Design of an air distribution system for a Multi-Story Office Building

Mr. Gaurav Tamrakar [1],

Mr. Shailesh Singh Thakur [2]

[1,2] Assistant Professor, Department of Mechanical Engineering,

kalingauniversity

Astract

Air-distribution systems include air handlers, ductwork, and associated components for heating, ventilating, and air-conditioning buildings. They provide fresh air to maintain adequate indoor-air quality while providing conditioned air to offset heating or cooling loads. Their many components need to operate in unison to properly maintain desired conditions. They use relatively large amounts of energy so applying smart operational strategies and good maintenance practice can significantly reduce energy consumption Equal friction method is used to design the duct, which is simple method as compared with the other design methods. These work gives the combination of theoretical and software tool to provide a comparative analysis of the duct size. It also gives the comparison between rectangular duct and circular duct.

Keyword : Idoor, Outdoor, Material, Rectangular duct, Circular duct. Pressure loss. Friction loss.

Introduction

In the preset as the population increases comfortness also increases. The human being needs more comfortness because of inferior environment (like light, sound, machine which produce heat). Sound, light and heat affect human comfort a lot. They may adversely affect the human comfort positively or negatively. Researchers suggest that, human body is used to be comfortable at a temperature of 22ºC to 25ºC. When the temperature of room is lower or higher than this temperature, than the human body feels uncomfortable. This is because, the human body is structured in a way that, it should receive a certain amount of light, failure to which it can cause sunburns and other skin conditions.

There are many types of air conditioning system like window air conditioners, split air conditioners etc. but these AC's system are used in small room or office where cooling load required is low. When the cooling load required is very high like multiplex building, hospital etc. central AC's system are used. In central AC's system the cooled air is directly not distributed to the rooms. The cooled air from the air conditioning equipment must be properly distributed to rooms or spaces to be cold in order to provide comfort condition. When the cooled air cannot be supplied directly from the air conditioning equipment to the spaces to be cooled, then the ducts are installed. The duct systems convey the cold air from the air conditioning equipment to the proper air distribution point and also carry the return air from the room back to the air conditioning equipment for reconditioning and recirculation.

Duct Material

As the duct system for the proper distribution of cold air, costs nearly 20% to 30% of the total cost of the equipment required. Thus, it is necessary to design the air duct system in such a way that the capital cost of ducts and the cost of running the fans is lower. The ducts are usually made from galvanized iron sheet metal, aluminium sheet metal or black sheet. The most commonly used duct material in the air conditioning system is galvanized sheet metal, because the zinc coating of this metal prevents rusting avoids the cost of painting. The sheet thickness of galvanized iron duct varies from 0.55 mm to 1.6 mm. The aluminium is used because of its lighter weight and resistance to moisture. The black sheet metal is always painted unless they withstand high temperature.

Now a day, the use of non-metal ducts has increased. The resin bounded glasses are used because they are quite strong and easy to manufacture according to the desired shape and size. They are used in low velocity application less than 600 m/min and for a static

pressure below 5 mm of water gauge. Sometimes cement asbestos duct also used for underground air distribution. The wooden duct may be used in places where moisture content in the air is not very large

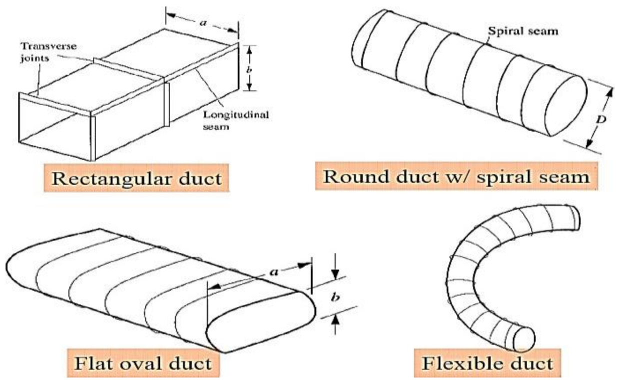

Fig. Shape Of Duct

Literature

G. S. Sharma et al. [1] designed a duct for an air conditioning system in an office building and analyzed the importance of duct design which creates an impact of system performance. Improper duct designs led to problems such as frictional loss, uneven cooling in the building, increased installation cast, increased noise level and power consumption. The above problems highlighted the need for an optimum duct design and effective layout of the duct. The authors used hand calculation and software tool both for designing the duct. They found that the circular duct has a less pressure drop than the rectangular duct. R. Whalley et al. [2] considered HVAC modeling methods for large scale, spatially dispersed systems. In this paper, they discussed existing techniques and proposals for the application of novel analysis. Tengfang T. Xu et al. [3] did field study on the performance of five thermal distributed systems in four large commercial buildings. They studied about the air leakage from duct, and concluded that the air leakage in large commercial systems varied significantly from a system to system. The energy loss due to a leak can be minimized by using duct sealing and duct insulation. Baris Ozerdem et al. [4] studied the energy loss related to the air leakage by using power law model. The measurements were made on different types of duct having different diameter. After measurements, they concluded that the most of the air leakage was from the joint and this air leakage was reduced by about 50% by using sealing gaskets. Michal Krajcík et al. [5] studied experimentally air distribution, ventilation effectiveness and thermal environments, in a simulated room in a low-energy building heated and ventilated by warm air. The measurements were performed at different outdoor conditions, internal heat gain, air change rates. Their study showed that the warm air heating and floor heating system did not affect the significant risk of thermal discomfort. William J. Fisk et al. [6] did field studies in large commercial buildings and they investigated the effective leakage areas ELAs, air-leakage rates, and conduction heat gains of duct systems. Air leakage rates were measured by using different method and their result were compared. They found that the air leakage rate varied from 0% to 30%. Also, heat gains between the cooling coils and the supply registers caused supply air temperatures to increase, on average, by 0.68°C to 28°C. Liping Pang et al. [7] determined the ratio of fresh air to recirculation air. The conditioned temperature of different types of inlets were designed carefully to achieve the high air quality,

Methodology

This project gives the fundamental principles of duct or air distribution system design for a multi-story building. There are mainly three types of duct sizing method namely (i) equal friction method, (ii) modified friction method (static regain method) and (iii) velocity reduction method. Now a days, the use of manual duct calculator is normal and computer aided duct design is becoming more popular. Also understanding the friction chart is very important to use this manual duct calculator, because these are the foundations of the other methods. This will provide the necessary knowledge to the duct design error and overcome to the errors.

For designing a proper duct system, it is necessary to estimate cooling load which is used to select the zone and air flow rate that the duct system distributes. Once the air flow rate is determined, the duct system component can be placed. This includes the supply and returns diffusers and decides to air handling unit (AHU) or fan coil unit (FCU) is good for that space.

General duct design

- Air should be conveyed as directly as possible to economize on power, material and shape.
- Sudden change in direction should be avoided.
- Air velocities in ducts should be within the permissible limits to minimize losses.
- Rectangular ducts should be made as nearly square as possible. This will ensure minimum ducts surface. An aspect ratio of less than 4:1 should be maintained.
- Damper should be provided in each branch outlet for balancing the system.

Duct design criteria

Many factors are considered when designing a duct system. They are as follows

1. Space availability
2. Installation cost
3. Air friction loss
4. Noise level
5. Duct heat transfer and airflow leakage

Space availibity

The sizing of a duct depends on the space available in the building. Ceiling plenums, duct chases, obstruction like walls and beam dictate the size of duct to be used, irrespective of the size at a least cost. At the time of design, the duct coordination is required to avoid sprinkler piping, power and light fixtures. For this, header duct and runouts are easier to locate. Larger the trunk and branch ducts greater the coordination required with equally large piping.

Installation cost

While designing, the duct installation cost is very important. This includes size of ducts, type of material used, number and complexity of the duct fitting and height of the site conditionsimpacting duct installation labor. Use least no of fitting as possible to lower the installation cost.

Air Friction loss

Air friction loss is affected mainly by the duct size and shape, the material used, fittings used. According to –Carrier Handbook‖ round galvanized sheet metal has the lowest friction loss per meter, while the flexible ductwork has the highest friction loss per meter. The quality of fitting has a direct effect on the overall pressure drop of a duct system, smooth and efficient fitting with a low turbulence reduce the duct system air pressure drop. A direct route using round duct with less fitting and size changes can have a less friction loss in comparison with the similar size rectangular system with a longer route and size changes at each branch duct.

Pressure in duct

The flow of air within a duct system is produced by the pressure difference existing between the different locations. The greater the pressure difference, the faster the air will flow. The following are the three types of pressures involved in a duct system.

Heat transfer and leakage

Ductwork that runs through very warm or cold areas can suffer heat gain or loss that effectively higher operating cost. Leakage in duct also affects the capacity of cooling equipment and may create odors.

The modern AC systems require control of noise level uncomfortable feeling. The equipment as blowers,humidifiers, motors and many others contribute noise to the air conditioned space. The air passing through the ducts and grills also create noise.

Static pressure (Ps)

The static pressure always exists in a duct system. The pressure which is independent upon the air movement called static pressure. This type of pressure pushes against the wall of the duct. It tends to rush a duct when its force is greater than that of atmospheric pressure and tends to collapse when its force is less than that of the atmosphere. These pressures overcome the friction and shock losses as the air is flow.

Velocity Pressure (Pv)

The velocity or dynamic pressure is equal to the drop in static pressure necessary to produce a given velocity of flow. In other words, it is equal to the increase of static pressure possible when velocity is reduced to zero.

Total Pressure (P_t)

It is the algebraic sum of the static pressure and dynamic pressure.

$P_{t=} = P_s + P_v$ ---(3.1)

P_t = total pressure, Pa

P_s = static pressure, Pa (measured by any pressure measuring instrument)

P_v = velocity pressure= for air

= , (for air = 1.024 kg/m3)

$=0.602V^2$ --(3.2)

V = fluid mean velocity, m/s---------------------------------- (3.3)

Where, Q = air flow rate, m^3/sec

A = cross sectional area, m^2

Pressure loss in Duct

Pressure is lost due to friction between the moving particle of the fluid and the interior surfaces of a duct. When the pressure loss occurs in a straight duct, then this loss is known as friction loss. The pressure loss is due to the changes of direction of air flow such as bends, elbows etc. and at the change of cross section of the duct, this loss is known as dynamic losses.

Pressure loss Due to Friction loss in Duct

The pressure loss due to friction in ducts may be obtained by using the Darcy's formula, i.e.

$P_f = \frac{fl\rho_a v^2}{2D_h}$-----------------------------------(3.4)

Where

P_f = pressure loss due to friction in N/m^2

L = length of the duct in meters

f= friction factor depending upon the surface of the duct

ρ_a = density of air in kg/m^3

V = mean velocity of the air flowing through the duct in m/s

D_h= hydraulic diameter in m

The value of friction factor (f) for different Reynolds numbers and different roughness factor find directly from the Moody chart as shown in Fig..

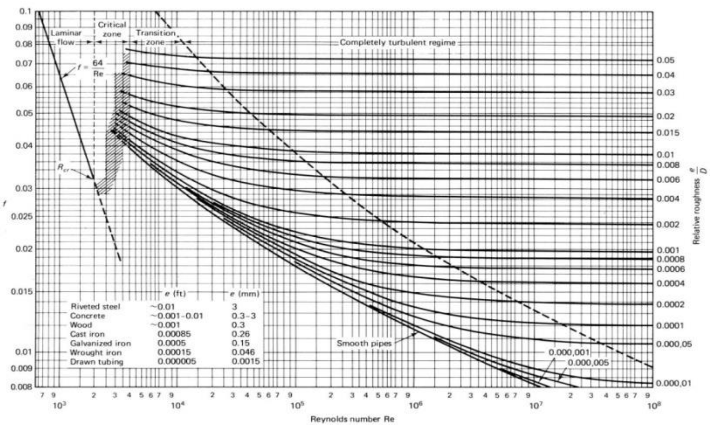

Fig. Moody chart

Dynamic Losses in Ducts

The dynamic losses are caused due to the change in direction or magnitude of velocity of the fluid in the duct. The change in the direction of the velocity occurs at bends and elbow. The change in the magnitude of velocity occurs when the area of duct changes i.e. enlargement, contraction, suction etc.

The dynamic pressure loss Δp_d is proportional to the velocity pressure and it is expressed as a product of the downstream velocity pressure p_v and a dynamic loss coefficient (K).

$$\Delta_{P_d} = kp_v = K\frac{\rho c^2}{2}$$

Where, V = downstream velocity.

The losses in elbows, fittings etc. are also expressed in terms of an equivalent length L_e of the duct, so that

$\Delta_{P_d} = kp_v = K\frac{4l_e P_v}{D}$--------------------(3.5)

Friction Chart

The frictional pressure loss for circular ducts (in mm of water) for various velocities (in m/s) and duct diameters (in mm) obtained directly from the friction chart as shown in Fig. 3.2. In this chart, the vertical ordinate represent volume flow rate of air in m^3/s and the horizontal ordinate represents frictional pressure loss in mm of water per unit length of the circular duct. These charts are valid for 20°C and 1.013 bar and clean galvanized iron ducts with joints and seams

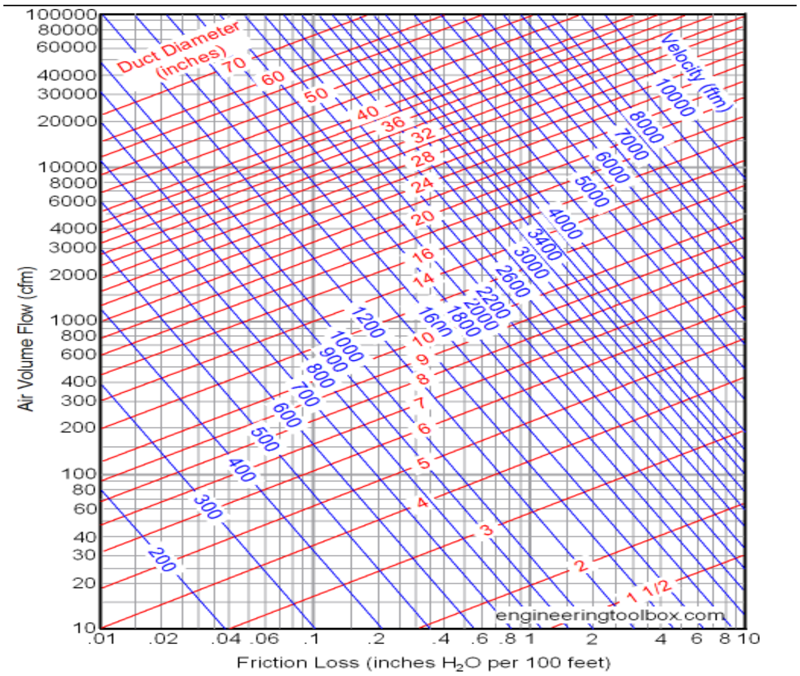

Figure. Duct Friction Chart

Conclusion

The duct design for TIIR building is done, by using equal friction method. All values are comparable with duct software called ductulator.The calculated value of frictional is less or near as calculated by software. Due to less value of friction drop, duct diameter is increased but loss in total pressure (i.e. static pressure, velocity pressure) can be avoided.Due to increased duct diameter the use of damper may be decreased.Also the circular duct can carry more air in less space, because of that, less duct material, less duct surface friction and less insulation is required.Pressure loss in duct fitting can be minimized by proper design the elbow shape

Referances

- G.S. Sharma and B. Sharma. –Duct designing in air conditioning system and its impact on system performance‖. VSRD International Journal of Mechanical, Automobile and Production Engineering, Vol. 2 No. 9 November 2012.
- R. Whalley, A. A. Ameer. –Heating, ventilation and air conditioning system modeling‖. Building and Environment 46

(2011) 643-656.Tengfang T. Xu, Francois R. Carrie, Darryl J Dickerhoff , William J. Fisk. ―Performance of thermal distribution systems in

- large commercial building‖. Building and Environment 34 (2002) 215-226.
- C. Aydin, B. Ozerdem. Air leakage measurement and analysis in duct systems. Energy and Buildings 38 (2006) 207–213.
- M. Krajcík, A. Simonea, B. W. Olesena. ―Air distribution and ventilation effectiveness in an occupied room heated by warm air‖. Energy and Buildings 55 (2012) 94–101.
- W. J. Fisk, W. Delp, R. Diamond, D. Dickerhoff, R. Levinson, M. Modera, M. Nematollahi, D. Wang. Duct systems in large commercial buildings: physical characterization, air leakage, and heat conduction gains. Energy and Buildings 32 (2000) 109–119.
- L. Pang, J. Xu, L. Fang, M. Gong, H. Zhang, Y. Zhang. Evaluation of an improved air distribution system for aircraft cabin. Building and Environment 59 (2013) 145-152.
- K. Srinivasan. Measurement of air leakage in air-handling units and air conditioning ducts. Energy and Buildings 37 (20