DESIGN OF CAR HEAT REMOVER BASED ON PRODUCT DESIGN AND DEVELOPMENT METHODOLOGY

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ABSTRACT: The greenhouse effect causes high temperatures inside the passenger cabin. The interior of a car can be much warmer than the outside air because when the sun hits the windshield the incoming shortwave radiation hits the windshield then passes through the windshield to come out as long wave (heat energy) radiation on the inside of the car. This long wave radiation is now trapped inside the car because the windshield will not allow the long wave radiation to escape back through the windshield and as a result heat builds up inside the car. Vehicle interior temperature increases after long hours under the sunlight. Conventional car heat removal device is under the hood, which is not significant to reduce the air temperature inside of car. This project presents the new design of car heat remover by applying Latent Energy Storage (LES). The benefits of this product are to control vehicle internal temperature and to protect the vehicle’s interior from damage due to high temperature. A car heat remover is a device designed for the purpose of reducing the surrounding high temperature to a cooler temperature in the interior of a vehicle. With the car heat remover, when the equilibrium state in the interior of the car is reached, the heat will be absorbed and the absorbed heat will then pass through the vents in the device and come in contact with a LES placed inside the device. The heat will then be condensed and converted to a cooler air and dissipate to the surrounding interior. As a result, a new design of car heat remover using latent energy storage was developed.

Keywords: Design, Car, Heat Remover, Latent Energy Storage, Prototyping.

1.0 INTRODUCTION

A car heat remover is a device designed for the purpose of reducing the surrounding high temperature to a cooler temperature in the interior of a vehicle. Most of the time, cars in the parking lot are exposed to the sun for a variation of time. Depending on how long the vehicle is static under the exposure of the sun, the longer the vehicle is exposed to the sun; the heat of the surrounding of the exterior of the car will eventually reach an equilibrium state with the heat in the interior of the car. Therefore, whenever a passenger enters a car which has been parked under the sun for long hours; they experience a hot sensation.
With the car heat remover, when the equilibrium state in the interior of the car is reached, the heat will be absorbed and the absorbed heat will then pass through the vents in the device and come in contact with a chiller placed inside the device. The heat will then be condensed and converted to a cooler air and dissipate to the surrounding interior. Therefore, the appropriate design of the car heat remover will be studied in this project and the position of the device will be determined as well. Besides that, the size of the car heat remover plays a crucial role as well as it determines the size of the chiller to be used and the amount of heat that can be stored in it.

Design for sustainability has been showed the extreme interest practice in building and home appliances because of its advantages in reducing the size and initial cost of cooling system, lower energy cost, reduce maintenance cost and increase life cycle. In recent years, researchers have viewed thermal energy storage used a material that changes phase, most commonly water and ice, and used temperature of material, most commonly water. Some techniques were introduces into the air cooling system to improve the coefficient of performance (COP) by reduced chiller energy consumption, lower horsepower, smaller pipes, better system balancing and control. The purpose of this practice is to ensure that the system chill a storage medium and then use that cold medium to cool air at a later point in time effectively. However, the temperature of thermal energy storage produced was not optimal due to uncertainty temperature condition. The application of design for sustainability faces various challenges in manufacturing. The most outstanding challenges to be resolved is to reduce the initial cost and increase coefficient of performance (COP) of product design based on design for sustainability methodology. The design of car heat remover needs to consider the high utility demand costs, high daily load variations, and infrequent or cyclical loads in automotive industries. In general, the effective applications of car heat remover based on design for sustainability methodology are shifting management the cooling load to off-peak hours reducing peak load of cooling system process in order to handle an increased load. Several experiments and investigations have been recently proposed in order to study the feasibility of using thermal energy storage (Dincer, I., Rosen, M.A., (2001), the latest thermal energy storage system of the shell-and-tube type during charging and discharging (Trp. A., (2005), and phase change materials (PCM), heat transfer and applications (Zalb, et al. 2003). However, these techniques were suitable applied only for large-scale building and home application.

Several techniques and mathematical models have attracted great interest recently due to their potential applications to improve the performance of thermal energy storage systems. There are many different methods proposed such as latent heat
thermal energy storage system of the shell-and-tube type by using paraffin in order to improve the Reynolds Number (Algun, et al., 2008), a control model (fuzzy logic controller) for operating a system that stores simultaneously sensible heat from solar and electric energy to maintain a comfortable thermal environment at all times (LeBraux, M., Lacroix, M., Lachiver, G., 2006), a solar cooker at constant temperature and variable electrical power for charging a thermal energy storage and developed a computer program for monitoring storage system (Mawire, MA. McPherson, M., (2008), a numerical method of a cold thermal energy storage system involving phase-change process dominated by heat conduction (Kayanan, N., Acar, M.A., 2006), and a fuzzy logic controller for operating a hybrid thermal energy storage system in order to remains robust and reliable (LeBraux, M., Lacroix, M., Lachiver, G., 2009). However, the behavior of thermal energy storage must be further studied in order to optimize the coefficient of performance of cooling system.

At the moment, none of the authors cited above have been designing of car heat remover using latent energy storage. The research was focused on investigation of design for sustainability in designing of car heat remover. The simulation was presented to represent the behavior of thermal energy storage system. As a result, rapid prototyping of car heat remover was developed.

2.0 METHODOLOGY

The Latent Energy Storage (LES) system will be applied on the car heat remover. The latent energy storage will be applied because in this storage system, it employs phase change materials, PCM; which is the chiller that will be used in the car heat remover. Besides that, the advantage of using latent energy storage is that the required storage size is small which is ideal for this research project as the car heat removers will be placed in the interior of the car.

Besides using latent energy storage, chillers will also be included in the car heat remover as the core cooling device. The function of the chiller is to reduce the temperature of the heat absorbed by the car heat remover when the car is exposed under direct sunlight. The absorbed heat will then be circulated through the chiller in the car heat remover. During the circulation, the chiller will play its role and cools the heat.

The mechanism used in the car heat remover is similar to the mechanism found in the chiller for the aquarium. There are various types of aquarium chiller to be found in the market and the price ranges from hundreds to thousands, depending on the
required functions by the users. Over the years, many have come up with DIY aquarium chiller where users are able to save money on making a chiller instead of buying a new one which is costly.

With the advancement of the technology, it has been made possible that we are able to store thermal energy as an alternative to energy usage in order to save natural resources, the fossil fuels. The thermal energy can be stored at temperatures that are lower than the environment and this process is known as cold storage (Atae, O.E. 2007). When ice thermal storage is applied, special ice-making equipment is used or selected chillers are employed for low-temperature duty. Normally, ice thermal storage is used for its potential to save operating cost. By applying cold storage, some companies are able to utilize less electricity and therefore reducing the operating cost. However, while ice thermal storage is able to reduce the operating cost, it also cost more capital investment than a conventional air conditioning system without ice thermal storage.

From Figure 1, the aquarium chiller is made from those recycled materials that are disposed or not usable anymore. The reference for the alphabets are ‘A’ = water in from pump, ‘B’ = chilled water return to pump, ‘C’ = freezer compartment with temperature probe attached to the inside wall of the cooling box, ‘D’ = coiled plastic tubing, and ‘E’ = refrigerator housing and inner plastic box.

Therefore, from the aquarium chiller, the car heat remover will also use the same mechanism. Instead of utilizing water, the car heat remover will utilize the natural energy, heat, and chiller. Once again, the heat will be absorbed and will be circulated in the car heat remover and the chiller will cool the temperature of the heat and the cooled heat will be dissipated to the interior of the car when the occupants enter. The figure below shows the mechanism of the car heat remover.

From the figure shown above, the arrows show the route of the heat circulation in the car heat remover. First, the heat will be absorbed from the interior of the car under direct sunlight. The heat will be absorbed into the car heat remover through
an inlet and will be directed to the chiller chamber. In the chiller chamber, the temperature of the heat will be reduced and the cooled heat will be directed to the inside of the car heat remover through an outlet. The heat will then be dissipated to the interior of the car through the outer chamber of the car heat remover. The design of car heat remover was generated as shown in Figure 2.

<table>
<thead>
<tr>
<th>Design 1</th>
<th>Design 2</th>
<th>Design 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1" alt="Design 1" /></td>
<td><img src="image2" alt="Design 2" /></td>
<td><img src="image3" alt="Design 3" /></td>
</tr>
</tbody>
</table>

Figure 2. Design concept of car heat remover

3.0 RESULTS AND DISCUSSION

The static pressure can be defined as the pressure exerted by a still liquid or gas, especially water or air (Frame, D.D. and Anderson, G.L., 2010). Based on Figure 5.1, it shows the comparison of static pressure between the different designs of the car heat remover. The author went on to explain that without the sufficient speed, cold air tends to fall downward. By referring to this statement made by (Frame et al., 2010), it can sufficiently explain the drastic change in static pressure at outlet 4 of design 2.

| (a) | (b) |
| ![Static Pressure](image4) | ![Dynamic Pressure](image5) |

Figure 3. (a) Static pressure, and (b) Dynamic pressure
From Figure 3 (a), it can be seen that design 1 and design 3 of the car heat remover have a more stable static pressure with the constant pressure the moment air enters the car heat remover. The phenomenon of the drastic change in outlet 4 of design 2 can be explained by referring to Figure 3 (b). Figure 3 (b) shows the dynamic pressure of design 1, 2 and 3 of the car heat remover. In the figure, both design 1 and design 2 of the car heat remover shows that dynamic pressure increases gradually while the dynamic pressure of design 3 decreases.

Figure 4 shows the velocity trajectories of air shows that only a number of outlets have moderate velocity of air flowing towards them, notably outlet 1, 2, 4 and 5. Other than that, the other outlets have close to none of slow velocity of air flowing towards them. Hence, the dynamic pressure of design 3 decreases gradually.

Figure 3 (b) shows the dynamic pressure of design 1, 2 and 3 of the car heat remover. In the figure, both design 1 and design 2 of the car heat remover shows that dynamic pressure increases gradually while the dynamic pressure of design 3 decreases.

![Figure 4](image)

**Figure 4.** (a) Velocity trajectories of air within car heat remover, (b) Velocity at outlet 1, 2, 4 and 5 of car heat remover design 3, and (c) Temperature flow trajectories in car heat remover design 2.

Dynamic pressure can be explained with the formula \( p = 0.5 \rho v^2 \), where \( p \) is the dynamic pressure measured in Pascals while \( \rho \) and \( v \) is the fluid density and fluid velocity respectively. In this case, the fluid referred to is the environment air that's absorbed into the car heat remover. Since the dynamic pressure is directly proportional to the velocity of air, therefore, when the velocity in the car heat remover increases, the dynamic pressure increases as well. In Figure 4 (b), the velocity trajectories of air shows that only a number of outlets have moderate velocity of air flowing towards them, notably outlet 1, 2, 4 and 5. Other than that, the other outlets have close to none of slow velocity of air flowing towards them. Hence, the dynamic pressure of design 3 decreases gradually.
The turbulent fluxes result meet the findings from other researcher (Mazzoni, et al., 1993), mentioned that the turbulent fluxes are usually derived from the temperature and the speed of wind. Therefore, by using the same concept, it can be used to explain the changes that are visible in the turbulent energy of design 1, 2 and 3 of the car heat remover. From Figure 5, design 2 of the car heat remover shows the most obvious changes in the turbulent energy with a drastic change at outlet 3 and outlet 6.

By referring to the Figure 4, the velocity trajectories show that there are air flowing through the outlet 3 and outlet 6 with the speed in the region of 0.12 m/s to 0.18 m/s. Since the turbulent energy is also related to the temperature of air, so, by referring to Figure 5, it shows that at outlet 3 and outlet 6 of the car heat remover design 2 the temperature is in the region of 293.755 K to 297.189 K.

On the other hand, Figure 5 also shows that amongst the three design of the car heat remover, design 3 of the car heat remover have the least turbulent energy where its value is close to zero. As shown in Figure 4, it is clear that there is few air flowing through the outlets of the design 3.

The concept screening method was used to make comparison between different concepts of the car heat remover in order to narrow the concepts quickly and to improve the concepts. Through the help of brainstorming, the attributes to help select the best concept for the car heat remover is generated and is shown in Table 1. Through the concept screening that was done, it was found that the concepts scored close to each other. Basically, the concept screening is to identify the major problem or the advantage of each concept and the choices made is not comprehensive; therefore, the concept scoring method is used to further increase the details of each concept in order to obtain a more accurate comparison of each concept.
Table 1 Concept screening matrix

<table>
<thead>
<tr>
<th>Weight Criteria</th>
<th>Design 1</th>
<th>Design 2</th>
<th>Design 3</th>
<th>Design 4</th>
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<tbody>
<tr>
<td>Feasibility</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Cost</td>
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<tr>
<td>Development</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Reliability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Reliability</td>
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<td>2</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Overall Score</td>
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<td>5</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 2 Concept scoring matrix

<table>
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<tr>
<th>Parameter</th>
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<th>Design 2</th>
<th>Design 3</th>
<th>Design 4</th>
</tr>
</thead>
<tbody>
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<td>Z</td>
<td>W</td>
</tr>
<tr>
<td>Weight</td>
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</tr>
<tr>
<td>Weight</td>
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<td>5</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Overall Score</td>
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<td>12</td>
<td>10</td>
<td>13</td>
</tr>
</tbody>
</table>

In concept scoring, a selection matrix was prepared similarly in the screening stage. The same selection criteria in screening stage were used in the scoring matrix and expanded on the original screening criteria with more detail. Based on the result of the scoring selection in Table 2, design 2 of the car heat remover acquires the highest score amongst the three designs. As a result, design 2 is the best and most suitable design among the designs generated in this research project. Therefore, design 2 was selected and will be implemented for the main design of the car heat remover in this research project. The prototype of design 2 of the car heat remover was built by using Fused Deposition Modeling of the rapid prototyping method as shown in Figure 6.

(a)

(b)

Figure 6. (a) Car heat Remover body produced using FDM, and (b) Isometric view of car heat remover
4.0 CONCLUSIONS

In this work, a design of car heat remover was developed using rapid prototyping. The design includes the application of latent energy storage. The product design and development of car heat remover was presented. Design 2 of car heat remover is selected. Parameters of the car heat remover include static pressure, dynamic pressure, turbulent energy, mass flow rate, velocity of air in the car heat remover, temperature of air and the temperature of the device itself was simulated using CAD software.

Based on the simulation and experiment results, the car heat remover showed when the equilibrium state in the interior of the car is reached, the heat will be absorbed and the absorbed heat will then pass through the vents in the device and come in contact with a LES placed inside the device. In addition, the design outlet contributes 12% of temperature decrease per cycle. Therefore, the design of car heat remover showed to control the interior vehicle significantly.

5.0 ACKNOWLEDGEMENT

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6.0 REFERENCES


