

An Overview of Industrial Ducts and Its Accessories

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Abstract: This paper has been created to assist structural engineers when performing the structural analysis and design of air and flue gas ducts for power station and industrial boiler applications. Air and gas ducts for fossil fuel power station and industrial boiler application are unique structures. Heavy ductwork is required in these applications and therefore the structural analysis and design is complicated by the need to accommodate large thermal movements and the need to assess the behavior of material at high temperature, pressures and harsh environment. This paper postulates the need of understanding basic ductwork and accessories related to ducts. The paper also covers basic design aspects related to the positioning of stiffeners and pipe struts to provide additional stiffness and support to a working duct.

Index Terms- Industrial Ducts, Accessories, Stiffeners, Pipe strut.

I. INTRODUCTION

In many heavy industrial processes, use of fluid such as hot gases and liquids is very important. Since these fluids are hazardous in nature. Therefore, they are kept isolated from process environment and different substations. Hence for transporting these fluids heavy ductwork is needed in various industrial applications. The duct structural systems associated with such industrial applications are significantly large and in some ways are quite unique structures. Duct are defined as air tight conduits that convey air or flue gas under positive or negative pressure, they may or may not be exposed to high temperature. Ducting can be of any configuration viz. square, rectangular, circular, straight or bend, elbow or any irregular shape as they transition into a piece of major equipment such as fan precipitator or scrubber. Duct undergoes various types of load according to their applications and therefore accessories are necessary for safe loading of duct. These accessories are mainly damper, insulation, lagging, stiffeners, pipe struts etc. This paper deals with the study of ducts and its types, material of ducts and duct accessories.

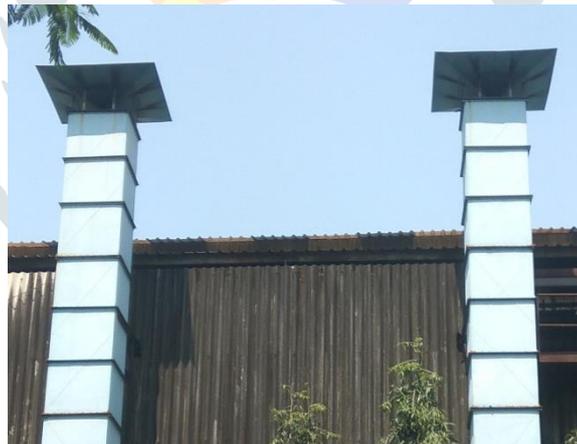


Figure 1: Exhaust duct with stiffeners

II. DUCT DETAILS

There are two possible ductwork systems which could exist in a conventional power plant or industrial boiler; the systems are called pressurized and balanced draft system. Pressurized system, a forced draft system, has forced draft (FD) fans up steam of the boiler which force air through the entire combustion system and eventually force resulting flue gases out to the atmosphere to the stack, a pressurized system results in positive pressure in all the ducts.

III. DUCT SERVICE CONDITIONS

A ducts system operates under various loading conditions that are described in details

Operating pressure: Ducts usually are exposed to a relatively predictable static pressure range. A static pressure range is decided by capability of fan and losses through the duct system. Each section of ductwork experiences a different static pressure which is constant in that section during a mode of operation. The maximum positive or minimum negative static pressure during normal operation is the operating pressure.

Unbalance Pressure: Whenever a duct has an expansion joint located so that there is a duct wall that does not have another duct wall directly across from it, an unbalanced pressure occurs in that section.

Dynamic Unbalanced pressure: Dynamic pressure is associated with the velocity and density of the flow. The pressure fluctuates with time and flow rate and does not remain constant therefore this pressure is dynamic unbalanced pressure.

Transient Pressure: During an abnormal event, ducts may experience a very high or very low static pressure for a relatively short period of time. The fluctuation of this pressure from its normal value is called transient pressure.

Operating Temperature: Ducts usually are exposed to a relatively predictable temperature range and as governed by boiler and preheater designs. The maximum expected temperature during normal operation is called design or operating temperature.

IV. DUCT GEOMETRY

Ductwork is generally either rectangular or circular in cross-section. The selection of basic cross-section is made based on its effect on the flow cost and structural behavior. While also considering external constraints such as available space, available means or support, connection to equipment, fabrication, shipping and erection.

Rectangular Ducts: Ducts with a rectangular cross-section are commonly used in utility and large industrial applications. Duct panels are typically fabricated from flat plate with a rolled steel shape welded to the exterior or interior at periodic intervals to stiffen and support the plate. The corners are often reinforced with the angles or bent blades and internal trusses may be used to maintain the squareness of the duct, transmit pressure forces and transfer the loads to support structures.

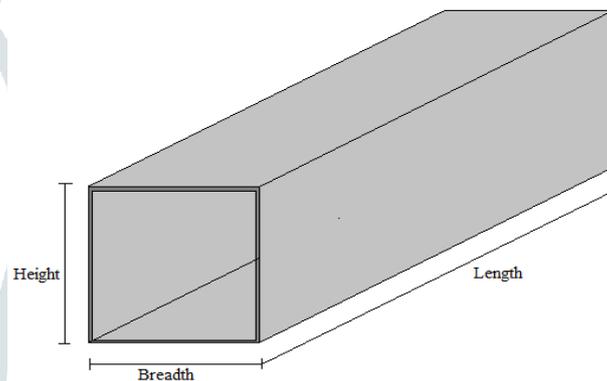


Figure 2: Rectangular duct

Circular Ducts: These ducts are most often used when the maximum diameter is 3.6m or less. These ducts are very efficient in resisting internal pressure loads. For an even cross-sectional area, a circular duct will have a smaller perimeter than a rectangular duct, which may reduce the duct weight and the insulation and lagging cost. Circular ducts usually have better internal flow characteristics than rectangular ducts and thus lower the pressure drop.

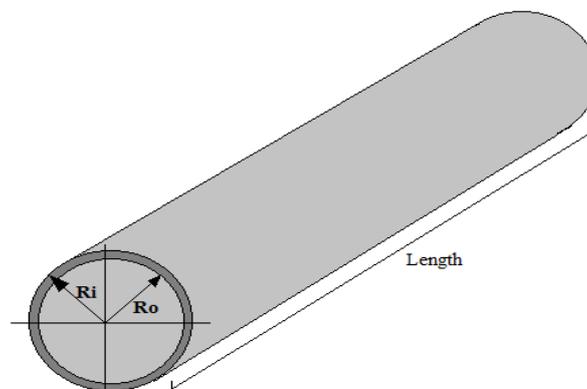


Figure 3: Circular duct

V. DUCTING MATERIAL

Ducts can be manufactured from different materials which are as follows:

Galvanized Steel: Galvanized mild steel is the most common material used in manufacturing and fabricating ductwork. Galvanized mild steel (MS) has a thin coating of zinc metal which reduces the chances of corrosion and rusting, which results in saving the cost for painting.

Aluminum (Al): Aluminum ductwork is very light in weight and hence very easy to install. Since moldability of aluminum is greater than that of MS therefore it can be easily fabricated for intricate shapes. Aluminum can be also used to manufacture round and spiral ducts. But it is rarely installed in industries because of more cost than galvanized steel.

Fiber Glass: This is advanced type of duct which provide built in thermal insulation and has ability to absorb interior surface sound which helps in smooth and quite operation.

PVC Low Profile Ducting: This type of ductwork has been developed to reduce cost and can be used as alternative to steel's low-profile ducting. This type of ducting is extensively used in apartment, societies and hotels. The use of this type ducting has grown significantly due to reduction in available space and very cost effective.

VI. DUCT ACCESSORIES

For proper functioning of ductwork system, the following accessories are used:

Damper: Dampers are the accessories which are installed in duct systems which allow the operation manager to control or redirect the fluid flow inside the duct system. Another type i.e. isolation dampers are also used in ducts to isolate different sections. There are four types of dampers that are generally used in ductwork viz. guillotion, louver, butterfly and poppet. The location of damper dictates the design and transient pressure forces acting on duct and it also supports the duct.

Insulation: Insulation can be used inside or outside of duct which keeps the heat inside and its major purpose is to protect workers from injurious burns which are on outside surface of the duct. Earlier ducts were used to be insulated on the inside with material either masonry or mortar. Now a days, ducts are insulated on outside with some fiber glass wool. If ducts are not properly insulated, then there will be condensation inside the duct which will eventually corrode the steel joints. Improper insulation will also cause thermal shocks which cause the duct to crack.

Lagging: Lagging is the term used for fiber glass, aluminum and light gauge steel sheet which are used to cover the insulation on the duct. Lagging maintains the insulation at proper place and protects the insulation from damage by weather or workers; it also keeps the water off of the insulation and the duct.

Pipe Strut: Pipe struts are also called as internal truss which are used to join two faces of duct which can be either on adjacent or opposite side. This also provides an additional support to the roof and floors of very wide ducts ranging from 3 to 6m and length can go up to 10-15m.



Figure 4: Cross-section of pipes strut and its arrangements

Where,

Ri= Inner radius

Ro= Outer radius

The use of internal trusses is generally minimized, if possible, because they tend to constrict the flow and increase the pressure losses within the duct. Another major purpose of installing pipe struts to reduce the stress and deflection of large rectangular duct by connecting between longer sides to prevent bending of strut. According to the loading conditions, different arrangement of pipe strut is shown.

Stiffeners:

Large industrial duct system consists of stiffened plates, where the stiffeners attached to plates resist the pressure loads to certain extent. Since the stiffeners are closely spaced, the plate element between the pair of parallel stiffeners is considered as a long plate fixed supported by those parallel spaced stiffeners. In previous designs, the internal pressure and serviceability limit determine the stiffener spacing. In modern designs, the stiffener spacing is determined on basis of large deflection theory.

Stiffeners which are used to reinforce the ductwork have various types and cross sections. Depending upon their types and cross section they are classified as follows:

Beam: Beam sections are referenced by BEAM188 and BEAM189 elements. Following are the subtypes of beam type stiffeners:

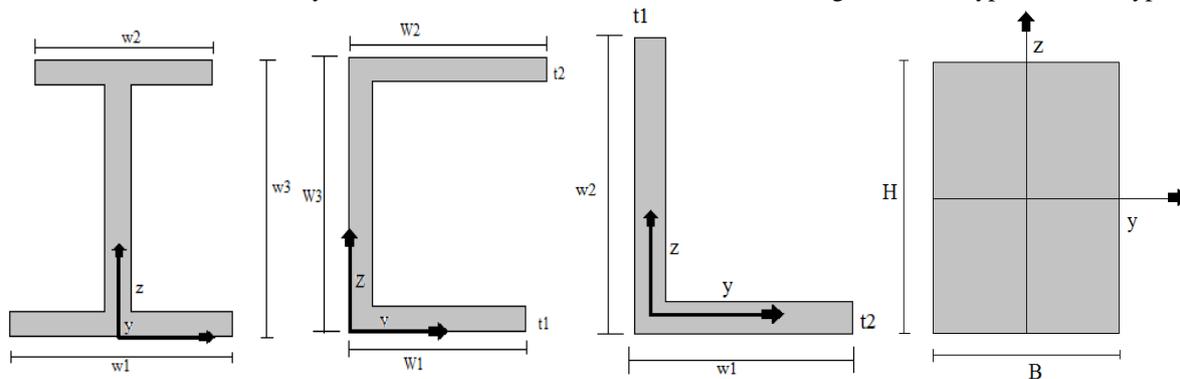


Figure 5: Different cross-sections of stiffener

Where,

w1, w2= Length of flanges

w3= Overall depth

t1, t2= Thickness of flanges

B= Breadth of rectangular stiffener

H= Height of rectangular stiffener

Link: Link sections are referenced by the LINK180 element.

Axisymmetric: General axisymmetric sections are referenced by the SURF159, SOLID272, and SOLID273 elements.

The detailed view of industrial boiler duct with various duct accessories is shown in Fig. 6

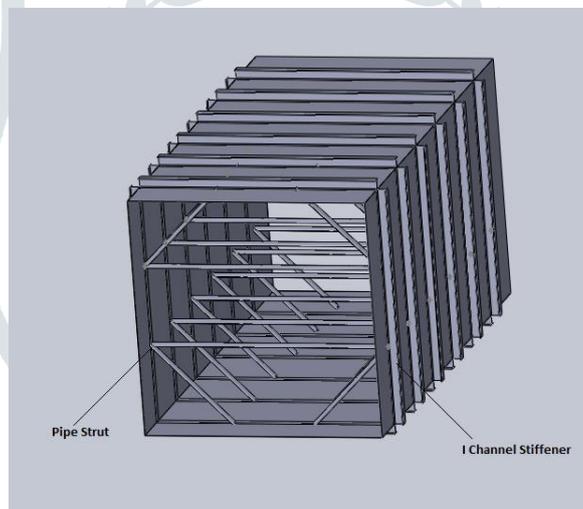


Figure 6: Detailed view of rectangular duct

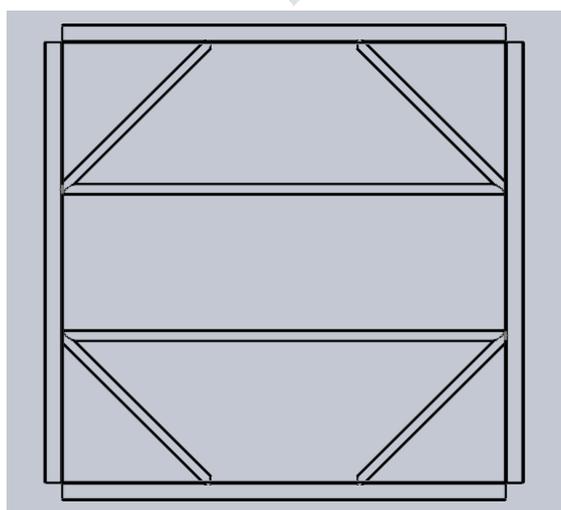


Figure 7: Top view of Duct with Single stiffener and pipe strut assembly

VII. DUCTWORK DESIGN ASPECTS

In order that the reader may appreciate the design environment, a brief description of the factors affecting ductwork design is presented.

Power Plant Components- The descriptions following cover major items of equipment associated with the air and flue gas flow path in a single power generation unit at a typical plant.

- Steam generator
- Air heater
- Fan and Filter
- Chimney

Pressure- Normal operation vacuums and pressures in the duct system vary depending on location along the air or gas flow path. Positive internal pressure occurs from the FD fan through the air side of the air heater to the steam generator. Negative internal pressure (vacuum) occurs from the boiler downstream to the ID fan. A slight decreasing positive pressure exists from the ID fan on, until atmospheric pressure is reached at the top of the stack. Specific values for design operating pressures and vacuums vary depending upon the configuration of the system and choice of equipment.

Temperature- Gas temperatures influence the design in several ways. With high enough temperatures (above approximately 3150C) the strength and stiffness properties of the duct and stiffener may be affected. Even at lower temperatures, thermal expansion must be considered and designed for. Also, as mentioned previously, the gas temperature can strongly influence the degree of corrosion encountered in a duct.

Duct geometric configuration- Ideally, the ductwork should be laid out to minimize gas flow restrictions and thus keep the fan size and operating costs as small as possible. This will also minimize ash buildup. Practically, however, the layout and shape of the duct are determined to a large extent by the placement of equipment and the requirement to avoid interference with other elements of the power plant. Consequently, gas flow paths and cross-section shapes may turn out to be more complicated than would seem necessary at first glance. Since the cross-sectional area of the duct is determined by gas flow requirements and not by structural considerations, extremely large width-to-thickness ratios are commonly encountered in the duct plate, making different buckling modes of prime concern in design.

VIII. CONCLUSION

This article elaborately discusses the need of ducts in industrial applications and for this the selection of proper accessories of duct is vital. For better life span, reliability and durability various accessories are installed on the ductwork out of which stiffeners and pipe struts are commonly used in industrial ductwork. From this discussion, in industrial ductwork system, it is observed that by implementing pipe strut and stiffeners we can reduce significant amount of stress and deflection on the walls of the duct. The paper also gives detailed idea about basic terms related to ductwork.

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