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# Numerical Analysis on Modelling Thermal Comfort Minor Operation Theatre

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**Abstract.** An operation theatre (OT) is a special room inside the hospital where medical surgery is carried out by a surgeon with the help of medical personnel. Technical standards or requirements which have been set for heating, ventilation and air conditioning (HVAC) inside an operation theatre is important not only for the comfort of surgeon, patient, and medical personnel, but also to reduce the risk of surgical site infection during surgery. This research focus on Minor Operation Theatre (MOT) which is dental surgery room at Universiti Malaysia Perlis Health Centre with room dimensions of 2.89 m(H)×3.12 m(W)×3.4 m(L) is used for numerical analysis. The air flow supplied to the MOT is from single unit air-conditioning system. Computational Fluid Dynamics (CFD) analysis is a part of an investigation to determine the air flow and temperature distribution inside the MOT. A simulation conducted by using ANSYS Fluent only consider dry air inside MOT. Therefore, the main aim of this research is to compare and analyze the simulation of dry air conducted with previously obtained experimental data of humid air distribution inside the MOT. The comparison of humid and dry air temperature throughout the MOT shows that the difference is 25.3%. The average temperature of humid air inside the MOT is 21.8 °C while for dry air is 16.3 °C. Moreover, the cooling capacity of humid air and dry air are 2.23 kW and 1.64 kW respectively. Thus, the difference between humid air and dry air-cooling capacity is 26.5%. However, the dry air simulation and humid air simulation is the same if only the process is considered as simple cooling.

## 1. Introduction

Thermal comfort is when a person is satisfied with the thermal environment and does not need to use their thermo-regulator mechanism[1]. In hospital, the needs to predict the thermal comfort perception of patients and medical personnel is essential for building system design and architectural. A healthy and comfortable environment for patient, medical personnel or any other occupant in hospital is important especially in an Operation Theatre (OT). Thus, indoor air quality can be control by installing HVAC system and appropriate filtering system in OT [2]. The risk of hospital infection is occurred in all medical procedures, especially when it comes to surgery, and in certain types of operations it can be particularly serious. The optimal indoor air quality and thermal comfort must be controlled in order to primarily reduce the risk of surgical site infection (SSI) [3]. A serious surgical site infection can often permanently



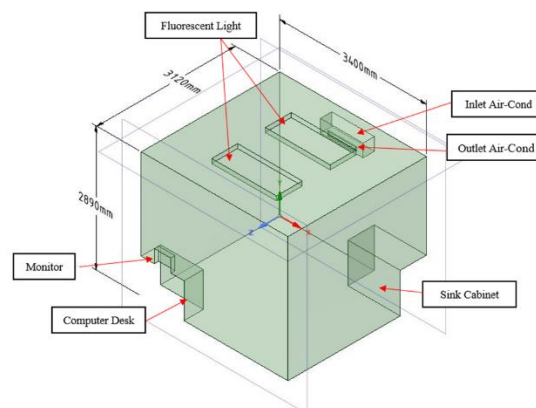
causes crucial pain and affect several aspects of the patient's lives [4]. This research work is based on the requirement to develop a realistic Computational Fluid Dynamic (CFD) model of the Minor Operation Theatre and study the airflow pattern in the MOT at the UniMAP Health Centre. By using a software simulation, an effort is made to model a hypothetical or real situation on a computer to study the working system. Changing variables in the simulation can predict the behavior of the system.

## 2. Methodology

This section includes all the methods or steps used to solve the problems related to this project. It comprises a few principles, theoretical analysis, and others. Previous researches had already done an experiment to record the temperature, humidity and air velocity based on MOT which is dental surgical room at UniMAP Health Centre [5]. The CFD analysis is a part of this investigation to determine the airflow patterns, temperature distribution and humidity in a MOT.

### 2.1 Modelling of MOT

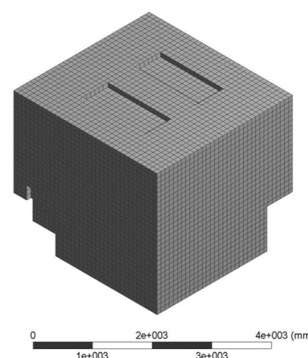
Measurement of the MOT is based on actual size of UniMAP Health Care dental room. Dimensions of the room is 3.4 m(Length) $\times$ 3.12 m(Width) $\times$ 2.89 m(Height) as shown in Figure 1. The velocity of air outlet conditioner is 2.8 m/s and from analysis of previous data shows the air outlet coil temperature of 9°C which has a size of 650 mm $\times$ 90 mm. The air return size of air-conditioning system is 990 mm $\times$ 263 mm. ANSYS Fluent is used for the numerical analysis of MOT [5] [6].



**Figure 1.** MOT 3D model.

### 2.2 Meshing

Cut cell method is used to generate the mesh with fine relevance center. Total nodes and elements are 35471 and 32163 respectively. All the specific details are shown in Figure 2.

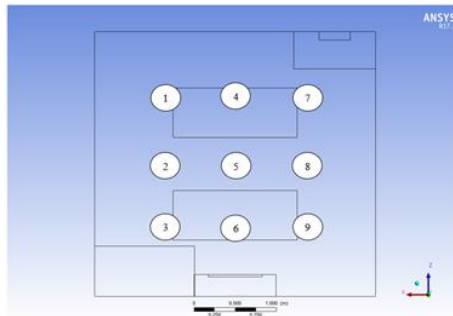


**Figure 2.** Meshing of MOT.

### 2.3 Marking Point Inside MOT

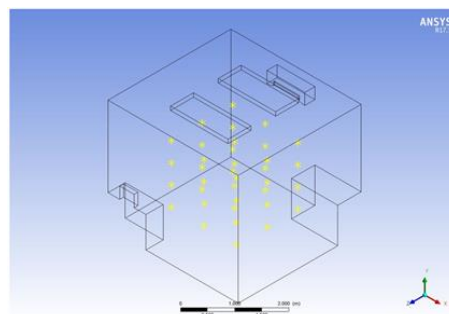
Two method is used to collect data in the MOT. First method is by using Colemeter and second method is by using data logger. The second method shows that for each location have four points. The first point starts from 0.5 m above the ground. Second point is 1.0m, third point is 1.5 m and fourth point is 2.0 m from ground. The total marking points inside this MOT is 36 points.

Figure 3 shows nine locations inside the Minor Operation Theatre (MOT). Each location consist of four points. For one location, the first point starts from 0.5 m above the ground. Second point is 1.0 m, third point is 1.5 m and fourth point is 2.0 m from ground. The total marking points inside this MOT is 36 points.



**Figure 3.** Top view of MOT.

Figure 4 shows 36 marking points inside this Minor Operation Theatre. These points are the same as per experimental data collection points. Therefore, dry air temperature data collected at these points can be compared with experimental humid air temperature data.



**Figure 4.** Marking Points in MOT.

### 2.4 Thermal Image Inside MOT

Inside the MOT, there are a few objects that generates heat. By using FLIR Ex-series infrared cameras, heat generated from objects can be identify. Therefore, these objects must be considered in the simulation process so that the condition of the MOT 3D model is similar as possible as the real MOT.

**Table 1.** Object and its temperature inside MOT.

Object	Maximum Temperature (°C)
Wall Exposed to Outside	26.7
Fluorescence Lamp	45.4
Computer Monitor	34.2

### 3. Result and Discussion

#### 3.1. Experimental data (Humid Air)

Tables 2 and 3 show data measured by using Colemeter and Data Logger respectively.

**Table 2.** Data Measured by using Colemeter.

Point	Temperature °C	Relative humidity %	Absolute Humidity kg/kg
1	22.2	42.9	0.0071
2	22.0	42.7	0.0070
3	22.1	44.0	0.0073
4	21.5	44.8	0.0071
5	21.8	43.3	0.0070
6	20.5	47.2	0.0071
7	21.9	47.2	0.0077
8	22.3	51.7	0.0087
9	22.1	47.6	0.0079

**Table 3.** Data Measured by using Data Logger.

Point	Temperature °C					
	T1	T2	T3	T4	T5 (Air Return)	T6 (Air Outlet)
1	22.6	22.7	22.2	21.8	26.7	21.6
2	22.8	22.6	22.7	22.5	25.6	21.3
3	22.2	22.2	22.0	23.1	25.4	21.2
4	23.6	21.7	21.5	21.2	25.1	20.8
5	21.4	21.5	21.8	21.4	24.7	21.3
6	21.7	20.3	21.3	21.2	24.5	21.0
7	22.5	21.9	21.5	21.0	24.0	21.3
8	22.5	22.0	21.5	21.0	23.6	21.0
9	22.2	22.0	21.8	21.0	23.2	23.0

#### 3.2. Simulation data (Dry Air)

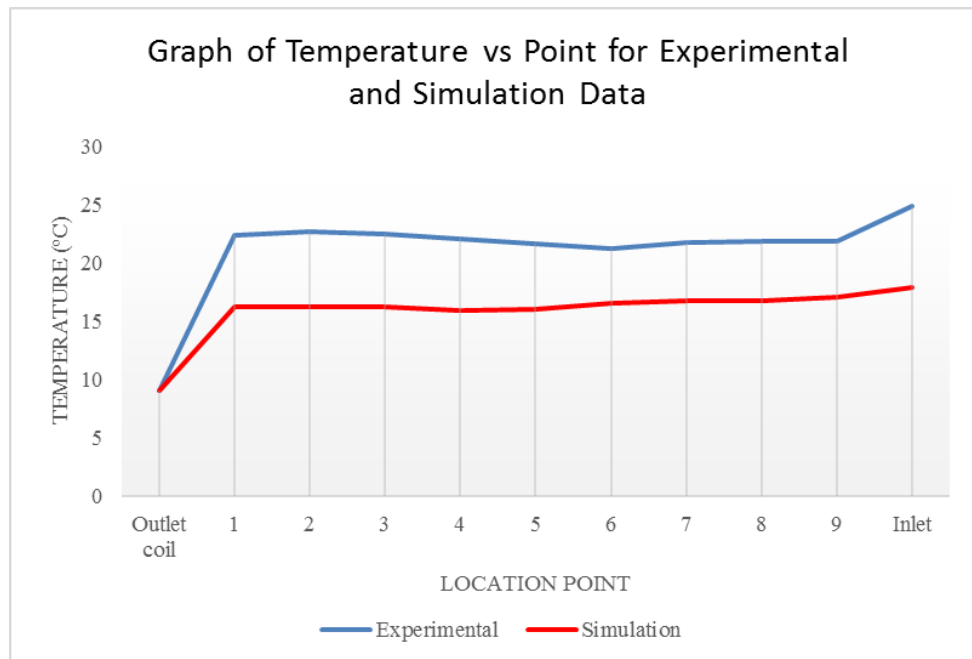
Data from Table 4 obtained in ANSYS Fluent simulation for dry air only indicates that the minimum and maximum temperature are 15.725 °C and 17.325 °C respectively. Moreover, the average temperature inside the MOT is 16.3 °C. The air outlet coil temperature of air-conditioning system is 9 °C. Meanwhile, the air return temperature is 16.95 °C. Absolute humidity is the measure of moisture in the air. Therefore, the absolute humidity is equal to 0 for dry air.

**Table 4.** Simulation data of temperature distribution.

Point	Temperature (°C)			
	T1	T2	T3	T4
1	15.841	16.369	16.298	16.130
2	15.792	16.382	16.283	16.238
3	16.240	16.043	16.315	16.203
4	15.808	15.804	15.850	15.900
5	15.725	15.949	16.115	16.212
6	15.743	16.082	16.354	16.553
7	16.337	16.382	16.480	16.612
8	16.192	16.924	16.973	16.802
9	16.344	17.056	17.325	17.106

### 3.3. Comparison Dry Air and Humid Air Temperature Inside Minor Operation Theatre

Figure 5 shows the relationship of humid and dry air temperature distribution inside the Minor Operation Theatre (MOT). The air outlet coil temperature is the same for both dry and humid air which is 9 °C. The graph indicates that the pattern for humid and dry air is the same. But, humid air temperature is higher throughout the MOT compare to dry air. This graph indicates that dry air needs less energy to cool.



**Figure 5.** Graph of experimental vs simulation.

The average differences between humid air and dry air temperature is 25.3%. The reason is that the relative humidity of dry air is less than 1% or zero absolute humidity [7]. However, humid or moist air is a mixture of dry air and water vapour [8]. There is higher amount of water vapour when the air is more humid. The specific heat,  $C_p$  for air and water is 1.005 kJ/kg.K and 4.18 kJ/kg.K [9]. Therefore, amount of heat needed to raise the temperature of water by one degree celsius is higher than air.

### 3.4. Relations of Dry Air Simulation Data and Humid Air

The cooling capacity obtained from dry air simulation is 1.64 kW and the air return of air-conditioning is 16.95 °C. The air return size is 990 mm×263 mm with velocity of 0.652 m/s. By increasing the absolute humidity, air outlet of air-conditioning for same cooling capacity can be determine. The volumetric flow rate at air return of air-conditioning system,  $\dot{V}$  is 0.1698  $m^3/s$ .

**Table 5.** Increasing absolute humidity in simulation data.

Cooling Capacity	Air Return Temperature	Absolute Humidity	Specific Volume, $m^3/kg$	Mass Flow Rate, kg/s	Enthalpy Differences, kJ/kg	Air Outlet Temperature, °C
1.64 kW	16.95°C	0g/kg	0.822	0.206	7.96	9.0
1.64 kW	16.95°C	5g/kg	0.828	0.205	8.00	9.1
1.64 kW	16.95°C	10g/kg	0.835	0.203	8.08	12.0

Higher amount of cooling capacity is required for humid air that undergoes process of cooling with dehumidification in order to achieve same amount of temperature differences in simulation of dry air [9]. Besides that, the dry air and humid air for simple cooling process shows the same result. Therefore, the dry air simulation and humid air simulation is the same if only the process is simple cooling.

#### 4. Conclusion

This study has succeeded in achieving all of the objectives of this research. In order to achieve thermal comfort of a MOT, the parameters that must be control are temperature, humidity, pressure, air change per hour (ACH) and air ventilation. According to Ministry of Health Malaysia (MOH), the acceptable temperature is between 18 °C to 21 °C, relative humidity is from 50% to 60%, air change rate is about 15 to 25 ACH and the room must be in positive pressure. A Minor Operation Theatre (MOT) which is Dental Surgery Room at UniMAP Health Centre is used for numerical analysis of air distribution throughout the room. Dimensions of the MOT are 2.89 m (height), 3.12 m (width) and 3.40 m (length). Single unit air-conditioning system is used as cooling system inside the MOT. Previous researcher had conducted an experiment and the data had been analyze shows that air outlet temperature of air-conditioning unit is 9 °C with velocity of 2.8 m/s. These data is used in the ANSYS Fluent to simulate the real MOT conditions. Dry air temperature results obtained from simulation by using ANSYS Fluent is used to compare with humid air temperature distribution inside the MOT. Therefore, the comparison of humid and dry air temperature throughout the MOT shows that the difference is 25.3%. Average temperature of humid air inside the MOT is 21.8 °C while for dry air is 16.3 °C. Moreover, the cooling capacity of humid air and dry air are 2.23 kW and 1.64 kW respectively. Thus, the difference between humid air and dry air cooling capacity is 26.5%. Finally, this research found that higher amount of cooling capacity is required for humid air that undergoes process of cooling with dehumidification in order to achieve same amount of temperature differences in simulation of dry air due to the presents of water vapour. However, the dry air simulation and humid air simulation is the same if only the process is simple cooling.

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