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An Experimental Study of Real-time Temperature Distribution using Iris Damper without Control System: A Justification Analysis

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ABSTRACT

Thermal comfort, influenced by temperature distribution, plays a crucial role in maintaining occupants' well-being and productivity within indoor environments. Most of the building with centralized air conditioning system is accommodated with inlet diffuser with fixed opening area of inlet air damper. This paper presents the justification that the indoor temperature distribution is struggling to be maintained at ideal temperature when using fixed inlet air damper. Experimental study has been conducted using iris damper pattern with three opening type and 4 occupancy conditions. Results show that when there is no occupant, the indoor temperature will keeps decreasing below 24°C. Meanwhile, with the increment of occupancy, the indoor temperature keeps increasing and able to reach up to 27°C. This condition will leads to thermal discomfort among occupants. Thus, a step-based control method is reliable to be implemented in manipulating the opening area of iris damper to maintain the indoor temperature at the ideal temperature.

Keywords:
Iris damper; thermal comfort; temperature distribution; experimental study

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1. Introduction

Indoor thermal comfort refers to the condition in which occupants of a building feel satisfied with the thermal environment inside. It is a subjective state of mind that varies from person to person.

However, achieving thermal comfort is crucial for ensuring the well-being, productivity, and overall satisfaction of individuals in indoor spaces, particularly in buildings equipped with centralized air conditioning systems. Besides that, maintaining thermal comfort is essential in indoor work environments as it directly affects workers' morale, performance, concentration, and productivity [1]. Prolonged exposure to thermal discomfort can result in fatigue, decreased productivity, and increased worker complaints and absenteeism [2].

Most popular research topics in HVAC field focused on understanding the relationship between thermal comfort and work performance [3-6]. Recent study has been conducted by Chong *et al.,* [7]

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in investigate the relationship between thermal sensation and student performance in a classroom which resulting in good academic performance can be gained when the classroom environment was cooler. Main factors that contribute to thermal comfort, including air temperature, radiant temperature, humidity, air speed, physical activity level, and clothing worn.

Centralized air conditioning systems play a significant role in regulating the indoor thermal environment by providing cooling or heating as needed. These systems use various components such as chillers, cooling towers, air handling units, and ductwork to distribute conditioned air throughout the building [8]. The goal is to maintain a comfortable temperature range, typically between 23°C and 26°C and control humidity levels within a comfortable range, generally between 40-60%. The comfortable temperature and humidity levels range is based on Malaysia climate that had been discussed further by Jamaluddin *et al.,* [9]. Afida *et al.,* [10] had review the approach used to optimize the energy efficiency in Malaysia office buildings with tropical climate. Same goes to Rajeanderan *et al.,* [11] which study the HVAC optimization strategy in utilizing the energy saving of building.

However, thermal discomfort issues are always a hot discussion among researchers. There are several problems related to centralized air conditioning systems that give significant effect on the thermal comfort, such as:

i. Inadequate temperature control
ii. Poor air distribution, [12]
iii. Inaccurate thermostat settings
iv. Humidity imbalances, [13]
v. Insufficient ventilation, [14]
vi. Energy inefficiency, [15]
vii. Lack of individual control
viii. Maintenance issues, [16]
ix. System design limitations

Even though a lot of problems highlighted, this research focused on solving the issues related to inadequate temperature control and poor air distribution which had a co-relation with the system design limitations.

Further explains, inadequate temperature control is a situation in which centralized air conditioning systems may struggle to maintain a consistent and comfortable temperature throughout the building. Variations in temperature can lead to discomfort for occupants, with some areas being too cold while others are too warm. Meanwhile, poor air distribution is an improper air distribution which can result in areas with stagnant or insufficient airflow, leading to temperature stratification and discomfort. Occupants near air vents may experience drafts, while those farther away may not receive sufficient airflow. The original design of a centralized air conditioning system may have limitations that impact thermal comfort. Inadequate sizing, improper placement of vents or diffusers, or insufficient insulation can all contribute to discomfort and inefficiencies.

Most of current research focused on manipulating the function of variable air volume (VAV) air handling configurations in HVAC systems. Adjusting the VAV air damper in HVAC systems can have an impact on air flow and temperature control. The VAV system is commonly used in commercial buildings for its energy efficiency. Zhao *et al.,* [17] come out with thermal sensation and occupancy-based control method for multi-zone VAV system which will be a good method to overcome the unnecessary operation when zones are unoccupied.

With the same objective towards enhancing thermal comfort, Mu *et al.,* [18] proposed the feed-forward control method to predict the VAV damper opening and fan frequency by demand flowrate. Similar with Cao *et al.,* [19] which proposed to implement PID control in VAV system to manipulate the inlet airflow in a zone based on step response of the room temperature.

Different with Nur'Amirah *et al.,* [20] which focused on manipulating the opening of iris damper on top of the inlet diffuser using PID strategy without changing the original set up of VAV system. This method was specifically to control a single effected room with low maintenance cost instead of restructuring the VAV system which will involve a high cost and time. After a few research currently conducted, PID strategy will consume more energy since the response will keep changing to meet the ideal temperature. Thus, it will be replaced with the step-based temperature control method.

This research aims it to integrate the step-based temperature control method with iris damper pattern into the inlet air diffuser's damper with the objective of maintaining the indoor temperature range between 23°C to 25°C. It was assumed that 24°C of indoor temperature is ideal for indoor thermal comfort. The selection of iris damper has been further explained by Nur'Amirah *et al.,* [21].

This paper presents the justification on why step-based temperature control is needed to maintain the indoor temperature. Thus, this paper focused on discussing on the real-time indoor temperature distribution using iris damper without any control system. The assumption in this experiment is that the indoor temperature with fixed opening area of iris damper will struggle to maintain its thermal comfort. The results will justify the significant of implementing step-based temperature control method in enhancing the indoor thermal performance.

2. Methodology

Experimental study is a reliable research approach used to investigate and understand the real-time indoor thermal performance of a room. By manipulating independent variables and measuring their effects on dependent variables, experimental analysis aims to establish cause-and-effect relationships, explore hypotheses, validate theories, and provide evidence-based insights. Experiment is performed using lab-scaled chamber with a dimension of 5ft x 5ft x 4ft. The chamber consists of a single inlet with square diffuser and iris damper as shown in Figure 1 and Figure 2.

Fig. 1. The installation of square diffuser and thermocouple type-K in chamber

Fig. 2. Iris damper installed on top of square diffuser

Thermocouple type-K is installed on five selected points. PicoLog TC-08 is used to read the temperature sensor. Channel 1 until channel 5 is connected to collect the real-time temperature data as shown in Figure 3.

Fig. 3. PicoLog TC-08 used to log real-time temperature data from thermocouple

Experiments are conducted for three different iris opening areas: maximum, medium, and minimum. In which each opening area will be tested in four different occupancy conditions: no occupant, one person, two persons and three persons. The detail of experimental condition is simplified in Table 1.

Table 1
Occupancy conditions in experimental study

Opening Type	Opening Diameter (mm)	Opening Area (m^2)	Occupancy Conditions			
			No Occupant	1 Person	2 Persons	3 Persons
Maximum	150	0.071	/	/	/	/
Medium	115	0.042	/	/	/	/
Minimum	65	0.013	/	/	/	/

Each condition is run for one hour after the indoor temperature is stabilized in the initial one hour. Every interval of one hour, a heat initiator with the heat generation of 50 watts will be turned on to represent the appearance of occupant from one person to 3 people respectively. Since lab scaled chamber is used, the heat generation of each person is also scaled into 1:2 from the 100 watts. As an approximation, it is considered a 100 watts LED bulb to represent the baseline heat release of a resting person, keeping in mind that it does not fully capture the complexity of human thermodynamics. The results of real-time temperature distribution of each condition are recorded and interpreted in graph.

3. Temperature Distributions Results

This section discusses the results obtained from the experimental study according to the opening type of iris damper. In general, a larger opening area allows for greater airflow, resulting in more efficient air distribution and improved temperature mixing within the chamber. Meanwhile, reducing the iris damper opening area restricts the airflow which resulting in lower air exchange rates and limited temperature mixing. The airflow may become concentrated in specific areas, leading to uneven temperature distribution within the chamber. Temperature stratification and the presence of hot or cold spots are more likely to occur when the damper opening area is decreased.

Figure 4 represents the combination of real-time temperature distribution of maximum opening type of iris damper with different occupancy conditions. In the first hour, the temperature was let for stabilization and able to achieve the lowest temperature of 21.4°C. Then followed by another one-hour temperature distribution recorded with no occupation, the indoor temperature keeps decreasing with the lowest temperature achieved is 20.37°C which fall below the ideal temperature of 24.0°C. At 120 minutes, the first heat initiator is turned on to indicate one person is present. The temperature started to increase from 20.38°C to 21.88°C with the increment of 1.5°C. Then, followed by the temperature increment of 2.0°C and 1.36°C for 2 person's and 3 person's occupancy conditions. The trend shows that by increasing the occupancy level, the temperature will increase. But still with 3 person occupancy condition, the maximum temperature achieved is 23.41°C which almost meet the ideal temperature for thermal comfort level.

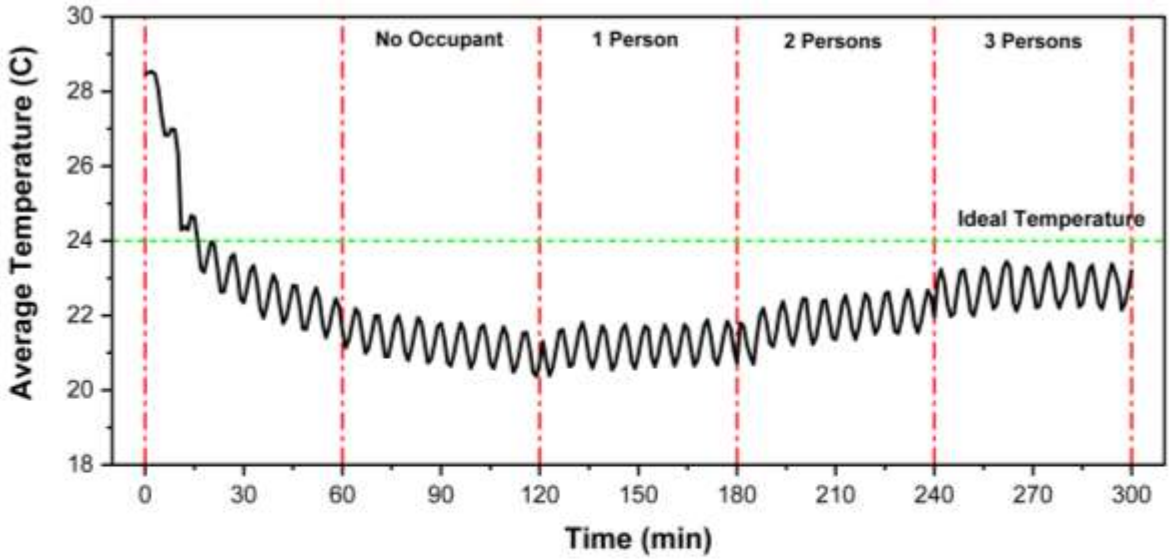

Fig. 4. Real-time temperature distribution during maximum opening area of iris damper with difference occupancy conditions

Referring to Figure 5 and Figure 6, the temperature distribution trends for medium and minimum opening type of iris damper is likely to the maximum opening type of iris damper. In this case, the minimum temperature achieved in all occupancy conditions is above the ideal temperature. But, during no occupant and 1 person conditions, medium opening type able to achieve the minimum temperature of 24.43°C and 24.47°C which most likely meet the ideal temperature after considering the approximation of ±0.5. Unfortunately, the temperature cannot be maintained, and the temperature distributions keeps increasing until maximum temperature of 27.21°C was recorded during the 3 person's occupancy conditions.

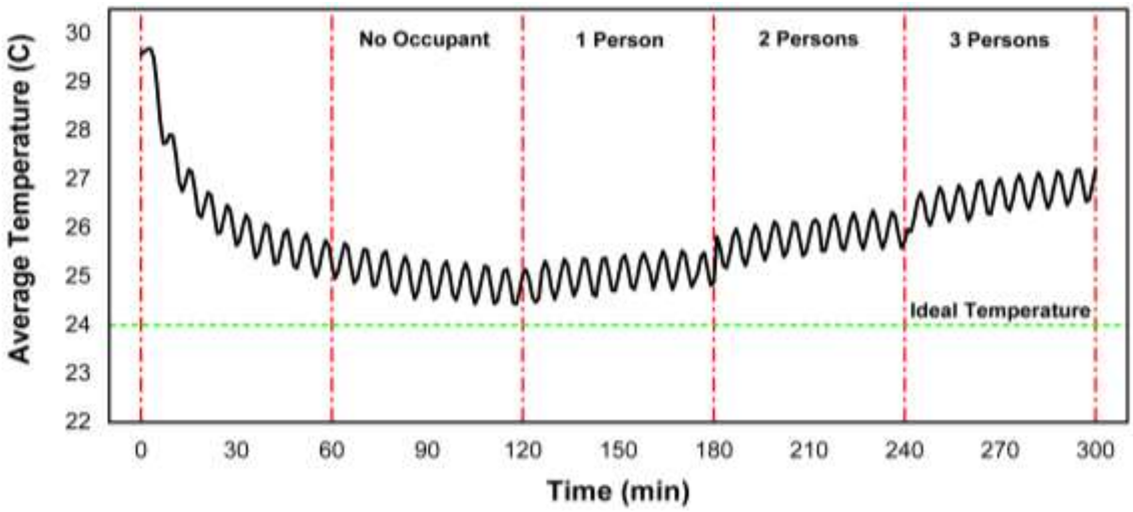

Fig. 5. Real-time temperature distribution during medium opening area of iris damper with difference occupancy conditions

Meanwhile, during no occupant condition of the minimum opening type in Figure 6, the minimum temperature only able to achieve 25.11°C which far from the expected ideal temperature. The maximum temperature achieved during the occupancy condition of 1, 2, and 3 persons are 26.46°C, 27.10°C and 27.68°C respectively. Overall, with the fixed opening area of iris damper, the indoor temperature distribution will keeps decreasing when there are no occupants and increasing when the occupants exist. Thus, the too cold and too hot conditions will take place and distort the indoor thermal performance.

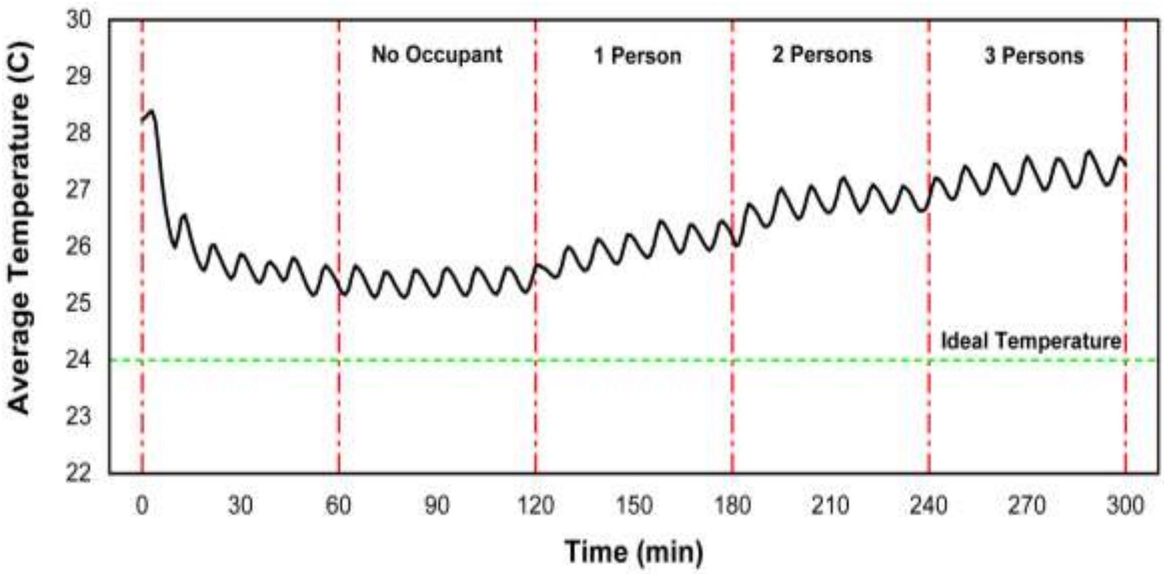

Fig. 6. Real-time temperature distribution during minimum opening area of iris damper with difference occupancy conditions

Table 2 summarizes the maximum and minimum temperature distribution of lab-scaled chamber in difference occupancy conditions and opening type of iris damper. According to the maximum temperature obtained, by reducing the diameter of iris damper from150mm to 115mm, the average temperature can be increased up to 3.65°C. Meanwhile, when the diameter of the 115mm reduced to 65mm, the average temperature shows slight increment which only 0.54°C. We believe that, regulating the opening diameter of iris damper able to enhance the thermal comfort of indoor area by maintaining the indoor temperature closed to the ideal temperature. By selecting an appropriate opening area and ensuring proper airflow distribution, it is possible to achieve more uniform temperature conditions throughout the space, creating a comfortable and pleasant indoor environment.

Table 2
Maximum and minimum temperature distribution of lab-scaled chamber

Occupancy Condition	Opening Type	Temperature (°C)		
		Maximum	Minimum	Difference
No Occupant	Maximum	22.19	20.37	1.82
	Medium	25.69	24.43	1.26
	Minimum	25.67	25.11	0.56
1 Person	Maximum	21.88	20.38	1.50
	Medium	25.53	24.47	1.06
	Minimum	26.46	25.46	1.00
2 Persons	Maximum	22.69	20.69	2.00
	Medium	26.36	25.18	1.18
	Minimum	27.10	26.02	1.08
3 Persons	Maximum	23.41	22.05	1.36
	Medium	27.21	25.93	1.28
	Minimum	27.68	26.84	0.84

4. Conclusions

In conclusion, room with fixed opening area of air damper will be struggling to maintain the indoor temperature. By analysing the temperature distribution against opening area provides valuable insights into the impact of opening area of air conditioner supply inlet on thermal comfort within a room. By studying the experimental data, it is possible to determine the optimal opening area that promotes more uniform temperature distribution and enhances occupants' comfort. This analysis can guide the design and optimization during the selection of openings diameter of iris damper and will be a helpful guideline in designing the temperature control strategies for improved thermal performance.

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