REMOVABLE PICNIC-TYPE COOLER BOX FOR TRAVEL THAT INTEGRATED WITH REFRIGERATOR

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Abstract

The industry-focused graduation project with Vestel Beyaz Eşya is the design and implementation of a cooler box that utilizes state of art phase change material technology, integrated into the fridge and has the characteristics of an environmentally friendly energy efficient cooling system. Phase change materials are used in a variety of fields in heating and cooling operations, due to their unique thermal energy storage properties. In literature there are many places where phase change materials are used in industry ranging from energy storage from renewable resources to household heating. There are also some examples of patents and solutions that utilize phase change materials however they are not in the same time fully integrated into the fridge as a cooling compartment, the project aims to design a cooling box that can function within the fridge and outside the fridge on its own. There are several important motivations for this project, the main is to create an environmentally friendly and energy efficient design by using phase change materials, another one is to implement phase change materials on a more daily life basis such as using them in a cooler box. There are several objectives of this project such as 10000 life cycles, around 5 hours of stable temperature that is the same as a refrigerators operating temperature (4-8 degrees Celsius), another objective and requirement of the project is to have it under 10 Euros to make the product competitive. The project has 6 main parts, the parts are as follows; literature and patent review, design, modelling, manufacturing, assembly and test, results and analysis.

Objectives

Given project requirements are:

I. The average temperature inside the box will be 5 C for at least 5 hours after leaving the refrigerator.

II. The expected service life is 1000 cycles.

III. The box should carry a total weight of 10 kilograms.

IV. The box must be designed for a refrigerator that dimensions of 183*70*72 cm (Vestel SN653)

V. This design/mechanism could work within the refrigerator temperature 4-8 C and ambient temperature of 25 C.

VI. Ease of assembly and accessibility for repair purposes are required.

VII. Safety precautions must be taken for users and for the designed assembly mechanism.

VIII. The design should be competitive. Therefore, we will support prototypes and cost mechanism for mass production should not exceed 10 € in order to be competitive.

Project Details

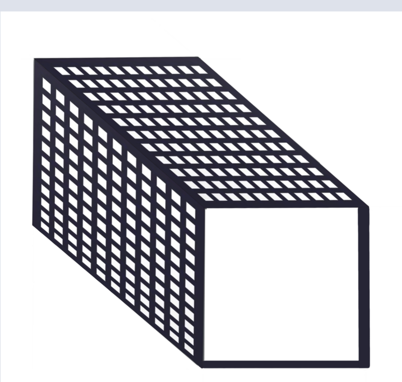

Fig 1: Grid Design

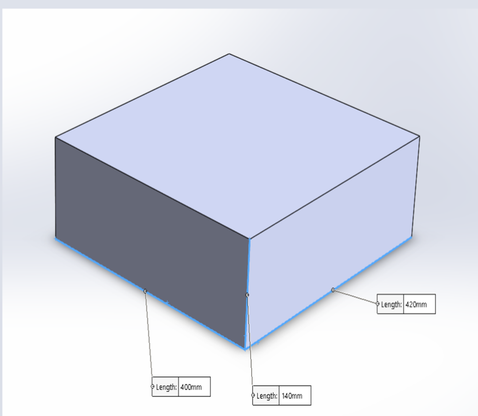

Fig 2: Basic Design

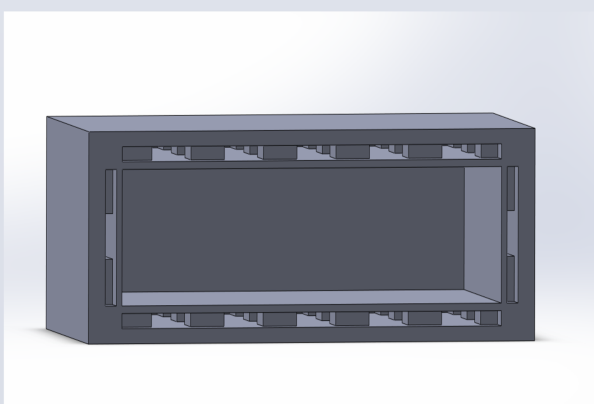

Fig 3: Dual box design

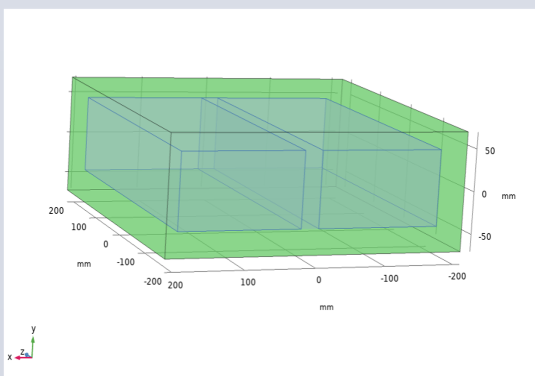

Fig 4: Dual box simulation

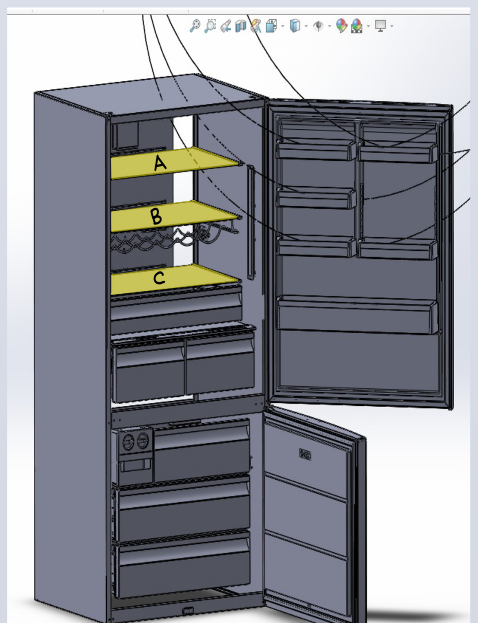

Fig 5: Placement of cooler box

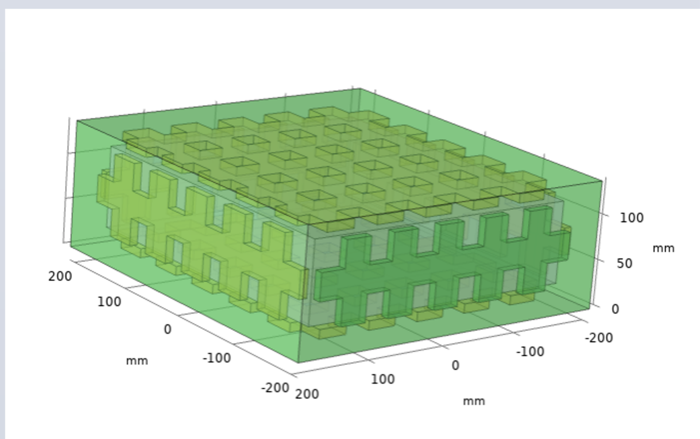

Fig 6: Grid design simulation

At the early stages of the project, significant literature and patent review was done, to grasp the idea of the concepts and the theories behind the cooler box with phase change materials. One of the most important parts of the project was finding and researching about phase change materials that fit the right criteria for the project, several parameters were taken into account; latent heat, phase change temperature (solid-liquid) and accessibility in terms of price and acquisition.From dozens of phase change materials and companies, we have deducted the list to 4 different types and analyzed the responses.

After this step, we've proceeded with customer surveys to help us with the designing process of the cooler box, as the product is intended to be mass produced and sold to customers. The survey had over 400 participants with around 130 of them finishing the questions. Results were analyzed and 3 different designs were made for the phase change material (PCM) layer, these were the normal PCM layer, dual box PCM layer and the grid PCM design. The designs were made using Solidworks program.

Project Details II

The table below shows the phase change materials to be simulated and their properties.

Parameter	BioPCM Q4	savE OM5	ATP 6	PureTemp 8
$T_{Transition}$	4 °C	5 °C	5 °C	8 °C
ΔT	1 K	1 K	1 K	1 K
Lm	230 kJ/kg	270 kJ/kg	275 kJ/kg	178 kJ/kg
T_0	2 °C	2 °C	2 °C	2 °C
T_{Room}	24 °C	24 °C	24 °C	24 °C
ρ_{solid}	1250 kg/m³	935 kg/m³	777 kg/m³	950 kg/m³
ρ_{liquid}	1300 kg/m³	835 kg/m³	740 kg/m³	860 kg/m³
K_{liquid}	2.5 W/m.K	0.146 W/m.K	0.2 W/m.K	0.22 W/m.K
K_{solid}	0.7 W/m.K	0.224 W/m.K	0.2 W/m.K	0.14 W/m.K
C_p	4.5 kJ/kg.K	3 kJ/kg*K	2 kJ/kg.K	2.15 kJ/kg.K
γ	1 [-]	1 [-]	1 [-]	1 [-]

Table 3. Phase change materials properties

Fig 7: Parameter table for the PCMs used

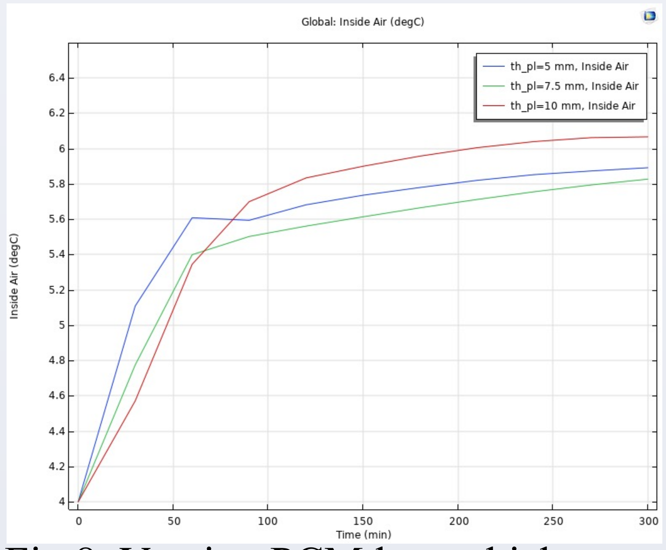

Fig 8: Varying PCM layer thicknesses

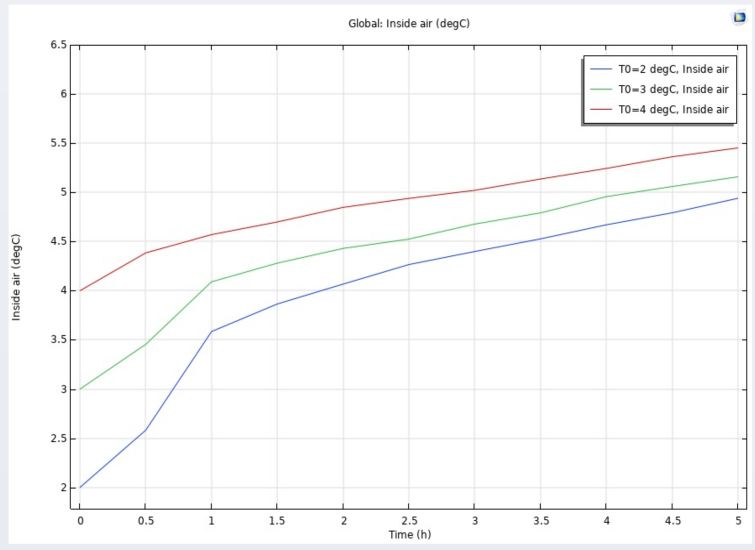

Fig 9: Different initial temperatures

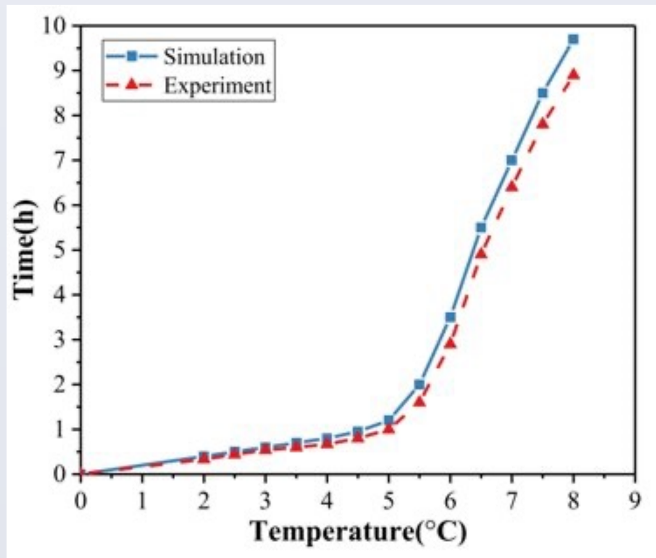

Fig 10: Results from the compared paper

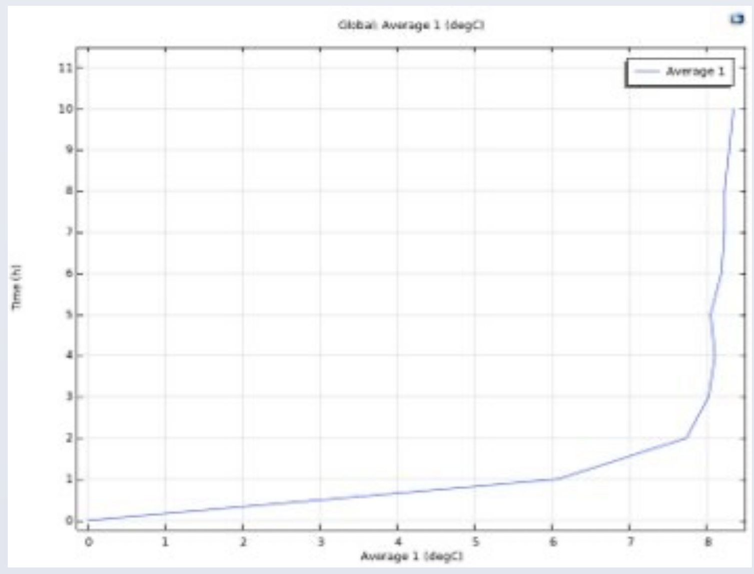

Fig 11: Simulation results of our design

After creating the 3 different designs for simulation purposes, we've used COMSOL to simulate the performance of the PCM materials that we have chosen with each design at different atmosphere and initial temperatures and varying PCM layer thickness. One of the objectives of the project was to create a cost effective design, thus it was one of the more important factors when it came to choosing the most efficient design method for the cooler box. Without the cost aspect, the dual box PCM layer design was the most effective however it used almost double the PCM material of the grid design, grid design also met the requirements for the project. It also had several advantages compared to the other 2 designs; by dividing into smaller compartments and filling PCMs, the amount of precipitation in phases transitions would affect the internal temperatures less. PCMs would also be less effected by temperature changes as they're more in contact with the insulation.

The analysis process needed a validation, comparing it to another scientific analysis and paper, and to replicate their results to see if our process and method was correct. As seen in the figures the validation was completed.

Conclusions

Ultimately, the grid design method was chosen from the analysis of the designs, from the PCMs, the most accessible one was the Axiotherm ATP 6, and this product was chosen to be used for the physical implementation and testing.

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