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Convective Heat Transfer in Air Conditioning Ducting (Internal Flow)

(Pemindahan Haba Perolakan dalam Sesalur Penyamanan Udara (Aliran Dalaman))

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Abstract

The prominent selections of ducting systems are based on design and size to determine the heat transfer and the impact of both ducting designs based on temperature differences. By using cooling load calculations such as the Rule of Thumb method and Ductsizer software, the analyses calculated the respective rooms involved in this study. The analysis's final finding revealed that the round (circular) duct has a smaller pressure drop than the rectangular duct. Additionally, it is discovered that a rectangular duct's temperature drop is significantly higher than a volumetrically equivalent round one because of friction between the fluid's moving particles and the duct's interior surfaces, the wall's difficult curvature and shape due to the rectangular duct's sharp corners, and the more challenging flow pattern. Apart from that, the noise level is also higher for the rectangular duct compared to the round duct.

Keywords: Airflow, heat transfer heat loss, temperature, ductulator

INTRODUCTION

In buildings with forced-air systems, the ducts that distribute cooled air are frequently found in attics or other unconditioned areas where the air's temperature is significantly different from that of the ducts. The air moving through the ducts may get warmer as a result of these temperature changes, which will raise the cost of the air conditioner. For an air duct, there are two main cross-sectional shapes rectangular and round ducts. Both technical and economic factors should be taken into account when choosing a duct system. In this paper, a literature study on rectangular and round (circular) ducts is carried out to determine the heat transfer and the impact of both ducts design-wise (Hassan & Yue, 2002; Gheji, Kamble, Gavde, & Mane, 2016). The design of rectangular and round ducts is demonstrated in Figure 1.

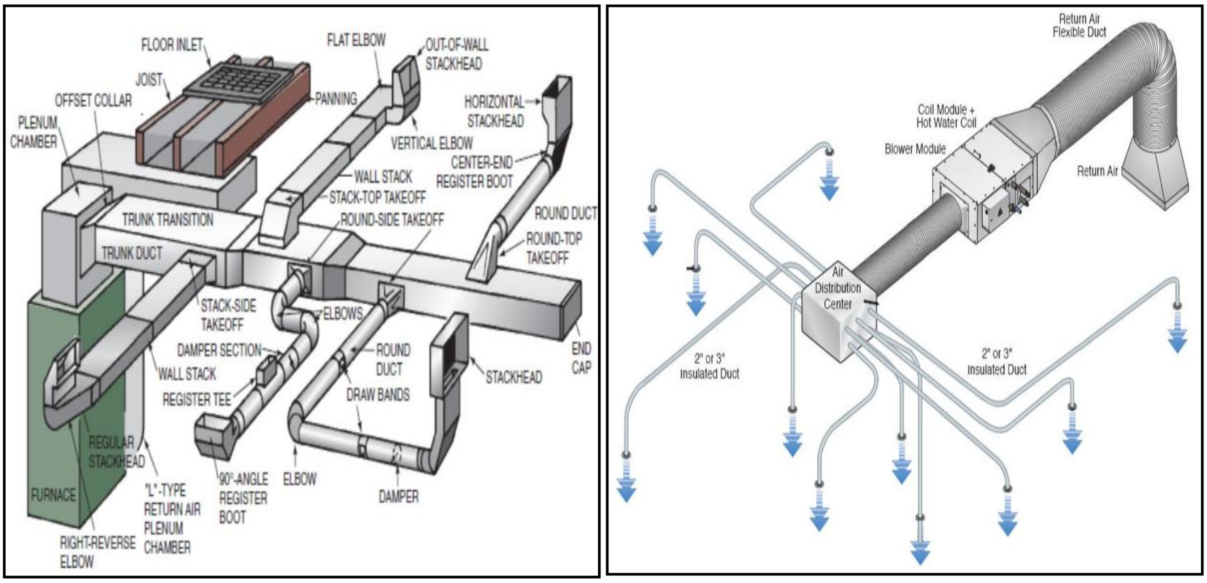

Figure 1. Design of rectangular ducts and round ducts

This investigation was intended to study the heat transfer heat loss from the galvanised-iron steel rectangular and round ducts carrying cooled air and to determine the resulting drop in temperature in the air flowing in the ducts. The studies were confined to insulated round and rectangular ducts of sizes commonly used in forced-air cooling systems.

The analysis made was to compare heat transfer between round and rectangular ducts for the air conditioning system in a building, particularly in an office space area (Hassan, Leman, Zafarullah, Salleh, Rahman, Madon, & Zamree, 2021). Figure 2 shows the airflow and heat transfer through air cooling ducts.

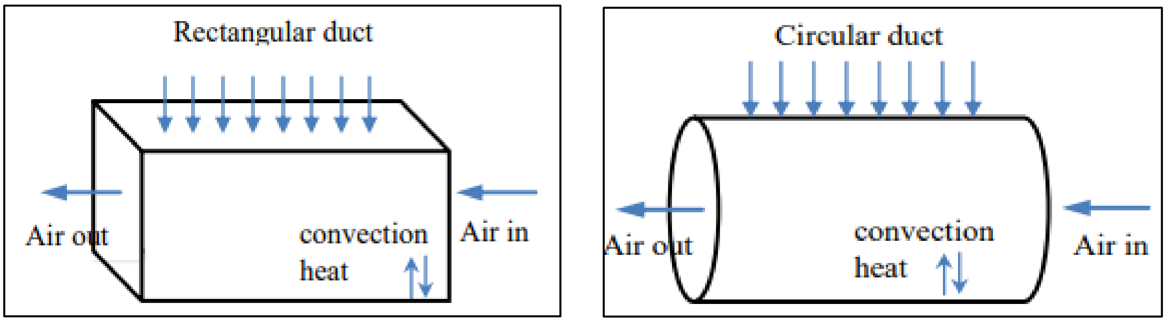

Figure 2. Air-cooled ducts air flow and heat transfer

METHODOLOGY

The importance of duct design, which has an impact on system performance, was considered when designing ducting for an air conditioning system in an office building (Sharma & Sharma, 2012). Frictional loss, unequal building cooling, higher installation costs, higher noise levels, and higher power consumption were all issues brought on by improper duct designs. The aforementioned issues demonstrated the requirement for an ideal duct design and efficient duct arrangement. Hence, considerations of using manual calculation and software calculation as a tool for designing the duct were applied. A study has been done on the ducts to analyze the heat transfer between rectangular and round ducts. Since both ducts are insulated, assuming the surface temperature is constant. Figure 3 depicts a cross-section of the ducting profile, and Figure 4 shows a flowchart of the ducts' heat transfer.

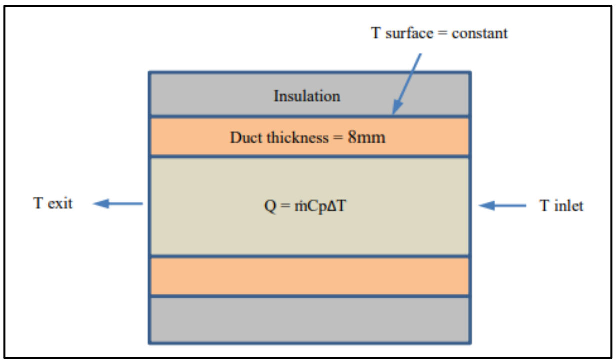

Figure 3. Cross-sectional ducting profile

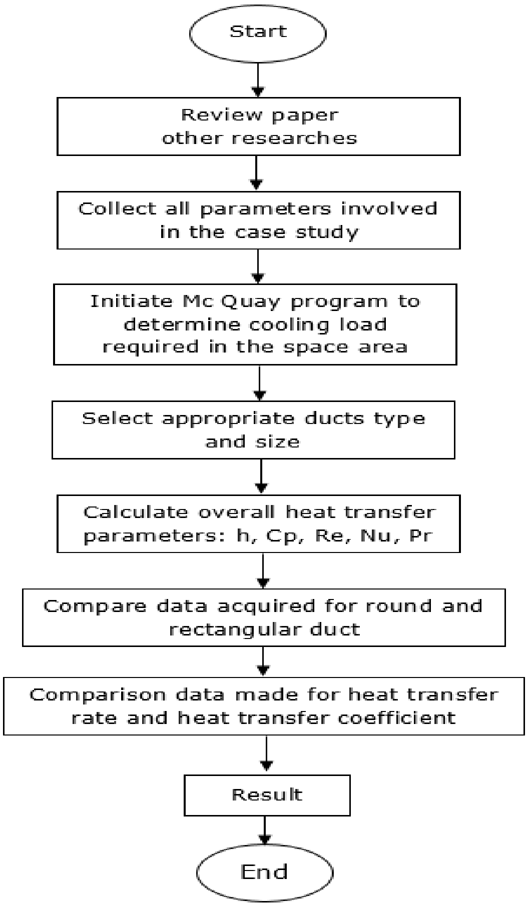

Figure 4. Flowchart heat transfer ducts

According to the first law of thermodynamics (also known as the conservation of energy principle), energy may only change its form during a process, not be created or destroyed (Wisniak, 2008).

$$E_{in} - E_{out} = \Delta E_{system} \quad (1)$$

$$E_{in} - E_{out} = \dot{m}C_p dT \quad (2)$$

Hence, these equations are used in this work under the assumption that the surface temperature, Ts, is constant,

$$Q = \dot{m}C_p dT = hA\,(T_s - T_e) \quad (3)$$

Cooling load calculation must be considered before these considerations are made. Estimating the cooling load is crucial for building an effective duct system since it determines the zones and air flow rates that the duct system distributes. The duct system component can be installed once the air flow rate has been established. This study initially needs to calculate the cooling load of the respective office room by using the Rule of Thumb (RoT) method. The data for air flow are shown in Table 1.

Table 1. Airflow data

Item	Room Name	Area(ft^2)	Btuh/ft^2	Btuh	CFM/ft^2	CFM
1	Office	169	60	10140	1.50	253.50

A ducting software programme design tool called Ductsizer. It was decided to use a 260cfm flow rate and a 0.1 in.Wc/100ft heat loss for the supply duct design for this application. Figure 5 uses Mc Quay Software to display the sizes of a round duct and a rectangle duct.

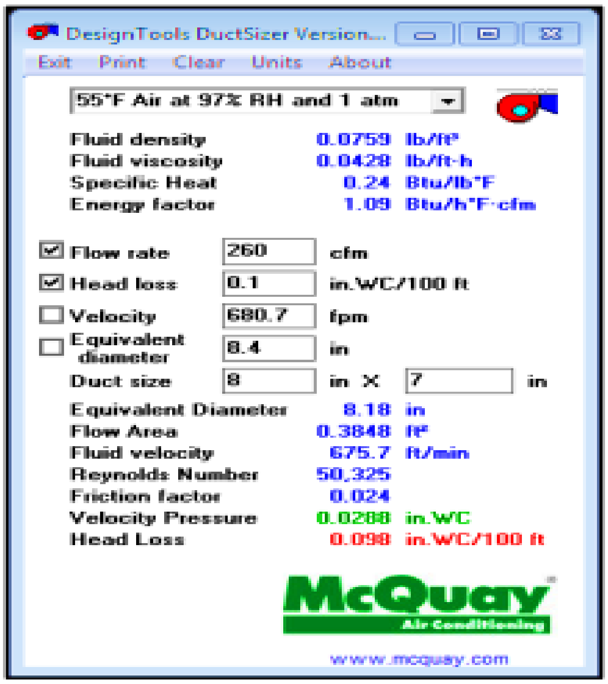

Figure 5. With courtesy of Mc Quay Software

RESULTS

A 3m long insulated square duct of cross section 0.203m x 0.178m and 0.213m in diameter. Cold air enters the duct at 1 atm and 12.8 °C at a velocity of 3.459 m/s. It is 14.8°C at the duct surface. The heat transfer coefficient and the duct's rate of heat loss should be calculated. The data research table is shown in Table 2.

Table 2. Table of data research

Parameters	Rectangular Duct	Round duct
Volume flow rate, v	260 cfm	260 cfm
Velocity, V	680.7 ft/m	680.7 ft/m
	3.459 m/s	3.459 m/s
Thickness, δ	0.0005 m	0.0005 m
Length, L	3 m	3 m
T_i (inlet)	12.8 °C	12.8 °C
T_s (surface)	14.8 °C	14.8 °C
T_{Avg}	13.8 °C	13.8 °C

According to the findings, the round duct has a less pressure drop than the rectangular duct due to the volume of the duct shapes has an impact on how well the velocity performs. The round duct has an excellent airflow characteristic. As written in Table 3 below, by assuming constant surface temperature condition and both ducts' inlet temperature is 12.8°C can be described as:

Table 3. Table of data collected

Parameters	Under Slab	
	Rectangular Duct	Round Duct
Surface Temperature, °C	14.8	14.8
Inlet Temperature, °C	12.8	12.8
Exit Temperature, °C	13.18	13.13
Heat Transfer Coefficient, $W/m^2.°C$	14.22	13.90
Heat Transfer Rate, Watt	58.65	51.09

From Table 3, the heat transfer rate and the heat transfer coefficient show the significance of the values acquired in more favourable round ducts compared to rectangular ducts.

CONCLUSION

The exit temperature will rise along with the rate of heat transfer when the ducting area (A) is raised. Since the round duct area is smaller than the rectangular duct based on McQuay's calculation of the area provided earlier, the exit temperature and the heat transfer rate of the round duct have decreased. This study demonstrates that the temperature drop through a rectangular duct is significantly higher than one that is volumetrically equal to a round one because of friction between the moving fluid particle and the interior surfaces of a duct, the difficult wall curvature, and the shape of the rectangular duct due to sharp corners, and the more difficult flow pattern compared to the round duct. Apart from that, the noise level is also higher for rectangular ducts compared to round ducts.

Finally, it is recommended that, when pressure drops and noise levels must be considered, architects and HVAC engineers cooperate to design environmentally efficient duct systems in sustainable buildings. Comparing duct systems with various cross-sections in terms of friction loss, pressure loss, noise, and other comparable factors continue to be of interest to the HVAC industry. The lowest head loss value compared to rectangular duct design makes round duct design the best duct design for the building. For instance, in comparison to lagged rectangular ducting, the space supplied above the ceiling tile for round ductwork can be particularly cost-effective.

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