SNOW MELTING MATS

Thesis submitted in partial fulfilment of the requirements for the degree of

Bachelor of Technology in Mechanical Engineering

By

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SCHOOL OF MECHANICAL ENGINEERING

VIT®

Vellore Institute of Technology

(Deemed to be University under section 3 of UGC Act, 1956)

CHENNAI

May 2020

DECLARATION

We, Shelvin Pauly(16BME1191) and Rajit Halder(16BME1189), B Tech Mechanical Engineering, VIT Chennai, hereby declare that the work being presented in the dissertation entitled **“SNOW MELTING MATS”** is an authentic record of the work that has been carried out at VIT, Chennai under the guidance of Dr Sasikumar M, School of Mechanical Engineering, VIT Chennai.

We hereby declare that the entire work embodied in this dissertation has been carried out by us and no part of it has been submitted for any degree or diploma of any institution previously.

Place: Chennai

Date:

Signature of the Students with names

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CERTIFICATE

This is to certify that the project thesis entitled "**SNOW MELTING MATS**" submitted by Shelvin Pauly(16BME1191) and Rajit Halder(16BME1189) for the award of the degree of *Bachelor of Technology* is a record of bonafide work carried out by them under my supervision, as per the VIT code of academic and research ethics. The contents of this report have not been submitted and will not be submitted either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university. The thesis fulfils the requirements and regulations of VIT and in my opinion meet the necessary standards for submission.

Place: Chennai

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The thesis is satisfactory / unsatisfactory

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ABSTRACT

Snow comprises of individual ice crystals that grow while suspended in the atmosphere, usually within the clouds, then fall, and accumulate on the ground where they undergo further changes. It consists of frozen crystalline water throughout its life cycle, starting when, under suitable conditions, the ice crystals form in the atmosphere, increase to millimetre size, precipitate and accumulate on surfaces, then metamorphose in place, and ultimately melt, slide or sublimate away.

During the winter months in regions that experience significant snowfall, snow and ice accumulate on the tops of all vehicle types, including automobiles, straight trucks, intermodal containers, large trucks, trailers and buses. This accumulation of snow and ice potentially causes a significant safety issue as chunks of ice may form when accumulated snow melts, then refreeze. During transit, a piece of ice may dislodge from the vehicle, potentially damaging vehicle components, causing property damage to other vehicles and even injuring other motorists.

- Snow blowing off the vehicle’s roof and impairing motorist visibility
- Ice falling from a vehicle and causing injury or property damage to other motorists or pedestrians
- Violations of snow and ice removal laws or fines for falling ice
- Violations of other vehicle operations-related regulations
- Cracks in the windshield
- Dents in the auto body
- Possibility of development of rust
- Nearby drivers may be blinded by light snow blowing off your vehicle.

Other benefits of routinely removing snow and ice accumulations are improved fuel economy (by reducing the weight of the accumulated snow and ice) and the reduction of potential insurance claims or civil litigation resulting from falling ice.

In addition to the safety concerns, there are legal implications for failing to remove snow and ice from your vehicle before driving. Most countries have laws that make it illegal for items to fall from a vehicle while on the road. Law enforcement may prohibit vehicles from using the roadway if debris, which includes snow and ice, could fall from the vehicle and endanger

individuals and/or property. Few places in the United States allow law enforcement to stop motorists who failed to clear their vehicles of snow and ice. These are often labelled “ice missile” laws. Law enforcement in several other states may issue citations if the vehicle is considered a danger due to the inability to see out of the windshield, such as Alaska, Oklahoma or Washington.

The project serves the purpose of avoiding the accumulation of snow over automobiles which can cause serious in/convenience.

Traditional methods of snow prevention like sprinkling rock salt over ice to melt it comes with its own flaws. During the wintertime, cars are vulnerable to damage from rock salt that is used to prevent the accumulation of snow and ice on roads. Large particles of salt can lead to corrosive damage on just about any car part that is exposed. From the brakes to the engine block, metal parts can easily get damaged by salt that reacts with water and oxygen. Of course, the water comes from the snow that melts. A combination of snow and rock salt is usually found in slush, which poses the greatest risk for wheels, brakes, exhaust pipes, mufflers and other components that are located relatively low to the ground. Care must be taken to ensure that the vehicle is washed after driving on roads that have been treated with rock salt. A car wash can remove salt particles from the brakes and wheels. Furthermore, a lot of time and energy is wasted in using a shovel or any other such equipment for removing the snow and hence a mat would be more convenient and useful.

Hence this project will take a more modern and scientific approach to snow prevention over cars. It derives its inspiration from heating mats that melts accumulated snow in front of households. The project will consist of a canopy-like structure that is portable and easy to install. We intend to make the structure flexible and connected with an electric circuit which will create the heat and thereby melting the ice. The circuit will consist of high resistance wires that can withstand immense an amount of heat. We also want to embed concepts of IoT to increase the functionality of the device. Due to the situation caused by the Covid-19 pandemic we had to settle on simulating the process over Ansys. The simulation proves the usage of the designed mat as sustainable and economical. A total of 6 transient thermal analyses were conducted. 3 types of snow were considered in 2 different initial temperatures to prove the versatility of the mats over different climates.

ACKNOWLEDGEMENT

I would like to express my very great appreciation to Dr Sasikumar M for his valuable and constructive suggestions during the planning and development of this research work. His willingness to give his time so generously has been very much appreciated. This project would not have been possible without the constant support of Dr Sivakumar, Dean, School of Mechanical Engineering; and VIT University for giving required access hardware laboratories and state of the art equipment.

Rajit Halder (16BME1189)

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SYMBOLS AND NOTATIONS

S. No	Symbol	Full Form	Units
1.	R_o	Outer Radius of the coil	Mm
2.	R_i	Inner Radius of the Coil	Mm
3.	Ө	Wire Diameter	Mm
4.	R_C	Resistance of the Coil	Ohms
5.	ρ	Resistivity of Nichrome	Ohm. Meter
6.	P	Power Rating	Watts
7.	V	Voltage Supply	Volts

CHAPTER 1

INTRODUCTION

The primary problem we have tried to tackle is to design a heating mat system that can be placed over cars and will help in removing the accumulated ice and snow over the vehicles. This design is to be included with a convenient heat source and should be structured properly as that it fits on the car roof without much hindrance and stays affixed there. About 33% of industrialized Earth experiences heavy snowfall. Snowfall creates various hindrances that which is mostly concentrated causing machinery to lose the edge and cause technical difficulties in moving parts. Snowfall accumulation over unmoving vehicles is a widely experienced problem.

1.1 Potential Dangers of not removing snow from your vehicles before driving

Dangerous winter storms and bad weather are a factor in nearly half a million crashes and more than two thousand road deaths every winter. About 46 percent of crashes involving bad weather take place in the winter, making it the worst time of year for driving in treacherous conditions. Snow, ice and sleet are not only a problem when driving on the roadways, where it can cause significant safety problems by making it difficult to maneuver or stop, but also when it accumulates on the vehicle. The accumulation of snow and ice on the vehicle can also have significant impacts on both the driver and those around. It is important to clear off your vehicle of snow and ice before hitting the roads, as it can have both legal and safety repercussions. The accumulation of snow and ice on your vehicle raises several safety concerns. It reduces visibility to the driver and it risks being dislodged during transit. If it is dislodged, it could cause property damage to other vehicles and even injure other motorists or pedestrians. In addition to the safety concerns, there are legal implications for failing to remove snow and ice from your vehicle before driving. "Currently, every state has laws that make it illegal for items to fall from a vehicle while on the road. Law enforcement may prohibit vehicles from using the roadway if debris, which includes snow and ice, could fall from the vehicle and endanger individuals and/or property", as said by a certain AAA authority.

1.1.1 Effect of snow accumulation on your vehicles and problems arising due to improper methods of snow removal

During the winter months, our vehicles tend to take a beating from all the salt on the roads. Public Authorities tend to salt roads to lower the melting point of the fallen snow, which might inversely harm our vehicles. Regardless of an SUV, or truck, all vehicles are highly susceptible to damage caused by the rock salt that is used to keep our roads free from snow and ice. Large particles of this salt can over time lead to corrosive damage on just about any vehicle part that is exposed. From the brakes to the engine block, all metal parts can easily corrode when the salt from the roads reacts with water and oxygen. So as the snow continues to melt and the water mixes with the salt and air, this can easily spell trouble for our vehicles. The parts of your car or truck that are most at risk are the wheels, brakes, exhaust pipes, mufflers and other metal components that are located relatively low to the ground. However, we don’t want to forget about your vehicle’s paint. The same salt that can corrode the metal on your vehicle can also cause the paint to lift away and peel off.

1.2 Advantages of using snow melting mats

Snow melting mats have existed for some time now although their applications have not used on vehicles though. Regardless they provide various advantages when compared to traditional methods of snow removal, such as:

1. Unlike a few other snow melting systems, snow melting mats are placed above the surface so there is no need for complicated installation. All you must do is place the mat on the top of your vehicle and plug it in. If you get multiple, you can connect the mats to prevent multiple extension cords. This corresponds to them having an easy installation.
2. To no surprise, snow-free vehicles are safer as mentioned above. Heat mats are made to handle ample amounts of snow as well as surrounding water once the snow has melted. It would take a lot of shovelling and salt to make our vehicles snow free which might in turn cause unnoticed damages on vehicles.
3. After safety, a key advantage of adding snow melting mats versus typical snow removal is cleanliness inside. When you throw salt or calcium chloride on your vehicle, it tends to make its way inside through cracks and openings. Additionally, calcium chloride can eat away at our vehicles while melting mats will do no such harm.

4. Most snow melting mats can last for years. Melting mats are durable because the electrically operated heating elements are sandwiched between two protective surfaces of non-slip rubber. As a result, no snow or water can penetrate the heating source, extending the lifespan of the mat.

1.3 Objectives

- The project aims to present a heating mat that shall be placed on the roof of automobiles and shall help in melting the ice accumulated during times of heavy snowing.
- It shall include smart sensing of snow accumulation. Prolonged usage of electricity and heat generation will not be required as heat will be supplied as long as there is unmelted snow present. This will also help in reducing costs.
- The Heating Mat itself shall me made with lightweight, flexible material so that portability is made easier.

CHAPTER 2

LITERATURE REVIEW

Precipitation is liquid or solid water falling from clouds to the Earth's surface. Snow is solid precipitation in the form of ice crystals. Due to many serious problems associated with snow accumulations during winter season, the removal of snow in winter seasons is not only a convenience but can as well enhance safety and prevent property damage. Residential, commercial, and industrial applications of snow melting have gained widespread acceptance. Snow melting systems are installed in a wide range of applications such as sidewalks, driveways, steps, toll plazas and bridges, to eliminate conventional snow removal methods such as shovelling, ploughing, sanding, and salting, to ensure safety. Melting snow and ice can be more effective, less expensive, and environmentally friendly than using mechanical and chemical alternatives. Snow melting on pavements using geothermal hot water and steam has been demonstrated in several countries including Argentina, Japan and the United States. These installations include sidewalks, roadways, and bridges. Some of the main benefits of these systems are that they eliminate the need for manual snow removal, provide greater safety for pedestrians and vehicles, and reduce the labour of slush removal. There are other alternative methods for snow or ice melting also. These alternatives include the use of exhaust heat of vehicles, infrared systems for snow melting and heating mats. The mats are made from special thermoplastics that distribute the heat evenly while maintaining an average temperature of few degrees above the ambient temperature. So, for example, if the ambient temperature is 0° F (-17.78° C), the mat's temperature will be approximately 40° F (4.44° C). This smart technology allows for mats to melt snow at a rate of up to 2 inches (5 cm) per hour. In infrared systems, heat is generated by an overhead high-intensity radiant panel for the snow melting. Methods such as salting, and sanding have been found to be problematic. Ice in general, will not be melted by the most commonly known salt (sodium chloride) if the temperature is below -10oC. Also due to the corrosive nature of salt to materials, it may penetrate down to metallic reinforced steels of the roof hence reducing the lifespan of the structure. Some alternative non-corrosive substances are available but are more expensive. Typical snow melting systems (e.g. hydronic systems) use either a gas-fired or electric boiler generally to heat the working fluid. However, such snow melting systems have been found to consume a much higher amount of thermal energy. Also snow melting methods such as using exhaust heat to melt snow was found not to be environmentally friendly due to CO_2

emission. From energy conservation, global warming and running cost point of view, new economic and environment-friendly solutions are needed in winter conditions to melt snow and to ensure maximum protection of life and property, also there have been numerous research works on the possibility of using new and renewable energy sources for snow melting systems compared with fossil fuel sources. It was recommended that, in the aspect of environmental friendliness (reduction in CO2) as well as energy consumption, new snow melting system designs should focus on adopting new and renewable energy sources.

Numerous researchers studied the thermal conductivity of polymer composites with regard to their importance to reach appreciable levels of thermal conductance in circuit boards, heat exchangers, appliances, and machinery. Amongst all thermal conductive fillers, graphite merits special interest not only due to its high thermal conductivity, that is, 25–470 W m^{-1} K^{-1}, but high thermal stability, exceptional chemical resistance, and mechanical properties. A comparative study of the thermal conductivity between graphite and other conductive fillers (viz. copper powder (Cu), aluminium powder (Al), silver powder (Ag), zinc oxide (ZnO), boron nitride (BN), aluminium oxide (Al2O3) and diamond) particles was done. It was reported that the highest thermal conductivity was obtained at the filling load of 44.3 wt% of graphite due to the layered structure of graphite forming heat pathways within the matrix.

The design of composites from graphite is inexpensive and available in abundance. This has initiated new ideas in the field of science for the development of a wide range of novel functional materials. Generally, the addition of graphite improved the thermal conductivity of the host polymer matrix irrespective of filler functionalization, the type of polymer and the method of preparation. Various processing techniques such as solvent casting melt blending and pan milling and masterbatch melt mixing have been used for the preparation of graphite composites. The type of mixing method seemed to have had an effect on the resultant thermal conductivity of the graphite/polymer composites. For instance, solution-casted composites had a high thermal conductivity as compared to the melt-mixed system. It is understood that during solution casting, the EG particles will have a sufficient surface-to-volume ratio; as a result, they can contact easily and form conducting path networks at low EG contents.

CHAPTER 3

TECHNICAL SPECIFICATIONS

3.1 Methodology

The project was based off on a persistent problem prevailing around areas of heavy snowfall. The solution conceptualized was what led to Snow Melting Mats for Vehicles. Problems arising due to accumulation of snow over vehicles often may lead to direct and indirect problems such as rusting, and moving parts going bad or it might also cause accidents later on due to such unresolved issues. In order to combat such problems, we designed a portable, easy to use, durable and safe heating mats for vehicles. So, we got our hands-on available heating technologies using mats and taking inspiration from such, applied to be able to work on vehicles too. The model includes an AC power source normally a power source in the wall which powers a wire with high resistivity which acts as a secondary heat source. The setup also an Arduino connected to various button load cells spread out throughout the area of the setup. This sensor senses load change over the area of the wires and releases heat in relation to the load change. This helps in reducing energy wastage or also stops overheating of the wires prolonging product life. The entire setup is enclosed in an appropriate material which shields it from the atmosphere and also prevents excessive heat loss.

3.1.2 WORK PLAN (CHART):

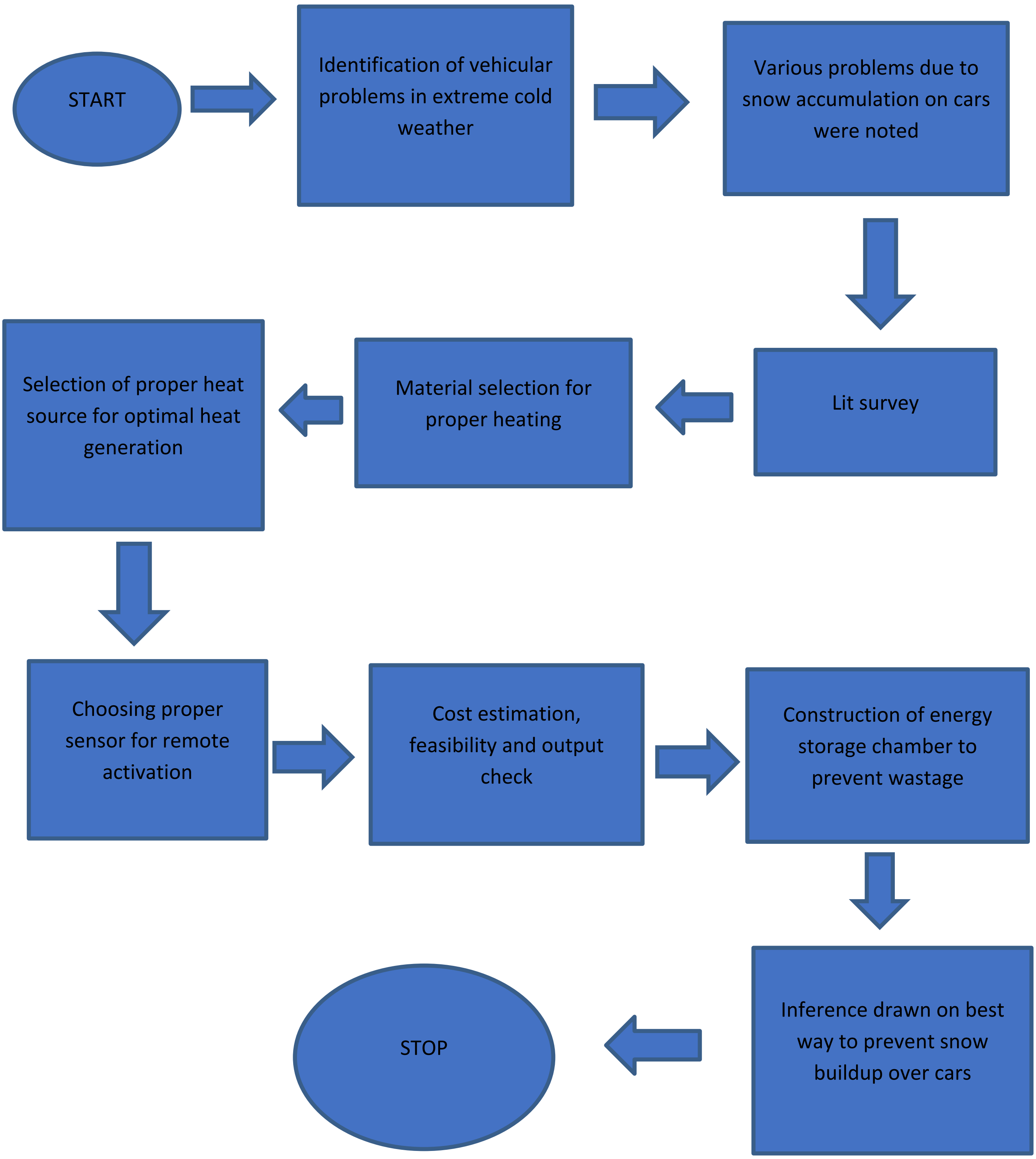

Figure 3. 1 Work Plan Flow Chart

3.2 Technical Details

A block diagram for the heat mats is provided in fig 2. The basic concept includes heat generation through resistance provided with high resistivity wires. These wires are connected to an Arduino which interprets information through a relay and a weight sensor. The wires are situated below a flexible and durable material that forms our mat. Snow accumulation on the surface of mat causes weight changes that gets relayed the Arduino present inside the adapter connected to an AC source. Current is generated through the adapter into the NodeMCU which converts the AC to DC and provides it to our thermally resistive wires. Removal of load signals the Arduino which in turn cuts off the flow of electricity hence signalling that all of the ice has melted.

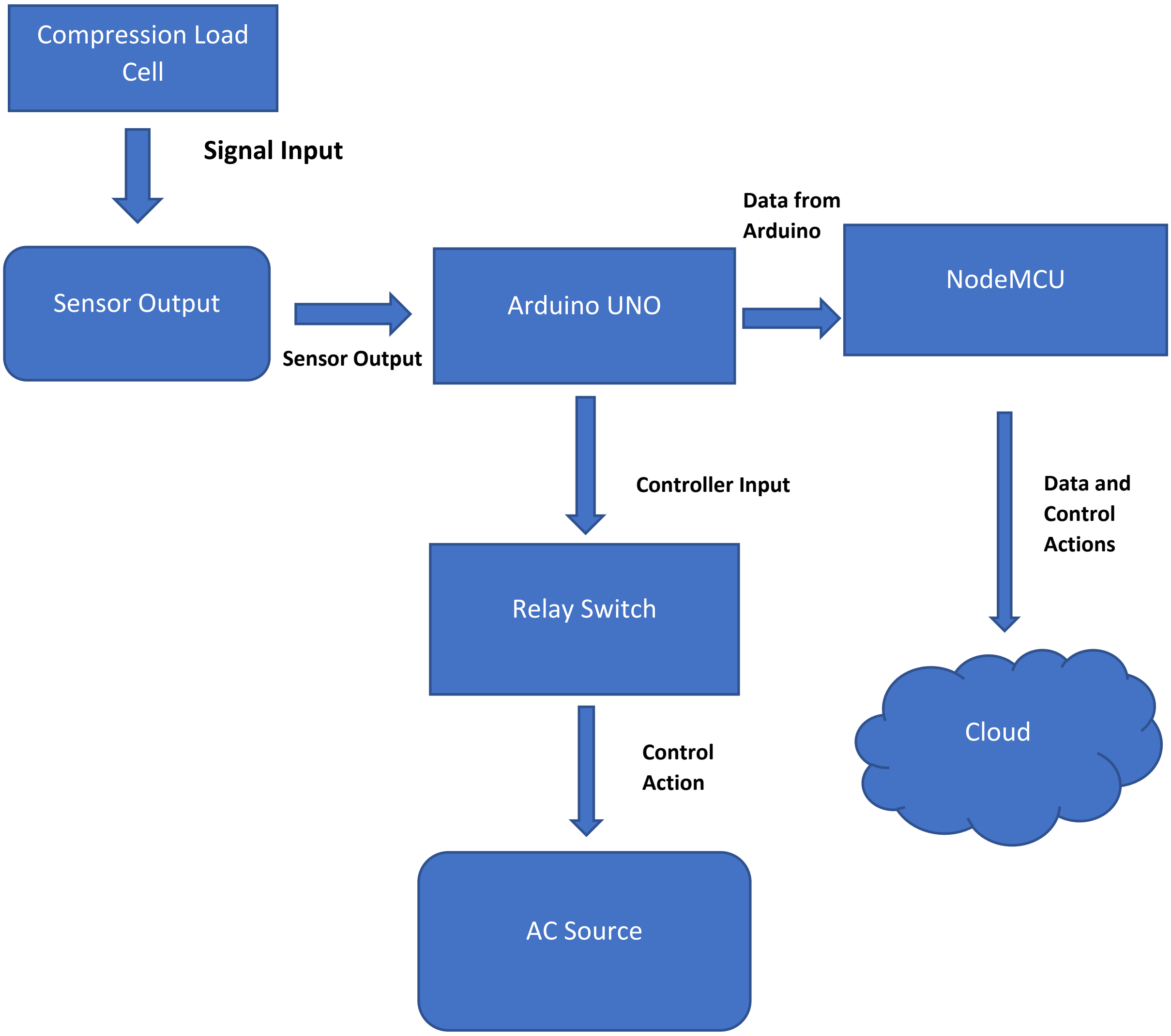

Figure 3. 2 Product Block Diagram

3.2.1 Components and Specifications

1. **Arduino UNO**

Table 3. 1 Arduino Specifications

Parameter	Value
Microcontroller	ATmega 328P
Operating Voltage	5V
Input Voltage	7V – 2V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by bootloader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz
Length	68.6 mm
Width	53.4 mm
Weight	25 g

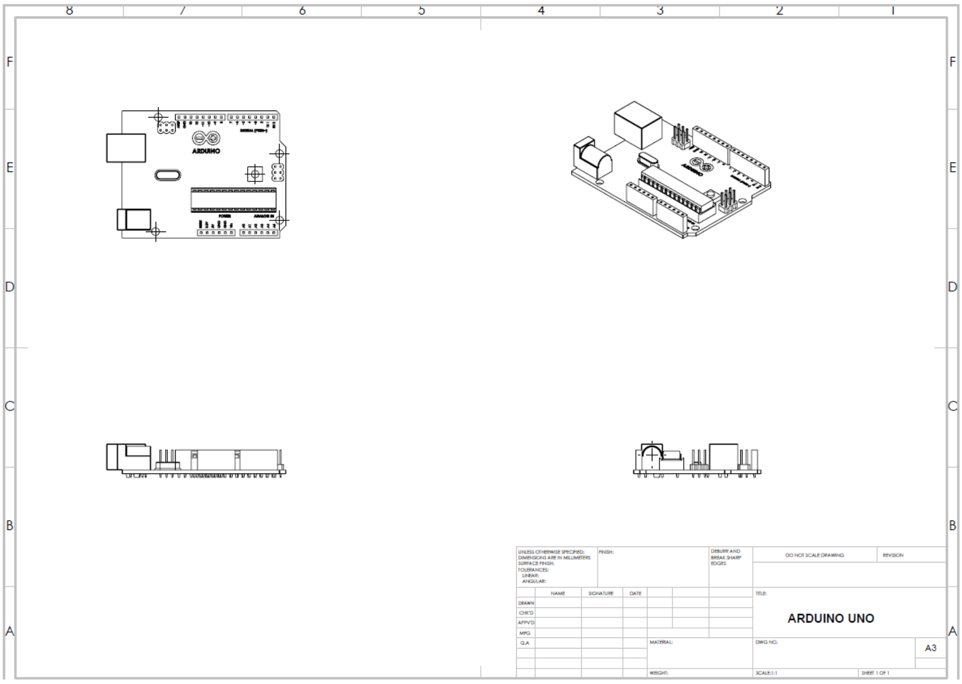

Figure 3. 3 Arduino Solidworks 2D Views

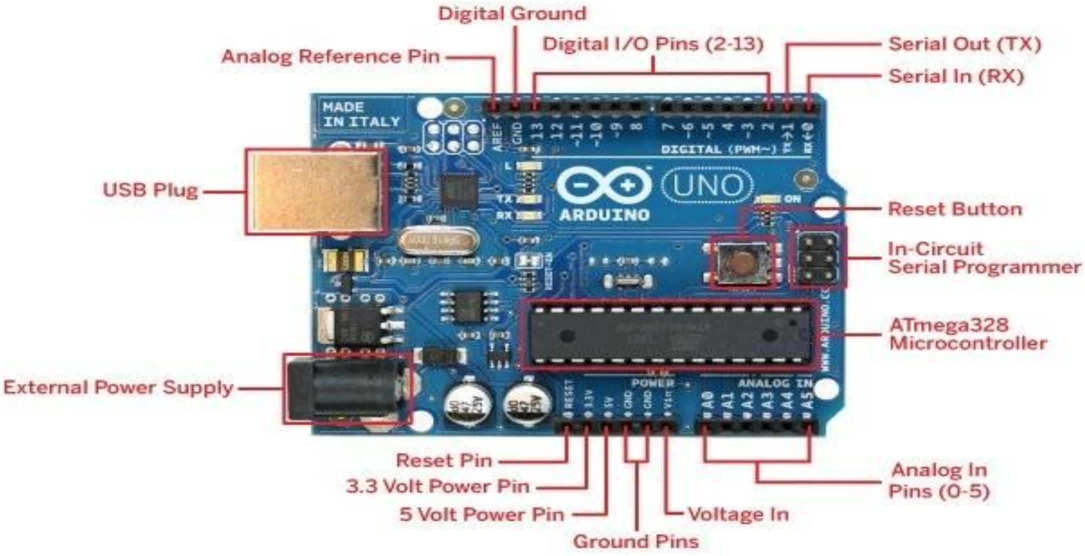

Figure 3. 4 Arduino UNO

2. Relay Module REES52 16220 4 CHANNEL 5V MODULE

Table 3. 2 Relay Specifications

Parameter	Value
High current relay	AC250V 10A, DC30V 10A
Indicators	2 LEDs
Working logic level signals	3.3V or 5V devices
Circuitry	Opto isolation circuitry
PCB size	50x45 mm

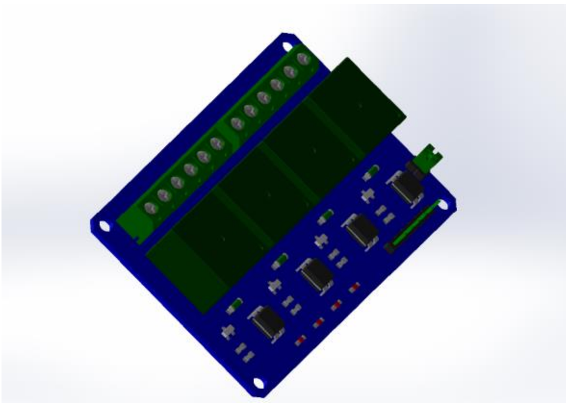

Figure 3. 5 Relay Top View

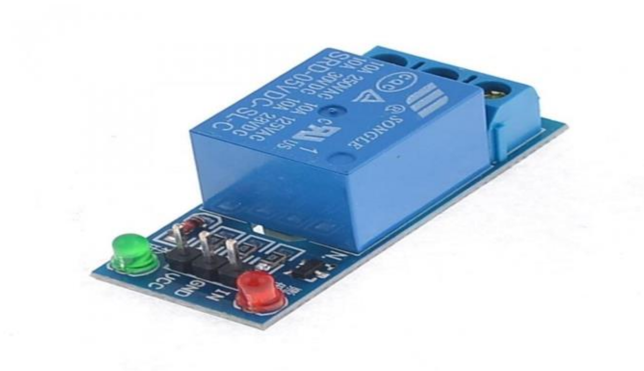

Figure 3. 6 Relay REES52

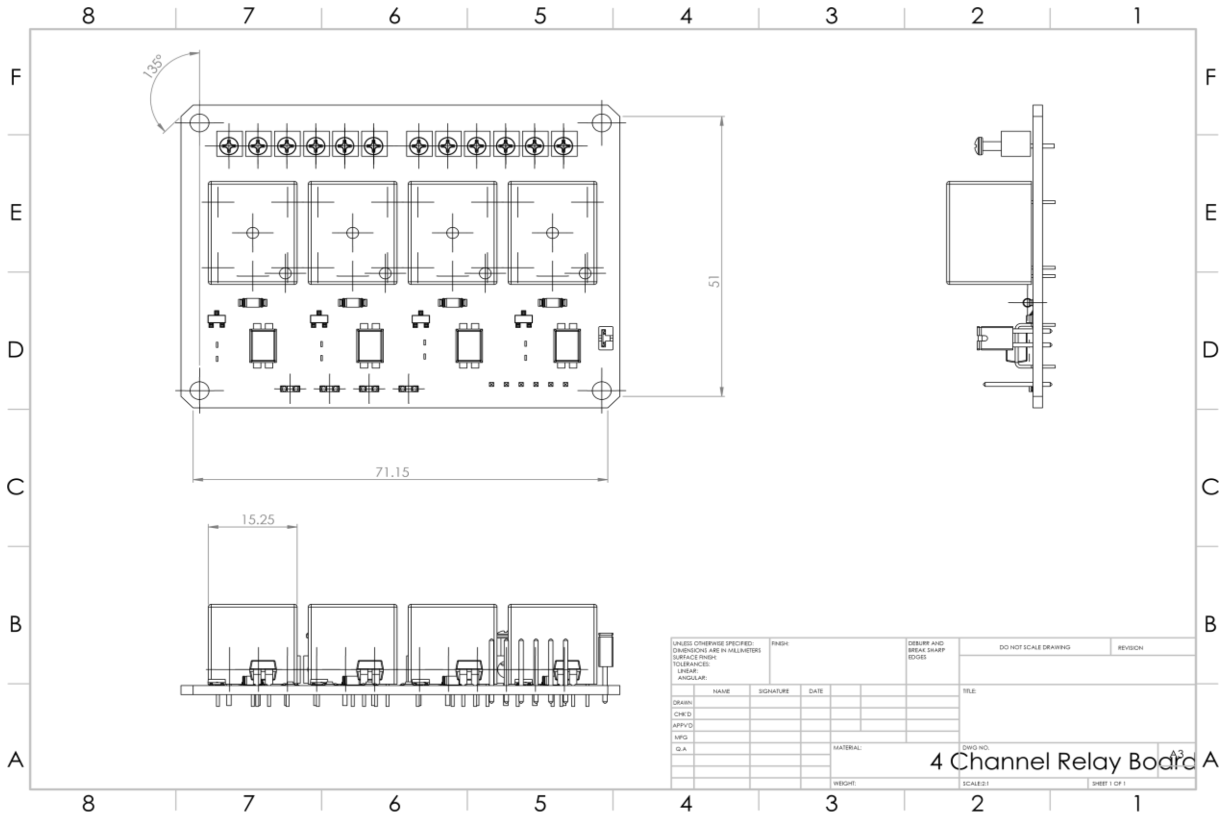

Figure 3. 7 Relay Solidworks 2D views

3. Compression Load Cell (TE CONNECTIVITY FX1901-0001-0025-L COMPRESSION LOAD CELL, 25LB, 5VDC)

Table 3. 3 Load Cell Specifications

Parameter	Value
Load Capacity	25lb
Supply Voltage	5VDC
Operating Temperature Min	0º C
Operating Temperature Max	50º C
Cell Output mV/V	20
Product Range	FX19 Series

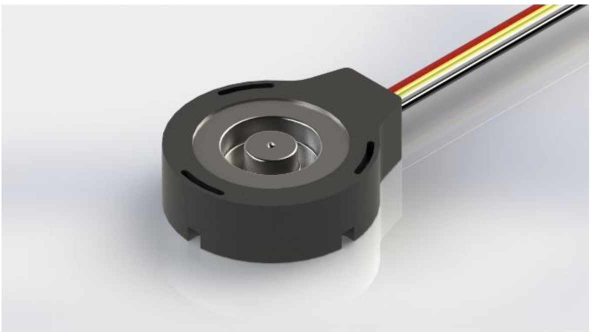

Figure 3. 8 Load Cell Top View

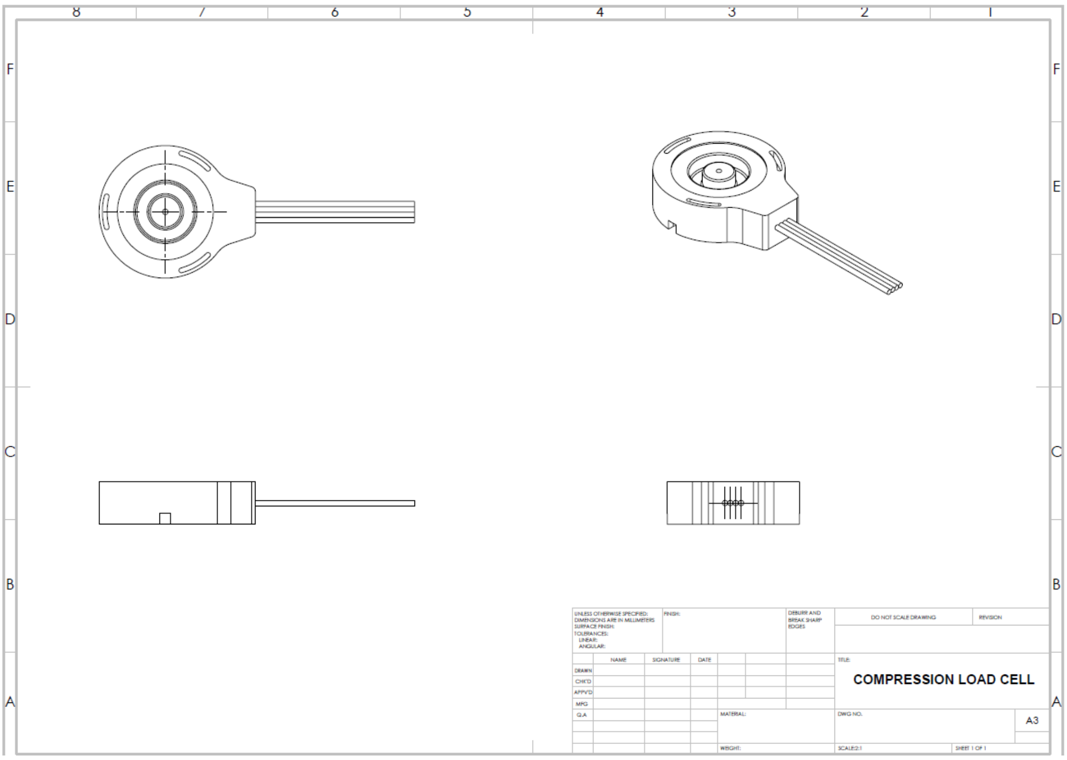

Figure 3. 9 Load Cell Solidworks 2D views

4. NodeMCU

NodeMCU is a LUA based interactive firmware for ESP8622 Wi-Fi SoC, as well as an open-source hardware board that contrary to the Wi-Fi modules; includes a CP2102 TTL to USB chip for programming and debugging, is breadboard-friendly, and can simply be powered via its micro USB port. We are using an mobile application known as Blynk for the controlling of the system. This application provides the user with the interface for the internet of things. Via this application the user can control the functioning of the pump.

Table 3. 4 NodeMCU Specifications

Parameter	**Value**
Wi-Fi Module	ESP-12E module similar to ESP-12 module but with 6 extra GPIOs.
USB	micro USB port for power, programming and debugging
Misc	Reset and Flash buttons
Power	5V via micro USB port
Dimensions	49 x 24.5 x 13mm

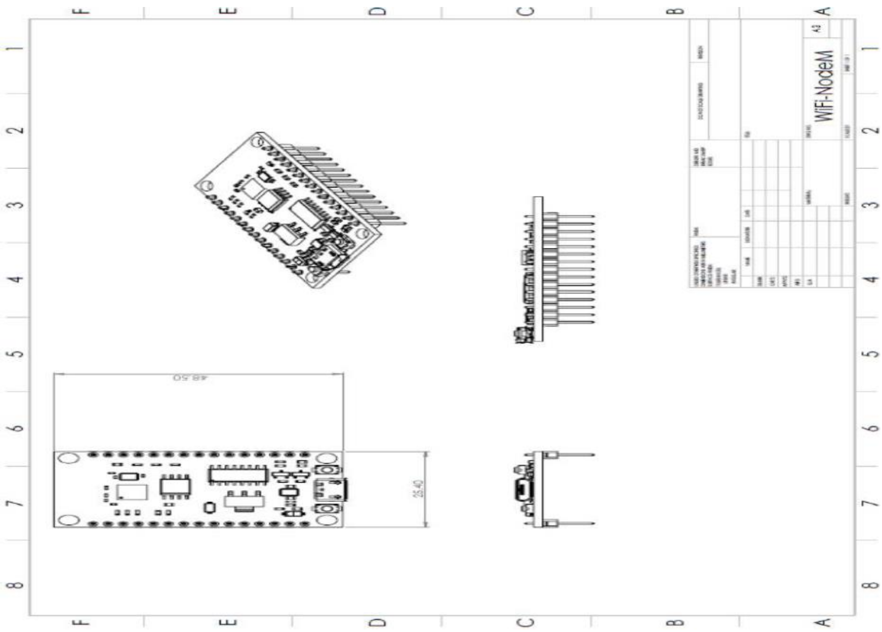

Figure 3. 10 NodeMCU Solidoworks 2D views

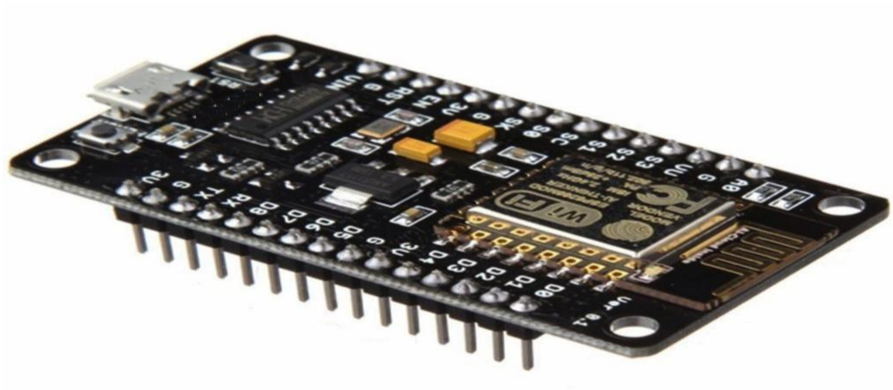

Figure 3. 11 NodeMCU

CHAPTER 4

DESIGN APPROACH AND DETAILS

4.1 Design Approach

A flexible heating mat for preventing the accumulation of snow or ice on a vehicle comprising: a flat flexible mat casing having upper and lower surfaces, a single flexible elongated heating strip of small cross-section sealed within said casing, a first flexible electric cord power entering an edge of the casing near a first side thereof and generally coplanar with the mat at the said edge, first cord having a male electric plug thereon for connecting the adaptor containing Arduino and NodeMCU to a source of power, said heating strip comprises of tightly wound coil of thermally resistant wires covered by a thermally conductive and flexible material. The bottom of the heating area is supported by a thermal insulator. The main considerations to be taken are choice of the materials that make our mat, the choice of a proper wire with high resistivity which produced enough heat to melt heavy snowfall accumulation and also the insulator which prevented heat to slip out to unwanted areas hence causing damage to our vehicles and also heat loss causing unwanted energy losses.

4.1.1 Grounding/Conductive Element

The grounding means is a good conductor of heat to uniformly distribute heat from both the upper and lower surfaces of the wires over to the entire surface of the mat. The lower surface of wires includes throughout its length a sheath of an electrically insulating material which thermally isolates the roof of the car and the major heat source. This heat conduction facilitates the transfer of heat from the heat providing wires to the upper surface of the mat on which snow or ice is being melted. These layers are in good electrical and heat conductive relationship with each other over the entire area of the mat. The grounding means overlies all portions of the heater strip so that any inadvertent change of weight can stop heat flow.

4.1.2 Heat Source

While considering the heat source various criteria had to be met. For instance, the amount of heat that needed to be generated, the overall weight of the product for easy portability and adverse effects on vehicles due to the presence of incompatible heat sources. Hydronic sources of heat in our mats would have reduced portability as they would include heavy heat sinks and also would put unwanted stress atop our vehicles. Infrared heating would shoot up product costs and sustainability would have been an issue. Hence using resistive wire heating is the best solution as they are lightweight, flexible hence can be weaved in easily and also heat generated can be easily controlled.

4.1.3 Insulator

This layer of insulating material is situated below the heating wires and both of them are enclosed in the protective heat conducting material which also serves as the main body of the mat. The insulator was required to prevent heat leakage of heat to car surfaces. Since heat leakage could lead to energy wastage. It could also damage the vehicle by causing expansion due to exposure of heat on the car roof. The material needs to be flexible also so that they can be incorporated in the mat.

4.2 Design Details/Products Used

4.2.1 Nichrome

Nichrome is used as our heating wire. Its wire is made of a non-magnetic alloy composed primarily of nickel, chromium, and iron. Nichrome is characterized by its high resistivity and good oxidation resistance. Nichrome wire also has good ductility after use and excellent weldability. Nichrome is a metal alloy consisting of primarily nickel and chromium. Varieties of nichrome are available with different proportions of nickel and chromium as well as small amounts of other elements. The more common varieties are nichrome-80 (most common) and nichrome-60 which are approximately 80% and 60% nickel, respectively. Both varieties have maximum operating temperatures of about 1100°C – 1200°C and melting temperatures above 1400°C. The chromium will form an oxide layer on the wire’s surface which protects the wire from corrosion. The corrosion resistance, the high melting temperature, and higher resistivity than many other metals make nichrome a good material for electrical heating elements.

4.2.2 Graphite Sheet

Graphite sheet has been used as our conducting material which encompasses our heating element. It spreads around the heating element and helps in conducting heat to the snow to be melted. Pyrolytic Graphite Sheet is a heat spreading material with high thermal conductivity. This material is lightweight and highly flexible. It can be cut into custom shapes, making it extremely useful for applications with limited space. In addition, it has excellent thermal conductivity properties, 600 to 800 W/(m-K), which is twice as high as copper, and three times as high as aluminium.

Table 4. 1 Graphite Sheet Advantages

Key features
Excellent thermal conductivity in its plane (600 to 1700 W/m.K) or 2 to 4 times as high as copper, 3 to 6 times as high as aluminum
Lightweight and ultra-thin: Specific gravity: 0.85 to 2.1g/cm3 (1/4 to 1/10 of copper, 1/1.3 to 1/3 of aluminum in density)
Flexible and easy to be cut or trimmed (withstands repeated bending)
Low thermal resistance
Shielding effect
Maintenance-free
Long life
RoHS compliant

4.2.3 Fibre Glass

This will be used as our insulating layer placed below the heat producing wires. Fiberglass is a composite material made of a plastic matrix reinforced by tiny glass fibres. It is lightweight yet strong, and since glass is not a good conductor of heat, it is a highly effective insulating material. Thermal insulation, like fiberglass, stops conductive heat transfer—which is the transfer of heat through solid objects. Most insulation materials prevent heat loss through conduction but Fiberglass insulation traps heat when it is moving to a colder area.

4.3 Design of Mat on Solidworks™

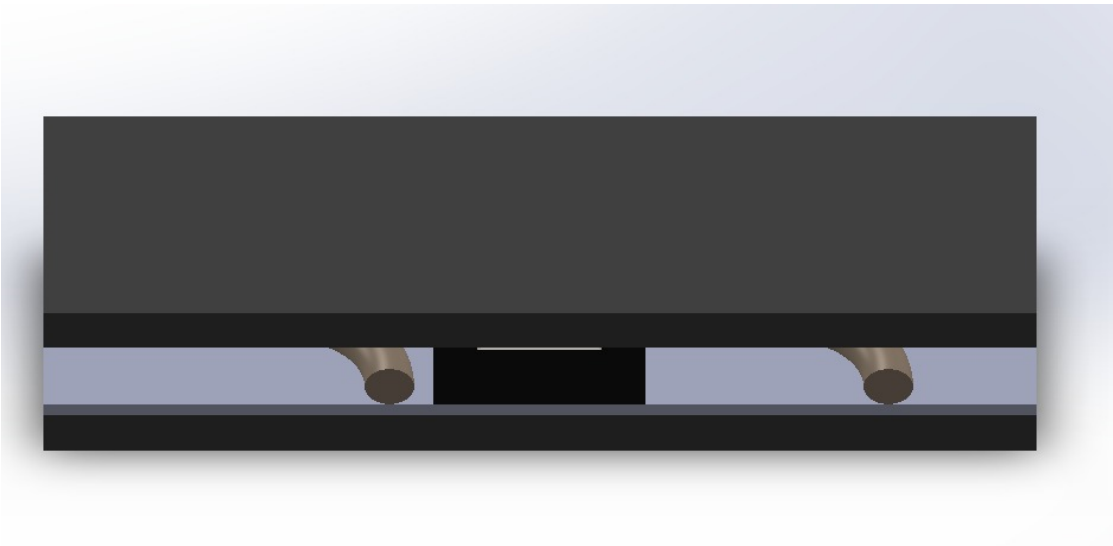

Figure 4. 1 Mat Isometric View

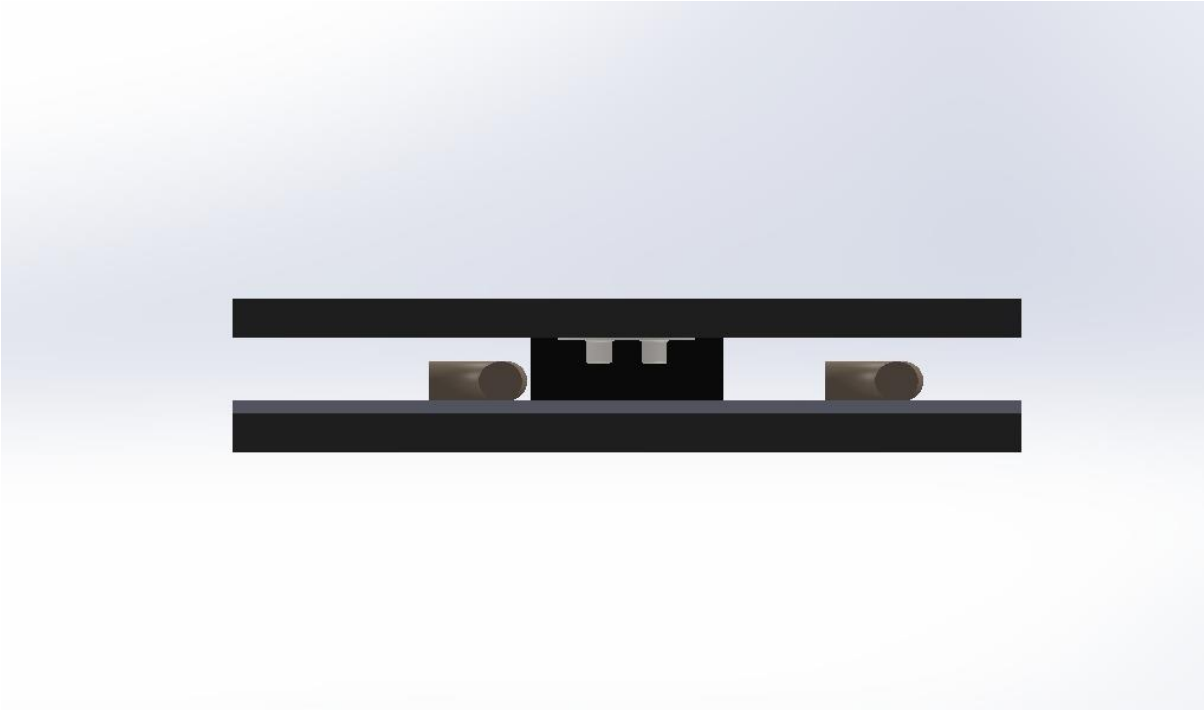

Figure 4. 2 Mat Front View

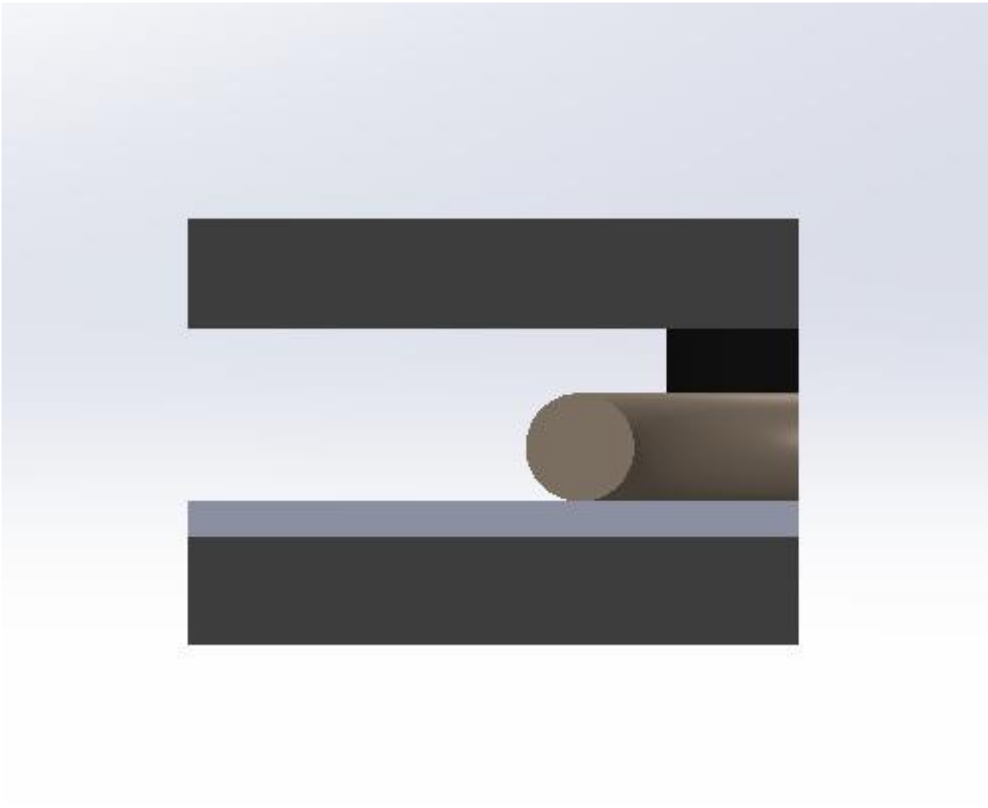

Figure 4. 3 Mat Side View

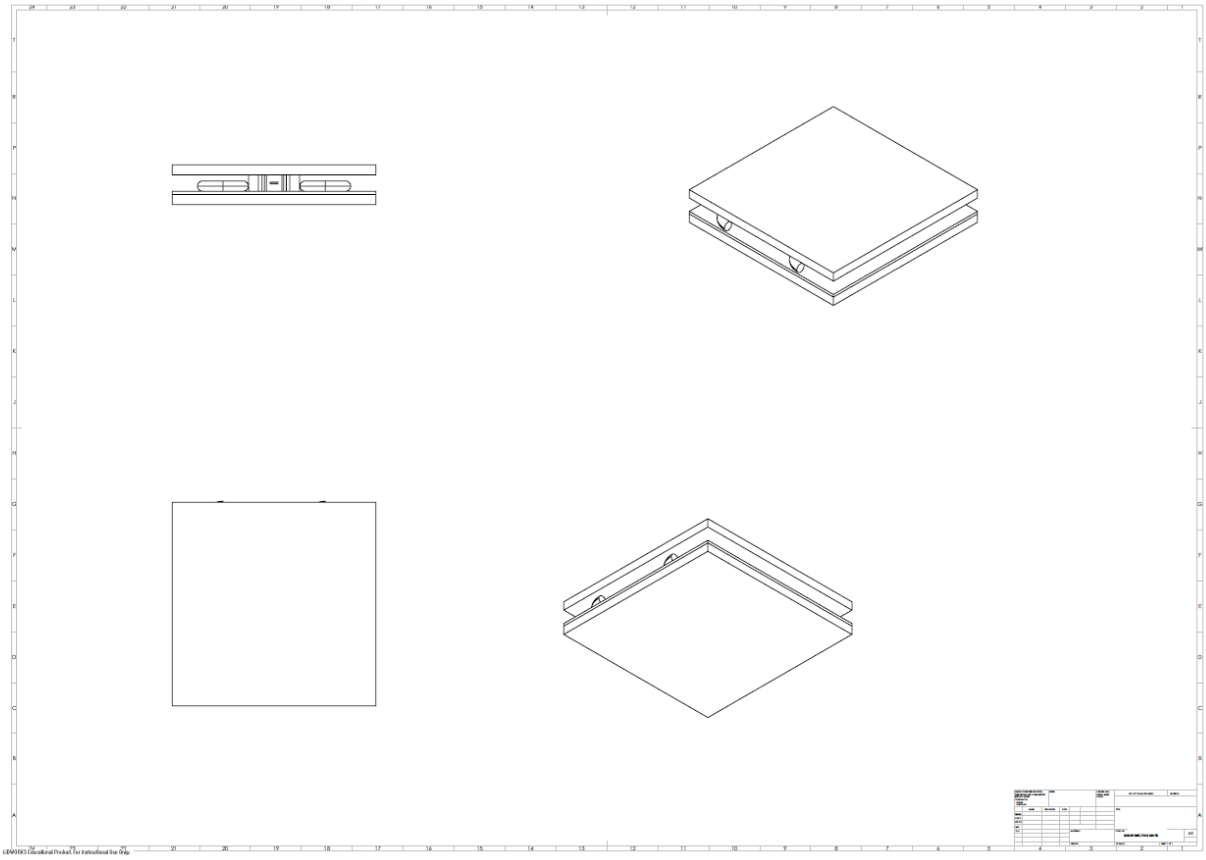

Figure 4. 4 Mat Solidworks 2D views

4.4 Constraints, Alternatives and Trade-offs

- Carbon fibre as the conducting material was not chosen due to its high manufacturing cost and not so easy availability although it had higher conductivity and was more durable.
- Tungsten was not chosen as the heating element because it oxidised when exposed to the atmosphere although it gave high heating values.
- Lack of snowfall in our regions suppresses proper testing methods of our product.

CHAPTER 5
PROJECT DESCRIPTION AND WORKING

The goal of our project was to create mats that would generate enough heat to melt accumulated snow over vehicles in regions of heavy snowfall. The heat generated was to be obtained by passing electricity through the wire of high resistivity i.e. Nichrome that we used in our product. The electricity was generated from a common AC power source for example in wall plugs. Concepts of IoT were included to reduce power wastage a load cell was placed in between the nichrome wires, which read changes in weight over the mat which then provided the signal to the relay to supply the electricity so that the ice can be melted. After the entire ice gets melted, the weight on the mat is removed and accordingly electricity supply is also cut.

Values to be Calculated:

- Inner radius of the wire
- Outer radius of the wire
- Diameter of wire
- Resistivity of coil
- Power rating of our coil
- heat generated

5.1 Heating a Nichrome Wire

1. For a given wire composition and gauge, the steady-state temperature in still air is entirely determined by the current through the wire. In other words, the wire length is irrelevant.
2. The resistance of the nichrome wire changes very little with temperature. Its resistance only increases by 7% when changing from 20°C to 400°C; and only increases another 1% from 400°C to 1000°C. The temperature coefficient of resistance of nichrome is much lower than that of most common metals
3. The thermal resistance of the straight wire in free still air is NOT constant over temperature.

4. For pulse width modulation of either a constant current or constant voltage supply, the temperature rise is approximately proportional to the square of the duty cycle. For example, compared to the 100% duty cycle, 50% duty cycle yields 25% temperature rise. This approximation holds true, ±10%, for $\Delta T < 600°C$.
5. Due to thermal expansion the nichrome wire will get about 1% longer for every 700°C of temperature rise.

5.1.1 These are the symbols used:

L = length of the wire

ρ = resistivity or resistance per unit length. (This is a constant for any given wire type.)

α = temperature coefficient of resistance (This is a property of the material.)

R = total resistance of the wire

P = total instantaneous power dissipated by the wire

ΔT = the temperature rise of the wire above ambient temperature, $\Delta T = T - T_o$

5.2 Physics of Snow Melting

5.2.1 Factors that control the process of outdoor melting of snow:

- Air temperature
- Intensity of the sun
- Humidity
- Wind speed
- Snow density and consistency
- Reaction time to applied heat (energy) to the slab surface on which the snow rests.
- To design and develop a practical and cost-effective snowmelt system, one must first address the actual true energy input requirements. Any in-ground snowmelt system actually performs three-phase changes of snow as follows:
    1. Melts Snow from below 0℃ c to 0℃
    2. Transforms water at 0℃ from a solid to 0℃ at a liquid state
    3. Transforms water at 0℃ liquid to gas (evaporation)

These changes mentioned above are called phase changes. With each phase change a specific amount of latent heat is released or absorbed. Below are the values in two different scales which are calories per gram (cal/g) and Joules per kilogram (J/kg).

5.2.2 Energy requirements to transform snow to water

1) You need to warm the snow up from -20℃ to 0℃. The amount of heat required to do this will depend on the mass of the snow and on the specific "heat capacity" of ice, which is: 2000 Joules/kg/℃.

2) Once you have ice at 0℃ you want to melt it, so you end up with water at 0℃. To do this you need to supply more heat. For water, this "latent heat of fusion" is 33,5000 Joules/kg.

5.2.2 Formulas Used

$\Theta = R_o - R_i$

$R_C = 4\rho(R_o^2 - R_i^2)/\Theta^2$

$P = V^2 / R_c$

5.2.3 Standard values

Table 5. 1 Standard Values

Parameter	Value
Standard Voltage Supplied	230 V
Resistivity of nichrome	1.1×10^{-6} Ωm
Diameter of nichrome wire	2 mm

5.3 Result values after Calculation

Table 5. 2 Calculated Values

Parameter	Value
Inner Radius of wire	8 mm (Hit and Trial)
Outer Radius of wire	10 mm (Hit and Trial)
Length of wire required	7 m (Hit and Trial)
Resistivity of wire used	69.3 Ω
Power Rating	763.85 ~ 800W

CHAPTER 6

RESULTS AND DISCUSSION

The simulation was set up in Ansys. The 2 D model was created using Solidworks and then imported to Ansys Workbench. A Transient thermal analysis system was used to simulate the process. Here we have considered 100mm*100mm of the mat which is used to melt 2.5 inches of snow spread throughout its geometry. The simulation tries to heat the snow until it reaches its vapour state. Meshing for all the cases is kept the same.

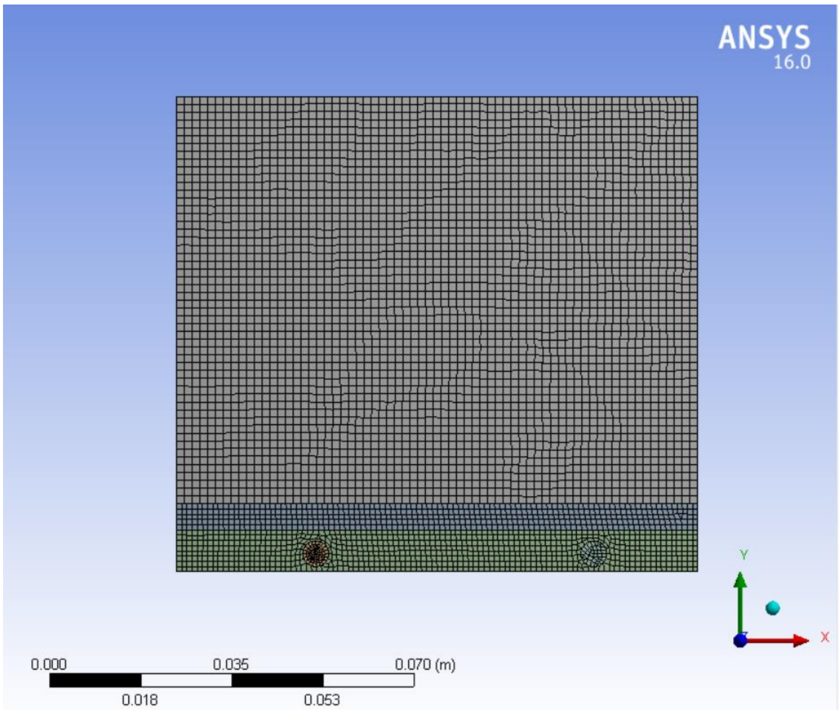

Figure 6. 1 Meshing

Two different temperatures are selected that are optimal for snow accumulation and the three types of snow selected are as follows: -

- Settled Snow ($\rho = 250kg/m^3$)
- Depth Hoar ($\rho = 350kg/m^3$)
- Wind Packed Snow ($\rho = 450kg/m^3$)

As all these types of snow have different densities, their moisture content also varies, which means that the time to melt each of them will also vary.

6.1 Analysis at -8°C

6.1.1 Settled Snow

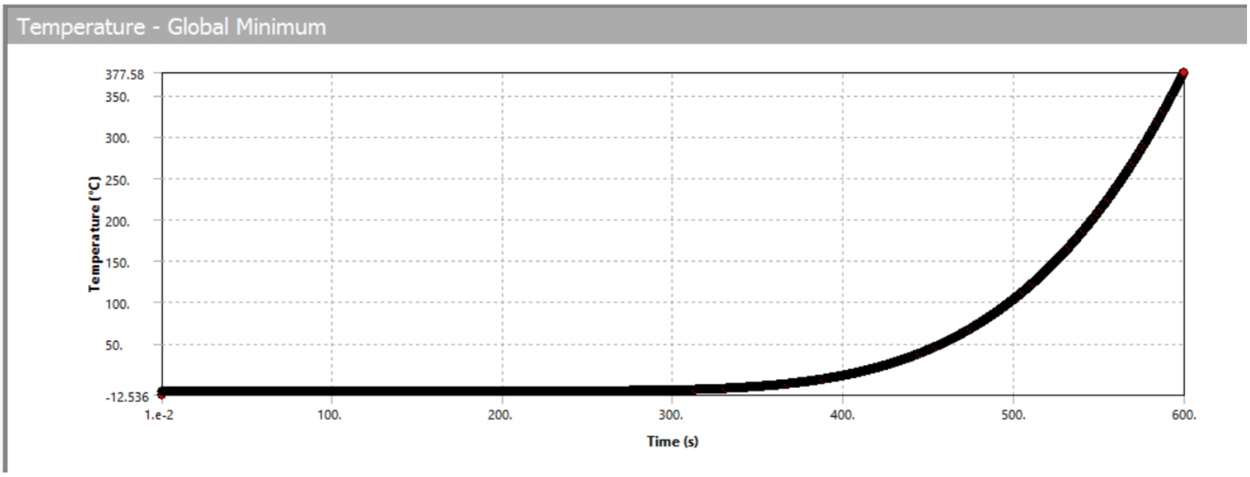

Figure 6. 2 Global Temperature Vs Time Graph

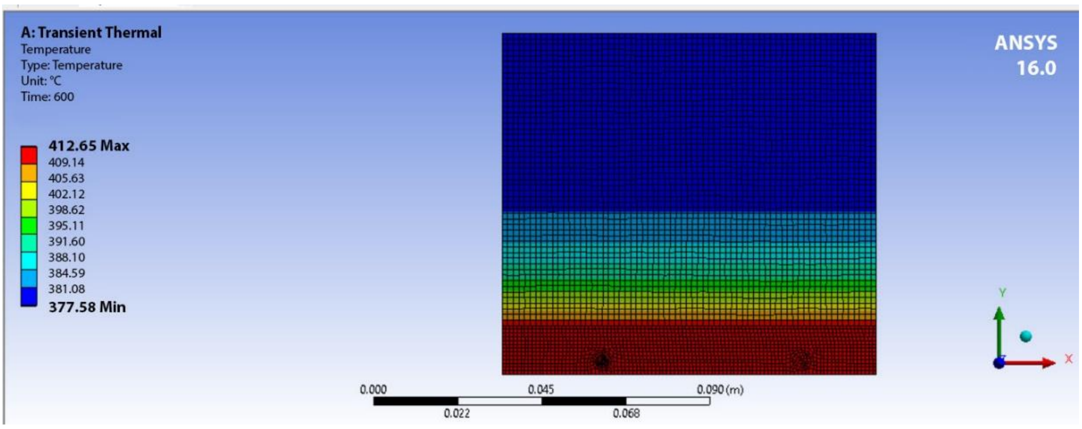

Figure 6. 3 Temperature Gradient of the System

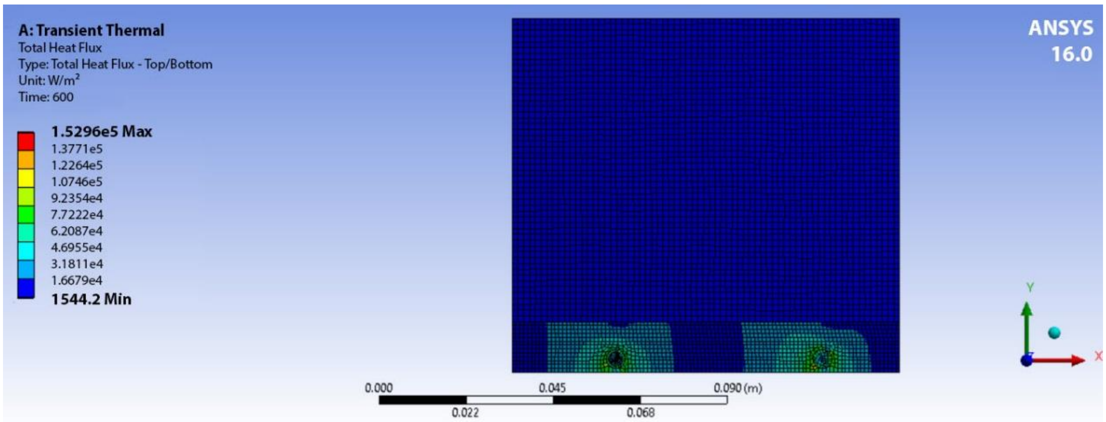

Figure 6. 4 Heat Flux Gradient of the System

6.1.2 Depth Hoar

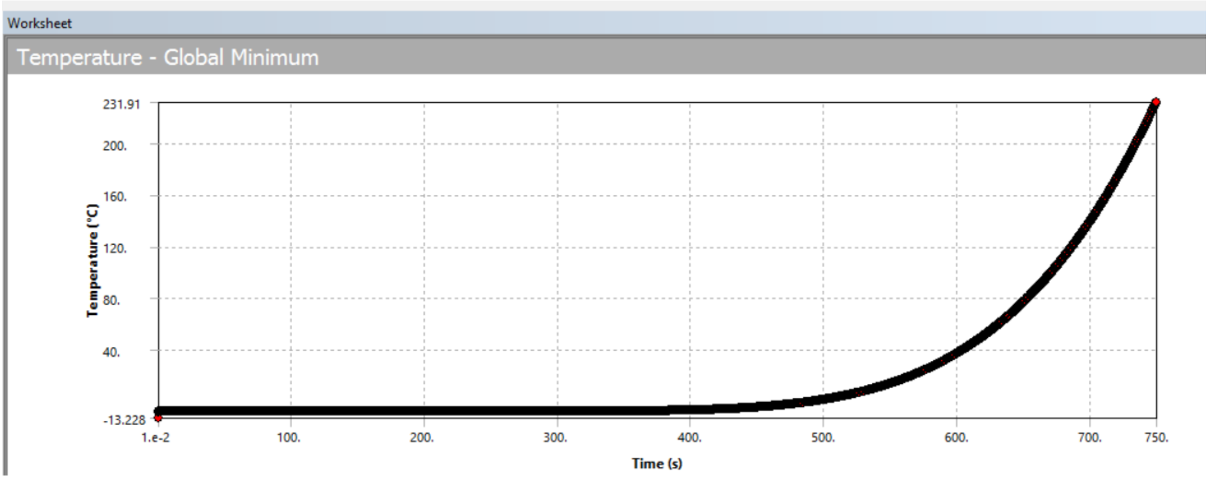

Figure 6. 5 Global Temperature Vs Time Graph

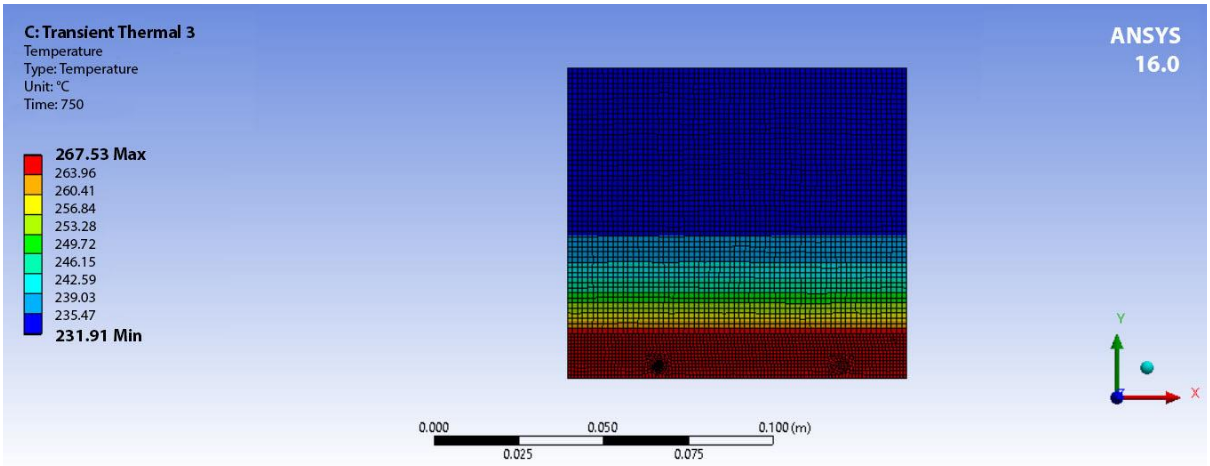

Figure 6. 6 Temperature Gradient of the System

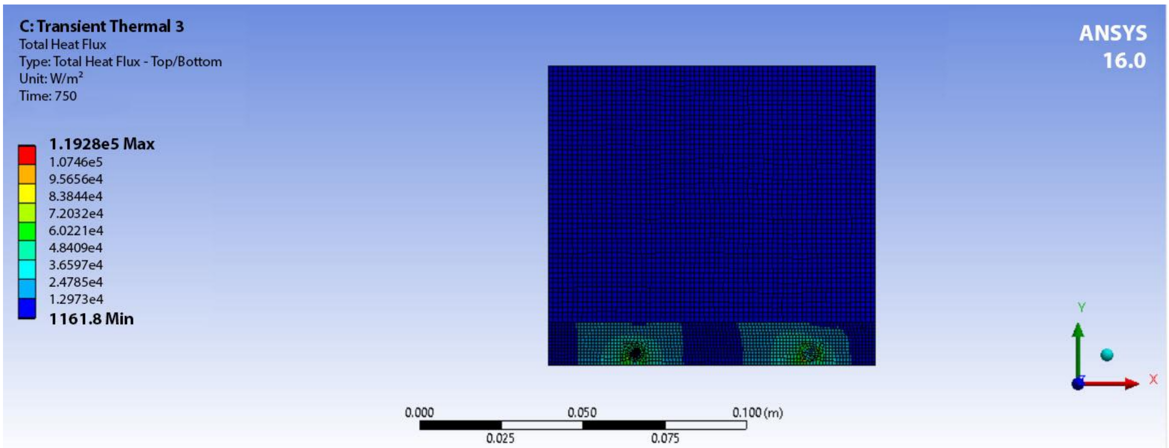

Figure 6. 7 Heat Flux Gradient of the System

6.1.3 Wind Packed Snow

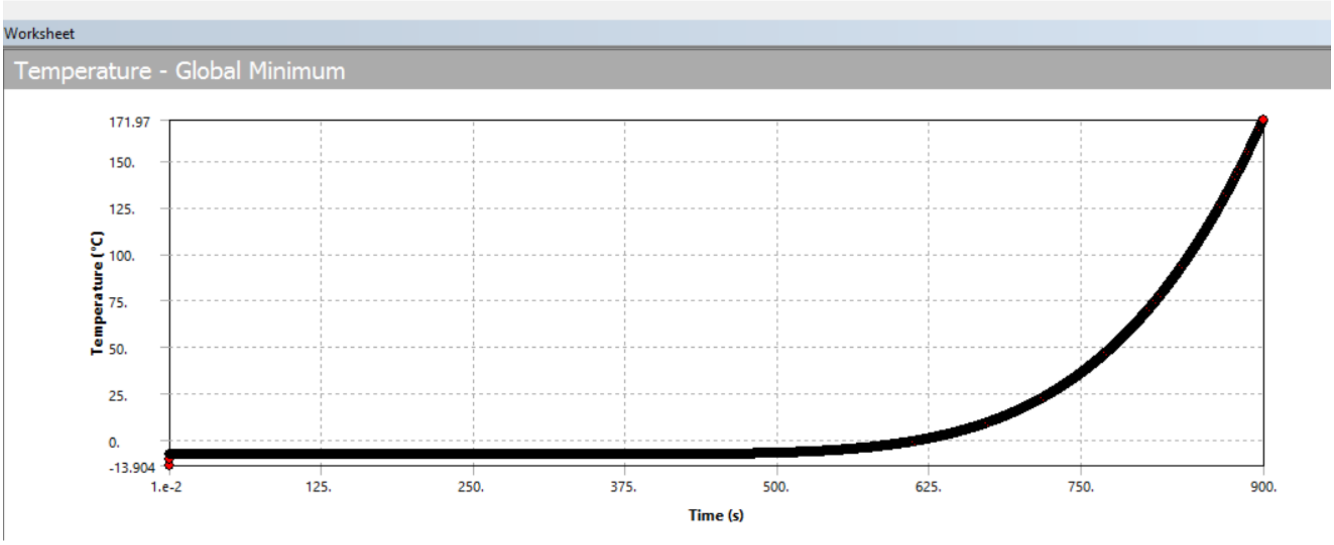

Figure 6. 8 Global Temperature Vs Time Graph

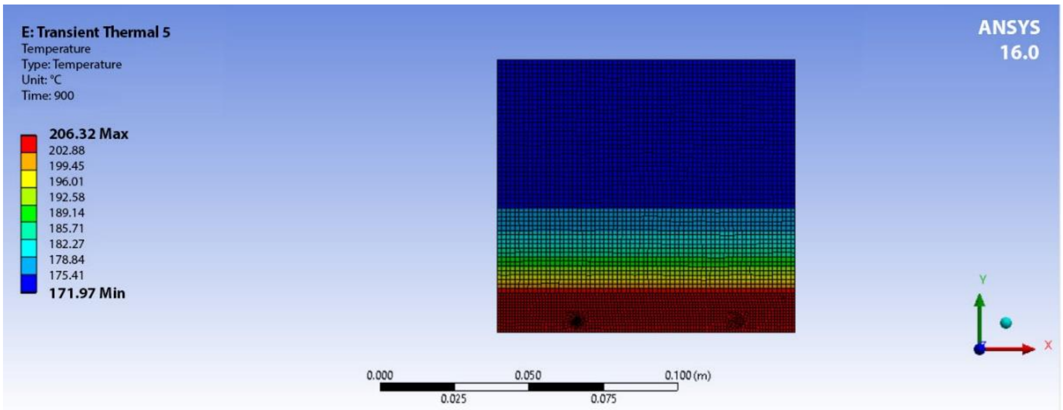

Figure 6. 9 Temperature Gradient of the System

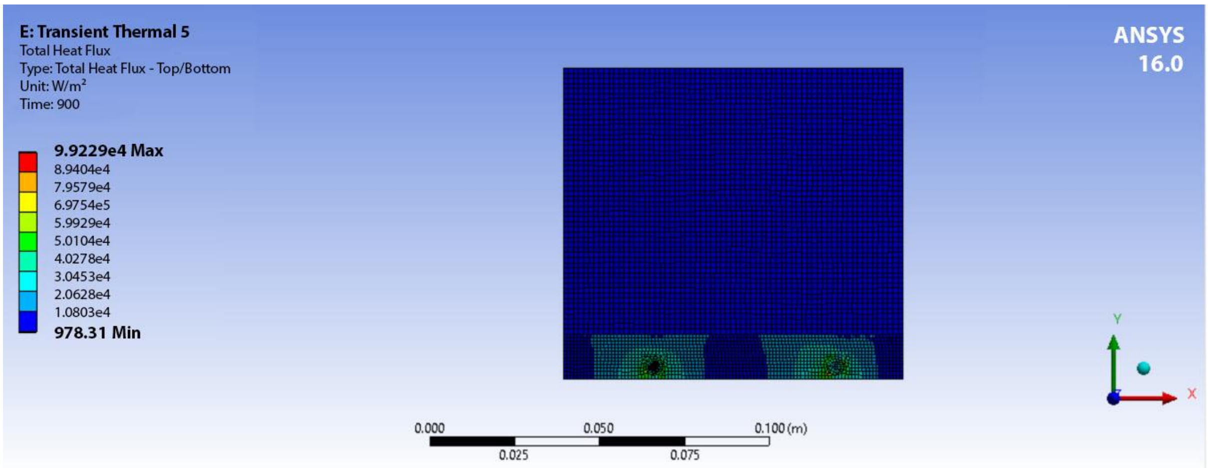

Figure 6. 10 Heat Flux Gradient of the System

6.2 Analysis at -15°C

6.2.1 Settled Snow

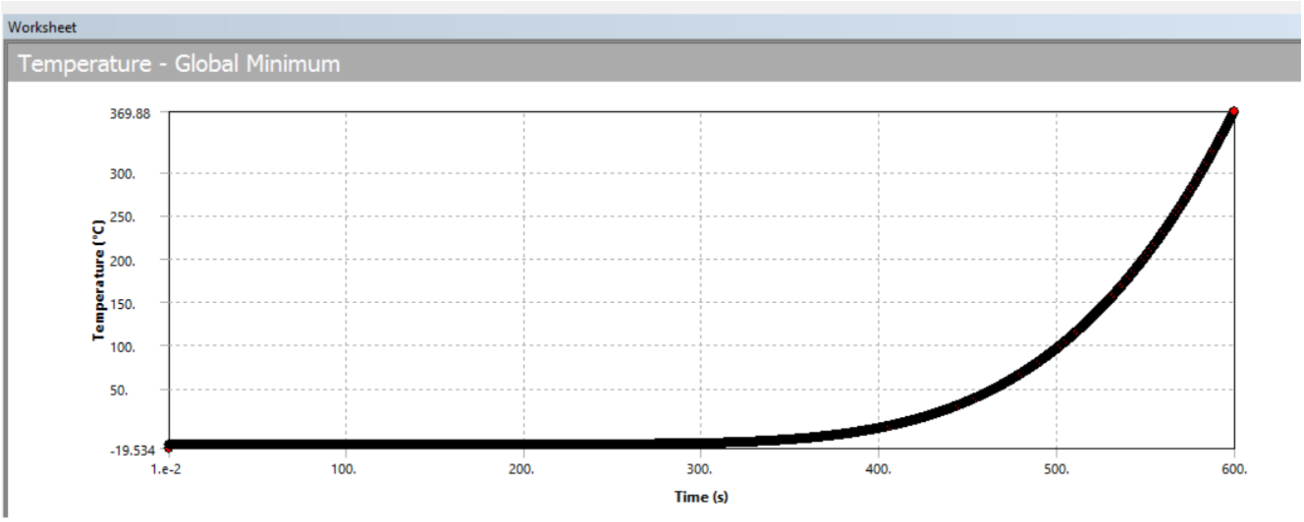

Figure 6. 11 Global Temperature Vs Time Graph

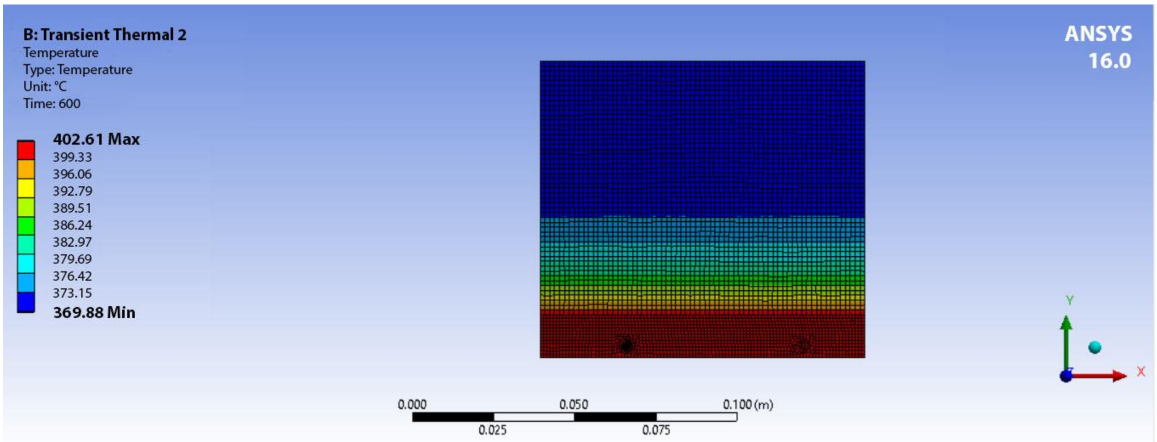

Figure 6. 12 Temperature Gradient of the System

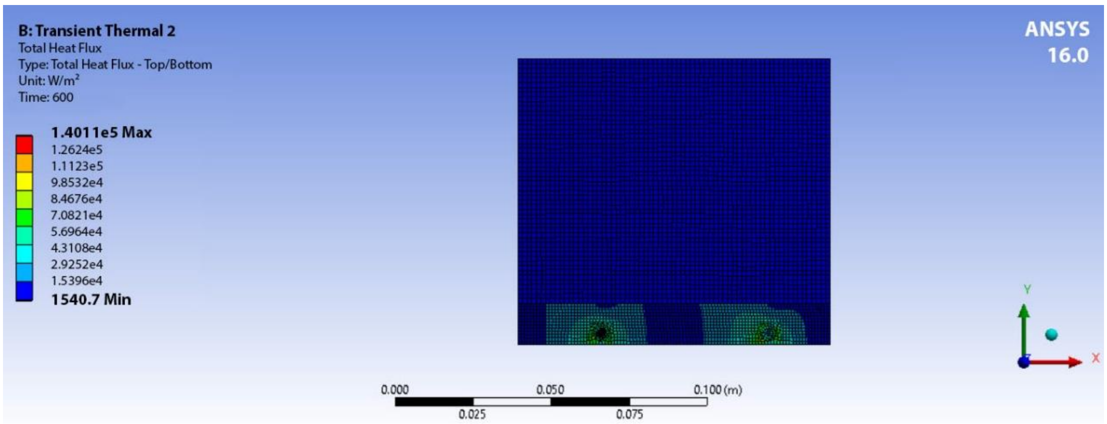

Figure 6. 13 Heat Flux Gradient of the Syste

6.2.2 Depth Hoar

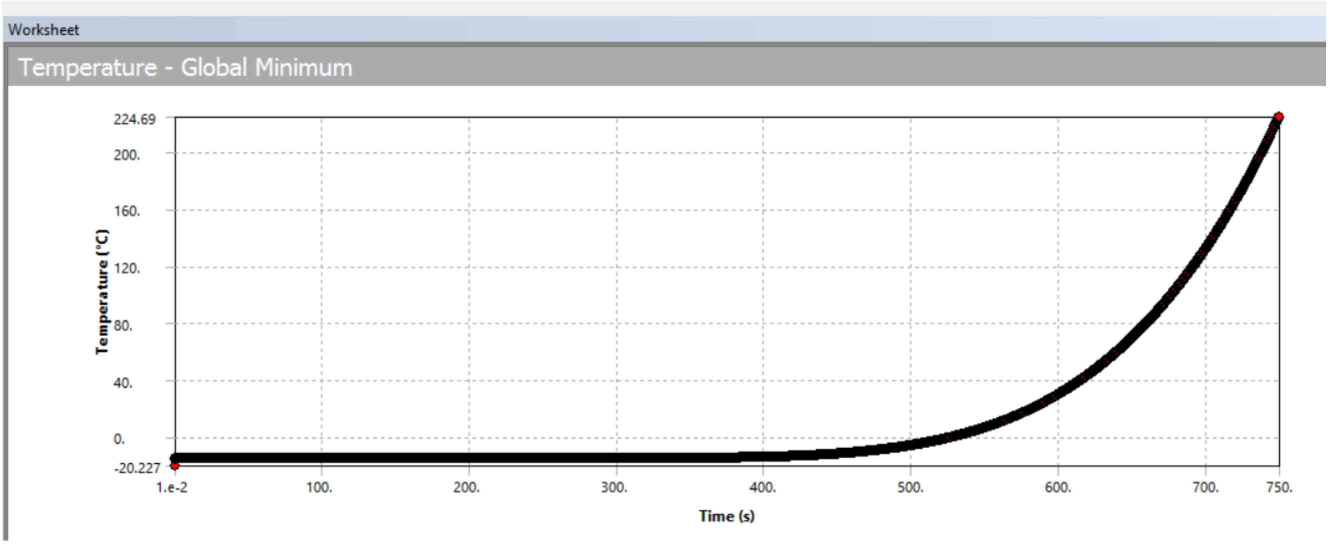

Figure 6. 14 Global Temperature Vs Time Graph

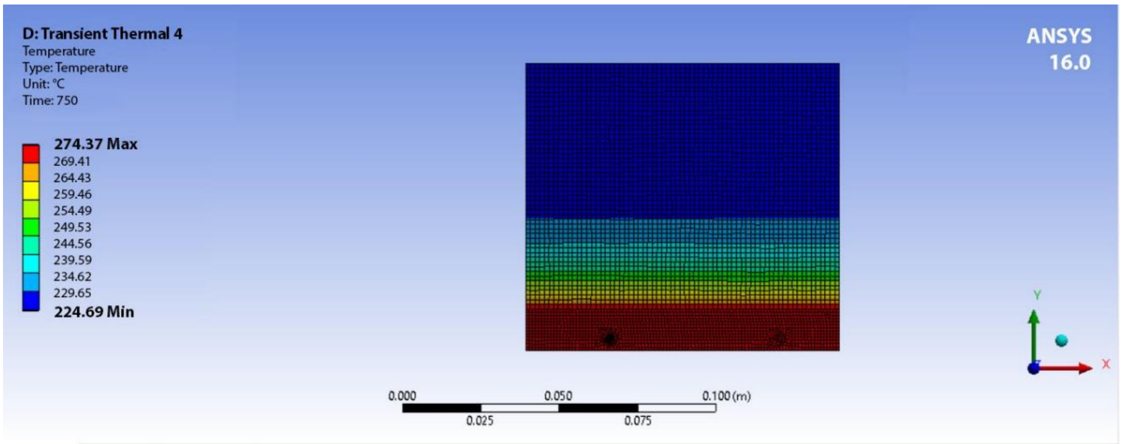

Figure 6. 15 Temperature Gradient of the System

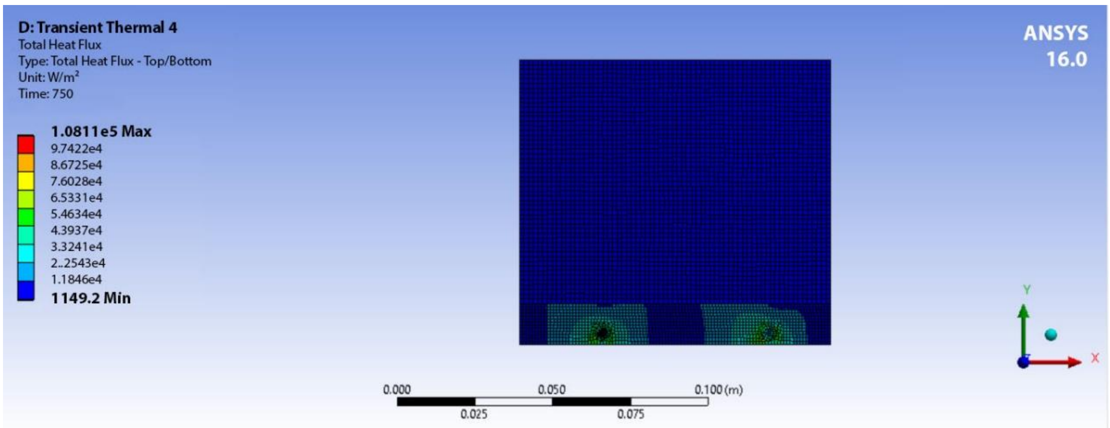

Figure 6. 16 Heat Flux Gradient of the Syste

6.2.3 Wind Packed Snow

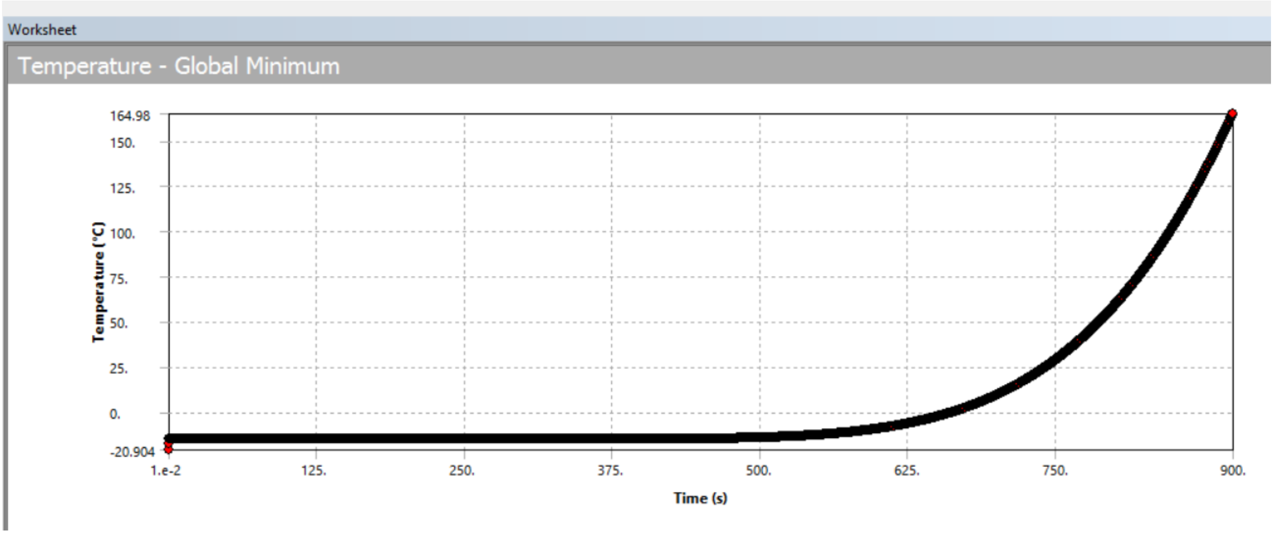

Figure 6. 17 Global Temperature Vs Time

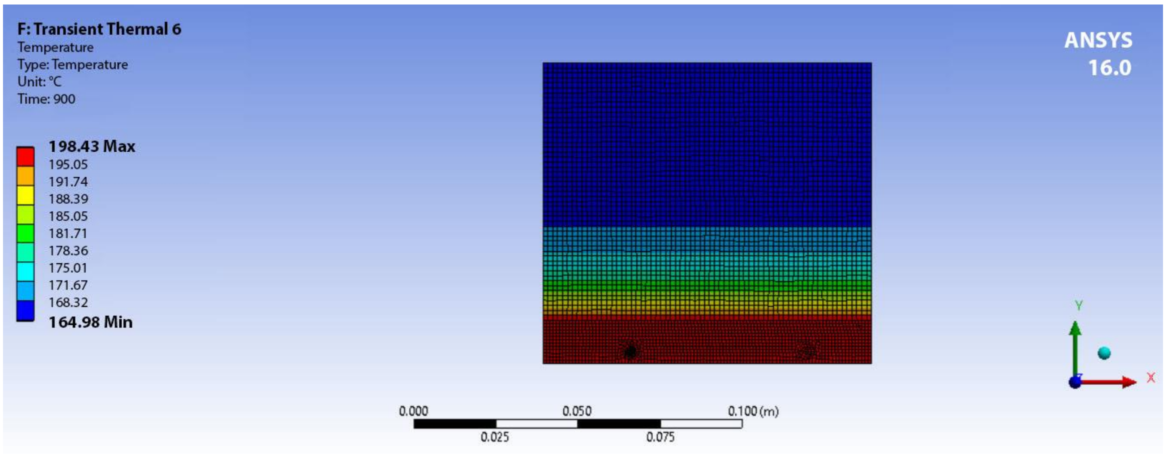

Figure 6. 18 Temperature Gradient of the System

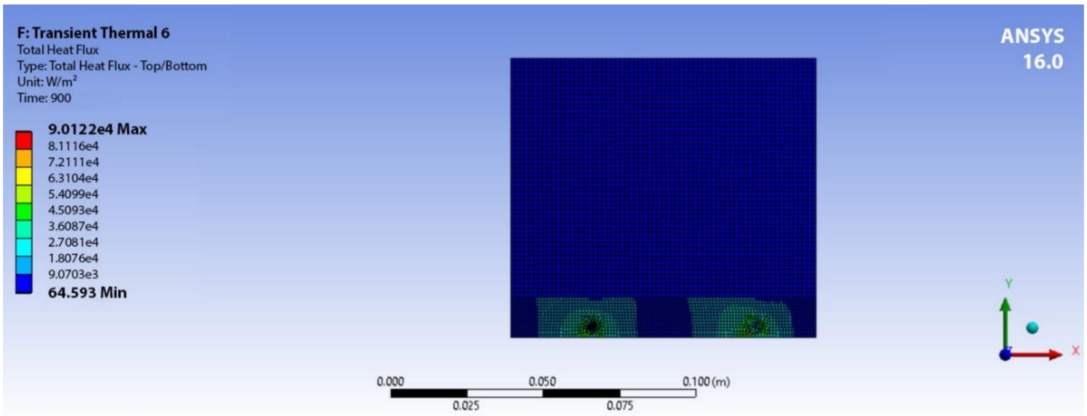

Figure 6. 19 Heat Flux Gradient of the System

The simulation was allowed to run for 600, 750 and 900 seconds for settled snow, depth hoar and wind packed snow respectively. It is observed that the final temperature obtained at the end of each simulation decreases as the initial temperature is decreased or the snow densities are increased.

It is also observed that the heat flux also decreases with global temperature, following a similar trend. For an 800 Watt rated appliance, the initial heat flux in many cases shown here is pretty low, but with time the heat flux also increases and thereby increases the global temperature.

We also arrive at the conclusion that running the mat for continuous 15 minutes is sufficient to all the above types of snow in both the given temperatures.

The 3D analysis was also conducted in the same conditions with a 3D Model but there seemed to be a recurring issue with the number of elements being very large even after varying the element sizes. A 3 D analysis of the same will give a vivid picture of the actual heat transfer. Many other variations can also be included in the analysis by changing the geometry of the snow or by varying the amount of snowfall and other properties.

CHAPTER 7

CONCLUSION

Our product aims at removing traditional methods of snow removal from vehicles which inadvertently can cause damage and replace them with safer more modern methods of snow removal.

- Our product uses a load cell to prevent energy wastage. In today's day and age high energy consumption is a highly prevalent problem. To reduce that we have added the usage of microcontrollers to stop electricity supply when said task of melting the snow gets completed. This technology reads changes in load atop the mat surface to determine whether or not heat is required and in turn if electricity should be provided or not.
- The mat is also made up of highly durable materials as the mat itself so that it lasts longer, and also the heat supplied from the heated wires does not damage. Due to the usage of flexible and lightweight materials it has easy portability.
- To check the proper melting of snow, simulations were carried out on 3 different types of snow i.e Settled Snow, Depth Hoar and Wind Packed Snow each of 2.5 inchs height.
    1. Analyis was carrid out on Settled Snow at -8^{o}C and -15^{o}C
        - Heat was supplied for about 600 seconds to the snow which started at -8^{o}C and the temperature of the top surface of the snow reached minimum temperatures of 377.58^{o}C, indicating that the snow was melted and removed by vaporising.
        - Heat was supplied for about 600 seconds to the snow which started at -15^{o}C and the temperature of the top surface of the snow reached minimum temperatures of 369.88^{o}C, indicating that the snow was melted and removed by vaporising.
    2. Analyis was carrid out on Depth Hoar at -8^{o}C and -15^{o}C
        - Heat was supplied for about 750 seconds to the snow which started at -8^{o}C and the temperature of the top surface of the snow reached minimum temperatures of 231.91^{o}C, indicating that the snow was melted and removed by vaporising

- Heat was supplied for about 750 seconds to the snow which started at -15ºC and the temperature of the top surface of the snow reached minimum temperatures of 224.69ºC, indicating that the snow was melted and removed by vaporising.

3. Analyis was carrid out on Wind Packed Snow at -8ºC and -15ºC
    - Heat was supplied for about 900 seconds to the snow which started at -8ºC and the temperature of the top surface of the snow reached minimum temperatures of 171.97ºC, indicating that the snow was melted and removed by vaporising
    - Heat was supplied for about 900 seconds to the snow which started at -15ºC and the temperature of the top surface of the snow reached minimum temperatures of 164.98ºC, indicating that the snow was melted and removed by vaporising.

- Theoritacal calculations suggested a power rating of 800 W over a 100x100 mm surface of the mat which was confirmed by the Heat Flux Gradient maping found through simulations on ANSYS.

The future scope for this product is quite broad. With better research and funds carbon polymers with a proper material blend can be used which has better conductivity and can spread the heat to melt the snow faster also. Construction of a heat reservoir to store excess heat so that even electricity is not supplied but snow melts would also vastly improve energy wastage.

CHAPTER 8

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