HVAC Cooling Load Analysis and Optimization

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Febuary 2025

1 Introduction

Heating, Ventilation, and Air Conditioning (HVAC) systems play a crucial role in maintaining indoor thermal comfort. This project focuses on calculating the cooling load using fundamental heat transfer principles and optimizing insulation to enhance efficiency.

2 Physics and Formulations

The total cooling load is calculated based on the following contributions:

2.1 Conduction Heat Transfer

Heat transfer through walls is modeled using Fourier's Law:

$$Q_{\text{conduction}} = \frac{kA\Delta T}{d} \tag{1}$$

where:

- k is the thermal conductivity (W/m•K),
- A is the wall area (m^2),
- ΔT is the temperature difference (K),
- d is the wall thickness (m).

2.2 Ventilation Load

The energy required to cool the incoming fresh air is given by:

$$Q_{\text{ventilation}} = \dot{m}C_p\Delta T \tag{2}$$

where:

- $\dot{m}$ is the mass flow rate of air (kg/s),
- C_p is the specific heat capacity of air ($kJ/kg \cdot K$).

2.3 Solar Heat Gain

Heat gain through windows due to solar radiation is calculated as:

$$Q_{\text{solar}} = A_{\text{window}} \times SHGC \times I_{\text{solar}} \tag{3}$$

where:

- A_{window} is the window area (m^2),
- $SHGC$ is the Solar Heat Gain Coefficient,
- I_{solar} is the incident solar radiation (W/m^2).

2.4 Total Cooling Load

The total cooling load is the sum of all contributions:

$$Q_{\text{total}} = Q_{\text{conduction}} + Q_{\text{ventilation}} + Q_{\text{solar}} + Q_{\text{internal}} \tag{4}$$

3 Implementation in Python

The calculations are implemented in Python, with visualization using Matplotlib. The script computes individual loads and optimizes insulation thickness for energy efficiency.

4 Input Parameters

- $C_{p,air} = 1.005\frac{kJ}{kg.K}$
- $\rho_a ir = 1.2\frac{kg}{m^3}$
- $L_{room} = 5\ m$
- $W_{room} = 4\ m$
- $H_{room} = 3\ m$
- $T_{indoor} = 22^{\cdot}\ C$
- $T_{outdoor} = 35^{\cdot}\ C$
- SHGC = 0.7
- $I_{solar} = 500\ \frac{W}{m^2}$
- $t_{wall} = 0.2\ m$
- $k_{wall} = 1.2\ \frac{W}{m.K}$

5 Results and Discussion

The analysis provides insights into major heat contributors and suggests insulation improvements to reduce cooling load requirements. The results are shown below in Fig 1 and 2:

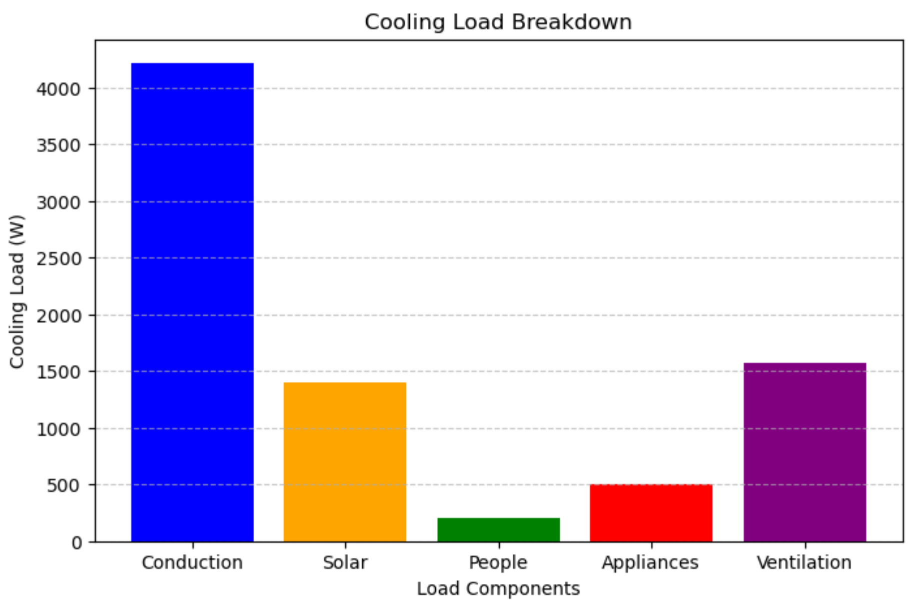

Figure 1: Cooling load for different components

6 Conclusion

This project demonstrates the application of thermodynamics and heat transfer principles to HVAC system design, with potential real-world energy savings.

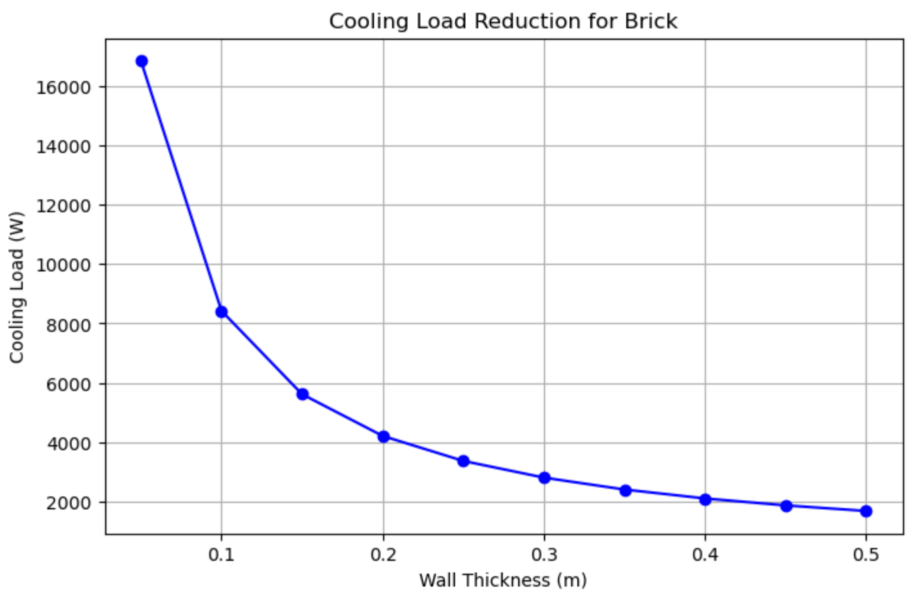

Figure 2: Cooling load along the varying thickness of wall