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Automatic damper system for energy saving in small office building : A survey and trainer kit development

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Automatic damper system for energy saving in small office building : A survey and trainer kit development

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Abstract. 50% of office building electricity consumption comes from air conditioning system. For the past years, researches have been focusing on air conditioning system parts, rather than the distribution of air to the space in order to reduce energy consumption. Thus, upgrading old air handling unit (AHU) is needed in order for old building to save energy. Therefore, this research provides a view of the importance to save energy for small office building with old AHU. Survey is done to 110 respondents that familiar with small office building. A prototype of small office building (4 rooms) with automatic damper equip with movement sensor in each room is developed based from the survey result. This system controls flow of cool air to each room based on occupant existence. Flowrate to each room, power consumption, and rough calculation for the cost of electricity for a month is determined. Based from the survey, 95% of respondents agree that implementation of automatic damper system is urgent and important for energy saving. Supplying air to only one room for 8 hours for the whole month, when three other room is vacant, with reduced fan speed, has significant result to the power consumption of the building.

1. Introduction

Nowadays numerous methods are being done to improve energy consumption in buildings in order to save energy. Among the methods are implementation of energy efficiency standards, using energy-saving electrical appliances, application of green roof, and implementations of energy intelligent system in buildings based on occupant activities [1-3]. However, based on past surveys done by researchers, 50% of the power consumption in buildings comes from the heating ventilation and air conditioning (HVAC) system followed by electrical appliances and lighting [4-5]. Therefore, it is crucial to ensure optimum energy consumption by the HVAC system in buildings. Most innovations and researches done for HVAC system previously focused in increasing the performance of air conditioning parts such as the compressor, chiller, heat exchangers and fan in the system in order to reduce the power consumption by HVAC system [6]. Lack of researches on the distribution of air, making it a new area to be explore. Air distribution system in air conditioning system mainly consists of fan, ducting system, damper and diffuser. A correct installation with proper design will contribute to better efficiency of the air distribution system. An efficient air distribution system contribute to less energy loss. In order to save energy through air distribution system, the current studies focused more on innovation of artificial intelligence based control system, implementation of fabric ducting, and installation of variable refrigerant volume flow system for air distribution system [7-9]. These methods require modification to

the system by installing new control system, or new air conditioning unit, and new air distributions parts. Automatic damper is also a common innovation for air distribution system in order to save energy usage. However, most of the automatic damper is linked with thermostat control system and is difficult to be installed to the available system, thus resulting in the needs to replace the current system in order to install automatic damper.

Therefore, in this research, a survey among respondents that has an individual office room is done to measure the criticality of implementation of energy saving method for air conditioning system in small office rooms. Based from the result, a method to reduce power consumption for a small unit office building that used fan coil unit and duct work as it's main air conditioning system is introduced in order to save energy through air distribution system. It is done by installing adruino program to the existing parts to control damper opening and fan speed from the FCU. No changing of air conditioning system is needed in this research. A trainer kit of four rooms with motion sensor in each room is developed as a prototype to test the validity of this system. The motion sensor in each room allows the damper to open and close based on occupants existence. The fan speed is controlled based on numbers of opened damper. Effects of using controllable motor blower fan to flow rate and power consumption for different speed of fan is also measured and analysed.

2. Methodology
2.1 Survey
A survey on air conditioning system for small office rooms is done to 110 respondents in Universiti Teknikal Malaysia Melaka (UTeM) that stays in individual office room. Questions are distributed using google form via link. Question consists of knowledge on air conditioning and energy saving, air conditioning system used in respondent office room, and importance of implementation of automatic damper for central unit air conditioning system. Result of questionnaire contribute to the importance of developing the automatic damper trainer kit.

2.2 Trainer Kit Design
A ducting trainer kit with 4 rooms, equip with a air handling unit (AHU) and rectangular ductwork is designed. The room size is 197.50 mm X 125 mm X 180 mm . The AHU is represented by a custom made centrifugal fan and located at the end of the rooms row and supply air to main ductwork and branch ductwork. The main ductwork is 70 mm width and 25 mm height while the branch ductwork is 35 mm width and 25 mm height. The length of each branch duct from the main duct is of 50 mm. Each branch duct is equip with a damper and diffuser while a motion sensor is placed on the ceiling of each room. Figure 1 shows the three-dimension view of the ductwork designed by Solid Work software while Figure 2 shows the trainer kit from top view with dimensions for each parts.
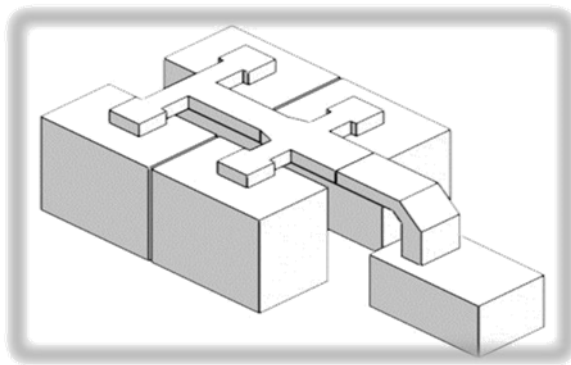

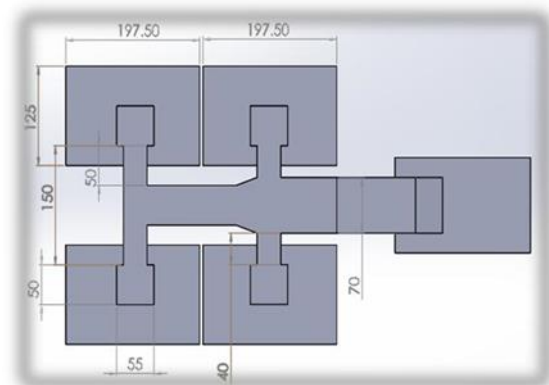**Figure 1**. Trainer kit ductwork in 3D   **Figure 2**. Trainer kit from top view

The rooms are made from acrylic plate and ductwork is made from stainless steel plate and acrylonitrile butadiene styrene (ABS) plastic for see through view of the damper. 3D printer and laser printing is used to build the trainer kit.An adruino program is developed and linked to each damper for each branch duct. The adruino program is also linked to a motion sensor located in each room. The damper open and close based on motion in the room detected by motion sensor. When a damper is closed, the adruino program will give signal to fan to reduce speed based on opened damper numbers. When all 4 dampers are closed, the fan will stop functioning.

2.3 Data Collection

Measurement is done for 4 different cases as there are 4 rooms in the trainer kit. Cases are explained in Table 1 below. "Open" or "Close" indicated the opening of the automatic damper in each room. Flow rate from outlet of each diffuser is measured for 3 times using anemometer for each cases. Average total air flowrate is calculated to study the reduction of flowrate based on fan speed. Flowrate for each room, for each cases is also studied to identify the effect of automatic damper and fan speed reduction to other rooms comfort level. Multimeter is used to measure current set by adruino program and and $P = IV$ is used to determine the power used by the fan based on fan speed for each case.

Table 1. Four different cases for data collection

Case/Room	Room A	Room B	Room C	Room D
Case 1	Open	Open	Open	Open
Case 2	Close	Open	Open	Open
Case 3	Close	Close	Open	Open
Case 4	Close	Close	Close	Open

3. Results and Discussion

3.1 Survey Result and Analysis

Based from the survey done, 98.2% respondent acknowledge that reducing the power consumption in a building contribute to energy saving. This shows that respondent answered this survey is aware of power consumption and energy saving connection. While 69.1% of respondent used central unit air conditioning system in their office room, another 30.9% use split unit air conditioning system. From the respondent that use central unit air conditioning system, 62.7% of the respondent couldn't shut off the air conditioning system when leaving the office room. This indicates that more than 50% of respondent leave the office room with air still flows inside their room despite the vacancy of the room. In Figure 3, indicating 5 as important and urgent and 1 as not important, the result of the survey on the importance of installing automatic damper in each room diffuser shows that 86.4% of respondent rate it as importance and 55.5% from them rate is as importance and urgent. Therefore, this study continue with the development of the sensor based automatic damper trainer kit to study the efficiency of the system for energy saving
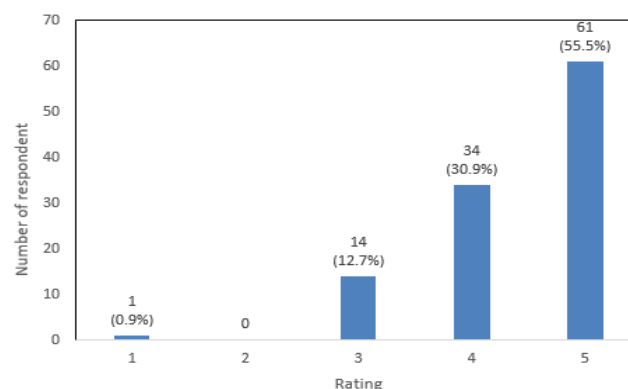

Figure 3 Result on the importance and urgency to install automatic damper in UTeM office room.

3.2 Trainer Kit Outcome

Figure 4 shows the complete trainer kit consist of 1 AHU, 4 branch ducts and 4 rooms with motion sensor in each room linked with adruino program, automatic damper and fan. Air flows from centrifugal fan to each branch duct and flows out through a diffuser in each room. Room surrounding is tinted to reduce the interruption from to the motion sensor. Figure 5 and 6 shows the condition of damper when opened and closed. When there is no motion, the damper is closed, and fan reduced it speed based on numbers of opened damper as set in adruino program. When a motion detected by the motion sensor, the damper is opened and allowed air to flow hence, the fan speed increased.
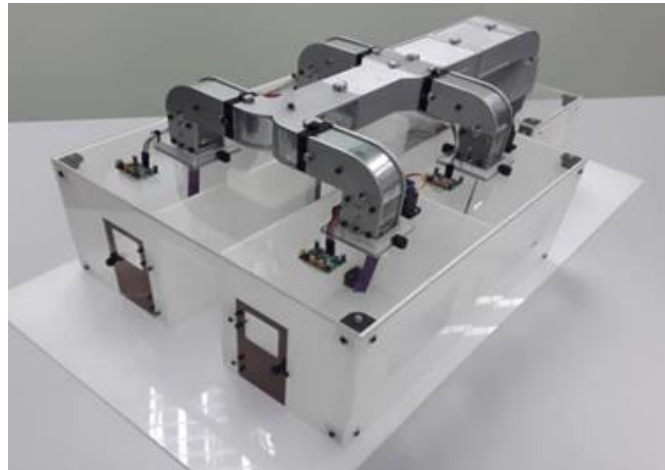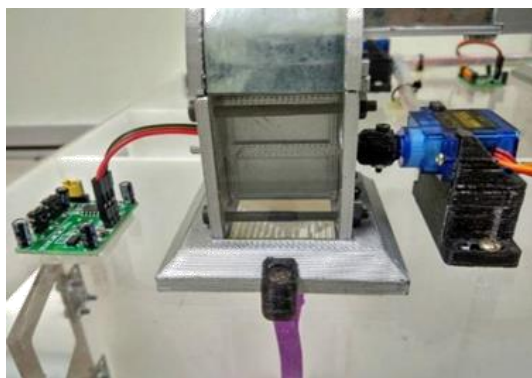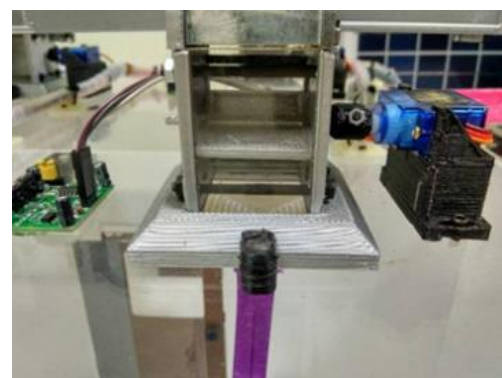

Figure 4 Automatic damper trainer kit

(a)   (b)

Figure 5 (a) Condition of opened damper

(b) Condition of closed damper

3.3 Air Flow Rate and Power Consumption

Figure 7 shows average air flow rate for each diffuser based on cases. Based from Figure 7, closing one damper for each cases subsequently increase the average air flow rate for each diffuser. However, the increase of air flow rate is not significant as it only increase about 0.4% for case 3 to case 4 and 7% for case 1 to case 2. This is an acceptable range for human comfort inside the room. Figure 8 shows average total air flow rate for each cases when the fan speed is reduce based on number of opened damper Based from Figure 8, the average total air flow rate is reduced in stages, from case 1 to case 2, to case 3 and case 4. This shows that the relation between number closed damper and fan speed reduction is proportional to each other. Power setting from the adruino program allows the current to be reduce for

each cases in order to reduce the fan speed. Figure 9 shows the power consumption for each case. The power for each case reduced approximately 50kW. This reduction in power allows building occupant to save power consumption in their office building hence, reducing cost for electricity for air conditioning system usage.
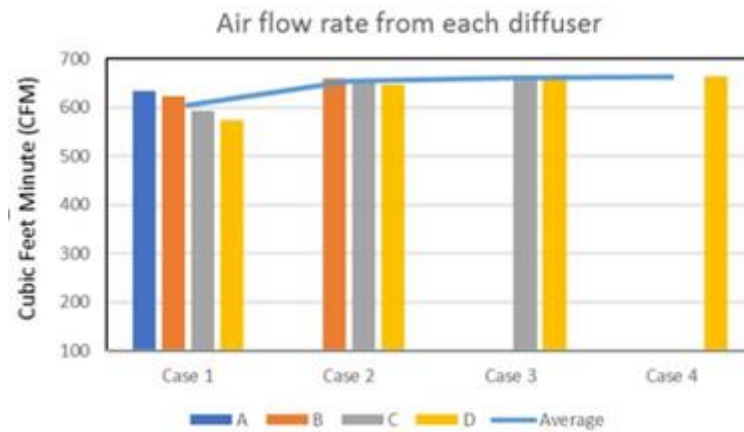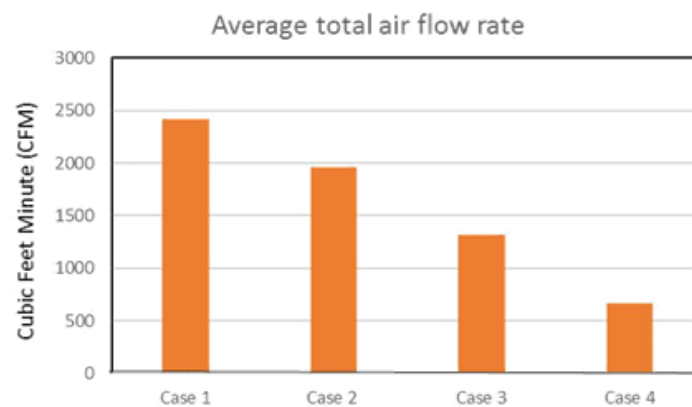

Figure 6 Average air flow rate from each diffuser

Figure 7 Average total air flow rate for each case
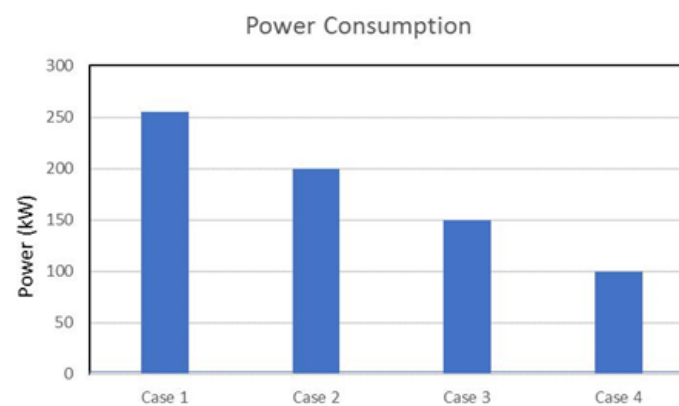

Figure 8 Power Consumption for each case.

4. Introduction

In conclusion, based on the survey done, most of the office room occupants agreed that the development and implementation of sensor based automatic damper is important and urgent. Therefore, a development of a trainer kit to study the effect of the sensor based automatic damper was done and study of flow rate with relation to the reduction of fan speed was exhibit. The result shows that the fan speed reduction is proportional with the reduction in air flow rate to each diffuser hence, proof that the automatic damper is suitable to be applied in a small office building as it does not affect the human comfort in each room. The power consumption was also observed as the fan reduced it speed based on the adruino program installed to the fan and automatic damper. This contributed to energy saving when less power is used in a building. Based from the above result,the objective of this research is achieved.

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