PROJECT TITLE – **DESIGN AND DEVELOPMENT OF SMART FISH BOX COOLER FOR MAINTAINNING FISH FRESHNESS DURING TRANSPORTATION**

By

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ME 325 - MECHANICAL ENGINEERING GROUP PROJECT

Presented in partial fulfilment of the requirements for
the degree of B.Sc. Engineering degree.

University of Peradeniya

02/07/2023

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DECLARATION

The work published in this report is the result of our own investigation, except where otherwise stated.

It has not already been accepted for any other course and is also not being concurrently submitted for any other person.

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CERTIFICATE OF APPROVAL

This project entitled "DESIGN AND DEVELOPMENT OF SMART FISH BOX COOLER FOR MAINTAINNING FISH FRESHNESS DURING TRANSPORTATION" is here by approved as a creditable engineering study carried out and presented in a satisfactory manner to narrate its acceptance as prerequisite to the degree for which it is being submitted.

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…………………………

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ACKNOWLEDGEMENT

First and foremost, we would like to express our sincere gratitude towards Prof.Leelananda Rajapaks, Department of Mechanical Engineering, faculty of Engineering, University of Peradeniya, for his guidance, advice, and the support throughout this project.

As a team, we show our gratitude towards all the academic staff members of the department for giving their comments and suggestions to improve the progress of the project.

Finally, we would like to thank Dr. I. W. Kularathne, Department of Mechanical Engineering, Faculty of Engineering, University of Peradeniya for coordinating the course ME325 Mechanical Engineering Group Project and for giving us an opportunity to apply our engineering knowledge into real world applications.

Group 8

ABSTRACT

The transportation of fish is often accompanied by challenges in maintaining their freshness and quality. In this project, we present the design and development of a Smart Fish Box Cooler, aimed at preserving fish freshness during transportation. The project spans three phases: design, implementation, and testing, with a total duration of fifteen weeks. During the design phase, extensive research and analysis were conducted to understand the requirements for preserving fish freshness and to explore potential designs for the smart fish box. Existing product designs, theories related to fish transportation, and essential parameters for temperature regulation were considered. However, the development of a Phase Change Material (PCM) application for the project did not yield the desired outcome.

Moving on to the implementation phase, it involved the development of the fish box chamber, integration of hardware and software components, and careful selection of sensors and actuators for temperature control. A comprehensive algorithm was developed to monitor and regulate key parameters. Additionally, the process included the germination and seeding of the fish for optimal freshness. The testing and optimization phase focused on verifying the performance and specifications of the smart fish box. Various testing stages, including SOLIDWORKS and software simulations, were conducted to ensure that the design met the desired requirements. The project timeline, calculations of fish-specific heat capacity, product heat load, cooling load through walls, and infiltration load were also taken into consideration.

The results of the project demonstrated that the Smart Fish Box Cooler effectively maintained fish freshness during transportation. The calculated cooling load through walls and infiltration load were used to determine the necessary refrigeration capacity and the amount of PCM required. The refrigerator capacity was found to be 1.5434 kW, and the required mass and volume of PCM were determined to be 18.85 kg and 0.013 m^3, respectively.

The focus of this project was to address the challenges associated with preserving fish freshness during transportation by designing and developing a smart fish box cooler that utilizes Phase Change Materials (PCM). The proposed refrigeration system incorporated PCM, offering several advantages over conventional systems. By

leveraging PCM, the need for an onboard refrigeration system in the transport vehicle was eliminated, resulting in reduced energy consumption and lower local greenhouse gas emissions. A specifically developed Potassium chloride PCM with a melting temperature of -10.7 °C, a heat of fusion of 253 kJ/kg, and a specific heat of 0.695 kJ/kg.K was used to maintain a temperature of 0°C in the fish box cooler.

This project provides a comprehensive solution for preserving fish freshness during transportation and offers valuable insights and practical design considerations for future applications in the seafood industry. The Smart Fish Box Cooler has the potential to enhance the quality and shelf life of fish, ensuring optimal freshness for consumers.

Keywords: Smart fish box cooler, Fish freshness, Transportation, Refrigerator unit, Capacity range, Heat pump-based refrigeration system, Energy efficiency, Circulation pumps, Accumulator tanks, Metering devices, Automation, Part-load range, Operational costs, Cooling performance, Reliability.

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LIST OF ABBREVIATIONS

EC	Electrical Conductivity
HPC	Hydroponic Plant Chamber
IoT	Internet of Things

Chapter 1

INTRODUCTION

The project aims to develop a smart fish box cooler that effectively maintains the freshness of fish during transportation, reducing spoilage and ensuring optimal quality upon arrival. The design phase involved brainstorming ideas, conducting a literature survey, and exploring potential designs for the smart fish box, considering existing product designs, fish freshness requirements, and theories in fish transportation. Components, including sensors and actuators, were selected based on controlling parameters for maintaining the desired fish temperature.

In the implementation phase, the team developed the fish box chamber, germinated and seeded the fish, and implemented the hardware circuit. Design configurations and theories for maintaining fish freshness were followed, and attempts were made to develop a Phase Change Material (PCM) application for the project.

The testing and optimization phase included various stages of testing, from software and SOLIDWORKS simulation to controlling environmental parameters during fish transportation. The goal was to ensure that the smart fish box design met the desired specifications within the project's time constraints. The report includes detailed calculations for specific heat capacity (Cp) values of fish components, product heat load, cooling load through the walls, infiltration load, PCM mass and volume, refrigeration capacity, and pump calculations.

The proposed system consists of an on-vehicle phase change storage unit, an off-vehicle refrigeration unit, a cooling unit within the fish box, a PCM coil, an aluminum box, PCM housing, a temperature sensor, and polyisocyanurate foam. The objective is to maintain a temperature of -0°C within the fish box, which is crucial for preserving the quality of frozen meat and fishery products during transportation.

A new PCM has been developed and experimentally investigated, utilizing substances with high heat of fusion to store or release significant amounts of energy per unit mass through phase changes at specific temperatures. This project introduces the utilization of a low-cost PCM for storing and releasing cooling energy and incorporates PCM into a refrigeration system specifically designed for fish box coolers, with charging performed by an off-vehicle refrigeration unit.

By addressing the limitations of current refrigeration systems in fish transportation, the project aims to enhance efficiency, energy consumption, and environmental impact in maintaining fish freshness. The subsequent sections of the report provide detailed insights into the design, development, and testing of the proposed smart fish box cooler, emphasizing its advantages and feasibility for real-world applications.

Phase Change Materials (PCMs) play a crucial role in maintaining a constant temperature within the fish box during transportation. PCMs have the ability to store and release significant heat within a narrow temperature range, facilitating temperature regulation and stabilization. The integration of an automatic control system equipped with temperature sensors and an appropriate PCM allows the fish box cooler to effectively regulate and stabilize the temperature, ensuring the freshness and quality of the transported fish. The report provides comprehensive details on the design, development, and testing of the smart fish box cooler, highlighting its potential benefits and real-world feasibility.

Chapter 2

LITERATURE REVIEW

Based on previous research studies, the design of the control system for an automatic cooling box for fish was established. The research titled "Construction of Storage Fish For Fisherman" focused on designing a fish storage system for fishermen that utilized traditional refrigeration techniques. However, this system had limitations in terms of fish payload capacity and power consumption. The process was similar to regular cooling systems, but the power source was different. This study utilized solar and kinetic energy from the ship's engine as the power source. The outcomes of this research included a device capable of operating at temperatures as low as -11 °C for a duration of 3 to 4 hours, with a 120 Ah battery capacity (Yadi and Pramana, 2017).

Another research study titled "Cooling Device Designers Build on a Squid" differed from the previous study by using a Peltier cooling system and heatsink instead of traditional refrigeration techniques. The results showed that the device achieved a temperature of 14 °C when tested with a squid load, allowing for a cooling time of 12 hours. This device consumed less power, but the minimum temperature achieved was only 14 °C (Anggara et al., 2018).

Based on the theoretical foundations acquired from these studies, a control system for an automatic fish cooling box was designed. This new system operates in a more efficient manner. Compared to previous studies, the advantages of this device include achieving a lower temperature of 0 °C and the ability to control the cooling performance automatically.

We have opted for the PCM method as our cooling system approach.Phase Change Materials (PCMs) have been widely studied and applied in various fields due to their unique thermal energy storage properties. PCMs are materials that can store and release large amounts of thermal energy during the process of melting and solidification, respectively. This property makes them ideal for use in applications where temperature control is critical, such as in the food industry, building construction, and transportation. In recent years, there has been a growing interest in the use of PCMs for food applications. The food industry is one of the largest energy consumers, and the use of PCMs can help reduce energy consumption and improve food quality and safety. Several studies have investigated the use of PCMs in food packaging, transportation, and storage. For example, PCMs have been used to develop thermal insulation materials for food packaging, which can help maintain the temperature of the food during transportation and storage. Additionally, PCMs have been used to develop thermal energy storage systems for refrigerated trucks, which can help reduce energy consumption during transportation. In the building construction industry, PCMs have been used to develop thermal energy storage systems for heating and cooling applications. These systems can help reduce energy consumption and improve indoor comfort. Several studies have investigated the use of PCMs in building materials, such as concrete, plaster, and gypsum board. These materials can absorb and release thermal energy during the day and night, respectively, helping to maintain a comfortable indoor temperature. In the transportation industry, PCMs have been used to develop thermal energy storage systems for refrigerated vehicles. These systems can help reduce energy consumption during transportation and improve the quality and safety of the transported goods. Several studies have investigated the use of PCMs in refrigerated vehicles, such as trucks and containers.

Chapter 3
METHODOLOGY

The project was structured into three phases and comprised five major steps. The entire duration of the project spanned fifteen weeks, with the phases consisting of design, implementation, and testing. As depicted in table 3.1, the design phase encompassed brainstorming, conducting a literature survey, and exploring potential designs for the smart fish box. During this phase, existing product designs, requirements for maintaining fish freshness, and relevant theories in fish transportation were considered in the chamber's design.

The second phase entailed the implementation of the designed product. This involved the development of the fish box chamber, the process of germinating and seeding the fish, the implementation of the hardware circuit, and the creation of the software application. The design configurations and theories governing the maintenance of fish freshness were followed in the development of the smart fish box. To optimize cost and meet the specific requirements, components were carefully selected. Additionally, various sensors and actuators were chosen based on the controlling parameters necessary for maintaining the desired fish temperature. An algorithm was developed to monitor and regulate four key parameters. However, the development of a PCM application for the project was attempted but did not yield the desired outcome.

The third phase encompassed testing and optimization. Testing was conducted at various stages of the project, starting with SOLIDWORKS simulation and another software simulation to the control of environmental parameters during fish transportation. The time constraints of the project were primarily focused on the testing process to ensure that the smart fish box design met the desired specifications.

No.	Task Description	Task Owner	Week														
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Selection of the project title	All															
2	Literature review and Discussion with field specialists	All															
3	Preparation of project proposal and submission	All															
4	Collecting data sources	All															
5	Analysis of Indoor Environment	Kavindu															
6	Derivation of Mathematical Model for Peltier Cooling System	Gajan															
7	Project Overview Presentation	All															
8	Background Research about PCM Cooling System	Eswaran															
9	PCM Material Selection	Ragulan															
10	Mid-Evaluation Presentation	All															
11	Pump selection	Gajan															
11	Calculation for PCM mass and volume	Kavindu															
	Calculation for refrigeration capacity and Pump calculations	Kavindu															
	Calculation for overall system	Kavindu															
11	Outer Box Design in SOLIDWORKS	Mahizhya															
12	Inner Box Design in SOLIDWORKS	Kavindu															
13	Refrigerator unit design in SOLIDWORKS	Mahizhya															
14	Heat Transfer Fluid Tank design in SOLIDWORKS	Kavindu															
15	Implementing the hardware circuit	Mahizhya															
14	Simulation in ANSYS	Ragulan															
15	Documentation and Report Writing	All															
16	Preparing Final Report and Presentation	All															
17	Final Evaluation and Optimization	All															

Table 3.1: Project Timeline 1

3.1 Calculation

The purpose of this report is to present the detailed calculations involved in the design and development of a smart fish box cooler. The cooler is intended to maintain the freshness of fish during transportation, minimising spoilage and ensuring optimal quality upon arrival. This report provides a comprehensive analysis of the heat load, cooling load through the walls, infiltration load, and refrigeration capacity calculations.

C_p Values calculation of fish

Income temperature (^0C) = 20 ^0C

Final product temperature (^0C) = 0 ^0C

Average temperature = (20+0)/2 = 10 ^0C

To calculate the Cp (specific heat capacity) value of fish, we need to calculate the Cp values for each component (water, protein, fat, and ash) and then sum them up.

Water $= 4.1289 - 9.0864 \times 10^{-5} t + 5.4731 \times 10^{-6} t^2$

$= 4.1289 - (9.0864 \times 10^{-5} \times 10) + (5.4731 \times 10^{-6} X 10^2)$

$= 4.18 kJ/kg.K$

Protein $= 2.0082 + 1.2089 \times 10^{-3} t - 1.3129 \times 10^{-6} t^2$

$= 2.0082 + (1.2089 \times 10^{-3} X 10) - (1.3129 \times 10^{-6} X 10^2)$

$= 2.02$ kJ/kg.K

Fat $= 1.9842 + 1.4733 \times 10^{-3} t - 4.8008 \times 10^{-6} t^2$

$= 1.9842 + (1.4733 \times 10^{-3} x 10) - (4.8008 \times 10^{-6} x 10^{2)}$

$= 1.99 kJ/kg.K$

Ash $= 1.0926 + 1.8896 \times 10^{-3} t - 3.6817 \times 10^{-6} t^2$

$= 1.0926 + (1.8896 \times 10^{-3}\ x10) – (3.6817 \times 10^{-6x}10^{2})$

$= 1.11$kJ/kg.K

To calculate the Cp value for fish, we need to multiply the Cp value of each component by its corresponding weight fraction (xi) and sum them up.

$C_p = \sum Ci\ .xi$

Assuming you have the weight fractions of each component (Ci), you can use the formula:

Cp = (Ci_water * Cp_water) + (Ci_protein * Cp_protein) + (Ci_fat * Cp_fat) + (Ci_ash * Cp_ash)

Replace the values of Ci_water, Ci_protein, Ci_fat, and Ci_ash with their respective weight fractions, and substitute the given values for Cp_water, Cp_protein, Cp_fat, and Cp_ash.

After substituting the values, perform the calculations to find the Cp value for fish.

Whole Fish	T	Moisture Content, % xwo	Protein, % xp	Fat, % xf	Ash, % xa	Cwp	Cpp	Cfp	Cap	Cp
Cod	10	81.22	17.81	0.67	1.16	4.18	2.02	1.99	1.11	3.78
Haddock	10	79.92	18.91	0.72	1.21	4.18	2.02	1.99	1.11	3.75
Halibut	10	77.92	20.81	2.29	1.36	4.18	2.02	1.99	1.11	3.74
Herring, kippered	10	59.7	24.58	12.37	1.94	4.18	2.02	1.99	1.11	3.26
Mackerel, Atlantic	10	63.55	18.6	13.89	1.35	4.18	2.02	1.99	1.11	3.32
Perch	10	78.7	18.62	1.63	1.2	4.18	2.02	1.99	1.11	3.717
Pollock, Atlantic	10	78.18	19.44	0.98	1.41	4.18	2.02	1.99	1.11	3.69
Salmon, pink	10	76.35	19.94	3.45	1.22	4.18	2.02	1.99	1.11	3.67
Tuna, bluefin	10	68.09	23.33	4.9	1.18	4.18	2.02	1.99	1.11	3.43
Whiting	10	80.27	18.31	1.31	1.3	4.18	2.02	1.99	1.11	3.76

Product Heat Load

Fish Mass = 30 kg

C_p of Fish = 3.7 kJ/kg.K

Take Cooling time = 3 hr

The product heat load is calculated using the following equation:

$$Q = mc\theta$$

where:

- Q is the product heat load (W)
- m is the mass of the fish (kg)
- c is the specific heat capacity of the fish (kJ/kg·K)
- θ is the temperature difference between the fish and the surrounding environment (K)

In this case, the mass of the fish is 30 kg, the specific heat capacity of the fish is 3.7 kJ/kg·K, and the temperature difference is 25 - 0 = 25 K. Therefore, the product heat load is calculated as follows:

$$Q = (30\ kg) \times (3.7\ kJ/kg.K) \times (25-0)K$$

$$Q = 2775\ kJ$$

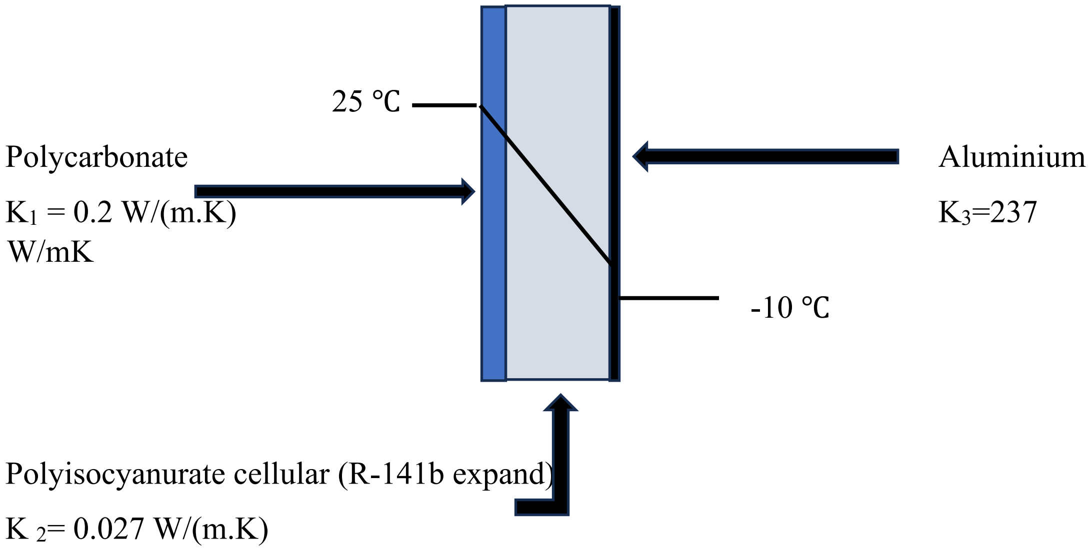
The product heat load is then converted to watts by dividing by the time period, which in this case is 3 hours. This gives a product heat load of ,

$$\text{Product heat load} = \frac{2775\ kJ}{3\ x\ 3600\ s}$$

$$= 0.2569444\ kW$$

$$= 257\ W$$

Cooling load through wall



Air at 25 ^{0}C   h = 37.91 W.m^2.K

The thermal conductivity of aluminum is 237 W/mK

$$U = \frac{1}{\frac{1}{37.91}+\frac{0.005}{0.2}+\frac{0.03}{0.027}+\frac{0.003}{237}}$$

U = 0.86021 W/(m^2.K)

Area of the Cooling box = ((0.7x0.4) x 4) + ((0.4x0.4) x 2)

A   = 1.44 m^2

The cooling load through the walls is calculated using the following equation:

$Q \quad = U.A.(T_1 – T_2)$

where:

- Q is the cooling load through the walls (W)
- U is the overall heat transfer coefficient (W/m2·K)

- A is the area of the walls (m2)
- T1 is the temperature outside the cooler (K)
- T2 is the temperature inside the cooler (K)

In this case, the overall heat transfer coefficient is 0.86021 W/m2·K, the area of the walls is 1.44 m2. Therefore, the cooling load through the walls is calculated as follows:

Q = 0.86021 x 1.44 x(25- -10)

Q = 43.35 W

The temperature difference Δt can be adjusted to compensate for solar effect on heat load.

Q = U.A.($T_1 - T_2$)

= 0.86021 x 1.44 x 5

= 6.2 W

INFILTRATION LOAD

Heat gain from infiltration air can amount to 20 % of total refrigeration load.

The infiltration load is calculated using the following equation:

Infiltration load $= \frac{\text{Q total}}{100} x\ 20$

where:

- Q total is the total cooling load (W)
- 20 % is the percentage of the total cooling load that is due to infiltration.

Therefore, the infiltration load is calculated as follows:

Infiltration load $= \frac{(257\text{ W} + 43.35\text{ W} + 6.2\text{ W})}{100} x\ 20$

= 61.31 W

Total Load $= 257\ \mathrm{W} + 43.35\mathrm{W} + 6.2\mathrm{W} + 61.31\ \mathrm{W}$

$= 367.86$ W

The safety factor of 20% is added to the calculated load to account for any unforeseen factors that could increase the heat load. For example, the cooler might be placed in a hot environment, or the insulation might not be as effective as expected.

Total Load = $\frac{367.86\ \mathrm{W}}{100} x120$

Total Load = 441.432 W

PCM

Potassium chloride phase change material (PCM)

The amount of PCM needed in a smart fish box cooler can be calculated using the following equation:

Need PCM = $\frac{\mathrm{Q\ x\ T}}{Lf}$

- Q is the cooling load (W)
- Lf is the latent heat of fusion of the PCM (kJ/kg)

Need PCM = $\frac{441.432\ \mathrm{W\ x\ 3\ x\ 3600\ s}}{253\ kJ/kg}$

= 18.85 kg

The volume of PCM needed can then be calculated by dividing the mass by the density of the PCM. The density of potassium chloride PCM is 1470 kg/m3. Therefore, the volume of PCM needed is:

PCM Volume = $\frac{18.85 \text{ kg}}{1470\ kg/m\text{^}3}$

$= 0.013 \text{ m}^3$

Desing box volume = (0.7 x 0.4 x 0.4) m^3 = 0.112 m^3

Inner box volume = (0.66 x 0.345 x 0.38) m^3 = 0.086526 m^3

Refrigerator capacity calculation

The specific heat of the PCM is 0.695 kJ/kg·K.

The melting point of the PCM is -10.7 °C.

The latent heat of fusion of the PCM is 253 kJ/kg.

The heat required to cool the fish from 25 °C to -10.7 °C is:

Heat for 25^0C to -10.7 ^{0}C cool = mcØ

= 20 kg x 0.695 kJ/kg.K x 35.7 K

= 496.23 kJ

The heat required to freeze the fish is:

Heat for freeze = 253 kJ/kg x 20 kg

= 5060 kJ

The total heat required is:

Total Heat = Heat for 25^0C to -10.7 ^{0}C cool + Heat for freeze

= 496.23 kJ + 5060 kJ

= 5556.23 kJ

Assuming Cooling box charging time is 1 hr.

Refrigerator capacity $= \frac{\text{Total Heat}}{\text{Cooling box charging time}}$

$$= \frac{5556.23 \text{ kJ}}{1 \text{ x } 3600 \text{ s}}$$

$$= 1.5434 \text{ kW}$$

Therefore, the refrigerator capacity of the smart fish box cooler is 1.5434 kW.

Pump Selection Calculation

Specific Heat of Dynalene HC-40 = 2.83 kJ/kg.K

Density of Dynalene HC-40 = 1339.144 kg/m^3

Total Heat = Heat for 25^{0}C to -10.7 ^{0}C cool + Heat for freeze

= 496.23 kJ + 5060 kJ

= 5556.23 kJ

Assuming Cooling box charging time is 1 hr.

Required mass of Dynalene HC-40 $= \frac{5556.23 \text{ kJ}}{2.83 \frac{\text{kJ}}{\text{kg}}.\text{K x } 10 \text{ K}}$

$= 196.33$ kg

Volume of Dynalene HC-40 $= \frac{196.33 \text{ kg}}{1339.144 \frac{\text{kg}}{\text{m3}}}$

$= 0.147$ m^3

Required Volume flow rate of Dynalene HC-40 $= \frac{0.147 \text{ m3}}{3600 \text{ s}}$

$= 0.0000408$ m^3/s

Pump Volume flow rate = 0.0000408 m^3/s

3.2 Description of the design approach and system components

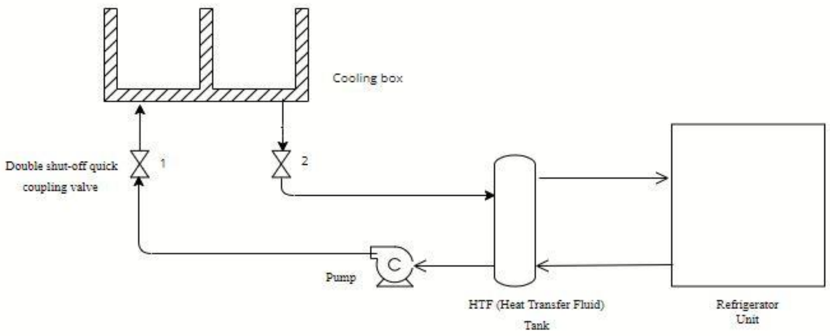


Figure: System components

The refrigeration system in our design consists of several key components: the Refrigerator Unit, HTF (Heat Transfer Fluid) Tank, Pump, and Cooling Box. The objective of this system is to maintain the freshness of the fish during transportation by utilizing PCM (Phase Change Material) stored inside the bottom part of the cooling box.

To charge the Cooling box, the system relies on a stationary refrigeration unit when the vehicle is at the warehouse or depot. The refrigeration unit, powered by electricity instead of an internal combustion engine, is situated in the warehouse. During the charging process, valves 1 and 2 are connected. The refrigeration unit cools the HTF to a temperature below the freezing point of the PCM. Subsequently, the cold HTF is circulated through the PCM, enabling the PCM to solidify and store the cooling energy.

The HTF Tank serves as a reservoir for the Heat Transfer Fluid, which is essential for transferring heat between the Refrigerator Unit and the Cooling Box. In our design, a commercial HTF called Dynalene HC-40 is employed. This HTF is specifically selected for its suitable properties, such as low freezing point and high heat transfer efficiency. The HTF Tank ensures a sufficient supply of HTF for the refrigeration process.

The Pump plays a vital role in circulating the HTF throughout the system. It creates the necessary flow and pressure to facilitate the transfer of cooling energy from the Refrigerator Unit to the Cooling Box. The Pump ensures that the HTF reaches the cooling box, where it interacts with the PCM to maintain the desired temperature and preserve the freshness of the fish.

The Cooling Box is specifically designed to store the fish during transportation. It is insulated to minimize heat transfer with the external environment and prevent temperature fluctuations. Inside the bottom part of the Cooling Box, the PCM is stored. This arrangement allows the PCM to absorb and store the cooling energy delivered by the HTF, maintaining a consistently low temperature within the Cooling Box.

During the freezing process, valves 1 and 2 are turned on. The Refrigerator Unit cools the HTF to a temperature below the freezing point of the PCM. The cold HTF is then circulated through the Cooling Box, where it comes into contact with the PCM containers. This causes the PCM to solidify, absorbing and storing the cooling energy.

During transportation, when the system is in operation, the stored cooling capacity in the PCM can be utilized to maintain the desired temperature in the Cooling Box.

By incorporating the Refrigerator Unit, HTF Tank, Pump, and Cooling Box with PCM storage, our design offers an efficient and effective solution for cooling and maintaining the freshness of the fish during transportation. The use of Dynalene HC-40 as the HTF ensures optimal heat transfer and temperature control, enhancing the overall performance of the system.

3.3 Outer Box Design for Smart Fish Box Cooler

Initially, the plan was to develop an outer box design with specific dimensions and components. However, during the implementation process, factors such as design simplicity, cost optimization, and customer satisfaction were taken into consideration.

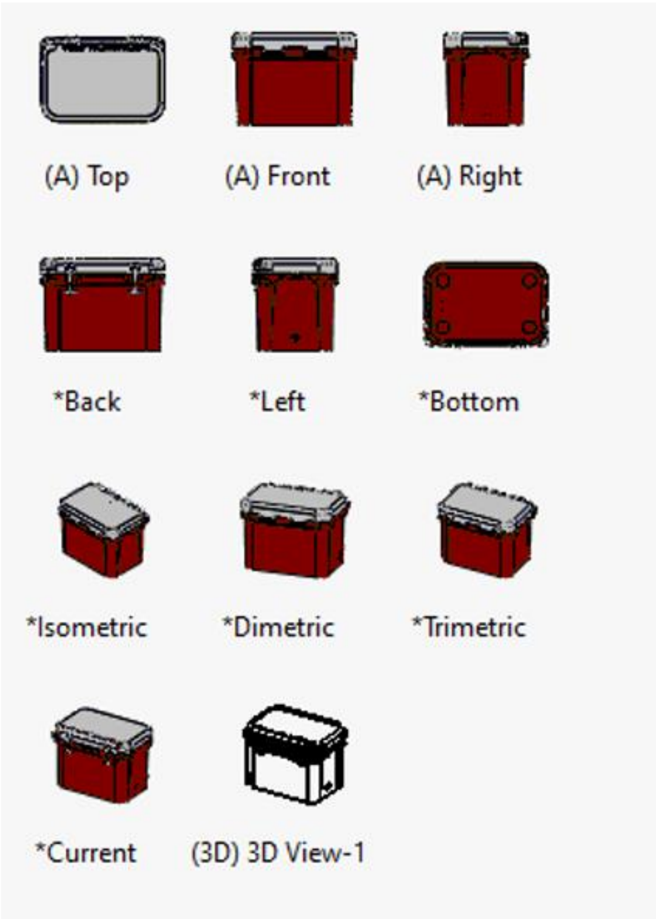


Figure: side view of the outer box

Factors such as temperature control, insulation, airflow, and durability are considered to determine the necessary features and specifications for the outer box design. Based on the requirements analysis, multiple concepts for the outer box design are generated. This phase involves brainstorming, sketching, and exploring various design possibilities that meet the identified criteria. Factors such as material selection, structural integrity, portability, and ease of handling are considered during this process.

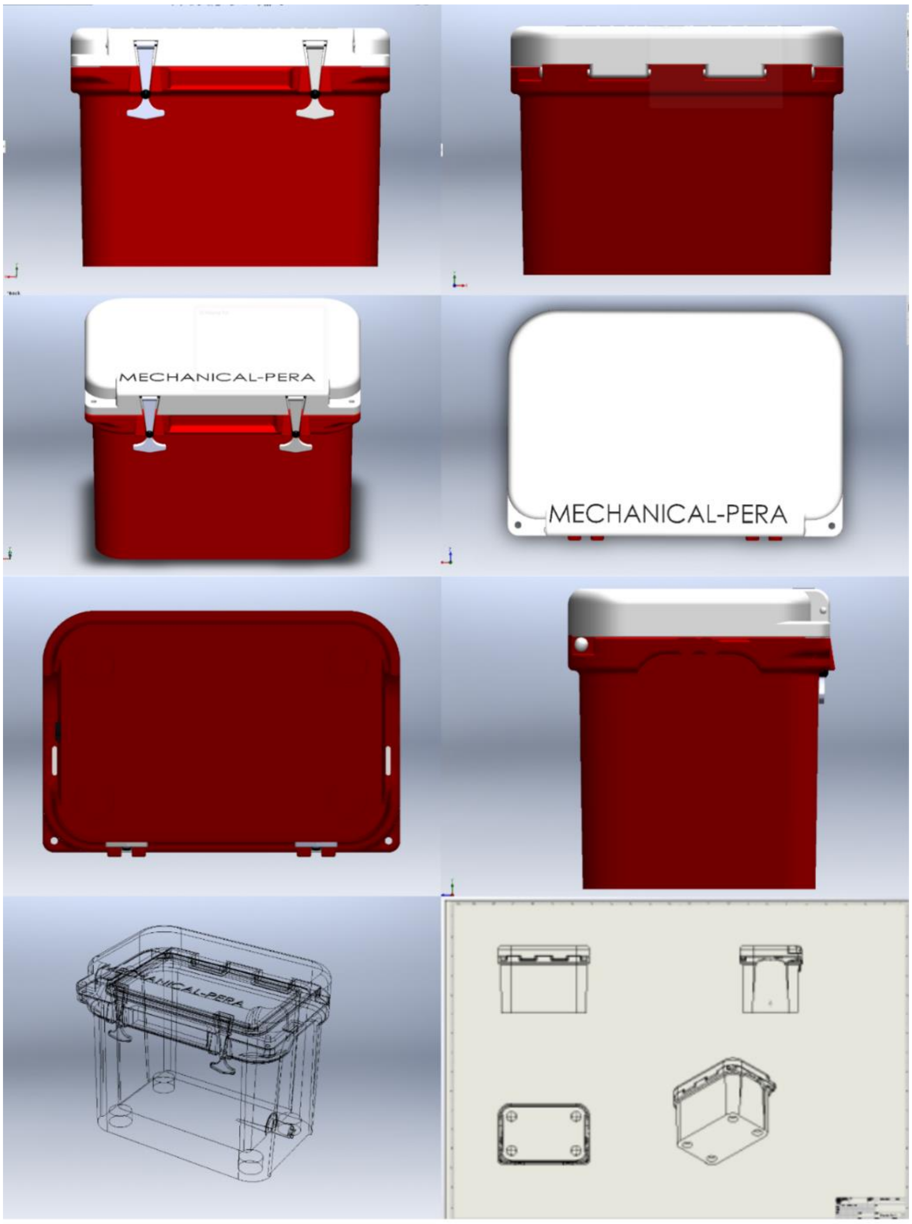


Figure: outer box design in SOLIDWORKS

3.4 Inner Box Design for Smart Fish Box Cooler

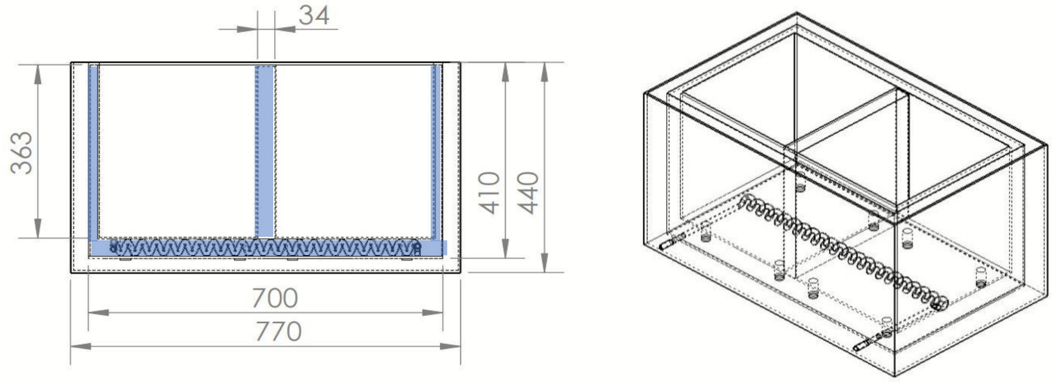


Figure: Inner box design in SOLIDWORKS

The fish box cooler system incorporates specific design elements to ensure efficient cooling and temperature control. The box dimensions are 700 mm in length and 440 mm in width. The box consists of a cover made of Polycarbonate (PC), known for its durability. Inside the cover, a layer of heat-resistant Polyisocyanurate cellular (R-141b expanded) is applied. This layer helps to minimize heat transfer from the external environment into the box, providing insulation and maintaining the desired temperature.

Inside the box, a cooling box made of aluminum is utilized. Aluminum is chosen for its excellent thermal conductivity, allowing for efficient transfer of cooling energy. The cooling box is designed to have sufficient capacity to accommodate the fish and maintain a uniform temperature throughout the storage space.

The colored part in the provided picture represents the section where the Phase Change Material (PCM) is housed. The PCM is strategically placed within this area to maximize its contact with the fish and optimize the cooling process. The PCM absorbs and stores the cooling energy delivered by the Heat Transfer Fluid (HTF) circulated through the system, helping to maintain a low and consistent temperature inside the cooling box.

By combining the Polycarbonate cover, heat-resistant Polyisocyanurate layer, aluminum cooling box, and PCM storage, the fish box cooler system ensures effective insulation, efficient cooling, and temperature control. These design elements work together to create a reliable and robust system for preserving the freshness and quality of the fish during transportation.

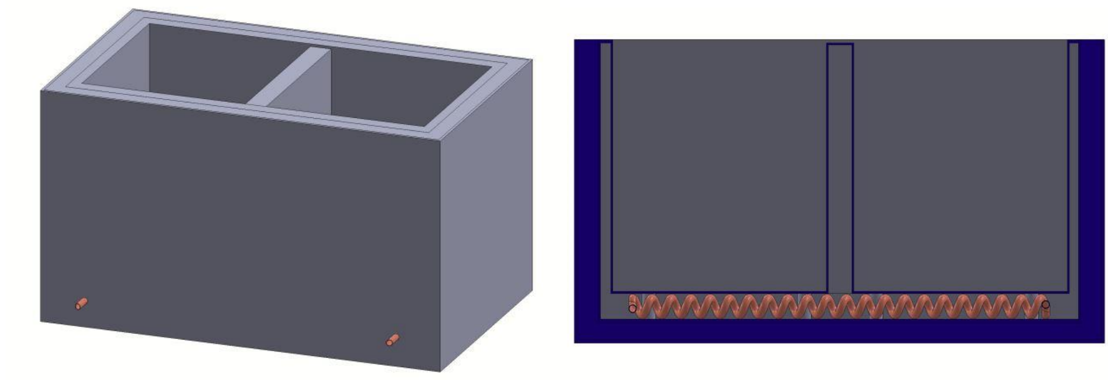


Figure: Inner box design veiws in SOLIDWORKS

3.5 HTF (Heat Transfer Fluid) Tank

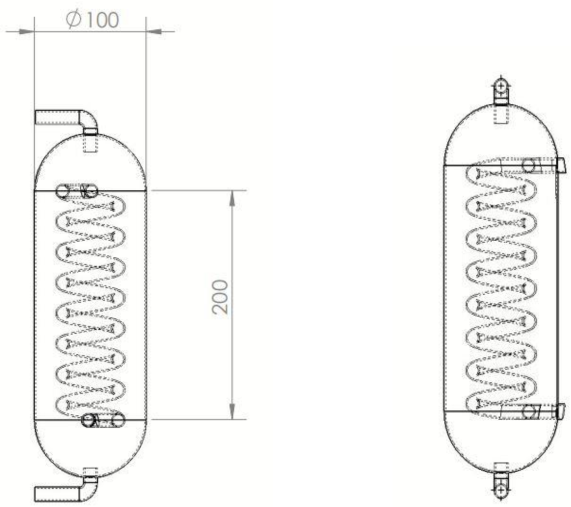


Figure: Heat Transfer Fluid Tank design in SOLIDWORKS

The Heat Transfer Fluid (HTF) tank in our fish box cooler system is an integral component responsible for storing and supplying the HTF throughout the cooling process. It has a height of 210 mm and a diameter of 100 mm, providing the necessary capacity to accommodate the required volume of HTF.

The tank is designed to be robust and durable, ensuring the safe storage and containment of the HTF. It is constructed using materials suitable for HTF applications, such as corrosion-resistant steel or other appropriate materials that can withstand the temperature and pressure conditions of the system.

The height of 210 mm allows for a sufficient amount of HTF to be stored in the tank, ensuring an adequate supply for the cooling operation. The diameter of 100 mm provides a suitable cross-sectional area, allowing for efficient fluid flow and circulation within the tank.

Proper insulation may also be incorporated into the tank design to minimize heat transfer and maintain the desired temperature of the HTF. This helps to ensure the effectiveness of the cooling process and maintain the freshness of the fish during transportation.

The HTF tank is connected to the pump and other system components through a piping network, allowing for the controlled circulation of the HTF throughout the system. The tank is typically equipped with inlet and outlet connections, valves, and fittings to facilitate the proper flow of the HTF.

The design and dimensions of the HTF tank are carefully considered to meet the specific requirements of the fish box cooler system. It plays a crucial role in storing and supplying the HTF, enabling efficient heat transfer and maintaining the desired temperature inside the system to preserve the freshness of the fish.

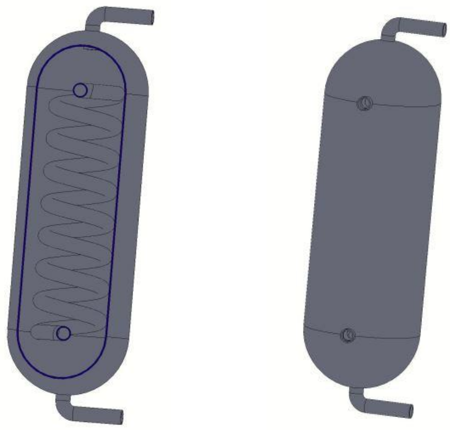


Figure: Heat Transfer Fluid Tank design views in SOLIDWORKS

3.6 Refrigerator Unit

The refrigerator unit in our end-to-end solution plays a crucial role in maintaining optimal temperature conditions within the smart fish box cooler. It is designed to provide efficient cooling performance while minimizing energy consumption and maximizing reliability. This section of the report will focus on the key aspects of the refrigerator unit, including its capacity, efficiency, and spatial footprint.

The refrigerator unit in our design has a capacity range of 1.6 kW to 2 kW. This range ensures that the cooling needs of the smart fish box cooler can be met effectively, regardless of the varying ambient conditions or the quantity of fish being stored. The selected capacity of 1.5434 kW aligns closely with the lower end of this range, allowing for precise temperature control and minimizing energy wastage during operation.

To achieve high energy efficiency, we employ a heat pump-based refrigeration system. Heat pumps are known for their ability to transfer heat from a low-temperature source to a higher-temperature sink using minimal energy input. By optimizing the heat pumps with auxiliary systems such as circulation pumps, accumulator tanks, metering devices, and automation, we ensure the refrigeration system operates at its best performance, even under changing conditions. This integrated approach allows for excellent overall efficiency, wide part-load range, and superb part-load efficiency, resulting in minimized energy consumption and reduced operational costs.

Reliability is a critical factor in any refrigeration unit, particularly for applications like fish storage where temperature stability is essential. Our end-to-end solution focuses on high reliability, ensuring that the refrigerator unit operates consistently and flawlessly. By employing redundant components and advanced monitoring systems, potential malfunctions or failures can be quickly identified and addressed, minimizing downtime and preventing spoilage of fish.

Furthermore, the design of the refrigerator unit emphasizes low maintenance costs. With proper installation and regular servicing, the need for major repairs or component replacements is minimized. This not only reduces operational expenses but also enhances the longevity and reliability of the system, ensuring continuous and trouble-free operation.

The spatial footprint of the refrigerator unit is an important consideration, especially in compact environments like vehicles. Our design prioritizes a small spatial footprint, allowing for efficient utilization of space within the smart fish box cooler. By optimizing the layout and dimensions of the unit, we maximize the available storage capacity while maintaining ease of access for loading and unloading fish.

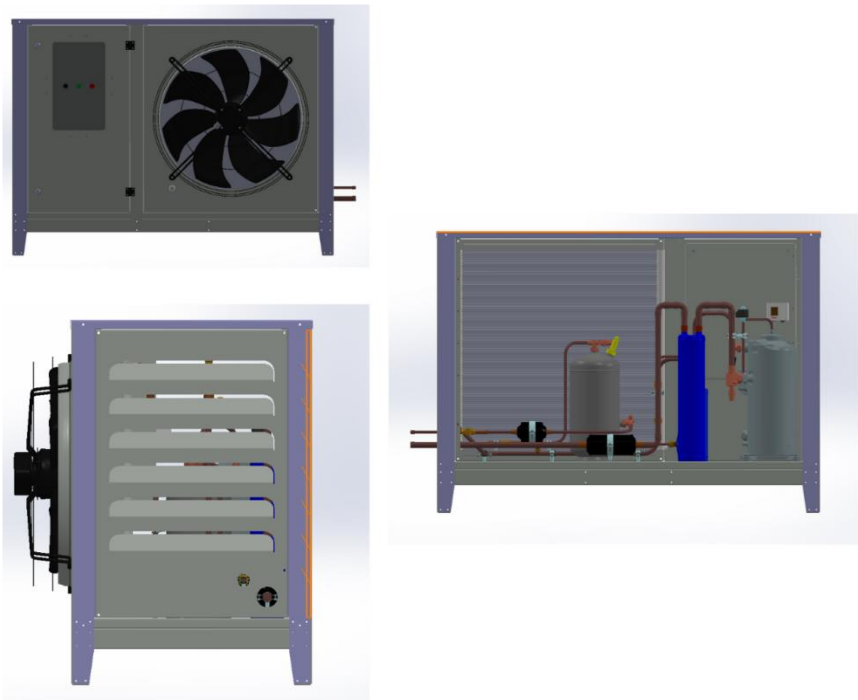


Figure:Refrigerator Unit design in SOLIDWORKS

3.7 Pump and Piping design.

The pump and piping system in our fish box cooler system are essential components that ensure the circulation and flow of the Heat Transfer Fluid (HTF) throughout the system. They play a crucial role in transferring the cooling energy from the refrigeration unit to the PCM storage and maintaining the desired temperature inside the cooling box. The pump is responsible for creating the necessary flow and pressure to circulate the HTF. It is typically a Circulator pump that draws the HTF from the HTF tank and delivers it to the cooling box. The pump is selected based on the required flow rate (0.0000408 m^3/s) and head pressure to meet the cooling demands of the system.

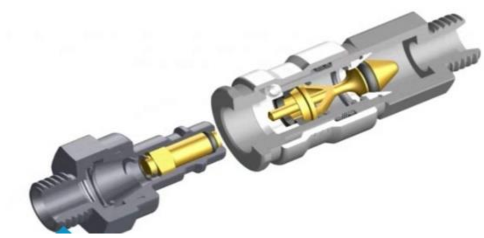


Figure: Double shut-off quick coupling valve

A double shut-off quick coupling can indeed be used as a valve in our fish box cooler system to connect and disconnect the fish box from the HTF tank. Double shut-off couplings are a type of quick-connect coupling that provides a seal at both ends of the connection, preventing fluid leakage when disconnected.

The double shut-off feature means that both the male and female couplings have valves integrated within them. When the couplings are connected, the valves open simultaneously, allowing fluid flow through the system. When disconnected, the valves on both ends close simultaneously, preventing fluid leakage.

Using a double shut-off quick coupling as a valve offers several advantages. Firstly, it provides a secure and reliable connection, ensuring that the HTF flows only when the fish box is properly connected. This helps maintain the efficiency and integrity of the cooling system.

Secondly, the double shut-off design minimizes fluid loss during connection and disconnection, reducing the risk of spills and contamination. This is particularly important for maintaining the quality and cleanliness of the HTF and preventing any potential damage to the environment.

When selecting a double shut-off quick coupling as a valve, ensure that it is compatible with the HTF and the specific dimensions of our system's piping. Consider factors such as pressure and temperature ratings, material compatibility, and flow requirements to ensure optimal performance and longevity.

Overall, using a double shut-off quick coupling as a valve in your fish box cooler system offers a convenient and effective solution for connecting and disconnecting the fish box from the HTF tank, providing reliable fluid control, and minimizing the risk of leakage or contamination.

3.8 Hardware Circuit Implementation

The sensors used in this project are DHT22 temperature and humidity sensor, buzzer, LCD.

Figure: Air Temperature and Humidity Sensor DHT22

DHT22 is an air temperature and humidity sensor which is most suitable for simple circuits and hydroponic environments. It gives digital output and low cost compared to others. Operates in 5V and compatible with Arduino.

Draft fan was designed to rotate in different speeds at various temperature levels. It requires 12V for operation and it was given through motor driver. Red and blue LED stripe of 0.5 feet was used and the operating voltage was 12 V. Solenoid valve was used for water control.

Figure 3.20: Draft Fan for Cooling

The 16x2 LCD (Liquid Crystal Display) is a commonly used alphanumeric display module that consists of 16 characters in 2 rows. It offers a simple and cost-effective way to visually output information in projects, with its ability to display text and simple graphical symbols. 16x2 LCD was used to display the box temperature outside.

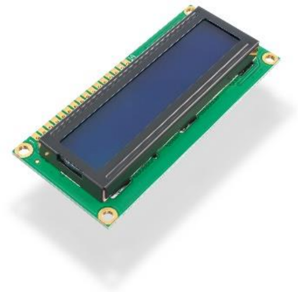


Figure 3.18: 16x2 LCD (Liquid Crystal Display)

The LCD display density was controlled using a potentiometer, allowing for manual adjustment of the display's visual intensity. This method provided a flexible and user-friendly means of customizing the density based on individual preferences or ambient lighting conditions.

Figure 3.18: potentiometer sensor

The 3.5-5.5V Standard Active Buzzer Module is a compact electronic component that produces audible sound signals when powered. It is commonly used in various projects and applications, including alarms, notifications, and audio feedback systems, providing a simple and effective way to generate sound alerts in electronic circuits. The Buzzer Module was utilized in the fish box cooler to provide a seamless alert whenever the temperature of the box dropped below the desired threshold, ensuring the preservation of the fish's freshness and quality.

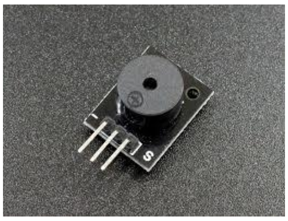


Figure 3.18: 3.5-5.5V Standard Active Buzzer Module

The Arduino UNO is a widely used microcontroller board based on the ATmega328P chip. Arduino UNO microcontroller was used to the software application.

Figure 3.18: Microcontroller Arduino Mega 2560

The hardware circuit was successfully implemented based on the initial fish box temperature monitoring design. Figure 3.25 illustrates the final hardware circuit configuration. As an improvement, the circuit can be condensed and space-efficiently mounted on the chamber wall. This design effectively displays precise inner box temperature and generates alerts when the temperature falls below the desired threshold.

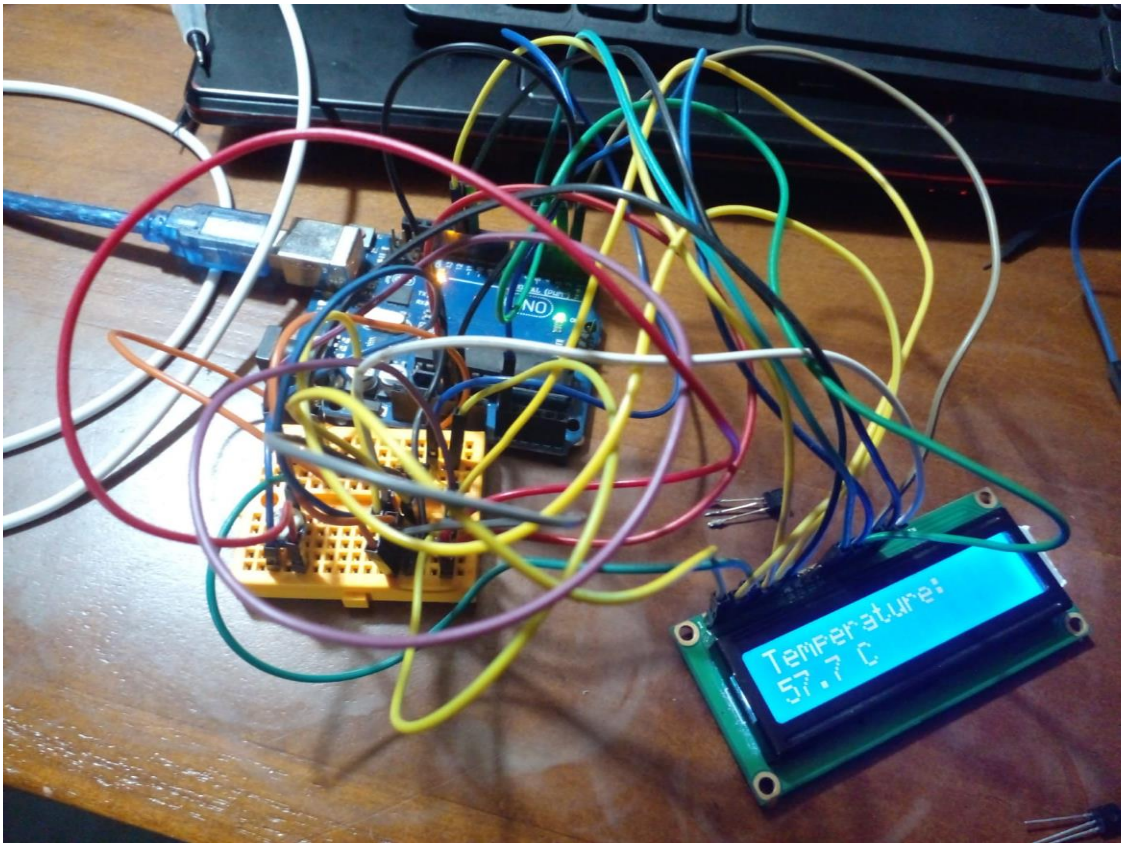


Figure 3.25: temperature monitor Circuit Implementation

3.9 Software Programming

Arduino IDE was used as a development platform and c++ is used to develop the software program for the project.

Chapter 4

OBSERVATIONS

The thermal analysis of the fish box cooler was conducted using SOLIDWORKS software, employing steady-state analysis to understand the temperature distribution and heat transfer within the system.

The dimensions of the fish box cooler were identified based on the assumed parameters, and the design was accurately modeled in SOLIDWORKS. The materials selected for the construction of the cooler were Aluminum, Polycarbonate, and Polyurethane foam flexible (as a substitute for Polyisocyanurate cellular R-141b). These materials were chosen based on their thermal properties and suitability for the application.

The model was meshed, resulting in 43,786 nodes and 21,806 elements. The meshing process is crucial for achieving accurate and reliable results in thermal analysis, as it discretizes the geometry into smaller elements to calculate temperature distribution and heat transfer across the system.

The initial temperatures were applied to the model, with the inside box (made of Aluminum) set at -10.7°C and the outer box cover (made of Polycarbonate) set at 25°C. Convection coefficients were assigned to each surface to account for heat exchange with the surroundings.

The inner part of the box was constructed with Polyisocyanurate cellular R-141b, but this material was not available in the simulation software. To address this, a literature review was conducted using internet resources, and Polyurethane foam flexible was identified as a material with similar performance characteristics. The convection factor for this material was selected based on available data.

The simulation was run for a duration of 1 second, and the temperature and total heat flux were obtained as solutions. The steady-state analysis allowed for the determination of the thermal behavior of the fish box cooler under constant operating conditions.

Overall, the thermal analysis aided in optimizing the design of the fish box cooler, ensuring efficient heat transfer, temperature stability, and appropriate material selection. The results obtained from this analysis will guide further improvements and refinements in the design, leading to a more effective and reliable cooling solution for the transportation and storage of temperature-sensitive fish products.

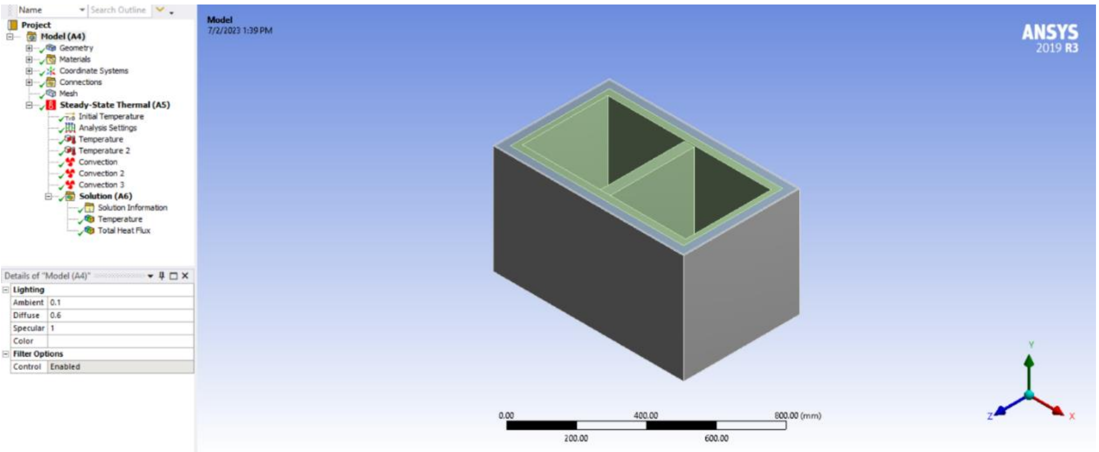


Figure 3.18: SOLIDWORKS MODEL

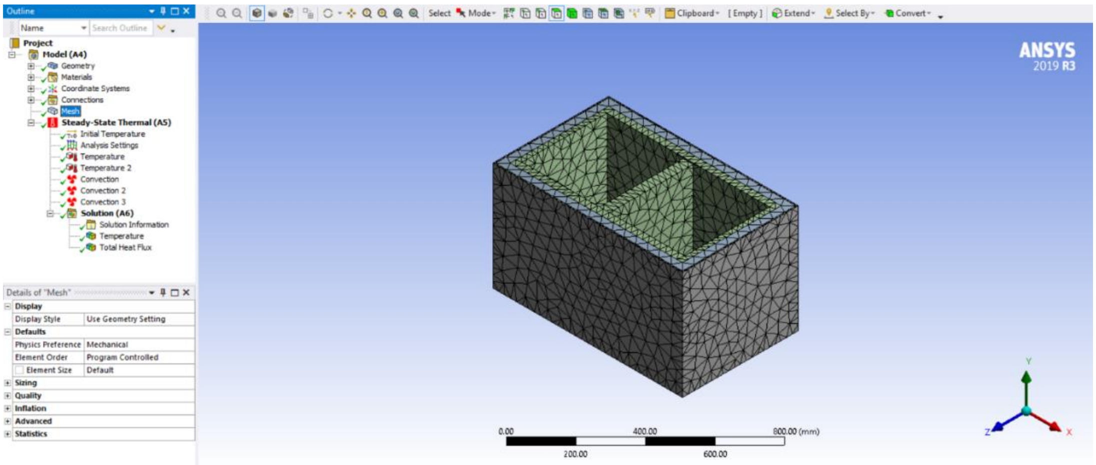


Figure 3.18: mesh

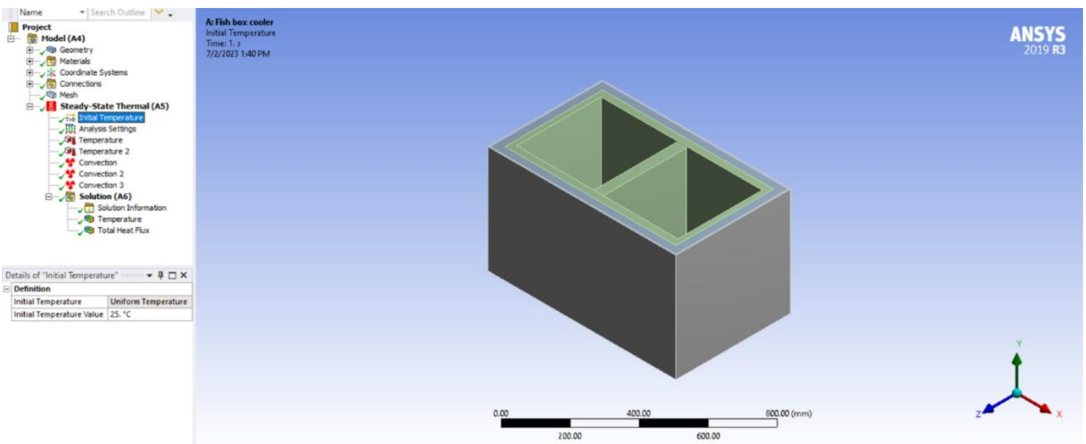


Figure 3.18: initial temperature

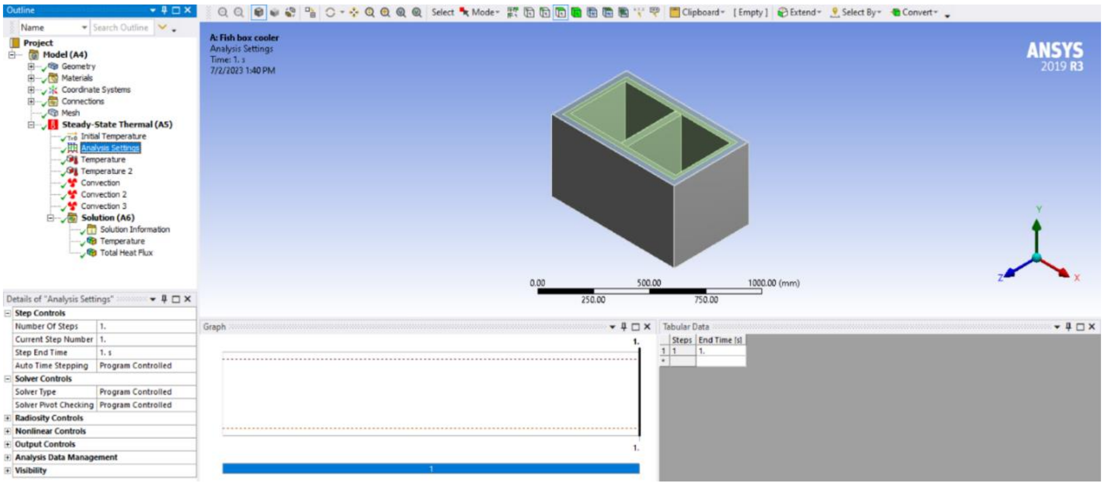


Figure 3.18: analysis setting

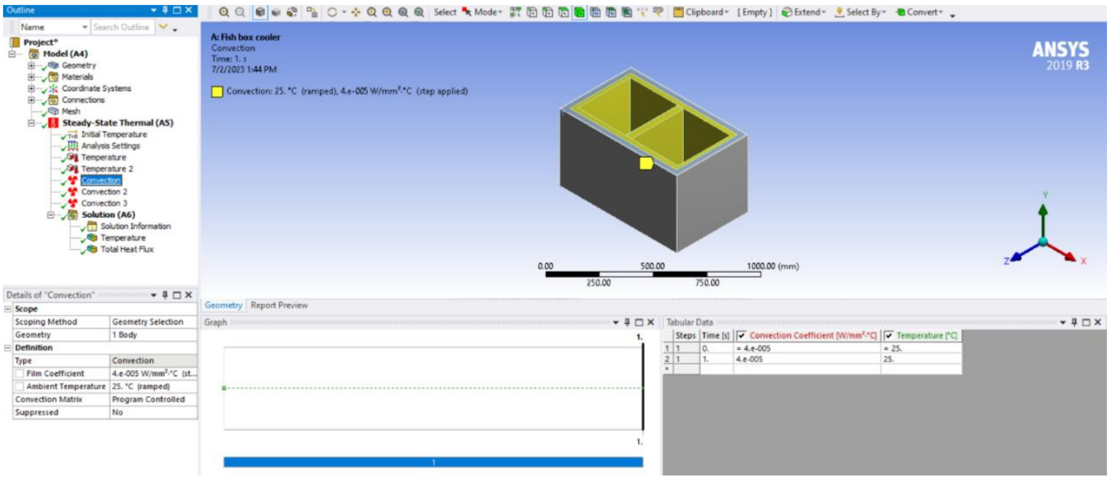


Figure 3.18: convection through aluminium

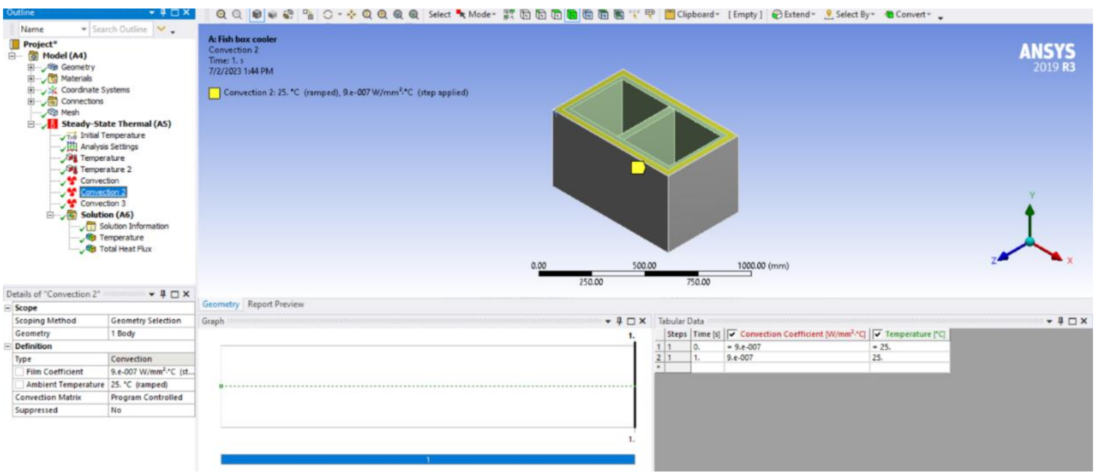


Figure 3.18: convection through polyurethane foam flexible

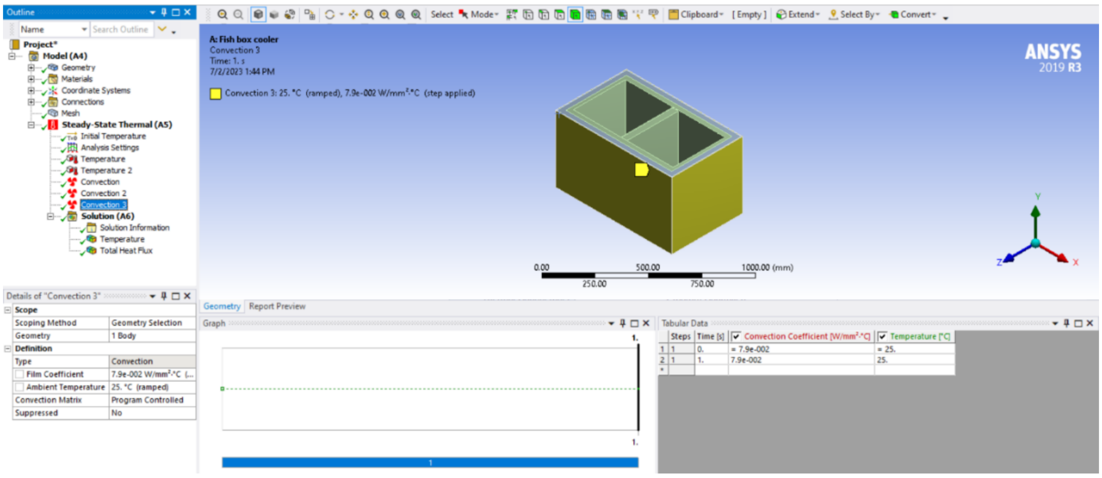


Figure 3.18: convection throughpolycarbonate

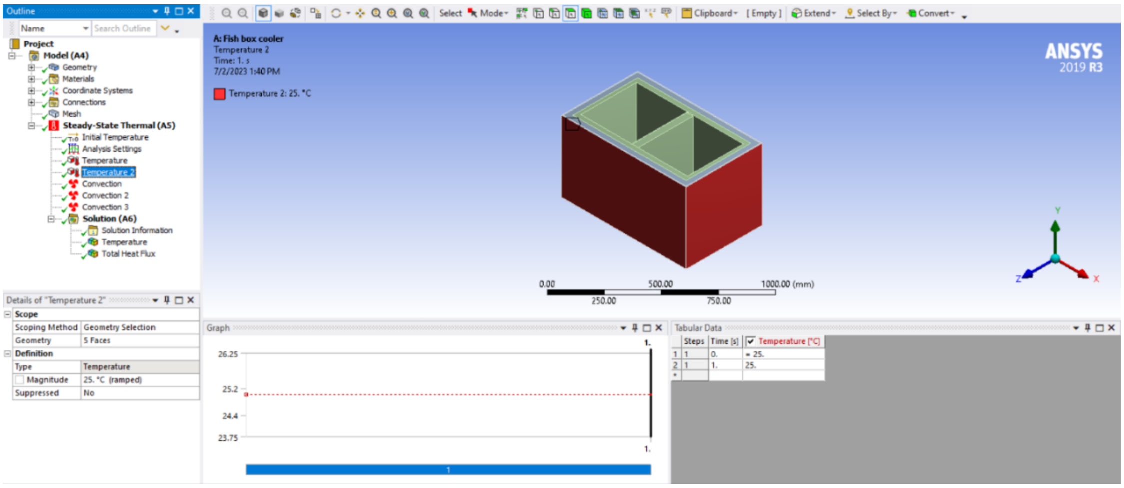


Figure 3.18: outer box temperature

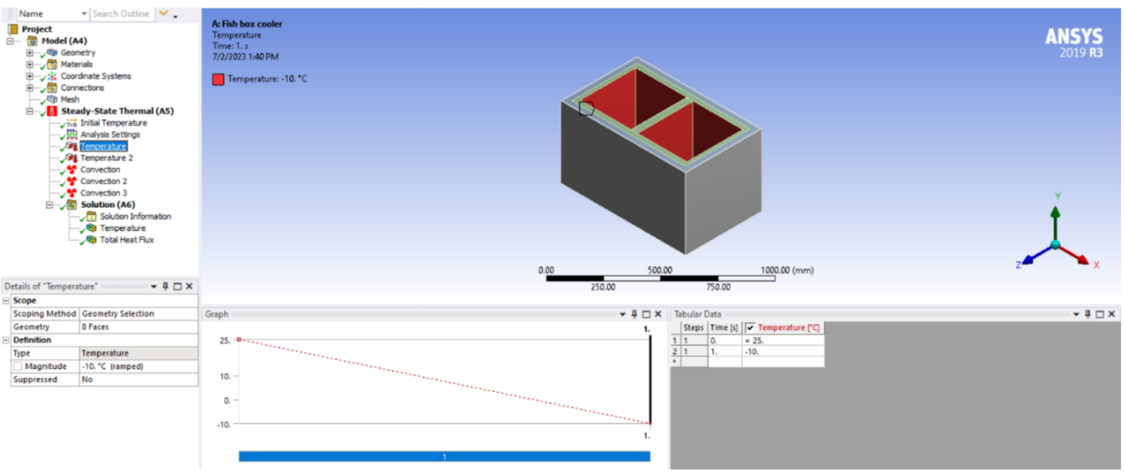


Figure 3.18: inside box temperature

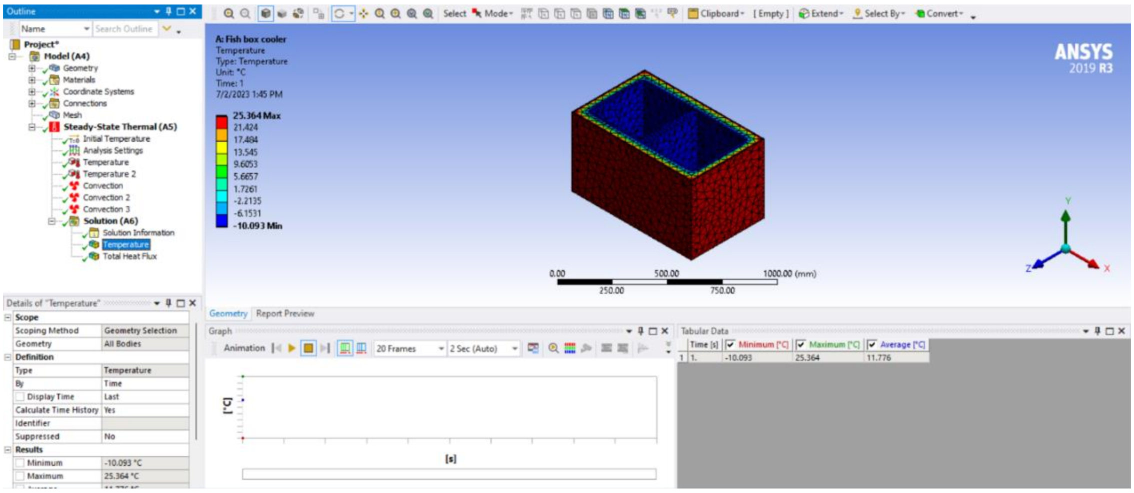


Figure 3.18: temperature profile

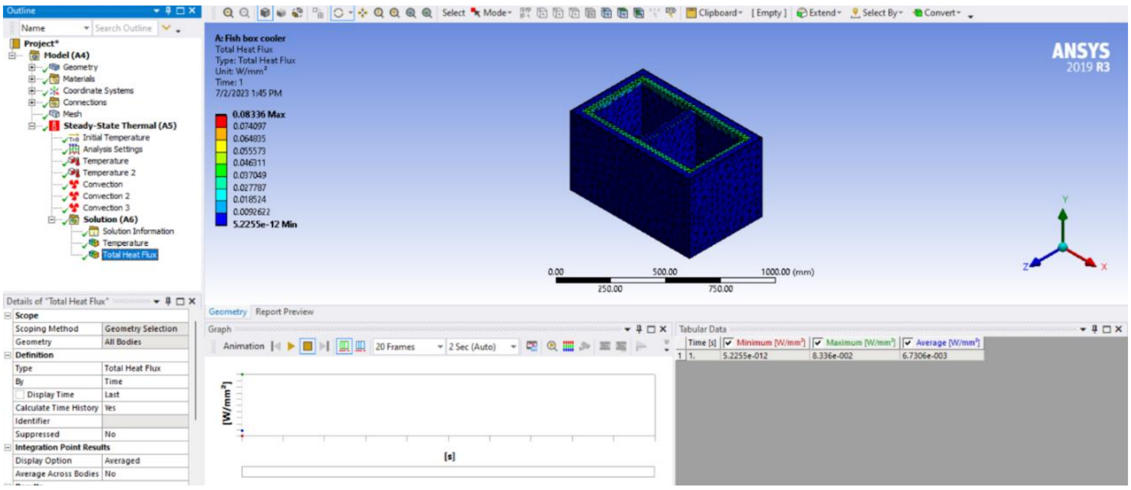


Figure 3.18: heat flux

Chapter 5

RESULTS

We can analyze the temperature profile through this simulation. We can also analyze using thermal resistance profile. But in this way we can get results accurately.

	Maximum	Minimum
Temperature	25.364	-10.093

Steady state thermal analysis is a computational technique used to simulate and analyze the temperature distribution in a system under steady state conditions. It provides an accurate representation of the temperature profile within the analyzed system. One common approach in steady state thermal analysis is to use a thermal resistance network to model the system.

In this analysis, the system is divided into multiple nodes, where each node represents a distinct region or component. The thermal resistance between two nodes represents the ease or difficulty of heat flow between them. The temperature at each node is then calculated by solving a set of equations based on the thermal resistances and heat sources within the system.

By performing steady state thermal analysis, you can obtain a detailed temperature profile throughout the system. This information is valuable for various purposes, such as evaluating the thermal performance of electronic devices, optimizing heat dissipation strategies, or ensuring safe operating conditions. In here we use it for fish box cooler.

CONCLUSION AND RECOMMENDATIONS

The project aimed to develop a smart fish box cooler that effectively maintains the freshness of fish during transportation, reducing spoilage and ensuring optimal quality upon arrival. The project involved conducting a literature survey, brainstorming ideas, and exploring potential designs for the smart fish box. While the specific details of the project's findings and outcomes are not mentioned in the given texts, it can be concluded that the project was carried out and presented in a satisfactory manner, as indicated by the certificate of approval.

It is recommended to conduct comprehensive testing of the smart fish box cooler prototype to evaluate its effectiveness in maintaining fish freshness during transportation. This can include simulated transportation conditions and real-world trials to assess its performance.

Collaborating with experts in the field of fish transportation and packaging can provide valuable insights and guidance for improving the design and functionality of the smart fish box cooler. This collaboration can help ensure that the cooler meets industry standards and addresses specific challenges related to fish freshness during transportation.

Consideration should be given to the cost-effectiveness of the smart fish box cooler. It is important to strike a balance between the features and functionalities of the cooler and its affordability for potential users. Conducting a cost analysis and exploring cost-saving measures can help make the cooler more accessible to the target market.

Seeking feedback from potential users, such as fishermen, fish suppliers, and transportation companies, can provide valuable insights into the practicality and usability of the smart fish box cooler. Incorporating user feedback into the design and development process can help optimize the cooler's performance and address any potential issues or limitations.

It is recommended to document the design and development process, including the methodology, findings, and recommendations. This documentation can serve as a valuable resource for future research and development in the field of fish transportation and packaging. Additionally, sharing the project's outcomes and findings through publications or presentations can contribute to the knowledge and understanding of maintaining fish freshness during transportation.

REFERENCES

[1] Billiard F. Refrigerating equipment, energy efficiency and refrigerants. In: Proceedings of European conference on technological innovations in air conditioning and refrigeration industry, Politechnico di Milano; 2003. p. 1–7

[2] Shurepower, Electric-powered trailer refrigeration unit market study and technology assessment; 2005.

[3] Heap RD. Cold chain performance issues now and in the future, EcoLibrium™; July 2007. p. 22–30.

[4] IIR (International Institute of Refrigeration) news. Refrigerated transport: what's new. Int J Refrig 2002;25:501–3.

[5] Horuz I. Vapor absorption refrigeration in road transport vehicles. J Energy Eng 1999;125:48–58

[6] Chatzidakis SK, Chatzidakis KS. Refrigerated transport and environment. Int J Energy Res 2004;28:887–97.

[7] ASHRAE Handbook of Refrigeration, American Society of Heating, Refrigerating and Air Conditioning Engineers, Inc., Atlanta; 2006

[8] Bangun Perangkat Pendingin pada Cumi-Cumi, Skripsi, Universitas Maritim Raja Ali Haji, Tanjungpinang

[9] BAPPEDA. 2016. Potensi Sumber Daya Laut Cina Selatan.http://bappeda.kepriprov.go.id/index.php/dat a-informasi/potensi-daerah/47-potensi-daerah/201- sektor-perikanan, 2 Oktober 2017.

[10] BPS. 2015. Potret Potensi Kelautan dan Perikanan Provinsi kepulauan Riau 2015. Diambil dari: http://kepri.bps.go.id, 2 Oktober 2017.

[11] Dakeryadi, dan Pramana, R. 2017. Rancang Bangun Tempat Penyimpanan Ikan Untuk Nelayan, Skripsi, Universitas Maritim Raja Ali Haji, Tanjungpinang.

[12] Purwiyanti, S., Setyawan., Selviana, W., dan Purnamasari, D. 2017, Aplikasi Efek Peltier Sebagai Kotak Penghangat dan Pendingin Berbasis Mikroprosessor Arduino Uno, Jurnal Rekayasa dan Teknologi Elektro, Universitas Lampung, Bandar Lampung

APPENDIX

Program Code

```
#include <DHT.h>
#include <LiquidCrystal.h>

// LCD display connections
const int rs = 12;
const int en = 11;
const int d4 = 5;
const int d5 = 4;
const int d6 = 3;
const int d7 = 2;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);

const int dhtPin = A0;  // DHT22 signal pin

DHT dht(dhtPin, DHT22);  // Initialize DHT22 sensor

const float temperatureThreshold = 29.0; // Temperature threshold in
Celsius

const int buzzerPin = 7;
const int alertDuration = 500; // Duration of each tone in milliseconds

void setup() {
  lcd.begin(16, 2);  // Initialize the LCD display
  lcd.print("Temperature:");
  Serial.begin(9600);  // Initialize serial communication

  pinMode(buzzerPin, OUTPUT);
  digitalWrite(buzzerPin, LOW);

  dht.begin();
}

void loop() {
  float temperature = dht.readTemperature();  // Read temperature from
DHT22 sensor

  lcd.setCursor(0, 1);
  lcd.print("     ");  // Clear the previous temperature reading
  lcd.setCursor(0, 1);
  lcd.print(temperature, 1);
  lcd.print(" C");
```

```
  Serial.print("Temperature: ");
  Serial.print(temperature);
  Serial.println("°C");

  if (temperature > temperatureThreshold) {
    // Activate the alert system
    tone(buzzerPin, 1000, alertDuration);
    delay(alertDuration);
    tone(buzzerPin, 1200, alertDuration);
    delay(alertDuration);
    tone(buzzerPin, 1400, alertDuration);
    delay(alertDuration);
    noTone(buzzerPin);
  }

  delay(1000);
}
```