Analysis of a Duct for Performance Improvement

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Abstract— This paper gives basic description about a duct. Ducts are broadly classified along with their applications, advantages and their limitations. Also, major geometries of ducts along with their classification and their applications are described. This paper will serve as a reference for improving the performance of a duct by incorporating suitable changes.

Index Terms—Ducts, Duct Materials, Duct Geometry,

1 Introduction

THE process of improving the performance of a heat transfer system or increase in heat transfer coefficient is referred to as heat transfer augmentation or enhancement.
An increase in heat transfer coefficient generally leads to additional advantage of reducing temperature driving force, which increases second law efficiency and decreases entropy generation [1].

2 Ducts

2.1 Definition

Duct is channel or tube used for transports fluid (mostly air) from one location to another location in spacified way. Ducts are long passage closed circumferencialy and open from both ends. One end of ducts open at location from where fluid to be remove and other end open at location to where fluid to be deliver.

2.2 Metallic Duct

Because of galvanized steel have good mechanical properties they used the most popular in metal ducts. Next a great majority of metallic ducts is made of aluminum due to light in weight, but costly than galvanized steel.Other metals used under special case are carbon steel and stainless steel. Since metals have propery good thermal conductivity, such ducts require thermal insulation to minimize heat loss to souroundind. The most common material for which is glass wool, usually in roll form, wrapped around the outer duct circumference.Insulation can also be installed on the inner circumference of the duct.
Followings are the properties of various duct materials:

I. Galvanised Steel

- Applications-Widely used as duct material for most air handling systems. but it not reffer for corrosive fluid handling or temperatures above 200^{o}c
- Advantages- Galvanized steel has higher strength. It is also rigid, durable, non corrosive , availability, non-porous, workability and having ability to weld easily
- Limitations-Galvanised steel not used in underground ducting system unless properly covered.

II. Carbon steel

- Application- Major Applications of carbon steel are in breechings, flues, stacks, hoods. It also used in high temperature duct systems, kitchen exhaust systems, ducts requiring paint or a special coating
- **Advantege**s- High strength, rigidity, durability, availability, paintability, weldability and non porous.
- Limitations- Brittle, unattractive, heavy

III. Aluminium

- Applications- Aluminum ducts are widly used in case of moist air supply, louvers, special exhaust systems and ornamental duct system.
- Advantages- Light waigth, resistance to moisture, corrosion and availability
- Limitation – Low strength, material cost, weldability, and thermal expansion.

IV. Stainless Steel

- Application - Major use in duct systems for kitchen exhaust, moisture laden air, and fume exhaust
- Advantages- High resistance to corrosion from moisture and most chemicals, ability to take a high polish.
- Limitation- labour and material costs, workability, and availability

V. Copper

- Application- Copper applications include duct systems exposed to outside elements and moisture laden air, certain chemical exhaust, and ornamental ductwork.
- Advantages- Durable and corrosion resistance are main advantages of copper ducts and that it accepts soldering readily and is nonmagnetic
- Limitation- characteristics are cost, ductility, electrolysis, thermal expansion, and stains

2.3 Non-Metallic Duct

I. **Fibreglass Reinforced Plastic (FRP)**:

- Applications- Majorly use in chemical exhaust, scrubbers, and underground duct work
- Advantages- Non corrosive, ease of modification
- Limitaions-Higher cost, higher weight, limiting range of chemical and physical properties, brittleness, fabrication (necessity of moulds and expertise in mixing basic materials), and code acceptance

II. Polyvinyl Chloride (PVC):

- Applications- Exhaust systems for chemical fumes and underground duct works
- Advantages- resistance to rusting, light weight, ability to weld, and easly modify.

- Limitations- resistance to rusting, light weight, ability to weld, and easly modify.

III. Polyvinyl Steel (PVS):

- Applications -Underground duct works, moisture contain air, and corrosive air systems
- Advantages- Resistance to corrosion, weight, workability, fabrication, and rigidity.
- Limitaions- Temperature limitations (250^{o}F maximum), unable to weld, code acceptance, and susceptibility to coating damage.

IV. Flexible Nonmetallic Duct

- Applications-Used extensively in commercial construction, has more than 60% higher pressure drop than galvanized metal duct of the same diameter .Flex duct is also commonly used as a return duct, for run outs, with metal collars used to connect the flexible duct to supply plenums, trunks, and branches constructed from sheet metal or duct board.
- Advantages- easily torn, crushed, pinched, or damaged during installation. It has the highest resistance to air flow

V. Concrete Duct

- Application-Concrete can be used for underground ducts and air shafts
  - Advantages -Compressive strength and corrosion resistance
  - Limitations- Cost, weight, porosity, and fabrication (requires forming processes)

VI. Rigid Fibrous Glass

- Applications- Chemical fume exhaust and underground duct system
- Advantages- Light weight, thermal insulation and vapor barrier, acoustical qualities, ease of modification, and inexpensive tooling for fabrication
- Limitations - Higher cost, susceptibility to damage, system pressure, and code acceptance [2].

3 GEOMETRIES OF DUCTS

This The flow distribution, pressure drop, and heat transfer characteristics through straight ducts of uniform cross section depend on a number of factors, especially cross sectional shape, inlet velocity and temperature profiles, and boundary condition The cross section of the duct can be both orthogonal (square or rectangular) and non orthogonal (triangular, trapezoidal, hexagonal) [3].

Ducts are usually manufactured in circular or rectangular shapes. Both types have some advantages and limitations, and both find references where one is definitely superior to the other.

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Figure 1- Non-Metallic Circular Ducts [7]

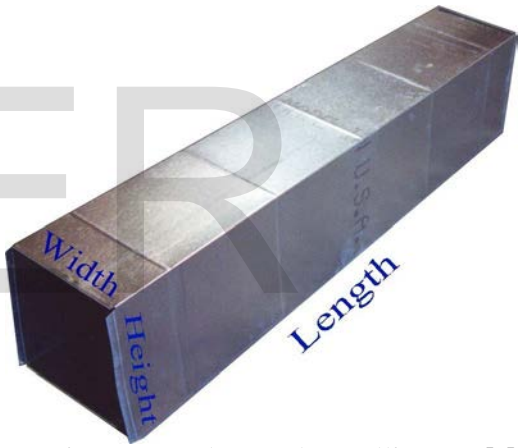

Figure 2- Orthogonal Metallic Duct [8]

3.1 Round Duct

A round or circular duct has a smaller circumferencial are exposed to moving are and also have smaller cross-sectional area. A 45 cm diameter duct, for example, has the same air-carrying capacity as a 32x 50 square cm rectangular duct. The round duct has a cross-sectional area 1590 sq-cm and a perimeter of 282.6cm, while the rectangular duct has 1600 sq-cm area and a perimeter of 164cm. The rectangular duct thus has 16% more metal in it and would cost proportionately more. Also the cost of insulation, supports and labor shall be higher for rectangular ducts of similar capacity. Round ducts have one benefit that a smaller pressure drop per unit area and are commonly the most cost effective.

Round duct system provides maximum air-carrying capacity

with minimum pressure loss. Round spiral duct leaks less as compare to rectangular duct because of the lack of longitudinal joints and generally fewer transverse joints when run in long straight duct sections. One big limitation of round duct is that they require more clear height for installation**.**

3.2 Oval Ducts

One of big advantage of flat oval ducts that they have smaller height requirements than round ducts and also have most of advantages of the round ducts. However, fitment of flat oval ducts is silly difficult to modify or febricate in the field. Other limitation of flat oval ducts include: problem in handling and shipping larger sizes; a tendency of these ducts to change shape and become more round under pressure; and, in large aspect ratios, also problem in process of assembling oval slip joints.

3.3 Orthogonal duct

Rectangular or square ducts can be applied to any space height restrictions and are easily shipped when broken down or nested. They provide flat surfaces for branch tap-ins and they are conveniently fabricated. For large plenums and duct sections containing many fittings, rectangular duct fittings are usually easier to assemble than round and oval fittings.Width to hight ratio should be keep lowand prefer not more than 1:4 when rectangular ducts must be used due to space problem. No hight restrictions for adapte rectangular. Limitations of rectangular ducts are they create higher pressure drop so that they use more amount of metal for the same air-flow rate as round duct.Also the Simulation results indicated that nusselt number and heat transfer coefficient are higher in case of circular tube when compared with the rectangular tube. Pressure drop for circular tube is found to be more when compared with the rectangular tube for identical conditions [4**].**

3.3 Non Orthogonal Polygonal duct

This day non orthogonal duct such as triangular, trapezoidal, hexagonal channels are widely used in a variety of compact heat exchangers such as the lamella and plate heat exchangers in paper, alcohol, food, chemical and power industries. The studies indicated that the performances of heat transfer and pressure drop for the polygonal ducts, such as trapezoidal and hexagonal ducts, are considerably affected by the duct geometry in terms of aspect ratio and included angle of a polygonal duct for laminar, fully developed flow through trapezoidal and hexagonal ducts. The studies shows that heat transfer and pressure drop for the polygonal ducts such as trapezoidal and hexagonal ducts are considerably affected by the duct shapes in terms of aspect ratio and included angle of a polygonal duct. For laminar, fully developed flow through polygonal ducts Study reported that the rather complex interconnection among the channel aspect ratio, the included angle and the developed flow field. As the aspect ratio of a trapezoidal or hexagonal duct goes up, the flow is directed toward the core region by sharp corners of the polygonal duct, resulting in the increased peak velocity [5]

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