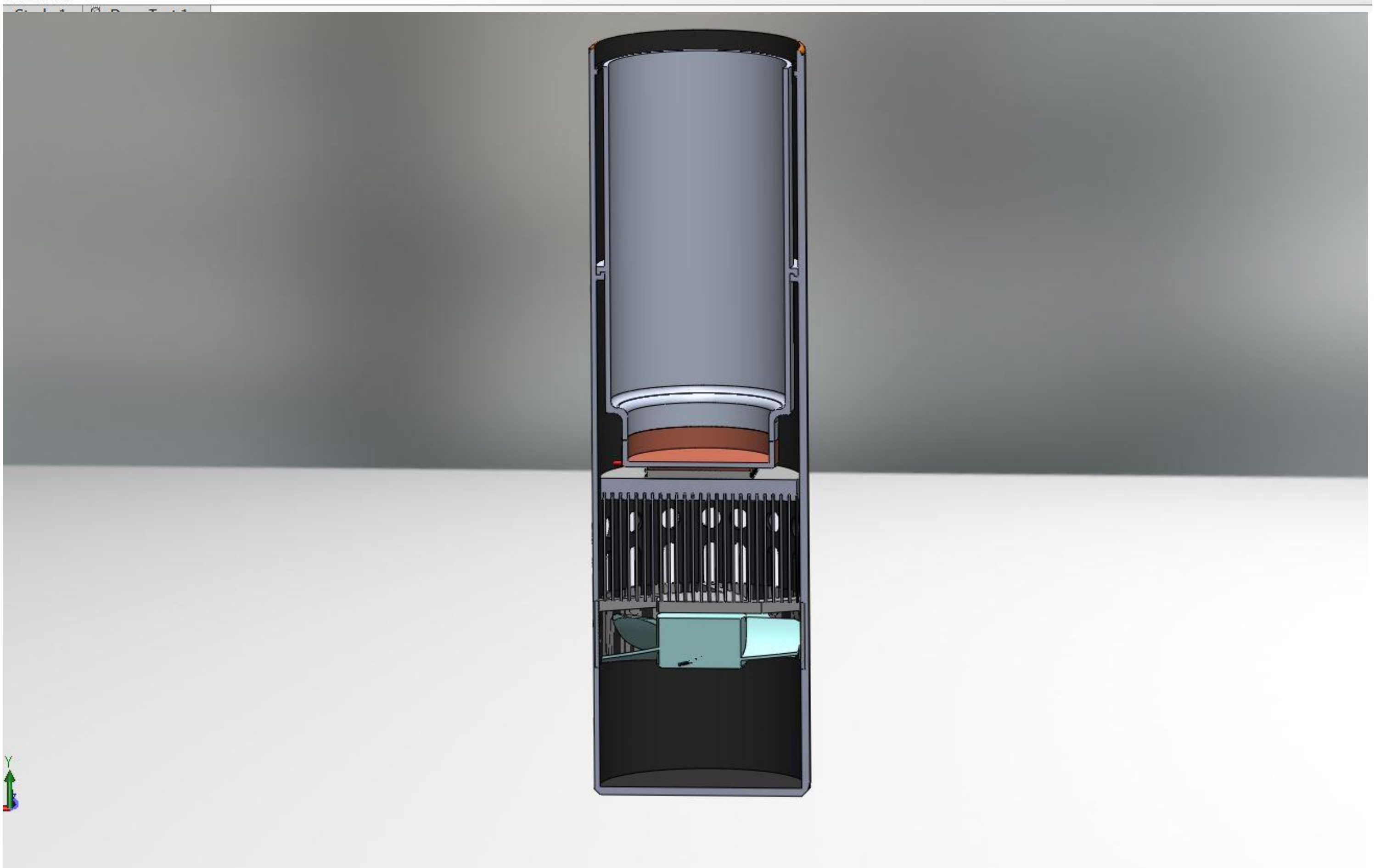
5.3 MODEL (Final Assembly)

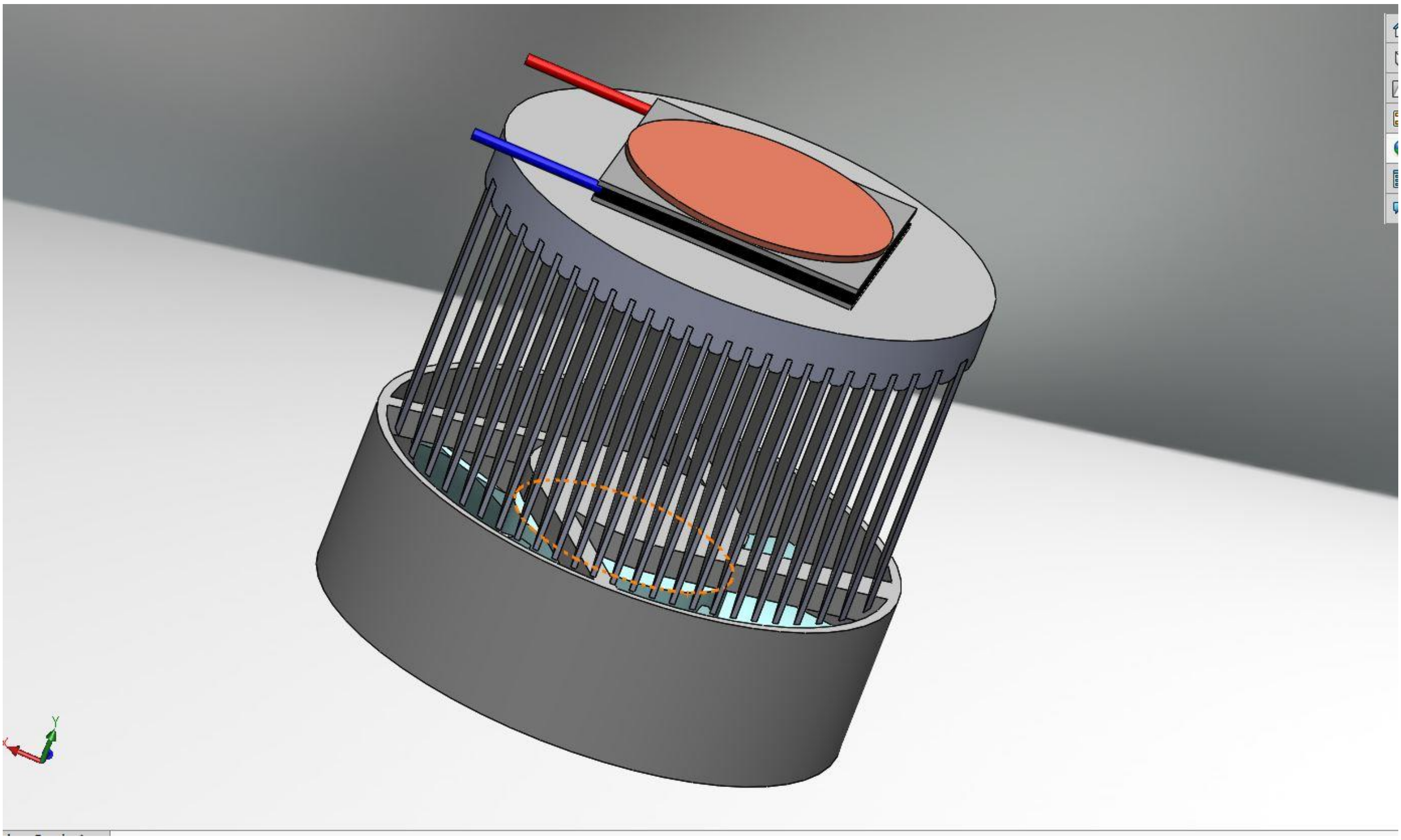


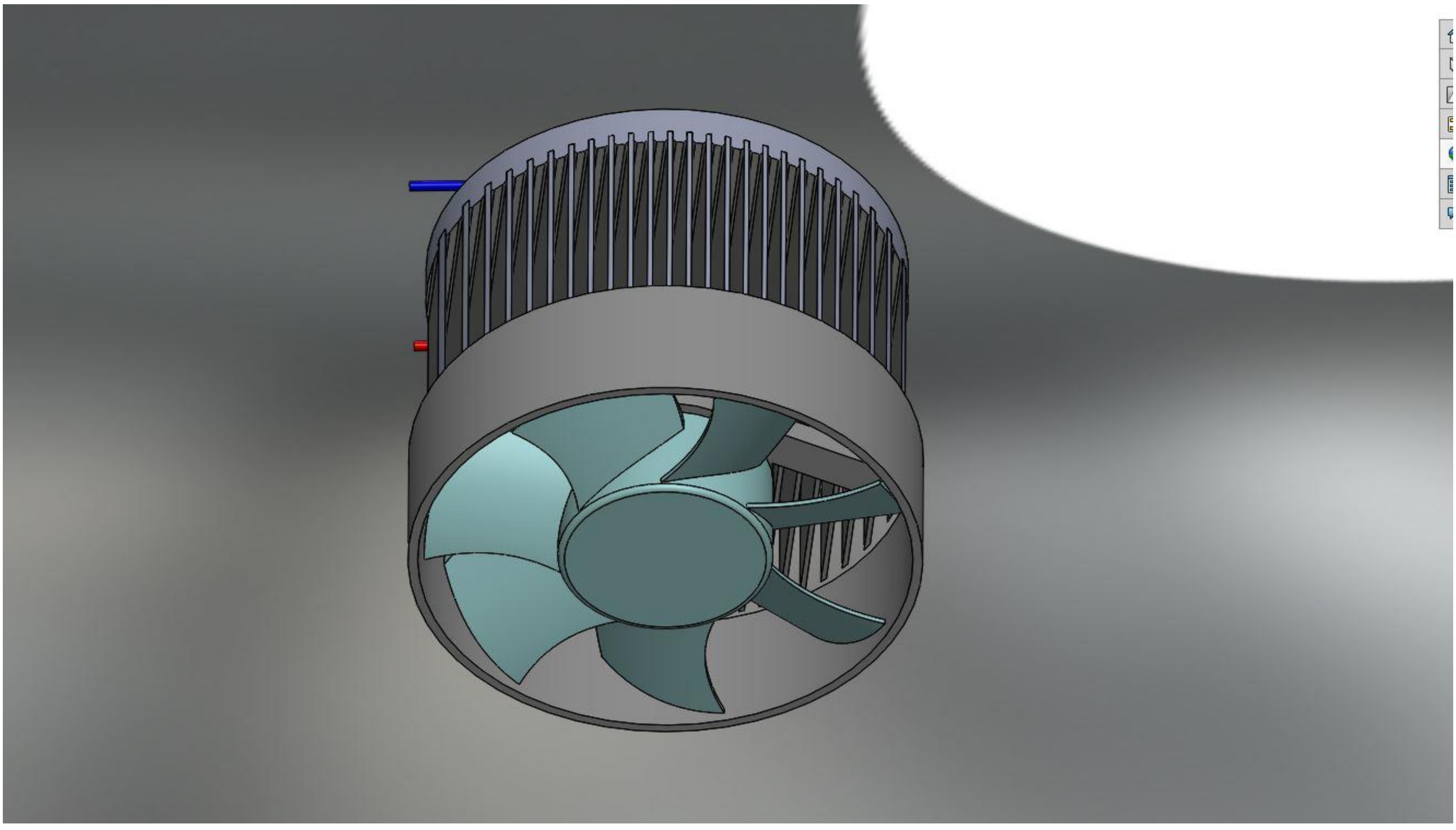

E20
otion Study 1




sometric








E20


E20

CHAPTER 6

MATERIAL CHARACTERIZATION

6.1 E2O SPECIFICATIONS

Peltier Model	TEC1-12706
Operating Voltage(VDC)	12
Maximum Voltage(V)	15
Maximum Current(A)	6.4
Maximum Power (W)	114
Internal Resistance(Ω)	1.98
Wire Length(mm)	200
Length (mm)	80
Width (mm)	80
Height (mm)	280
Weight(gm)	30
Shipment Weight	kg

CHAPTER 7

FUTURE OF SMART & PORTABLE THERMOELECTRIC HEATING/COOLING DERIVED FOODWARE

Advantages

- Revolutionaries the Foodware by eliminating the inefficiencies of thermal insulated utensils currently present in the market.
- Internal heat generation and manipulation achieves the desired results without using bulky refrigeration system and high power consuming induction coils.
- App controlled IOT infrastructure enables to monitor and control over various settings of the product.
- Provides preferred food/drug temperature to the user at anytime and anywhere unlike the conventional storage which relies on thermal insulation.
- Accessibility and portability enables to carry it anywhere on the go.

Disadvantage

- Using Peltier module limits the size of the product and as the size increases so the inefficiencies of the module.
- The temperature maintained by the product only varies from 10°C To 80°C

Application

- This product will monopolise and dominate the market due to its distinctive technology to acquire temperature modulation in storage container(Tiffin, Bottles, Electric Tiffin using induction coils)
- The modern alternative for the portable food/drug storage utensils.
- The internal heat generation and manipulation enables it use anytime without much heat loss to the environment.

CHAPTER 8

8.1 CONCLUSION

- As per the calculation and heat transfer rate required, Peltier module TEC-12706 is selected for cooling and heat generation.

- And TEC1089E-SV or Arduino Uno with Wi-Fi shield can be used as the circuit driving IC.

- Through the Peltier effect, thermoelectric coolers (TECs) are able to cool many different products both at large industrial scale and for individual consumer needs.

- The market for refrigerators powered by TECs has been growing steadily for the last 10 years and this is a trend that we expect will continue.

- These refrigeration devices have been an integral part of maintaining healthy conditions for areas where electricity is not as reliable or not affordable for struggling families. These devices provide them reliable, solar powered refrigeration to help prevent food-borne illnesses from improper storage of products like meat and dairy.

- In coastal regions, individual families are reliant on seafood for sustenance and income: TEC refrigerators offer these individuals a safe way to transport and store marine produce for sale at market and prevent exposure to potential contamination

- With ongoing advancements in the field of TECs the application of these non-conventional devices in medical field looks promising and also provides an opportunity for a huge consumer market for it in the near future.

8.2 REFERENCES

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4. S. Riffat, S.A. Omer, Xiaoli Ma, A novel thermoelectric refrigeration system employing heat pipes and a phase change, Renewable Energy 23 (2001) 313–323

5. R. Chein, Y. Chen, "Performances of thermoelectric cooler integrated with microchannel heat sinks", International Journal of Refrigeration 28 (2005) 828–839

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