Analysis of Problems Occuring in Performance of Ducts and Pipes

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Abstract— To overcome the any problem need to well known about the problem and this paper presents description of the physical problems which occurred in the ducts and pipes when fluid flow inside it. The problem is based on fluid flow as well as heat transfer. The problems are presents with their root cause along with their effect on performance and general method of overcome. Conclusion of this paper is that selection of proper duct materials, geometries, and supply path according to need may reduce the problem occurring in performance of duct.

Key words: Ducts and Pipes

I. INTRODUCTION

Each and every thing existing in world with their positive points as well as negativity. It is impossible to overcome the problem permanently but there are many opportunity to minimize this problem at maximum limit. To overcome these problems we have to know well about problem relating to it as well as the root cause of the problem. A duct is a mechanical component used to transport fluid from one place to another place in a specified way [1] and obviously there are many problems occur in performance of duct when fluid is transport from it. These problem is occur in many form for example the biggest problem in duct is friction which take place between two adjust tent fluid layer as well as fluid and inner wall of duct. These problem cause losses of energy and reduce the overall efficiency of system also cause to mechanical damage of system by vibration. This problem also causes to reduce the life of ducts. The problems are genrally depends upon ducts materials, surrounding conditions, duct networking system, fluid properties and application for which it is used.

II. MAJOR PROBLEMS IN PERFORMANCE OF DUCT

A. Fluid Friction

Friction is the major reason of reduction of air flow rate generally occurs due to fluid viscosity and turbulence in the flow through the ductwork and occurs along the entire length of the ductwork. Transmitting fluid in duct is resisted certain amount by duct inner wall which cause additional losses of energy. It cause pressure drops. The higher it rubs the higher loss of energy take place. Fluid Friction is categorized in two types, first one is the internal friction and second one is the external friction. The internal friction, which is a result of the interactions between molecules of the fluid and the external friction, which is a result of the interactions between the fluid and duct material. Fluid Frictional loss depends following factors

- The nature and physical state of the fluid
- Velocity of fluid
- The nature of the material the duct is made of
- How it was installed
- How dirty it is,
- Duct dimensions (length and diameter)
- Roughness of the duct material

Friction loss is presented mathematically in form of head (m) as follows

$$h_f = \frac{flV^2}{2gD}$$

Where V stands for fluid velocity, l stands for duct lengt, D is diameter of duct, g is gravitational acceleration and f is stands for the friction factor [2]. Friction factor depends upon the type of flow such as laminar or turbulence and duct material. And given as follows

For the laminar flow, frictional losses are function of the velocity of fluid, V; that velocity maximum at the center of duct radius and zero at the pipe surface. In this region the roughness of the pipe surface effect neither to fluid transmission velocity nor the friction loss. For laminar flow i.e. Re<2000, the friction factor is given as

$$f_{laminar} = \frac{64}{Re}$$

In turbulent flow, losses are function to the fluid velocity square $(V)^2$. In this region, the surface roughness of pipe material plays important for and gives considerable effects. The term relative roughness is characterized by the roughness height (ε) divided by the pipe diameter (D). For turbulence flow (Reynolds number >4000) the friction factor is given as [3]

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left[\left(\frac{k_s}{3.71D}\right) - \left(\frac{5.1286}{Re^{0.89}}\right)\right]$$

Smooth pipe region, rough pipe domain and the transition region is three sub-regions associated to turbulent flow. In first sub-region friction loss relatively insensitive to roughness and depends upon Reynolds number. In second sub-region the friction loss is proposal to the surface roughness and is not depends upon Reynolds number. Whereas in the transition region where flow isn't stable and vary with time and here friction loss is depends upon to Reynolds number as well as roughness of surface. [4].

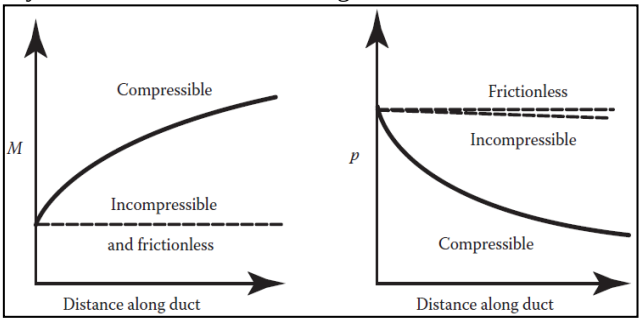

Fig. 1: Effect of Frictional Loss in Mach number (M) and Pressure (p) [5]

1) Method for Reduction Friction

- Velocity of fluid should be maintain as low as possible to avoid friction loss and energy consumptions.
- Frictional loss reduced 32 times by doubling the duct diameter.
- Designing of low velocity is play important for the efficiency of power of the fluid flow system.

- Frictional loss can be reduced by choosing the smooth duct material.
- Fluid should be delivered as short distance as possible to reduce friction, power, space, losses and material.

B. Turbulence

Turbulence is second important reason responsible for reduction of velocity of air result from flow disturbances caused by fittings that change the airflow direction or area. The pressure drop increase more quickly with decreasing the diameter ducts. When abruptly reduction of cross section of duct taken place then it result to increase in the velocity of fluid as well as change in direction of flow. Turbulence is like of internal friction of the fluid molecules fight together.[6]

1) The Main Cause of Turbulence

- Turning of air in any angle. When air flow through a 90° turn, the type of fitting you use to do so can make a big difference
- Increase in fluid velocity suddenly from 0 to the velocity along the duct.
- The resistance of fluid by the inside surface of the duct.
- Changes of cross-sectional area of duct, where there are sudden increases the cross section or sudden decrease in cross or changes of shape.
- Changes of direction of flow, such as elbow, bends and L joint T-joint are waste great amount of energy and causes of high turbulence.
- Due to large aspect ratio turbulence increase highly

2) Effect of Turbulence

- The first effect is due to the relative velocity between the fluid and the particles, and a model for the relative velocity is presented
- The second effect is due to the group of particles, where the rate of the transfer of is quiet due to the fast deficiency of the consumed verity in the heavy particle group.
- In a pipe and duct the transfer of heat and friction enhanced because of increase in turbulence [7].

3) Method for Reduce Turbulence

- Keep air velocity at entry as low as possible. Also velocity in duct should be low.
- Instead of sudden increase in area, sudden decrease in area and other changes of size or shape should be made by gradual taper sections, not abruptly.
- Changes of direction should be by easy bends and well-rounded corners, not by sharp elbows, unless fitted with guide vanes (expensive).

C. Heat Transfer

In HVAC system ducts are either applicable for the purpose of transport of hot air during the winter or lots of day of the year applicable for the purpose of transport of hot air in hotter areas . They transport cold air all over leaving place. During supply of air, due to effect of surrounding the heat losses take placed by transfer of heat to surrounding. Due to this heat transfer process, warmer air become cooled and cold air become warm and these cause to result of insufficient heating and cooling. Similarly in case of power plant ducts (steam pipe) is applicable supply high temperature of fluid with high speed which loss high amount heat to surrounding cause to reduction in efficiency of plant. This is one of the major problems occurring in performance of duct.

1) Method for Reducing Heat Loss

- Use duct material of low thermal conductivity
- Keep duct supply system as short as possible
- Keep fluid velocity within limit.
- Use insulation may reduced some amount of heat loss

III. OTHER PROBLEMS IN DUCT

A. Maximum Working Temperature and Thermal Conductivity of Duct Materials

In steam pipe the fluid (steam) temperature is very high about 500-600 degree Celsius. So that the first property required pipe material should have lower thermal conductivity so that they transfer small amount of heat to surrounding. The one more property required to duct material is that they should withstand with high temperature and handle more pressure. The thermal conductivity of material should not increase with temperature. Similarly the pipe (tube) used in heat exchanger should have higher thermal conductivity and withstand with high temperature so that they transfer heat to surrounding with higher rate.

B. Duct Fitting

Fittings are where the majority of pressure losses occur. Selection of the right fittings in the right places can have a considerable effect on energy application, and also capital cost. . Dynamic losses in duct systems terms as pressure losses occur due to the change in the direction of air flow by use of elbows as well as offsets and take-offs. This loss also caused by resistance in the air stream such as dampers, filters, and coils. Due to change in duct size velocity difference occur which also caused the dynamic losses [8].

C. Height Clearance Ratio

The major limitation of circular duct is that they need more clear height for installation. Combination of an orthogonal quorum and round branches sometimes is a good selection. Orthogonal ducts can be used to any clear height restrictions and can easily ship when broken down. They provide flat surfaces for branch tap-insulation and they are conveniently fabricated [8].

D. Noise

The ability of a HVAC duct to retain the internal sound power is presented by its break out sound transmission loss. The leak out transmission reduces performance of a duct. The circular duct is characterized by its higher transmission loss and it can prevent duct-radiated rumble noise problems. A round duct is far better to a orthogonal duct in containing lower-frequency noise. [9]

IV. CONCLUSION

From above discussion we conclude that the friction is the biggest problem of duct. And all other problem such as fitting, turbulence is root cause of the friction. Heat transfer in duct is also one of the big problem in view of heat energy

saving. Following are the points should be consider before selecting the duct -

1) Fluid should be delivered as short distance as possible to reduce friction, power, space, losses and material.
2) Use turning vanes in instead of sudden change in the flow directions to reduce turbulence. Sudden change in direction should be avoided as more as possible
3) Keep width to height ratio should be as near to 1.0 as possible. Generally, it should not exceed four.
4) Keep velocity of air within permissible limits for reducing the friction, noise and vibration.
5) Roughness of duct material should be as low as possible i.e. smooth duct material should be used to reduce frictional losses.
6) For per unit air-handling capacity the orthogonal ducts take 27% extra metal as compare to circular ducts and have higher installation costs. So use of circular duct may provide in big saving of capital cost along with lower weight.
7) Orthogonal metal ducts are better flexible as compare to circular duct when it is applicable for limited spaces and these are using in many duct systems. So it is better solution of clear height problem
8) Leakages with medium as well as higher pressure systems can generate huge noise. So need to control and rectified it.

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