Investigation And Improvement The Thermal Comfort Of The Air Conditioning mosque At Hot – Dry Climate In Baghdad

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Abstract. This study is concerned with investigating and improving the thermal comfort conditions of the worshipers in Omar bin Abdul Aziz Mosque in Iraq - Baghdad, which is characterized by a hot- dry climate in the summer. The study was conducted at the time of noon prayer on Friday (Friday prayer) on July 20 at 1 pm, at external temperature 50°C and relative humidity 20%. Numerical methods (CFD) were used for simulation by Ansys –Fluent v.18 and divided the domain at 4 million mesh element. Thermal comfort was assessed by finding the values of the predicted mean vote (pmv) and predicted the percentage of dissatisfied (ppd) it depended by ASHRAE standard -55. The strategy of re-distribution of the adaptive devices was used to obtain the best level of thermal comfort. The third case was the best in terms of thermal comfort. The temperature was 0.4°C lower than the original state. The improvement rate of PMV was 4.43%, ppd 5.96% lower than the original state. Also, it is found that the best model of the flow is turbulent K-e (RNG) for the studied case.

1. Introduction
Comfort thermal humans are one of the most important goals for air conditioning, where is defined as follows "as the condition of mind which expresses satisfaction to the thermal environment." Fanger [1] It is important to provide the thermal comfort in public places, especially the mosques, which are the focus of research. It is important to provide them. People go to public places continuously and in great numbers, which is also a challenge in providing the thermal comfort of the place. The mosque is considered important because it is a place of prayer and they for worshipers five times They spend 15 to 30 minutes each time, especially in Islamic countries. This research focuses on assessing the thermal comfort in Friday prayers at noon., In July, where the highest temperature in Iraq is reach to 50°C. Many researchers studied the field of thermal comfort over the past century and were one of the most important researchers Fanger in the 1970's and most of the research relies on his study to calculate the level of thermal comfort of enclosed spaces. In their research, the researchers relied on practical surveys to calculate the thermal comfort of the occupants in the studied places. In the last few years, after the development of numerical simulation programs, work began to evaluate thermal comfort numerically as it will be considered research.
The research study in the hot - dry atmosphere is as follows: Essam E. Khalil et al [2] checked the thermal comfort of the Nabha Yukon mosque in Cairo, which is described as a dry hot summer. The bodies of the occupants were considered as rectangle bodies with dimensions (0.75 * 0.5 * 0.25) m. The body temperature was 34 degrees at the metabolic level of 1.2 met, and the internal conditions of the mosque do not achieve the thermal comfort of the worshipers. Farraj F. AL - ajmi [3] studied six mosques in Kuwait during a hot- dry atmosphere at a maximum temperature of 45 degrees, all of which use central air conditioning to cool the place. The calculations started at the beginning of the summer in April to the end of October and the poll was conducted for more than 140 people. The result of the survey was that the neutral temperature was 26.1 at PMV = 23.3, and at AMV the neutral temperature was higher by 2.8C. Thus the contributing of the energy consumption reduction should be considered. Akeel Noori Abdul Hameed [4] studied the effect of building materials, the design of the mosque, the thickness of walls and ceilings and the transparent areas of the dark on the thermal comfort inside the mosques in Baghdad in the hot - dry atmosphere. He found that the ideal thickness of the walls and ceiling at 36 and reduce the transparent areas in half improves the thermal comfort inside the mosque. S. A. R. Saeed [5] was carried out survey for a 500 – person of the mosque in Friday prayers in the city of Riyadh in Saudi Arabia as a hot-dry climate. Assessment of thermal comfort in clothes stands between 0.4 - 0.6 clo. The poll results showed a good agreement with Fanger . S. A. R. Saeed [6] a practical survey of the classrooms was conducted to check the thermal comfort inside King Saud University in Riyadh. The reading was taken at the level of 0.9 m for the setting and at 1.2 m for the standing. I. Hayatu et al [7] checked the thermal comfort in the classrooms of the University of Bayrou Kano in hot-dry climate. The results were that 66% of the students voted for discomfort. The thermal comfort of a classroom and a variable number of ventilation slots and air conditioners. By the Ansys - fluent program and use of the K-e model for the turbulent flow in the representation of the situation. Krzysztof Cena and Richard de Dear [8] studied the thermal comfort in the classroom in hot-dry climate in Australia, and at the insulated of the clothes are between 0.5 clo in summer and 0.7 clo in winter and 0.1 clo insulated for chairs are added to them. The results show that there is 3 C between the temperatures of summer neutrality for winter due to the difference between summer clothes and the winter. Maatouk Khokhi and Naïma Fezziou [9] evaluated thermal comfort in the traditional houses in hot-dry climate in southern Algeria. The traditional houses provide the thermal comfort for their occupants. While the modern homes do not offer the thermal comfort of the occupants in extreme conditions except with the use of air conditioners were used numerical methods to compare the two type of homes. Linh G. Jbara et al [10] reported the thermal comfort in a mosque during the five prayers in a hot-dry climate in Egypt Cairo. The use of numerical simulation to calculate the temperature of the air and its speed and relative humidity and the concentration of carbon dioxide and thermal radiation within the space. There were four distributions of air conditioning in the mosque until the best distribution that provides thermal comfort. I. Budaiwi and A. Abdon [11] Divided the space of the mosque into sections and study the effect on the thermal comfort in a hot-dry climate of the mosque when using the appropriate air conditioning for each section according to need and the presence of occupants. The results proved a reduction of 23% of the energy used throughout the year. As well as a reduction of 30% when using the appropriate air conditioning. Compared to mosques isolated with the continuity of operation of the air conditioning and mosques isolated with the intermittent operation is saving energy up to 46%. Qasim Hammodi Hassan et al [12] checked the thermal comfort in an office room in Iraq in a hot-dry atmosphere. Numerical simulation by Ansys to calculate parameters. It was found that the reduction of air ventilation and the reduction of the temperature of the air equipped space improves the thermal comfort and that the presence of an exit air in the roof of the room does not affect the thermal comfort of the occupants. Furthermore, there are several types of research studied comfort thermal in the atmosphere of tropical hot – humid. Sallah et al [13] studied the thermal comfort in the hot humid climate in Malaysia, especially the effect of the traditional clothing, which has a value of 0.528 clo during the five prayers. They also conducted a field survey of the mosque occupants and found that the neutral temperature of thermal comfort 30.44C at AMV and 25.88C at PMV. Bakhlah and Hassan [14] In the King Khalid Mosque in Malaysia in a hot-humid atmosphere verified the direction of the correct qibla to this mosque when the sun interview him on 17/7/2010 and check the thermal comfort inside the mosque on this day and the day after
which followed and collected the data at a height of 0.9 m above the ground. Fawaz Ghaleb Noman et al [15] In the hot and humid atmosphere of Malaysia, at the Jawhara Mosque, simulation was carried out by means of numerical methods, by Ansys - fluent, four distributions of four air ventilators and the choice of the most suitable condition to achieve thermal comfort at a height of 1.1 m at the breathing level of the occupants. Emad Muhtaha & Omar Helmy [16] Assessed of thermal comfort of mosques in hot- humid weather in the United Arab Emirates. In edition they studied the effect of the shape of the surrounding perimeter (rectangular, square, and octagonal) as well as shading devices on the thermal comfort inside the mosque. The results showed that the octagonal shape of the mosque is the best forms and it reduces 10% of energy consumption. Oluwafemi K. Akande and Micheal A. Adebamowo [17] Evaluated of thermal comfort using natural ventilation in a hot and humid atmosphere in southern Nigeria Puja where a survey of 206 respondents was conducted for 68 buildings using natural ventilation to provide thermal comfort. The results were that the temperature of neutrality in the rain atmosphere is 28.44 and in the hot weather 25.04 higher than theoretical calculations 3.34 in the heat and 2.64 in the rain. The objective of the study is to evaluate the thermal comfort of the mosque's occupants at the Friday prayers. The improvement of thermal comfort is achieved through the re-distribution of the air conditioning system, which provides the best thermal comfort inside the mosque. Furthermore the other objective is to find the best model of turbulence k-ε after simulating the practical results of the measured factors in the mosque studied and find more model compatible with these results.

2. Mathematical model
To assessment thermal comfort, temperature, air velocity, and water vapor need to be calculated. These can be calculated by solving the system of coupled governing equations for the conservation of mass, momentum, and energy. Assume Steady-state, the incompressible flow of air as a multi-component fluid which includes dry air, water vapor. The fluid properties are taken as constants. Assuming that there is no heat generation, energy fluxes due to inter-diffusion, and the equation is given by:

2.1 Conservation of mass equation
\[ \frac{\partial u}{\partial x} + \frac{\partial v}{\partial y} + \frac{\partial w}{\partial z} = 0 \]  \hspace{1cm} (1)

2.2 Momentum equation (x- direction)
\[ \rho g_x - \frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 v}{\partial x \partial y} + \frac{\partial^2 w}{\partial x \partial z} \right) = \rho \left( \frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} + w \frac{\partial u}{\partial z} \right) \] \hspace{1cm} (2)

2.3 Momentum equation (y- direction)
\[ \rho g_x - \frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 v}{\partial y^2} + \frac{\partial^2 v}{\partial x \partial y} + \frac{\partial^2 v}{\partial x \partial z} \right) = \rho \left( \frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + w \frac{\partial v}{\partial z} \right) \] \hspace{1cm} (3)

2.4 Momentum equation (z- direction)
\[ \rho g_x - \frac{\partial p}{\partial x} + \mu \left( \frac{\partial^2 w}{\partial z^2} + \frac{\partial^2 w}{\partial x \partial z} + \frac{\partial^2 w}{\partial x \partial z} \right) = \rho \left( \frac{\partial w}{\partial t} + u \frac{\partial w}{\partial x} + v \frac{\partial w}{\partial y} + w \frac{\partial w}{\partial z} \right) \] \hspace{1cm} (4)

2.5 Energy equation
\[ \rho c_p \frac{dT}{dt} = K \nabla^2 T + \phi \] \hspace{1cm} (5)

\[ \phi = \mu \left[ 2 \left( \frac{\partial u}{\partial x} \right)^2 + 2 \left( \frac{\partial v}{\partial y} \right)^2 + 2 \left( \frac{\partial w}{\partial z} \right)^2 + \left( \frac{\partial v}{\partial x} + \frac{\partial u}{\partial y} \right)^2 + \left( \frac{\partial w}{\partial x} + \frac{\partial v}{\partial y} \right)^2 + \left( \frac{\partial w}{\partial x} + \frac{\partial v}{\partial y} \right)^2 \right] \] \hspace{1cm} (6)
2.6 Turbulence K-e (RNG) equation

Kinetic energy equation

\[
\frac{DK}{Dt} = \frac{\partial}{\partial y} \left( \nu_t \frac{\partial K}{\partial y} \right) + \nu_t \frac{\partial \bar{u}}{\partial y} \left( \frac{\partial \bar{u}}{\partial y} + \frac{\partial \bar{v}}{\partial x} \right) - \varepsilon
\]

Dissipation energy equation

\[
\frac{De}{Dt} = \frac{\partial}{\partial y} \left( \nu_t \frac{\partial e}{\partial y} \right) + C_1n \nu_t \frac{\partial \bar{u}}{\partial y} \left( \frac{\partial \bar{u}}{\partial y} + \frac{\partial \bar{v}}{\partial x} \right) - C_2 \frac{\varepsilon^2}{k}
\]

\[
C1\varepsilon = 1.24 \quad , \quad C2\varepsilon = 1.68
\]

2.7 Transport equation

The solution of the conservation equations for chemical species present in the domain of the CFD model, the CFD code should predict the local mass fraction of each species \( Y_i \) in each control volume. This can be made by solving the convection-diffusion equation for the species \( i \). The general differential form for the species is:

\[
\frac{\partial}{\partial t} (\rho Y_i) + \nabla \cdot (\rho \bar{v} Y_i) = -\nabla \cdot \bar{J}_i + R_i + S_i
\]

2.8 Fanger’s PMV and PPD method equation.

The PMV is based on the heat balance of the human body: in thermal balance, the internal heat production in the body is equal to the loss of heat to the environment. The PMV method combines four physical variables (air temperature, air velocity, mean radiant temperature, and relative humidity), and two personal variables (clothing insulation and activity level) into an index that can be used to predict the average thermal sensation of a large group of people in a space.

\[
\text{pmv} = \left( 0.352 e^{-0.036M} + 0.028 \right) \left( 6.23(M - W) - 3.05 \right)
\]
\[
10^{-3} \left( 5733 - 6.99(M - W) - P_a \right) - 0.42 \left[ (M - W) - 58.15 \right] - 1.7
\]
\[
10^{-5} M (5867 - P_a) - 0.0014 M (34 - t_a) - 3.96
\]
\[
10^{-8} f_{cl} \left( (t_{cl} + 273)^4 - (t_{mr} + 273)^4 \right) - f_{cl} \cdot h_c \cdot (t_{cl} - t_a)
\]

\[
t_{cl} = 35.7 - 0.0275(M - W) - R_{cl} \left[ (M - W) - 3.05 \left( 5.73 - 0.007(M - W)P_a \right) - 0.42 \left( (M - W) - 58.15 \right) - 0.0173 M(5.87 - P_a) + 0.0014 M(34 - t_a) \right]
\]

\[
f_{cl} = \begin{cases} 1.0 + 0.2 I_{cl} & \text{if } I_{cl} \leq 0.5 \text{clo} \\ 1.05 + 0.1 I_{cl} & \text{if } I_{cl} > 0.5 \text{clo} \end{cases}
\]

\[
h_c = \begin{cases} 2.38(t_{cl} - t_a)^{0.25} & 2.38(t_{cl} - t_a)^{0.25} > 12.1 \sqrt{V} \\ 12.1 \sqrt{V} & 2.38(t_{cl} - t_a)^{0.25} < 12.1 \sqrt{V} \end{cases}
\]
Ppd = 100 − 95 \cdot e^{(-0.03353 \cdot PMV^4-0.2179 \cdot PMV^2)} \quad (14)

3. Case study
The Mosque of Omar Ibn Abdul Aziz is located in Iraq in the capital Baghdad in the city of Dora as a case study to investigate the thermal comfort of the mosque and improve. The city of Baghdad on the line length 44.4 and latitude 33.3 at a height of 34 m above sea level and hot-dry climate in summer. The summer months in Iraq generally extend from April to October, with temperatures reaching a peak of more than 50 °C in mid-July, which will be the study of thermal comfort at this time in Friday prayers. This chart in Figure (1) shows the minimum and maximum temperatures of the city of Baghdad along the days Year of 2017.

4. Numerical model and simulation
The building of the mosque was represented in its full form, as is the case with the soldwork 2016 program, as well as representing all of the mosque's mosques, worshipers, air conditioning units and ventilation openings, as will be explained in detail. The area of the mosque is 400m² with a length of 20 m and a width of 20 m. The height of the walls is up to a ceiling of 6.5 m. The middle of the mosque is a dome of a hemisphere with a diameter of 10.5 m and a height of 10 m. The walls on the eastern and western sides contain glass windows with a distance of 1.5m * 2m, with six windows on one side spread over two upper and lower rows. The effect of heat transfer from outside to inside the mosque will be spread out from the windows on the walls and windows as a whole. It is divided into the perimeter of the mosque from the inside at almost equal distances and the opposite of the two sides. The air conditioners of the two internal, external and internal parts are in a ground-based form. The inner piece is in the form of parallel rectangles with dimensions of 2.19m high, 0.55m width, and 0.34m thickness. It has a cold air intake slot with a distance of 0.26 m* 0.45m and contains five blades for steering the air. It also has an air exit slot with a distance of 0.45m * 0.5m show Figure (2). The number of persons involved in the mosque is represented by a parallel of the rectangles in the distance of (1.7 m * 0.5 m * 0.25 m) per person [2], [10]. When the whole row is represented in parallel, it is also rectangular with a height of 1.7m and a thickness of 0.25. The width of the rectangles is the number of persons multiplied by (0.5m). Because the worshipers stand beside some shoulder on the shoulder and the worshipers wear traditional dress in the Arab countries (Dishdasha) representation is very close to reality. The human breathing vents were also represented as one for
exhalation (entering the breathing air of the space) with an area of one square by the distance (3cm*3cm), and one for the exhalation (return of air outside the space).

With the same dimensions. These openings at the top of the body at a distance of 10cm on the upper end of the parallel rectangles is the real attenuation of the presence of nose and mouth in the head of a man as shown in Figure (3). We will re-distribute the adaptive devices inside the mosque to reach the best case of thermal comfort inside the mosque and six different distributions, taken into account the possibility of re-changing the location of the device inside so as not to interfere with the location of the window or worshipers inside the mosque shown in Figure (2). The representation of the form and all the inputs, outputs and surfaces on the studied state of the work of the Mash to the inner space of the mosque (the liquid substance), it is started by Ansys at the first attempt at 440000 mesh Thus it is increased the number of mesh to the limit the change in the values of the results of the factors measured by the simulation of temperature and air speed is very small so that we suffice with this amount of mesh which provides the highest accuracy in the results. The temperature values at a selected point in the center of the collector at a height of 2 meters are almost constant after 3.5 million mesh the adoption of 4 million mesh to apply the boundary condition of the case studied and in all cases as shown in the Figure (4).

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**Figure (2) air condition device**

**Figure (3) worshiper**

**Figure (4) Domain mesh**

**Figure (5) Section of domain mesh**
The airflow and air temperature values for the air inside the space of the air conditions device, depend on the manufacturer's supplied catalog, as well as their practical measurements in the mosque, as well as studies that have the same conditions for the same device [2]. As for the temperature of the surface of the body of people taken from the literature review [2], this subject at the same effectiveness of the use of the state of sitting and rest of the person sitting at the same rate of metabolism described in standard ASHRAE-55 [21]. Furthermore, the temperature of the wall was measured based on the program of hap 4.9 air conditioning loads for external conditions to the highest thermal load during the year, which gets on July 20 at 1 pm. The following table shows the values of input to the initial and boundary conditions of the mosque studied as shown in Table 1. Activation of the ruling equations of the solution of the second order and boundary condition entered and resolved by Ansys fluent until the convergence is obtained by solving the error 0.001 for the momentum and $10^{-6}$ for the energy equation. At the end of the solution, the values of the factors required for the rest calculation are extracted in the PMV and PPD equations, which were inserted into the Ansys program so that we could draw their own cantors.

Table 1 Boundary condition

| Boundary condition detail       | Boundary condition value          |
|--------------------------------|-----------------------------------|
| Activity type                  | Standing, relaxed                |
| Metabolic rate                 | 1.2 met                          |
| Skin temperature               | 307 k                            |
| breathing rate                 | 8 [L/min]                        |
| humidity from air breathing    | 0.042 [kg$_w$ / kg$_{d,a}$]      |
| Temperature from air breathing | 310 k                            |
| Air cooling rate               | 0.5664 m$^3$/s                   |
| The temperature of air cooling | 286 k                            |
| Humidity of air cooling        | 0.0046 [kg$_w$ / kg$_{d,a}$]     |
| Walls temperature              | 303 k                            |
| Roof temperature               | 307 k                            |
| Fan inlet air rate             | 0.3152 [m$^3$/s]                 |
| Humidity of Fan inlet air      | 0.013 [kg$_w$ / kg$_{d,a}$]      |
The temperature of Fan inlet air | 322 k
Clothing insulation | 0.073 [m²·K/w]
Initial air temperature | 303 K

5. **Scenario of cases**
Through this work, six different cases will be discussed; a common between the six cases is that the mosque is occupied by worshipers to its full capacity limit as mentioned above. While the difference between the cases appears in the distribution of air – condition units in order to study the effect of varying their positions with respect to each other on worshipers’ thermal comfort.
6. Experimental and validation

A practical experiment was conducted to measure the temperature and relative humidity of the interior of the mosque in ten points along the middle of the mosque, 1.7 meters above the surface of the earth. Electronic devices were used to measure the temperature of the air as well as to measure air moisture and used lasers to measure the temperature of the surfaces of the wall and roof. The results were taken at 2 pm after running the cooling equipment in the mosque for two hours to reach the state of thermal stability. The practical results are shown in the following Table 2. A simulation of the mosque was performed within the surrounding conditions at which the practical results were measured, the temperature of the space and its relative humidity were found. The results of the simulation were compared with the practical results as shown in Figure (8) and Figure (9). The results were approximated by error 0.05% between the results of the process and the numerical results.

| No. point | Location of point At (x, y, z ) | Temperature For experimental | Temperature For numerical | Humidity For experimental | Humidity For numerical |
|-----------|---------------------------------|-----------------------------|--------------------------|--------------------------|------------------------|
| Point 1   | (0,1.7,-10)                     | 291.9                       | 290.889                  | 48                       | 53                     |
| Point 2   | (0,1.7,-8)                      | 291.4                       | 291.000                  | 47                       | 53                     |
| Point 3   | (0,1.7,-6)                      | 291.2                       | 291.420                  | 50                       | 52                     |
| Point 4   | (0,1.7,-4)                      | 291.6                       | 290.105                  | 50                       | 51                     |
| Point 5   | (0,1.7,-2)                      | 290.3                       | 289.596                  | 51                       | 51                     |
| Point 6   | (0,1.7, 0)                      | 291.1                       | 290.361                  | 49                       | 51                     |
| Point 7   | (0,1.7, 2)                      | 290.8                       | 289.346                  | 49                       | 53                     |
| Point 8   | (0,1.7, 4)                      | 290.8                       | 289.313                  | 49                       | 56                     |
| Point 9   | (0,1.7, 6)                      | 291.2                       | 290.177                  | 49                       | 55                     |
| Point 10  | (0,1.7, 8)                      | 291.3                       | 289.798                  | 47                       | 53                     |
7. Result and desiccation

For six different cases of re-distribution of air conditioners within the mosque are numerically simulated by the Ansys- Fluent v.18 program. The results of the average temperature of the, relative humidity and air velocity within the space at the respiratory level for humans is still at 1.7 m. The results of these factors will be calculated the thermal comfort equations that approved by (ASHRAE) the predicted mean vote (PMV) and predicted percentage of dissatisfied (ppd). This is calculated through the ANSYS – Fluent v.18 program after solute equations have been introduced and it will be also presented the contours that show the values of these factors. At the beginning of the calculation of the results of the studied cases, the results of the original case for the distribution of the devices inside the mosque were extracted. The average air temperature is (296.45 k), relative humidity (31.71) and airspeed (0.383 m/s). The results of PMV, PPD were (0.721), (15.93), respectively, as shown in the contours in the Figure (10). The results of the original case will be compared with the results of the other five cases to determine the extent of the resulting
The first case of distribution of the induction devices was the result air temperature (296.32 K) and relative humidity (32.24) and the airspeed (0.473 m/s). The values of PMV and PPD were 0.693, 15.0 respectively. Compared to the original case, the improvement rate was (3.88%), (5.83%) in PMV and PPD. From the observation of the results, it is known that there is no improvement of thermal comfort in this case where the distribution of air is undesirable inside the space and as shown in Figure (10). The distribution of air conditioners between the rows, which reduces the spread of air well, as the ranks of worshipers served as barriers to the distribution of air.

For the second distribution case the temperature air is (296.51 K) and the relative humidity is 31.07 and the air velocity is (0.448 m/s). The PMV and PPD results were (0.734) and (16.34), respectively. There was a decrease in the values of ppm and PPD, compared to the first case but so far higher than the original case where the rates of improvement of pmv are (-1.8%), PPD is (-2.57%).show in Figure (11).
The third case of distribution was temperature (296.3 k), relative humidity (32.05) and air velocity (0.41) and the values of pmv and ppd were (0.689), (14.98), respectively. The results of the third case show a decrease in pmv and ppd values. For the first and second case as well as the original case, i.e., there is an improvement in thermal comfort in a positive direction. The pmv improvement rate was (4.43%) and ppd is (5.96%), show in Figure (13).

The fourth case of distribution was temperature (296.49 k), relative humidity (31.55) and air velocity (0.389) and the values of pmv and ppd were (0.729), (16.18), respectively. The results of the four case show a decrease in pmv and ppd values. For the first and second and three but above the original case, i.e., there is an improvement in thermal comfort in the negative direction. The pmv improvement rate was (-1.1%). And ppd is( -1.56%). Show in Figure (14).
The fifth case of distribution was temperature (296.631 k), relative humidity (31.3) and air velocity (0.36) and the values of PMV and PPD were (0.759), (17.13), respectively. The improvement in thermal comfort in the negative direction. The PMV improvement rate was (-5.27%) and PPD is (-7.27%). Show in Figure (15).

A comparison of the results of the five cases with the original case shows that the third case of distribution is the best case and provides an improvement in thermal comfort from the original state in PMV values, PPD, as shown in Figure (16) which shows the proportion of the histories of the studied cases.
Using experimental results and numerically simulated, the turbulent flow models of k-e, k-w, and the model, which results in closer to practical results, have been tested. The results showed that the most accurate model in the studied case is RNG in the k-e model as in Figure (17).

![Figure (17)](image)

**Figure (17)** comparison of turbulent flow models with practical results.

8. Conclusion
This study aims to verify and improve the thermal comfort conditions for worshipers inside the mosque in case the mosque is filled with worshipers, and on the hottest day of the year for the hot-dry climate in Iraq, which falls on July 20 at 1:00 pm at the time of Friday prayers. Numerical methods of solution were used by Ansys – fluent v.18 program. The thermal comfort conditions inside the mosque have been improved in a way that redistributes the air conditioners inside the mosque to provide the best air quality and thus the distribution of temperature and relative humidity are best. Five cases of non-original air conditioning were carried out in the mosque. The results of PMV, ppd, for the original case, were 0.721 and 15.93 respectively. The best results that provide an improvement in the thermal comfort conditions inside the mosque are in the third case where the improvement rate in the value of pmv, 4.43%, and the percentage improvement in the value of ppd is 5.96%. Comparison of the results of turbulent flow models used in numerical solutions with the practical results of relative temperature and humidity within the mosque. It was concluded that the k-e (RNG) model is the best model in terms of the accuracy of the results of the studied.

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