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Calculation of Energy Consumption Optimization Using by Software Simulation of Comsol Multiphysics (Case Study; Faculty of Physics, University of Tehran)

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ABSTRACT

In this paper, the attic space of the building of the Faculty of Physics, University of Tehran has been simulated by Comsol Multiphysics software. Before the energy consumption optimization is applied in it, the building of the Faculty of Physics, University of Tehran has dimensions (80.5 × 17 × 3.2 m) and 50 years have passed since its construction, and so during the summer (July to October), the temperature reaches 50 ^{0}C. In these months, energy consumption is higher than in other months of the year. Previously, 18 automatic fans were installed on the roof to lower the attic temperature. But its installation was insignificant in reducing the temperature difference between the attic and the outside space. Now to reduce the temperature, can use a gentle airflow (fan). Before to install the fan on both sides of the gable, it was simulated by Comsol Multiphysics. The simulation of six hypothetical fans is considered reducing the temperature. After calculation by this software, the use of installing six fans at both ends of the attic shows a reduction of 10 degrees, which can be said to save energy.

Keywords- Energy consumption, Optimization, Attic, Temperature, Comsol multiphysics, Simulation.

I. INTRODUCTION

The water scarcity situation [2,1], which is nearly directly tied to energy usage [3,], is one of the most important elements in optimising energy consumption. We may witness a decrease in water usage by improving energy utilisation [4]. Changing habits and procedures, increasing energy efficiency, and using renewable energy are three approaches to reduce energy use [6,5]. Since 1970, people have been trying to figure out how to reduce global energy usage [7]. Global energy consumption now stands at 10 GT/y (equal to 10 billion tonnes of oil per year) [8]. Buildings utilise 40 to 45 percent of this energy [9]. The energy consumption of wealthy nations per capita is around 20 times that of developing countries [10]. The release of enormous quantities of pollutants such as carbon monoxide, sulphur, methane, and others into the atmosphere and human environment has resulted from the combustion of such a vast volume of hydrocarbons [12]. Annually, for example, 6 Giga Tons of carbon (6GT / yr) are emitted into the atmosphere [10]. Exterior insulation need novel approaches [11]. Insulation is often installed within the walls (between the inner and outer surfaces) or on the building's inner surface [12]. The most typical design issue for installing insulation outside of a concrete or stone structure is protecting it from moisture, rain, sun, and interaction with humans and animals [13]. Between concrete or stone walls and the exterior earth, polystyrene is a broad, wide, and robust insulation [11]. Many energy-saving methods do not directly trap heat within the structure, but they do have indirect impacts [14]. Here are some examples of this kind. Items including the kind and size of heating equipment, aeration and air conditioning (HVAC devices), realistic strategies for reducing energy use, and required controls in this area [11]. Using natural light as an alternative to artificial (electric) lighting necessitates the use of open pores and ducts in the building (such as windows), which may result in increased heat loss in the winter and heat absorption in the summer [15]. Light is expected to utilise over 20% of the world's power [16]. Traditional incandescent bulbs are around 5% more efficient, whereas modern lighting is far more efficient. LED brightness, for example, is roughly 20% efficient [17]. Electricity usage is reduced by roughly 70% per year when lighting control is used[18]. According to the results of a study to optimise energy consumption in high-rise office buildings equipped with intelligent management systems using Design builder simulation software [19] and computational fluid dynamics, it is possible to reduce energy consumption and optimise the building in the lighting sector 39 percent, hot water consumption 5.5 percent, heating 9.21 percent, cooling 2.73 percent [20], equipment 5.50 percent, and other sectors 12 percent. In addition, the combined usage of the strategies decreases the building's overall energy consumption by 7.38 percent [21]. The findings of this research revealed that improved natural ventilation and shade arrangements in the cooling section of an office building equipped with an energy management system in Tehran's environment result in the greatest savings [22]. Uninsulated walls are 8 to 14 degrees cooler inside than insulated walls in the winter [23]. In the summer, the

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situation is reversed, and heated surfaces make it harder to keep the structure cold [24]. Insulation raises the warmth of interior surfaces, allowing inhabitants to feel more at ease [25]. People will feel uncomfortable and chilly if heat is lost fast via body radiation to a cool wall, floor, or ceiling [26]. Additional insulation helps preserve sound security between the building and the outside in addition to decreasing energy usage [25]. The COMSOL programme may also be used to model attic airflow and heat transfer investigations [27]. Given the finite supplies of fossil fuels (gas, oil, etc.) and the rising demand for energy, particularly in industrial and family usage, He focused on energy consumption optimization [28]. In order to assess the influence of the 6 fans before they were installed, the Multiphysics Comsol was used to model the building of the Faculty of Physics at the University of Tehran, Iran. If the test results are positive, six fans will be put on both sides of the structure. The major goal of installing six fans is to reduce the amount of energy used. Heating the attic, on the other hand, increases the amount of energy used by the cooling engine (electricity). Furthermore, energy usage may be reduced by installing six fans.

II. MATERIALS AND METHODS

To attain the purpose, two approaches were taken. The first option is to produce air movement by placing 18 fans on the roof, and the second option is to build 6 vents or fans on each sides of the attic.

2.1 Experimental method.

The attic of the University of Tehran's Faculty of Physics (Figure 1) is 17.6 metres wide, 3.2 metres high, and 80.5 metres long.

Figure 1: Inside the attic of the building of the Faculty of Physics, University of Tehran.

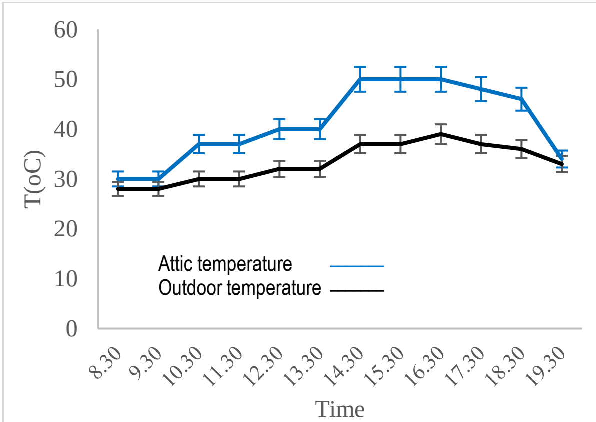

Figure 2: (Blue line) attic temperature and (black line) outside temperature in daylight hours. The average number of days noted from July 10 to September 10, 2019.

In the summer of 2019, when the outside temperature was 40^0, the temperature under the attic showed 50^0. Its temperature difference with the outside is shown in Figure (2). The first solution to optimize energy consumption is to install 18 fans above the roof. The purpose of its installation is to remove the air inside the attic, which is done automatically without consuming additional energy (Figure 3).

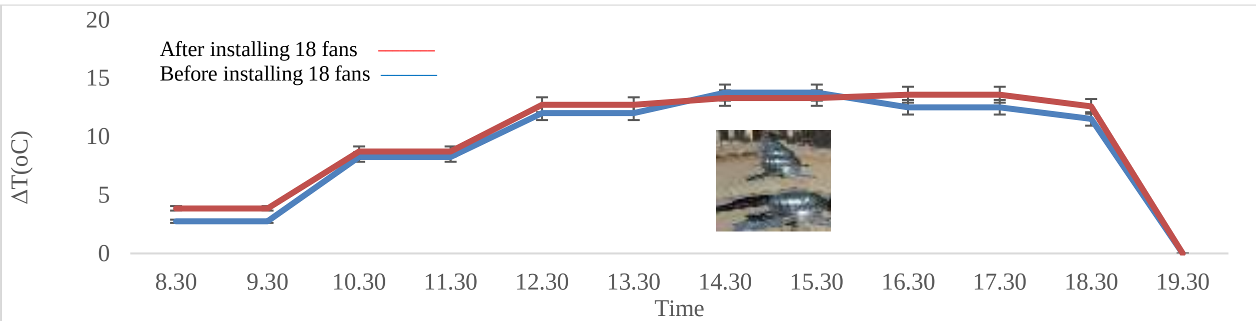

Figure 3. (Red line) The average difference in attic temperature after installation of 18 ventilators with outside temperature and (blue line) before installation of 18 ventilators with outside temperature in the Faculty of Physics, University of Tehran in terms of time of day. The average number of days is from July 10 to August 26, *.2019*

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The temperature fluctuations in the attic after installing the ventilators are minor, as shown in Figure (3). The installation of 18 fans seems to have had little impact in lowering the attic temperature. The cause for this is a shortage of air input to feed the roof-mounted ventilators. The sun's light and absorption by the roof-mounted Iraneet raise the temperature of the air trapped under the roof from morning until roughly 6 p.m. The temperature differential between the attic and the outside environment drops fast when the sun sets and no longer reaches the roof. Now we need to figure out how to get the attic temperature back to normal. To study this problem, we first open the 38 ventilation valves of the water and sewage pipes of the floors of the Faculty of Physics building, to see whether opening the 38 valves (in reality, the inspection valve of water and sewage pipes.) causes the floors to cool down. What will the attic's impact be? (See Figure 4) These vents are linked to the attic area, and air flows from the bottom to the attic space in a very gentle manner.

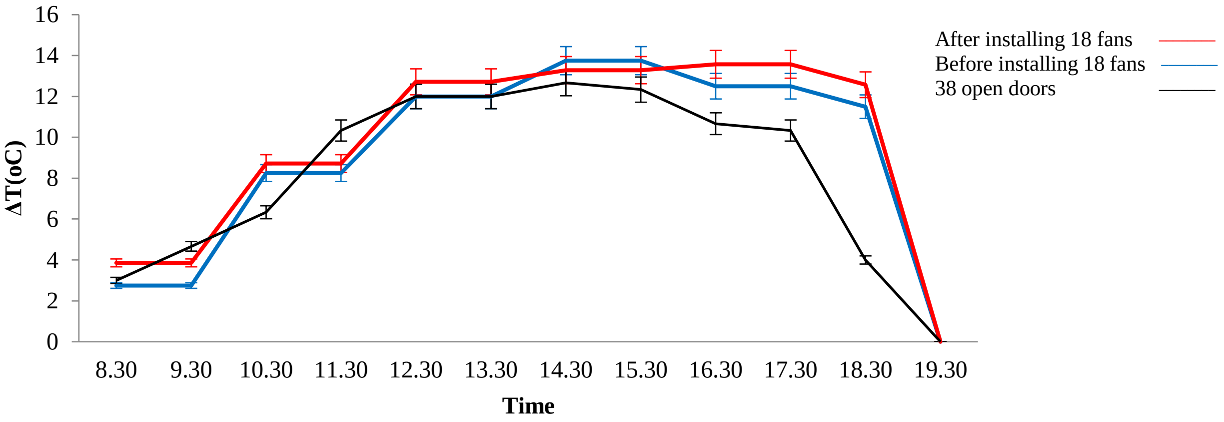

Figure 4. The average difference between the attic temperature and outside the campus (blue line before installing 18 fans and red line after installing 18 fans) with 38 valves open after installing 18 fans (black line) according to the time of day The average temperature of the days with 38 open vents on the floors of the building from 7 to 10 August 2019.

When comparing the temperatures in Figure (4), it can be observed that opening the 38 vents on the building levels has a good impact on lowering the temperature of the attic area, resulting in a reduction of 1.5 to 2 degrees per hour. 15 degrees, followed by 4 to 10 degrees. The 38 vents open to assist bring air to the attic and ventilators to get them out from under the roof, and the sun's rays are less likely to raise the temperature of the air in the attic. However, since the suction of air via the vents is quite laminar, the temperature drop during the day is not as noticeable. Other remedies are required in order to lower the attic temperature even more. One of these options is to divert a stream of air under the roof. A fan has been installed in the input valve beneath the roof to direct additional air flow under the roof. This reduction in temperature may be noticed in Figure in this example (5).

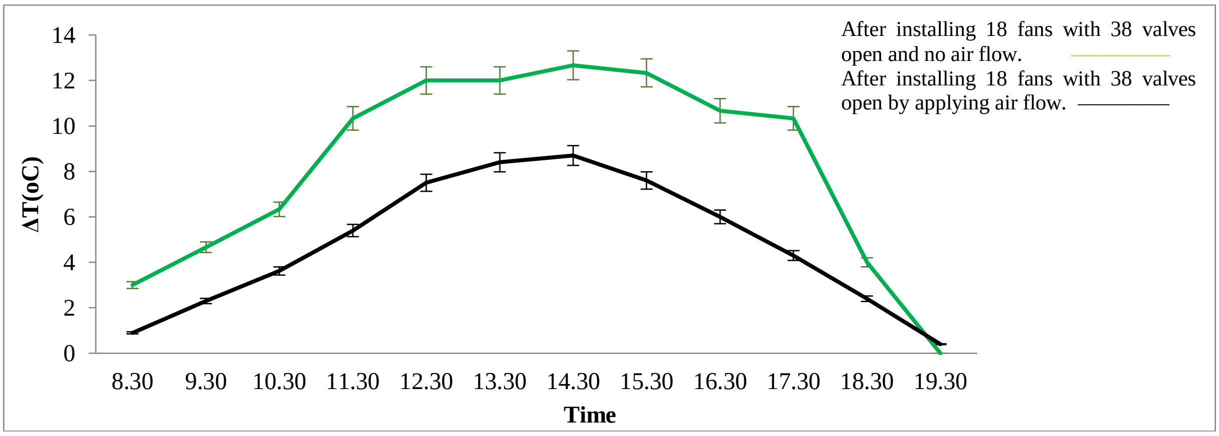

Figure 5: (Green line) Comparison of average attic temperature after installation of 18 ventilators with 38 ventilation openings of building floors without applying air flow and (black line) with applying air flow by fan in terms of day time. Air flow from 24 August to 1 September 2019.

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Figure (5) shows that the airflow under the attic has caused the temperature to drop by 3 to 8 degrees throughout the day. Therefore, it can be concluded that airflow should be established under the attic so that we can bring its temperature to ambient temperature.

2.2. Attic simulation method

The final solution to supply air to the attic is to install several fans on both sides of the building in the attic space to produce air by using electricity to evacuate the air vents of this roof and finally the air under the attic roof. Isothermal with outside air. This is costly, so numerical simulation will go a long way in predicting results. Here, in order to solve my problem, I use the laminar flow and heat transfer fluid (Heat Transfer Fluid). Non-compressible fluids are used in modeling and simulation. The Navier-Stokes equations, the law of mass conservation, and the continuity equation are used to solve the laminar flow. These equations are as follows in Comsol software;

$$\frac{\partial \rho}{\partial t} + \nabla.(\rho u) = 0 \qquad (1)$$

Equation (1) shows the equation of continuity and the law of mass survival.

$$\rho \frac{\partial u}{\partial t} + \rho(u.\nabla)u = \nabla.[-pI + \tau] + F \qquad (2)$$

Equation (2) is a vector equation that represents momentum survival.

$$\rho C_p \left(\frac{\partial T}{\partial t} + (u.\nabla)T\right) = -(\nabla.\mathbf{q}) + \tau; S - \frac{T}{\rho}\frac{\partial \rho}{\partial T}\left(\frac{\partial T}{\partial t} + (u.\nabla)T\right) + Q \qquad (3)$$

Equation (3) describes the energy survival equation where temperature exists. In the above statements ρ is the density of the fluid (unit in SI: kg/m^3), u velocity vector (unit in SI: m/s), p pressure (unit in SI: Pa), τ adhesive stress tensor (unit in SI: Pa), F force vector per unit volume (unit in SI: N/m^3), C_p specific heat capacity at constant pressure (unit in SI: J / (kg. K)), T absolute temperature (unit In SI: K), q is the flux vector (unit in SI: W/m^2), Q is the heat source (unit in SI: W/m^3), S is the stress tensor rate (unit in SI: Pa). In Comsol software, there are two possibilities for heat transfer, one is heat transfer in solid and the other is heat transfer in fluid. Here, due to the necessity of the subject, only the part of heat transfer in fluid is discussed more. The solution equations for heat transfer in a solid are as follows;

$$\rho C_p \left(\frac{\partial T}{\partial t} + u_{trans}.\nabla T\right) + \nabla(\mathbf{q} + \mathbf{q}_r) = -\alpha T: \frac{\partial s}{\partial t} + Q \qquad (4)$$

The solution equations for heat transfer in a fluid are as follows;

$$\rho C_p \left(\frac{\partial T}{\partial t} + u.\nabla T\right) + \nabla.(\mathbf{q} + \mathbf{q}_r) = \alpha_p T\left(\frac{\partial p}{\partial t} + u.\nabla p\right) + \tau: \nabla u + Q \qquad (5)$$

In Equations (4) and (5), ρ density (unit in SI: kg/m^3), C_p specific heat capacity at constant pressure (unit in SI: J/(kg.K)), T absolute temperature (unit It in SI: K), p pressure (unit in SI: Pa), u_{trans} velocity vector (unit in SI: m/s), q heat flux by conduction (unit in SI: W/m^2), q_r heat flux by radiation method (unit in SI: W/m^2), α heat dissipation coefficient (unit in SI: 1/K), Q heat source (unit in SI:W/m^3) and S The stress tensor is Piola-Kirchhoff (unit in SI: Pa). Attic simulation models with fans are presented in Figures 18 and 19. The numerical parameters used in the simulation model (geometry) are listed in Table (1).

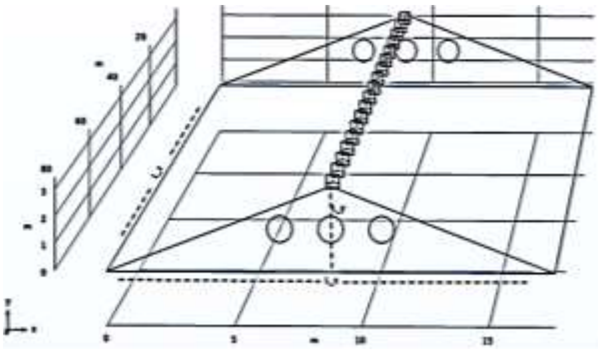

Figure 6: Dimensions of the simulation model in meters.

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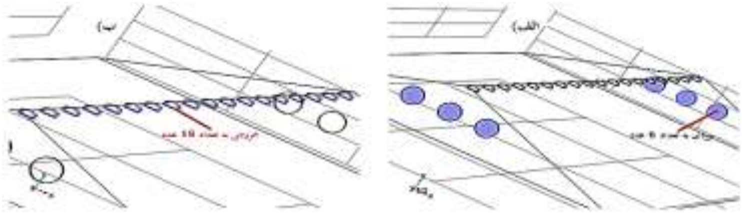

Figure 7: a) air inlet with 6 vents from the side of the gable roof and b) air flow outlet with 18 vents from the gable roof.

Table 1: Numerical values of simulation model parameters (geometry).

Name	Expression	Value	Description
L_x	17.6[m]	17.6 m	Model width to direction x
L_y	3.2[m]	3.2 m	Model height in the direction y
L_z	80.5[m]	80.5 m	Model length to direction Z
Rediuse_cylinder	0.5[m]	0.5 m	Cylinder radius
height_cylinder	0.1[m]	0.1 m	Cylinder Height
width_block	0.5[m]	0.5 m	Width block
Depth_block	0.5[m]	0.5 m	Depth block
Height_block	0.5[m]	0.5 m	Block Height
cyl_x_position	8.8[m]	8.8 m	Position the cylinder in the direction x
cyl_y_position	1.6[m]	1.6 m	Position the cylinder in the direction y
cyl_z_position	0[m]	0 m	Position the cylinder in the direction z
between_two_cyl	2[m]	2 m	The distance between each cylinder
blk_x_position	8.8[m]	8.8 m	Position the block in the direction x
blk_y_positon	3.2[m]	3.2 m	Position the block in the direction y
blk_y_position	2[m]	2 m	Position the block in the direction z
between_blk	4.5[m]	4.5 m	The distance between each of the 18 blocks
in_tem_flow	288[K]	288 K	Inlet temperature flow
hot_surface	315[K]	315 K	The outside surface is warm
in_velocity	2 [m/s]	2 m/s	Fluid input speed

III. RESULT

Numerical parameters used in the simulation model (geometry). According to Equations (1), (3) and the determination of boundary conditions, the results we have obtained are changes in velocity and temperature. First you see the speed changes in Figure 15.

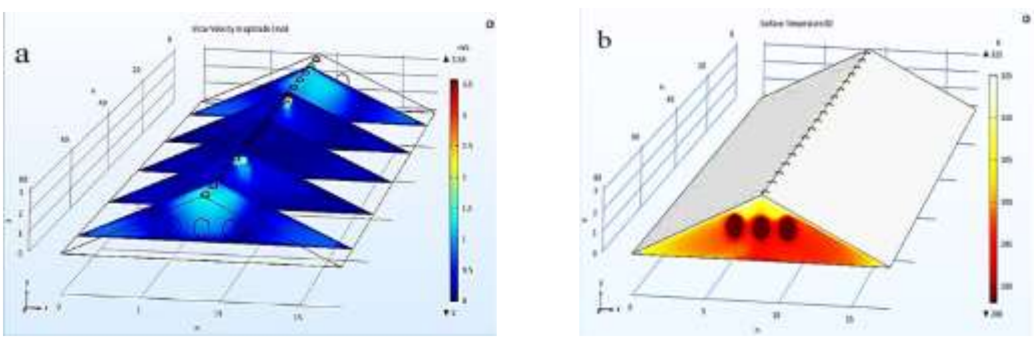

Figure 8. a) Slice air velocity changes to 5 sheets. b) Temperature changes superficially.

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Figure (8) depicts a five-number shift in slice velocity (Slice). Because the slow flow input speed is 4 m/s, the velocity varies from 0 to 3.5 m/s, as shown in the diagram. The outside temperature is 315K, while the inlet temperature is 288 K (about 150C) (420C). Due to the existence of air movement, the temperature in the centre of the model (geometry) of the simulation has lowered by 10 degrees (Figure 8). Figure 15 depicts the continued drop in temperature. Figure 1 depicts the velocity change curve in the attic (8). In the centre of the building, the speed is 0.5 m/s. Because air enters the model area from both sides at a speed of 4 metres per second. As a result, the pace progressively slows. It should be noticed that the ventilators are located where the velocity changes in length and the velocity peaks. Now, in the simulation model (geometry), we modify the speed from 4 m/s to 2 m/s and 8 m/s along the slope. In Figure, I look at the outcome of these velocity variations (9).

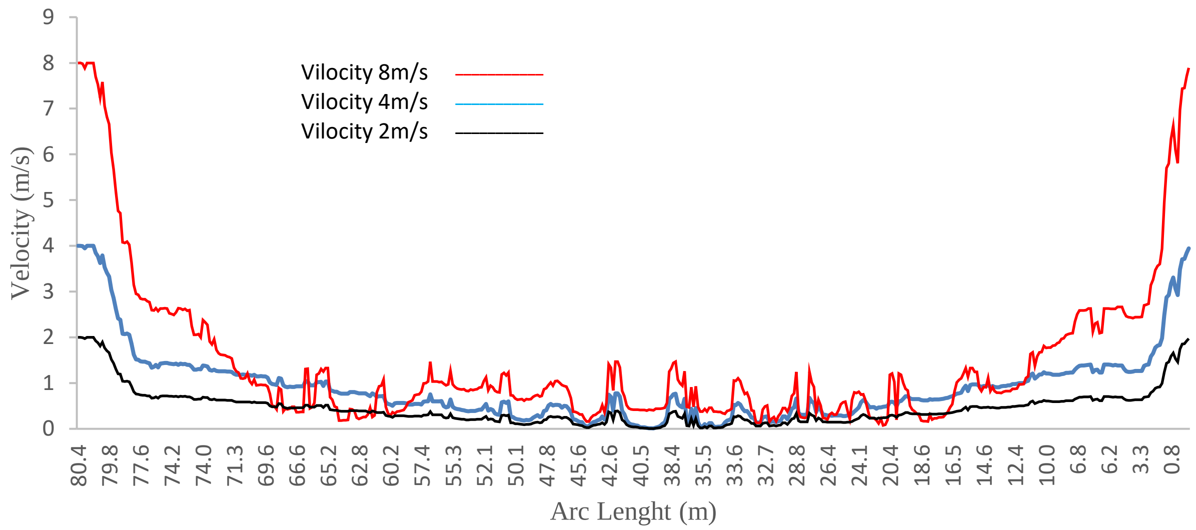

Figure 9. Comparison of air inlet velocity change curves in terms of gable length for velocities of 2 m/s (black line), 4 m/s (blue line) and 8 m/s (red line).

Figure (9) shows that the unique (red) 8 m/s has more changes than the size of 2 m/s in the middle of the simulation model. But these changes are less (approximately the same) in the 2 m/s (black) and 4m/s (blue) curves. In the following figures, we observe the effects of this change in air velocity in the simulation model (Figure 10).

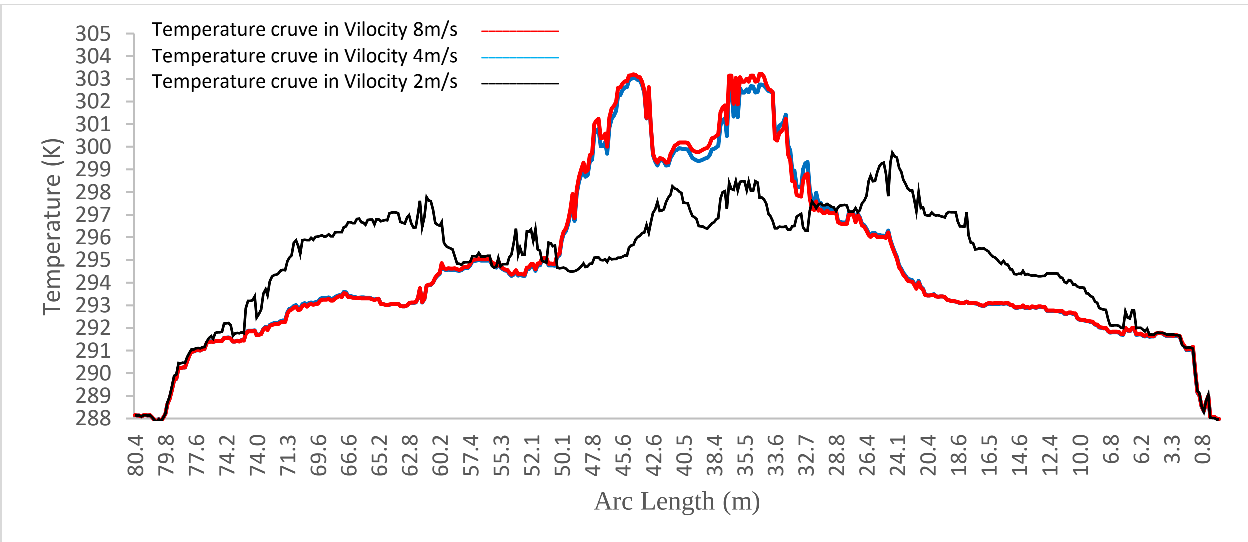

Figure 10: Comparison of temperature reduction curves at speeds of 2 m/s (blue line), 4 m/s (red line) and 8 m/s (black line) according to the length of the simulation model.

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Figure (10) Comparison of temperature reduction curves at inlet air velocities of 2 m/s, 4 m/s and 8 m/s shows the length of the simulation model. Figure (10) shows that the speed of 8 m/s had a greater effect on reducing the simulation temperature. This temperature decrease is 7 degrees compared to the speeds of 2 m/s and 4 m/s. Therefore, this point should be considered when choosing a fan and the speed of blowing air. According to Equations (1), (3) and the determination of the boundary conditions, the results we have obtained are changes in velocity and temperature. First you see the speed changes in Figure (11).

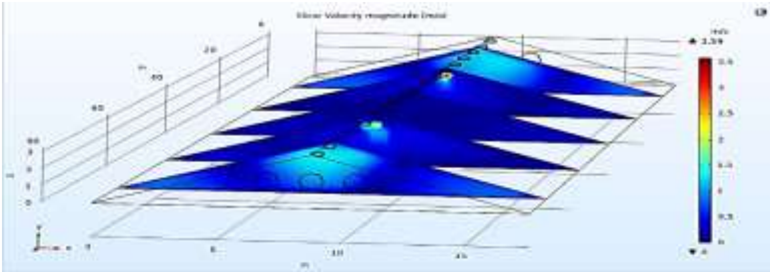

Figure 11: Slice changes in air velocity to 5 sheets.

In this figure, the speed changes are shown as 5 slice. Since the slow flow input speed is 4 m/sec, the figure shows that the velocity changes from 0 to 3.5 m/s. The velocity change curve along the attic is shown in Figure (12).

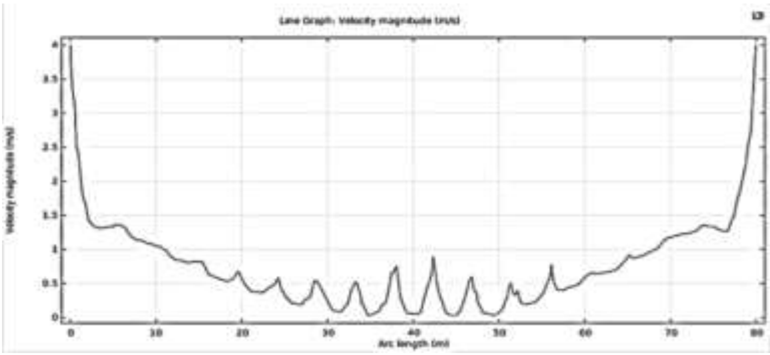

Figure 12: Curve of velocity changes along the slope.

The speed in the middle of the building is 0.5 m/s. Because air enters the model area from both sides and the value of air entry speed is 4 m/s. So the speed gradually decreases. It should be noted that velocity changes in length and velocity peaks are the location of ventilators. We now change the velocity in the simulation model (geometry) from 4 m/s to 2 m/s and 8m / s along the slope. And I examine the result of these speed changes in Figure (13).

IV. DISCUSSION

The outcomes of the experiments are the subject of this discussion. The major purpose is to look up ways to reduce energy use. As a result, the attic temperature was decreased by 3-8 degrees utilising various treatments. The first option is to put 18 fans on the top of the Physics Faculty. The installation's goal is to evacuate air from the attic, which becomes quite hot during the summer due to the sun. The effects of 18 fans in decreasing attic air temperature are insignificant, as shown in Figure (3). However, it may be deduced that a pattern exists, and that pattern is to remove or exchange air in the attic. Overheating in the attic may be avoided by removing or exchanging air. As a result, the second stage is to leave 38 doors open in order to visit all of the building's floors. A mild flow of air is delivered into the attic by leaving the 38 vents open. Figure 1 depicts the impact of opening 38 valves on temperature decrease (4). As shown in Figure (4), opening 38 inspection valves and installing 18 fans had a stronger impact, reducing the temperature by around 2 to 3 degrees. To accomplish the intended outcome, we employed a fan at the entrance to the attic instead of a moderate breeze (Figure 5). Figure (5) shows that by directing the attic air flow via the fan, the temperature was reduced by 6 to 8 degrees compared to the 38 open valves. Because the fan directs airflow under the attic, heat exchange occurs. When the sun shines on Iraneet, it warms up, and heat is transported into the attic since the region surrounding the attic is closed. In fact, it is here where the phenomena of heat transmission in a fluid occurs. A fluid with a chilly

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temperature enters the attic when air flow is driven into the attic by a fan, causing the attic temperature to drop by 6 to 8 degrees.

We're now utilising Comsol software to model the attic. Six vents were created to let air into the attic. I note that the effects of six air intake valves in lowering the temperature of the simulation attic model are extremely considerable in Figure (9). As air enters via six vents, the outside temperature of the 315K (42oC) simulation chamber is dropped by 303K (equal to 30oC) (i.e. the indoor temperature is reduced by 15 degrees relative to the outside surface). The air intake rate is 4 m/s via six vents. The impact of changing the entrance speed from 4 m/s on lowering the temperature within the simulation room can be observed in Figure (10). Figure ten shows that decreasing the speed from 4 m/s had no impact on lowering the temperature of the simulation room, however raising the speed from 4 m/s to 8 m/s raised the temperature of the simulation room more (by 7 degrees compared to 4 m/s). As a result, it can be deduced that raising the speed of the simulation room's inflow valve causes the temperature to shift more.

V. CONCLUSION

Air flow was used to reduce the attic temperature, which had a positive effect. It can be said that this method is one of the ways to optimize energy consumption. Because most buildings use more energy for cooling. 18 fans are installed. Polystyrene is installed all over the roof. To complete the process of thermal insulation of the building, 6 fans can be installed on each side of the building under the roof. It also painted the entire ceiling glossy oily white.

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