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Analyzed of Convection Heat Transfer in Cabin Car Equipped with Air Conditioner (AC) Using A Simple Method Assisted by Microsoft Excel

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Abstract

Visualization of heat flow often uses complex and challenging programs such as Matlab and Ansys Fluent with expensive licenses, and the operation is also difficult. This study aims to demonstrate the phenomenon of convection heat transfer in a simple way. The phenomenon of convection is fairly difficult, and the heat transfer process can cause misconceptions in students. An appropriate and easy-to-use method is needed in preparing for classroom learning. This study was conducted to review the air condition in the car cabin, which is influenced by airflow from the air conditioner, and visualize it. This visualization can be used to explain the phenomenon of heat transfer by convection to students, especially while cooling the car's air conditioner. This research was conducted using a car model with three rows of seats where the air conditioner is only on the front cabin dashboard. On the dashboard, the AC flows are located on the left, right, and center. The calculation is carried out by applying the Black Principle, where other particles around it influence the particle temperature. Microsoft Excel is used to perform mathematical operations and visualize the results in graphs. It successfully delivers a 2D image showing heat distribution in the car cabin space. Visualization of this convection phenomenon can provide an overview of the convection flow phenomenon. So, this method is very easy to operate and apply by teachers in preparing lessons on the phenomenon of temperature convection.

Keywords: *Convection, heat, simple, car, cabin, excel*

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INTRODUCTION

Thermodynamics is a crucial learning topic for students to learn. However, thermodynamics is challenging to study because the concept is primarily microscopic, so it is difficult to describe. One of the thermodynamic phenomena is the flow of temperature in a fluid (Cascetta & Musto, 2007). Thermal flow is one of the concepts that are quite difficult to learn, so it causes many misconceptions in students. In this topic, students will learn how heat flow occurs, namely convection flow (Giri & Tripathi, 2018). Convection is a heat flow where heat flows along with the intermediary media, and convection flow only occurs in fluid materials (gas and liquids) (Konstantinov et al., 2014).

The case study in this study is the phenomenon of convection flow that occurs in the cabin of a passenger car vehicle. This phenomenon needs to be studied because it is related to the convection phenomenon with passenger comfort in the car (Gach et al., 1997). Simulation of airflow in the passenger cabin is becoming increasingly important as a complement to wind tunnel testing and field testing in helping to achieve increased thermal comfort while reducing vehicle

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development time and costs (Warey et al., 2021). Thermal analysis of the passenger compartment involves geometric complexity and strong interaction between airflow and the three forms of heat transfer, namely conduction, convection, and radiation. In addition, the need to reduce the heat load on the passenger cabin has become an essential issue in the early stages of vehicle design (Kristanto & Leephakpreeda, 2017).

The energy balance equation can describe the heat flow in the vehicle cabin under steady conditions (Mboreha et al., 2021). This equation is used to calculate the thermodynamic interaction between interior temperature, atmospheric temperature, and interior airflow. A simulation was also developed to determine the steady heat load in the cabin (Ibrahim & Mehta, 2018). The heat load includes solar radiation through the glass, conduction through the cabin body wall, and the heat load on passengers and equipment in the car (Muhammad et al., 2018).

According to the American Society of Heating Refrigeration and Air Conditioning Engineers (Chen et al., 2019), thermal comfort is defined as a condition of the human mind that shows satisfaction with its thermal environment. Thermal comfort was created to achieve the human desire to feel thermally comfortable (Yigit, 2005). Comfort is closely related to heat balance. Heat balance means that the rate of heat produced by our body is equal to the rate of heat lost from our body. Thermoregulator is our body's control system that regulates the balance of this heat input and output (Munahar et al., 2022).

The most challenging part of the simulation is getting good visualization results. Visualization requires special software (e.g., Matlab or others) with good programming skills. Therefore, this study provides an easy alternative solution to assist teachers in providing visualization of heat transfer, namely convection. Visualization will be done using Microsoft Excel.

Microsoft Excel, a number processing program, has a feature to condition the cells in it. Cells can be formatted to represent specific colors according to the values contained in the cells. Microsoft Excel can describe heat transfer in the convection process based on this feature. With this feature, teachers do not require special skills and are easy to operate. In the future, this feature can be developed for use in other physics topics, especially in the case of thermals, not only in lectures but also in schools.

LITERATURE REVIEW

Convection Heat Transfer, Convection occurs when a flow or fluid (gas or liquid) carries heat along with the flow of matter. Fluid flow can occur due to external processes, such as gravity or buoyancy, due to thermal energy expanding the volume of the fluid. Forced convection occurs when a fluid is forced to flow using a pump, fan, or other mechanical means (Vale et al., 2021). Heat is energy that moves due to temperature differences, where heat moves from high-temperature areas to low-temperature areas. Every object has an internal energy associated with the random motion of its constituent atoms or molecules. This internal energy is directly proportional to the temperature of the object. When two objects with different temperatures are close together, they will exchange internal energy until the temperatures of the two objects are balanced (Fujita et al., 2001).

Convection is the transfer of heat between solid surfaces adjacent to a flowing fluid, and the fluid can be either a liquid or a gas. The main requirement of the convection heat transfer mechanism is the presence of fluid flow. Convection naturally occurs due to temperature differences; the density of the fluid will be different so that the fluid with a higher temperature becomes lighter (Xiang & Wang, 2010). As a result, the fluid will flow by itself or without an external force. Meanwhile, forced convection occurs when the fluid as a heat transfer medium is forced to flow, for example, by using a fan or pump.

Two processes can cause fluid motion. Fluids can move due to differences in density caused by differences in temperature within the fluid (Chien et al., 2008). This mechanism is called free convection or natural convection. Examples of free convection are air movement in the desert on a calm day after sunset. We are talking about forced convection, when some external energy, such as a pump or fan, causes the motion. An example is cooling a car radiator with air blown across it by a fan (Lethwala & Garg, 2017). The total heat transfer rate for any time in the convection process is equal to the exposed surface area, which contacts the liquid in the temperature difference as follows in Equation (1).

$$\boldsymbol{Q = hA\Delta T} \qquad (1)$$

where,
Q = heat transfer rate (J s−1)
h = convection heat-transfer coefficient (W m−2 K−1)
A = exposed surface area (m^2)
ΔT = temperature difference (K)

RESEARCH METHOD

The thermal convection process will be visualized in this study using Microsoft Excel. The data is obtained from the temperature in the car room directly and numerically. Furthermore, the visualization will be displayed in the form of 2D images.

In the first stage, the selection of vehicles that will be calculated is the type of passenger vehicle with three rows of seats. The vehicle is equipped with vehicle cooling (AC) located in the dashboard's center, right, and left. The type of car air conditioner cooling is ac cooled with one blower. The dimensions of the car cabin that will be observed are the sizes of public transportation in Indonesia: L x W x H is 3100 x 1200 x 1000 mm.

The first data is the temperature of the vehicle cabin wall. The data is obtained by measuring the temperature of the walls of the car cabin as a whole. The car cabin wall temperature is measured using a digital thermometer (Thermo gun). The temperature measurement follows the following rules, the temperature measurement rotates counterclockwise. The wall of the car is divided into four parts, the front, the back, the left, and the right. Measurement starts from the front of the cabin, then the left cabin wall continues to the rear cabin, and finally, the right wall measurement is shown in Figure 1. To make it easier to measure temperature, the car wall is further divided into several parts with dimensions of 15 x 15 cm2. The temperature of the passenger seat is not measured because the seat will be considered an object that hinders the rate of heat transfer by convection. The seat will be made to neither receive nor dissipate heat.

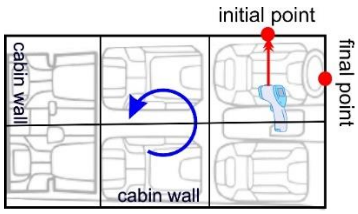


Figure 1. The process of measuring the cabin wall temperature

After data on the temperature of the walls of the vehicle cabin is obtained, the cabin wall temperature data is used as input data in performing numerical calculations to determine the temperature of the air inside the cabin. The area in the cabin is divided into grids represented by Microsoft Excel cells. This cell will have the air temperature value due to convection heat transfer. The cell value is obtained by applying the black principle, which states that the air temperature is affected by the air temperature around it. Heat transfer will stop after reaching thermal equilibrium. Because the object, in this case, is air, then the thermal equilibrium will be achieved influenced by the temperature value around it, so its value can be calculated using Equation (2).

$$T_e = \frac{\sum_{i=1}^{n=8} T_i}{n} \qquad (2)$$

Then, Equation (2) is calculated by Excel using the solver feature so that the temperature values in other cells can be known. The value of each cell will represent the value of the room temperature in the cabin, and then it will be visualized with the cell format feature in Excel.

FINDINGS AND DISCUSSION

Based on the results of calculations and visualization, the results of convection heat distribution in the car cabin have been obtained. By using Microsoft Excel, 2-dimensional visualization is obtained. Using Equation 2, the temperature value in each cell of Microsoft Excel is obtained. The cell value is used to represent the temperature in color. The cell changes color according to its value using the cell format menu shown in Figure 2. By giving color to the data, the distribution of heat in each area in the car cabin can be seen clearly. The area in red indicates a higher temperature than the green area, as shown in Figure 3.

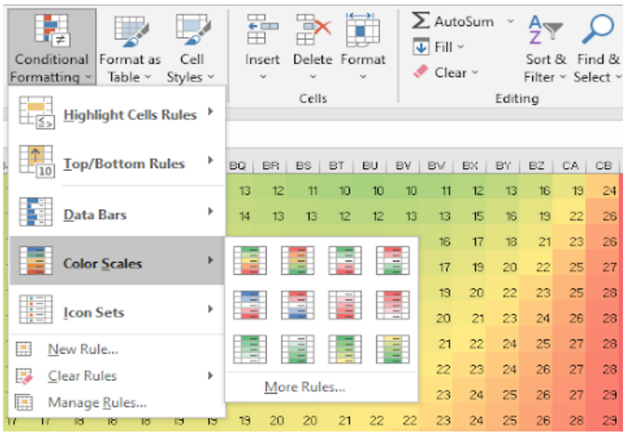
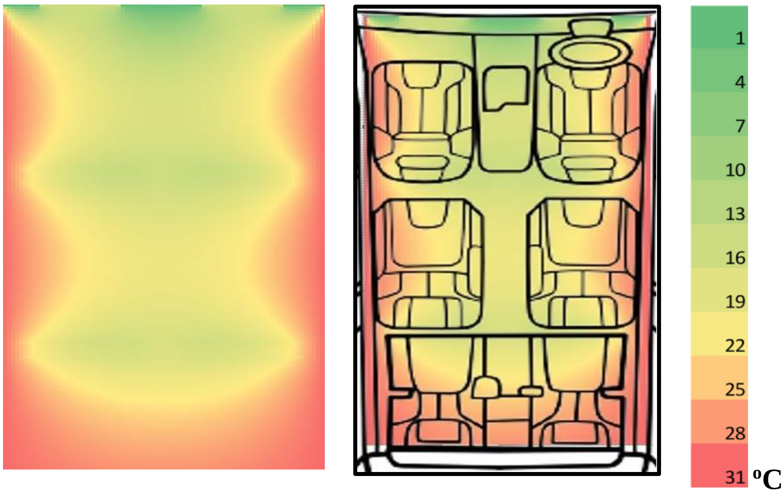


Figure 2. Cell color settings in Microsoft Excel

The area covered in Figure 3 is adjusted to the layout of the seats in the car cabin, as shown in Figure 3a. From Figure 3b, it can be seen that the back of the chair has a lower temperature because the airflow from the AC hits the wall of the chair more often. The further behind the seat position, the air temperature in the car cabin gets hotter; this happens because the AC airflow from the front of the cabin is not optimal until the seat in front blocks the back seat. This is also due to the heavy flow of cold temperatures falling on the front first (Mohiuddin et al., 2019). Regarding comfort, areas with low air temperatures will make the driver more comfortable in the car. The passenger in the front row seats is the most comfortable area, and if you go back, it will get hotter (Elarusi et al., 2017).



(a) (b)

Figure 3. (a) Visualization results of convection heat transfer in the car cabin using Microsoft Excel (b) overlaying the visualization results with a car cabin plan

After the visualization is obtained, it can simply be used in explaining to students about the convection heat transfer that occurs in the car. It is expected that student's understanding of the phenomenon of convection heat transfer will increase. Teachers will also find it easier to provide explanations related to the topic of convection to students that should be clear and concise. Discussion should explore and elaborate on the significance of the results of the work, not repeat them. Avoid extensive citations and discussion of published literature (Ramadhan, 2019).

CONCLUSION AND FURTHER RESEARCH

The phenomenon of convection heat flow in the car cabin has been successfully visualized in 2D. The method of calculating air temperature and its visualization using Microsoft Excel can be an alternative method that is easy to operate and apply by lecturers in conveying the phenomenon of heat transfer by convection. From the results obtained, it can be seen that passengers sitting at the very front will feel comfortable because the cabin air temperature is cooler than the seats at the back.

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