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The Heat Transfer Rate of Composite Wall with Series and Parallel Configuration

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ABSTRACT

Insulation serves as a barrier to heat transfer and is therefore crucial for keeping your home warm in the winter and cool in the summer months. A well-insulated and well-designed home delivers year-round comfort while reducing cooling and heating expenditures by as much as 50%, depending on the climate. It follows that greenhouse gas emissions will be reduced as a result. The R-value of the products available can be used to compare the insulating properties of the many options available. The R-value is a measurement of heat flow resistance. When it comes to insulation, the higher the R-value, the greater the level of protection. The strategy for arranging insulating layers in its application influences the rate of heat transfer as well. The value of heat flow/heat transfer rate can be used to determine how much energy is propagated down the insulating wall and how quickly it does so. By using the ANSYS software and the Steady State analysis approach, this study seeks to provide an overview of how much influence the configuration system for installing an insulating wall layer. From the results of the simulation, it can be concluded that the heat transfer rate is lower when the insulating layer installation systems are placed in series than when they are attached in parallel.

Keywords: *Insulation, Heat transfer, ANSYS, Wall, Energy.*

1. INTRODUCTION

A comfortable environment required by people for their activities, especially in terms of temperature. For that reason, thermal comfort becomes a key factor in designing and constructing a building as a place for activities, especially a house as a place for everyday life. In general, the process of creating building comfort cannot be separated from efforts to limit the influence of outside temperature on the building. The hot temperature from outside is the most difficult problem to solve in tropical countries so that it does not affect the indoor temperature. For a country with four seasons, the challenge becomes a little more complex because building performance in winter must also be able to withstand heat (warm temperatures) inside the building without being easily lost. Heat losses from buildings mostly occur from external walls, ceiling, windows, and basement and by infiltration [1]. As a response, a well-designed building insulation system is required to assist in achieving thermal comfort in buildings.

Insulation serves as a barrier to heat transfer and is therefore crucial for keeping your home warm in the

winter and cool in the summer months [2]. Not only building material for wall that can be used as insulation, even a green wall of plants on the exterior of a building can serve as an additional layer of insulation, lowering the temperature outside the building before it enters [3]. A well-insulated and well-designed home delivers year-round comfort while reducing cooling and heating expenditures, depending on the climate [4]. It follows that greenhouse gas emissions will be reduced as a result. Building insulation systems itself are often made up of several different types of materials. These materials are then called composites. The term "composite" refers to a material made up of at least two materials (either independent phases or combinations of phases) that are linked together at the interface and each of which derives from a separate elements material that existed prior to the composite [5]. The greater the thickness of the thermal insulation, the lower the cooling and heating loads of the building and the greater the energy savings benefit. However, increasing the thickness of thermal insulation can result in an increase in investment costs. Previous research discovered the optimal thickness of a building material by performing a

calculation using the thermal conductivity value [6]. As a result, the thickness of thermal insulation should be determined by both the energy savings and the investment cost [7].

Insulating a building requires an understanding of how heat is transferred between different components of the structure. Later, this heat transfer will play a significant role in deciding how efficient the building is when it comes to heating and cooling it. Heat transfer, in general, refers to the movement of heat (thermal energy) caused by temperature differences, as well as the following temperature distribution and changes. Transport phenomena are concerned with the transfer of momentum, energy, and mass via conduction, convection, and radiation. These three are also known as heat transfer modes. And, regardless of the mode of heat transfer, there is both steady-state and transient heat transfer. The temperature in steady-state heat transfer remains constant throughout time, whereas the temperature in transient heat transfer fluctuates. Mathematical formulas can be used to describe these processes. Even today, a variety of software is available to assist the calculation process by providing more visual displays that make reading and providing information easier to generate.

This study aims to provide an overview of how much influence the configuration system has on the installation of an insulating wall layer by using ANSYS software and the steady state analysis approach [8]. It is possible to assess how quickly and how much energy is transferred down the insulating wall by using the value of heat flow or heat transfer rate. This study will compare walls that have an insulating layer in series and parallel configurations.

2. METHODS

ANSYS Workbench software will be used to figure out the heat transfer rate in steady-state conditions. Fourier's law will then be used to validate that the software is correct. Then, a comparison will be made between the wall insulation configurations in series and parallel. Prior to beginning the computation simulation in ANSYS, several stages were completed. To begin, a geometry for the walls – series and parallel (modeling) – is created depending on the intended size. The following step is to apply the building material properties to the wall layer, in this case differentiating the material type based on its thermal conductivity value. Table 1 describes the type of material used and the dimensions (volume) of the wall. Fig. 1 and Fig. 2 shows the model for series and parallel configuration, respectively.

The temperature settings on the outside and inside the wall that represents the temperature outside and inside the room. The temperature of the outer and inner walls is adjusted to 20 degrees Celsius and 220 degrees

Celsius, respectively. Additionally, for heat flow to occur, a convection value must be placed in one area, either inside or outside the wall, or both. A value of 10 has been set for the convection as the heat transfer coefficient or film coefficient in the area on the outside wall. The temperature setting on the inside of the wall was set much higher than the temperature on the outside of the wall to provide information on significant changes.

Table 1. Details of wall insulation

Identity of the Wall	Area (m)	Width (m)	Thermal Conductivity (W/mC)
Inner wall	1 x 1	0.1	0.8
Outer wall	1 x 1	0.1	50
Insulation A (series)	1 x 1	0.05	0.01
Insulation A (parallel)	1 x 0.5	0.1	
Insulation B (series)	1 x 1	0.05	0.05
Insulation B (parallel)	1 x 0.5	0.1	

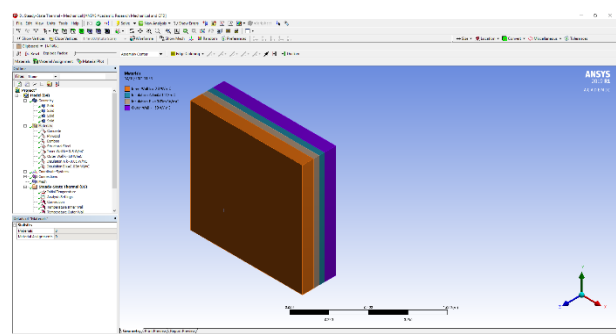


Figure 1 Wall insulation with series configuration.

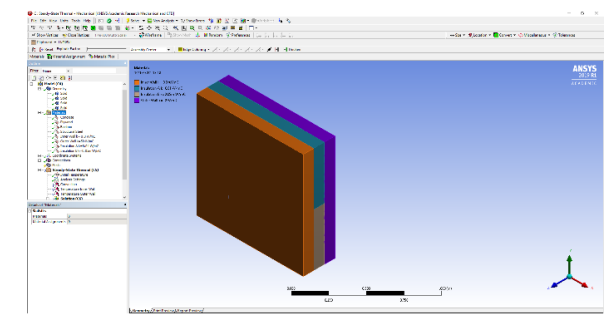


Figure 2 Wall insulation with parallel configuration.

3. RESULTS AND DISCUSSION

The results of the ANSYS Workbench simulation demonstrate the amount of temperature that happens in each section of the wall, as well as the value of heat flow. The term "heat flux" refers to the rate at which heat energy is transferred through the surface of a material in a defined area. It is expressed in Watts per square meter (W/m^2). Because the wall area in the

simulation is 1x1 meter, this Heat Flux value is equivalent to the heat transfer value given in watts (W), which indicates the amount of energy transferred as heat on the wall.

3.1. Insulation Layer with Series Configuration

The temperature distribution is depicted in Fig. 3 by the ANSYS software calculation results for the series configuration wall. The surface temperature of the inner and outer walls is the same. The average temperature passing on the wall is 131.29 °C.

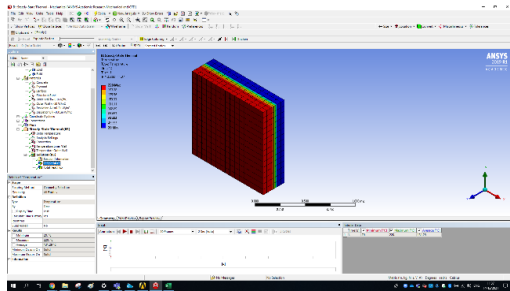


Figure 3 Temperature on wall with series configuration.

The series configuration of the insulation layer resulted in more consistent heat transfer. These were demonstrated by the ANSYS software's consistent appearance, which is blue (Fig. 4) and has a Heat Flux value of 32,642 W/m².

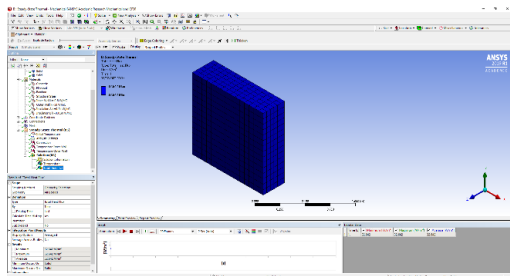


Figure 4 Heat flux value at wall with series configuration.

3.2. Validation

To ensure that the simulation and analysis process adheres to the well-established concept of heat transfer, the value must be validated using Fourier's law. The following formula (equation (1)) was used to validate the above value:

$$Q = -k.A.\frac{dT}{dx} \dots\dots\dots (1)$$

Whereas:

Q= heat transfer rate (W)

k = thermal conductivity of wall or insulation (W/mC)

A= surface area of wall or insulation (m²)

dT = temperature difference between inner and outer wall (C)

dx = width of wall or insulation (m)

In principle, the formula above (1) can be employed if the computation is performed on a single material type. However, if the wall is made up of multiple layers of material, the shown formula can be developed by factoring in the resistance of the material to heat (R-value), which is frequently referred to as the thermal resistance of a material. The following formula can be used to determine this R value (equation (2)):

$$R = \frac{dx}{k \cdot A} \dots \dots \dots (2)$$

The following formula, which is based on electrical principles (Ohm's law), can be used to calculate the total R value for materials that are arranged in series (equation (3)):

$$R_{Total} = R_1 + R_2 + R_3 + R_{...} \dots\dots\dots (3)$$

The number of layers of insulation/walls present is indicated by the numbers 1, 2, 3, and so on. As a result, combining formulas (2) and (3) provides the reference formula for determining heat transfer in a series configuration (equation (4)):

$$Q = \frac{dT}{R_{Total}} \dots \dots \dots (4)$$

To facilitate calculations, all numerical data from the study components was subsequently imported into Microsoft Excel, as illustrated in Fig.5. From it, it was known that the heat flow value produced were the same based on the results of the formula calculation and the results of the simulation conducted using the ANSYS program. This demonstrates that the input process, modelling, and analysis performed at ANSYS adhere to well-established heat transfer concepts/theories.

Inner Wall	k=	0.8 W/mC					
Insulation A	k=	0.05 W/mC					
Insulation D	k=	0.05 W/mC					
Outer Wall	k=	50 W/mC					

Thermal Circuit			1	2	3	4
Inner Wall	Insulation A	Insulation D	Outer Wall	Outer Wall Temperature		
Inner Wall Temperature		9.0				

Surface area	A=	1 m ²
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Thermal resistance	$\frac{1}{k}$	Thickness
Thermal Conductivity	$\frac{1}{k}$	

R.1	0.125
R.2	5
R.3	1
R.4	0.002
	0.127

Heat Flux (W/m ²) =	Upper temperature - Lower temperature
	Total thermal resistance
	200
	6.127

Heat Flux	32.62452 W/m ²	qs=32.64 watt (Because A=1m ²)
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Thermal Resistance - R C/W or K/W

- Thermal conductance = kA/L , measured in W/mC⁻¹
 - Thermal resistance = $L/(kA)$, measured in W/mC⁻¹
 - Heat transfer coefficient = k/L , measured in W/m²C⁻¹
 - Thermal insulation = L/k , measured in K.m²W⁻¹

R1	K2	K3	K4
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Figure 5 Heat flux calculation in MS. Excel for wall with series configuration.

3.3. Insulation Layer with Parallel Configuration

From the ANSYS software, Fig. 4 shows how the heat from the parallel configuration wall moves through the wall. The surface temperature conditions between the inner and outer walls are identical to those for series-connected walls. What is intriguing here is the average temperature reading of 117.58 °C that travels through the wall. This wall's average temperature condition was lower than that of a series-configured wall.

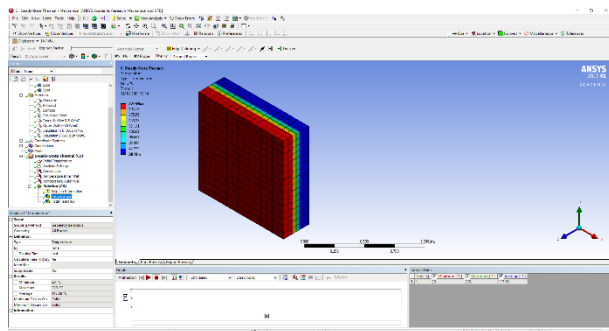


Figure 6 Temperature on wall with parallel configuration.

In comparison to the series design with consistent heat flux values, the parallel configuration has a range of heat flux values (figure 6). The difference in values is visible in the central part of the wall, which was the boundary between the insulating layers, as illustrated in Fig. 7. The simulation results showed that the lowest heat flux value was 18,887 W/m² and the highest was 108.86 W/m². Meanwhile, the average heat flux of 57,576 W/m² was measured.

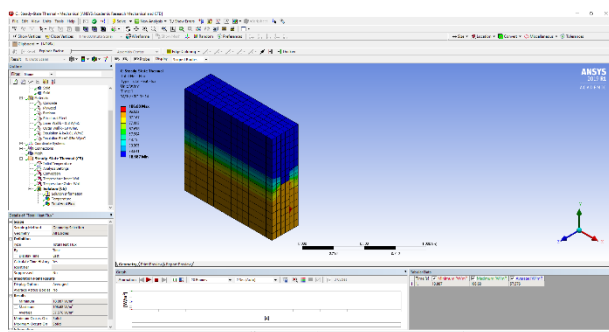


Figure 7 Heat flux value at wall with parallel configuration.

3.4. Comparison

As a result of the investigation, it has been determined that the energy transfer value in the series configuration wall is less than the energy transfer value in the parallel configuration wall. The average temperature passing through walls with parallel configurations is, on the other hand, lower than the

average temperature flowing through walls with series designs. Table 2 contains the comparison data to make it easy to see the differences between the two groups.

Table 2. Comparison result

Type of the Wall Insulation	Average Heat Flux (W/m ²)	Average Temperature (°C)
Series	32.642	131.29
Parallel	57.576	117.58
Difference (%)	76%	-10%

According to table 2, the energy transfer rate increases by 76 percent when applied in parallel, even though the average temperature inside the wall might be reduced by 10%.

Using the probe function in the ANSYS software, we can quickly obtain a specific value of temperature or heat flux (Fig. 8). If we place the probe at the desired location point, we can more easily read the different heat flux values of the parallel wall configuration (Fig. 9). However, if the heat flux values for all parts of the area are the same (evenly), as is the case for walls with a series configuration, this will have no effect.

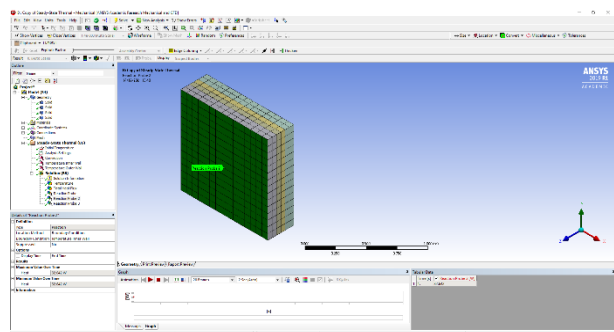


Figure 8 Using probe to observe the value of heat flux on certain spot.

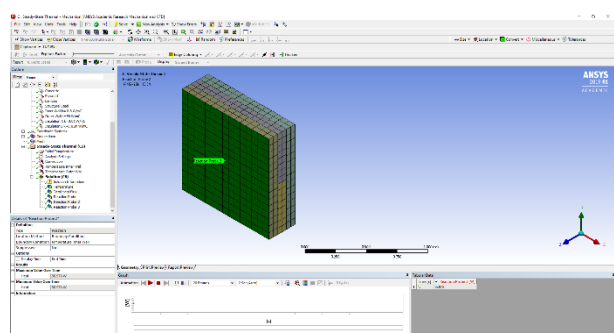


Figure 9 Heat flux at the middle of wall insulation with parallel configuration.

4. CONCLUSIONS

The primary goal of this research is to investigate the effectiveness of heat energy transfer on insulated walls. The effect of the configuration of the insulating layer arrangement in series and parallel is evaluated in this study. Furthermore, the heat transfer values will be compared to determine which configuration is the most efficient, as well as other observations made during the simulation analysis process using ANSYS Workbench software. In general, insulating layers arranged in series can provide a lower energy transfer value than insulating layers arranged in parallel. Based on the experimental results obtained in this study, the following details conclusions can be drawn:

- The heat transfer rate is reduced when the insulating layer installation systems are placed in series rather than parallel. However, the temperature passing via parallel layouts will be lower on average than through series configurations.
- Improved building energy efficiency can be achieved in part by reducing heat transfer.
- Conduction will be reduced if insulation materials have a low thermal conductivity and a significant layer thickness.

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