Optimization of Air Conditioner (AC) Use on a Room with Finite Element Method

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Article Info

ABSTRACT

The process of working Air Conditioner (AC) in the cooling of a room is a process of heat transfer. This study aims to find out how the distribution of temperature in a room contained AC in it which is solved by implementing the finite element method on the energy transfer equation which is the differential equation used for heat transfer. In the finite element method, the flow field is broken down into a set of small fluid elements (domain discretization). In this study the researcher describes the space in three-dimensional space (3D), then selected linear interpolation function for 3D element, and decreases the matrix and vector elements by Galerkin method to obtain Global equation. Results from computer-assisted studies show the temperature distribution in the room.

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1. INTRODUCTION

Changes in the era of globalization have an impact on the development of science and technology, where the discovery of increasingly sophisticated technological tools to provide comfort for humans. Knowledge about the function of air cooling is growing rapidly[1]. People not only use cooling systems to preserve food, but also for air conditioning, namely Air Conditioner (AC)[2].

AC is a tool that can function to condition the air by controlling the temperature of the air in a certain room. AC changes the state of hot air temperature to cold air in a room to be more comfortable[3]. This tool can perform its function as a cooling device because in the air conditioner there are many components, both mechanical and electrical, which require a large enough energy source.

In the process of changing hot air to cold air, AC has a way of working. According to Sharafian, at all [4] how AC works, namely, refrigerants (fluids that absorb heat, usually Freon) are
pressurized by the compressor in the cooling engine system. As a result of cooling in the condenser the refrigerant is pressurized to melt and through the capillary tube flows to the evaporator[5]. In the evaporator, the refrigerant undergoes a "trotling" process, which is a phase change from liquid to gas, causing the area around the evaporator to cool. Then the gas in the form of cold steam is circulated into the room with the help of a circulation fan so that the room temperature drops. The refrigerant gas that is formed due to the absorption is then flowed into the compressor using the compressor's suction and then compressed again following the initial cycle, or in other words, AC is only an electronic device that regulates air circulation in the room[6]. The inhaled air is circulated continuously by the circulation fan (blower) through the evaporator fins. As it passes through the evaporator, air which is at a higher temperature than the evaporator is absorbed by the coolant, then released outside the room when the refrigerant flows through the condenser[7]. So, the low or cold air temperature that is felt in the room is actually the result of circulating air that is released by the evaporator. AC is only an electronic device that regulates air circulation in the room[8]. The inhaled air is circulated continuously by the circulation fan (blower) through the evaporator fins[9]. As it passes through the evaporator, air which is at a higher temperature than the evaporator is absorbed by the coolant, then released outside the room when the refrigerant flows through the condenser[10]. So, the low or cold air temperature that is felt in the room is actually the result of circulating air that is released by the evaporator. AC is only an electronic device that regulates air circulation in the room. The inhaled air is circulated continuously by the circulation fan (blower) through the evaporator fins[10]. As it passes through the evaporator, air which is at a higher temperature than the evaporator is absorbed by the coolant, then released outside the room when the refrigerant flows through the condenser[7]. So, the low or cold air temperature that is felt in the room is actually the result of circulating air that is released by the evaporator. Then it is released outdoors when the refrigerant flows through the condenser[11]. So, the low or cold air temperature that is felt in the room is actually the result of circulating air that is released by the evaporator. Not the air produced by the AC device. So, the low or cold air temperature that is felt in the room is actually the result of circulating air that is released by the evaporator. Not the air produced by the AC device. The AC unit is only a place for air to circulate which at the same time captures heat (heat) in the room air until it reaches the desired temperature.

2. **RESEARCH METHODOLOGY**

2.1 **Analysis Stages**

a. **Differential Equations for Energy Transfer**

For the comfort of a particular room, a heat transfer model is used whose basic global theory includes parameters, settings of heat conduction, convection and radiation from the surface to the environment[14][15]. Radiation to the surface is used the luminous by diffuse and shadow reflection method[6]. In the heat transfer process of a fluid, energy transfer occurs. Convection heat transfer is associated with the exchange of energy between a surface and a nearby fluid[17]. Most of the important energy transfer situations to some extent always involve the movement of fluids[18]. The following is the Energy Transfer Equation:

\[ \nabla \cdot (-k \nabla T) + \rho C_p u \cdot \nabla T = q \]

Where, \( q \), \( \rho \), \( C_p \), \( \nabla T \) respectively represent the heat source, density, constant pressure capacity and temperature gradient.

b. **Turbulent indoor flow**

Turbulent and incompressible flow model equations are as follows[19].

\[ \rho (u \cdot \nabla) u = \nabla \left[ -p I + (\mu + \mu_T)(\nabla u + (\nabla u)^T) \right] + F \]

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Where $\mu_T$ is the turbulent viscosity, $\mu$ is dynamic viscosity, $p$ is pressure, $I$ is the logarithm of the turbulent dissipation rate.

c. **Domain Settings section**
The types of materials used are taken from the inbuilt material library in COMSOL Multiphysics 5.0[20]. The material used for both domains is air, the material for the walls of the brick room, and the material for humans is skin. The domain portion of air is identified and assigned the properties of air.

2.2 **Model Simulation with COMSOL Multiphysics**
COMSOL Multiphysics is a software for finite element analysis. In this study, the temperature distribution of the room in which there is an air conditioner as an inlet (cold air entry) will be seen, the room is conditioned to have ventilation as an outlet (air discharge), and in the room suppose there is a human being[21][22][23].

![Figure 1. Model Simulation[22]](image)

3. **RESULT AND DISCUSSION**

3.1 **Simulation Using COMSOL Multiphysics**
COMSOL is a finite element simulation software, which can simulate basically anything you want: simulating heat transfer through complex structures, photonic crystals at the nanoscale, beam mechanical bending, fluid flow, electrochemical processes, plasma physics and much more. COMSOL Multiphysics 5.0 represents a significant expansion of software applications, features and functions[24]. Version 5.0 empowers current users to do more with simulated environments, while new industries will now be able to take advantage of simulated multiphysics innovations[25].

a. **Room Geometry Shapes with COMSOL Multiphysics**
In this modeling, conditioning a room in the shape of a block with a size of 4x3x4 in meters, in the room there are two air conditioners which are the inlet of a rectangular geometry measuring 0.05x0.6 in meters, and a rectangular outlet measuring 0.5x0.5 in meters. and there is a human being in the room, for example, in the form of a block. The temperature in the conditioned room is 309 K, the human temperature in the room is 307 K, and the air conditioner temperature is 293 K.

b. **AC Optimization Parameters and Properties with COMSOL Multiphysics**

| PARAMETER | Name | Expression | Score | Description |
|-----------|------|------------|-------|-------------|
|           | $T_h$ | 36 [degC]  | 309.15 K | Human body temperature |
|           | $T_{amb}$ | 34 [degC]  | 307.15 K | Room temperature |
|           | $T_{source}$ | 17 [degC]  | 290.15 K | Air Conditioner Temperature |
|           | $T_{av}$ | $(T_{amb} + T_h + T_{source}) / 3$ | 302.15 K | Average temperature |
|           | $u_{in}$ | 0.3 [m / s] | 0.3 m / s | Air speed |
|           | $W_R$ | 4 [m]  | 4m | Width Room |
|           | $D_R$ | 3 [m]  | 3m | Depth Room |
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PARAMETER

| Name | Expression | Score | Description          |
|------|------------|-------|----------------------|
| H_R  | 4 [m]      | 4 m   | Height Room          |
| W_AC | 60 [cm]    | 0.6 m | Air Conditioner Width|
| L_AC | 5 [cm]     | 0.05 m| Air Conditioner Length|
| S_ot | 50 [cm]    | 0.5 m | Side Outlet          |

c. AC Optimization Materials with COMSOL Multiphysics

In AC optimization with COMSOL Multiphysics, Water is used with the following properties:

Table 2. AC Optimization Properties

| Property                              | Score |
|---------------------------------------|-------|
| Density                               | 1,127 Kg / m³ |
| Dynamic Viscosity                     | 1,983×10⁻⁵ Pa.s |
| Heat capacity constant pressure       | 1,005 J / (kg. K) |
| Thermal conductivity                  | 0.0271 W (mK) |

d. AC Optimization Mesh with COMSOL Multiphysics

With the above parameter data, a mesh is modeled and drawn for the AC optimization room with COMSOL.

Table 3. Mesh statistics for AC rooms

| Property                                      | Score |
|-----------------------------------------------|-------|
| The maximum size of the element               | 0.4   |
| Minimum element size                          | 0.07  |
| Average maximum element                       | 1.5   |
| Curvature factor                              | 0.6   |
| The resolution of the narrow section          | 0.5   |

The following is a mesh image of the room in AC optimization

Figure 2. Room Mesh

e. Temperature Distribution

The following is a picture of the temperature distribution in a room that has two air conditioners in it.
Figure 3. Curve relationship between temperature and curvature length

Room temperature distribution with an inlet temperature of 16°C shows the room temperature near the air conditioner is dark blue, the temperature is cooler with a temperature below 20°C. The room temperature has an average light blue color whose temperature ranges from 24-26°C. The temperature on the surface of the room is redder which indicates the temperature is hotter than the room temperature ranging from 30-32°C due to solar radiation to the room surface.

Room temperature distribution with an inlet temperature of 17°C shows the room temperature near the air conditioner is dark blue, the temperature is cooler with a temperature below 20°C. The average room temperature is bright blue with a temperature of 26°C. The temperature on the surface of the room is redder which indicates the temperature is hotter than the room temperature ranging from 30-32°C due to solar radiation to the room surface.

Room temperature distribution with an inlet temperature of 18°C shows the room temperature near the air conditioner is dark blue so that the temperature is cooler with temperatures below 20°C. The room temperature has an average yellow color whose temperature ranges from 26-28°C. The temperature on the surface of the room is redder which indicates the temperature is hotter than the room temperature ranging from 30-32°C due to solar radiation to the room surface.

Room temperature distribution with an inlet temperature of 20°C shows the room temperature near the air conditioner is dark blue so that the temperature is cooler with a temperature below 20°C. The average room temperature is green, where the temperature ranges from 28-30°C. The temperature on the surface of the room is redder which indicates the temperature is hotter than the room temperature ranging from 32-34°C due to solar radiation to the room surface.

4. CONCLUSION

From the simulation results with COMSOL shows that there is a relationship between the inlet temperature (AC initial temperature) and the optimal temperature in the room. The inlet temperature of 20°C is more optimal than 16°C, 17°C and 18°C with room temperature of 28-30°C.
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