Design and Analysis of Diverter Damper using CAD Modelling

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Abstract

Diverter dampers are used in process industries. They are used to divert the hot flue gases from the source to the boiler or to the atmosphere through the chimney during the boiler maintenance. They have advantage of flexibility in their design as per the requirement of the site. Diverter dampers were invented decades ago and are used widely in present era. This is a Box type diverter damper whose structure is small. It is more reliable with easy construction. Maintenance and installation of this type of damper is easy. Y-type, Butterfly, T-type are the few other diverter dampers used now a days. A Box type damper has many advantages over a T-type damper. It is more reliable. This is economical to construct. A Box type diverter damper can replace the low pressure shut off valves in the future.

The life of an actuator is extended by reducing heat conduction from the damper along the control linkage to the actuator link and into the actuator, thereby protecting sensitive electronic components. To this end, the control linkage may be equipped with cooling fins, or be made hollow rather than solid, in order to retard heat from the turbine housing assembly reaching the actuator. In this project, we designed a box type diverter damper, which is easy to assemble on-site and also the linkage having fins to reduce the heat transferred to the actuator from the damper.

1.INTRODUCTION

Damper is a valve or movable plate in flue or other part of a stove, furnace, etc used to check or regulate draft of air. The use of waste heat for various applications by using various heat recovery systems is common nowadays. Diverter dampers are specially designed dampers as per the user's requirement.

Fig. 1.1 Box Type Diverter Damper.

The project is based on the discovery that a useful degree of protection can be provided to the electronic components of a actuator by providing means to retard heat energy transfer along the control linkage connecting the actuator to the diverter damper. A plurality of cooling fins could be provided along at least one axial segment of the control linkage connecting the electronic actuator to the damper. The cooling fins extend radially outward, e.g., may be axially spaced, generally annular, cooling fins extending generally perpendicular to the axis of the control linkage, whereby the effective surface of the control linkage is increased. The cooling fins radiate heat and reduce heat transfer to the electronic actuator. A useful degree of radioactive cooling is achieved, given the elevated temperature of the ambient environment around the damper and the limited length of the control linkage. The provision of cooling fins affords a much more cost-effective solution to the problem of protection of electronic components from excess thermal energy.

Finally, compared to the complexity of water cooling or other temperature control measures, the present invention provides a simple, assembly- fool proof, low cost solution to minimize the heat flow from the turbine housing assembly to the actuator, while increasing the robustness of the assembly.

2. COMPONENT STUDY

Design, Development and manufacturing of box type Diverter damper with following input parameters:

Duct diameter = 300 mm

Operating temperature = 560 C

Operating time = 30-45 sec

Pressure= 500 mm of water column

Velocity = 20 m/s

During the Damper Design it is necessary to ensure that

- There should be 100% sealing i.e., no gas leakage should take place.
- Size of the damper should be less.
- There should be minimum heat transfer from the box to actuator.
- Easy maintenance and installation
- Improve the life of seals and gaskets.
- on site assembly.

3. Methodology

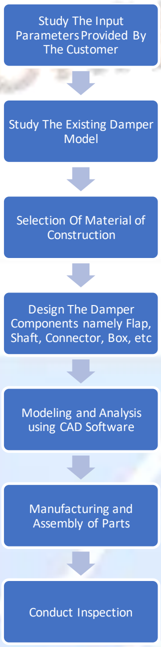


Chart. Proposed Methodology

4. MATERIAL SELECTION

After studying the requirement and operating conditions of the box type diverter damper we studied the following materials and their physical and chemical properties.

Materials: Stainless Steel, Alloy Steel, Mild Steel and Cast Iron.

4.1 Final Material Selected

After the study of different materials and their properties we found the material

Chromium (low) steels: $\frac{1}{2}$Cr — $\frac{1}{4}$Mo — Si (0.18% C, 0.65% Cr, 0.23% Mo, 0.6% Si)

This material has thermal conductivity 36.7 W/m-K at Temp. 600 K.

The above material was discussed with our industrial project guide and a new material was introduced to us i.e., **SA 387 Grade II.**

This material can withstand high temperature of 700-1000°C.

SA387 GII

C- 0.04/0.17% , Si- 0.44/0.86% , Mn- 0.35/0.73%

P- 0.025% , S- 0.025% , Cr- 0.94/1.56% ,Mo- 0.4/0.7%

Mechanical Properties

Tensile Strength	515/ 690 (N/mm2)
Yield Stress	310 (N/mm2)

5. DESIGN OF DAMPER

5.1 Existing Design

Thickness of flap = 8 mm

Diameter of flap = 420

Diameter of Duct = 312

Inner Diameter of Flange = 312 mm

Outer diameter of Flange = 412 mm

Thickness of Flange = 6 mm

Diameter of shaft = 32 mm

Length of shaft = 80 mm

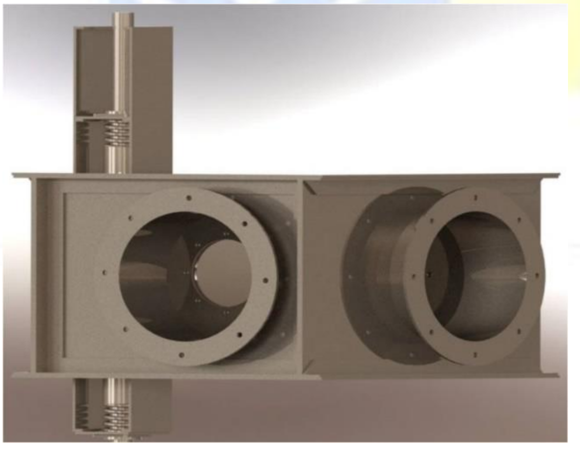


Fig. 4.1 Old Design Model

5.2 Design Modifications and New Design

5.2.1 Design of Flap:

Input Parameters:

Material of construction- SA387 GII,

Thermal Conductivity- 34.5 W/mk

Calculations-

Area of exposure (A4) = Area exposed to hot gases at left side (A1) + Area exposed to hot gases at right side (A3)

Area exposed to hot gases at left side (A1) = 0.4*0.5 = 0.20 m^2

Area exposed to atmosphere at right side (A2) = 0.3*0.3 = 0.09 m^2

Area exposed to hot gases at right side (A3) = (A1)-(A2) = 0.2 - 0.09 = 0.11 m^2

Area of exposure (A4) = 0.2(A1) + 0.11(A3) = 0.31 m^2..... (I)

In given data heat transfer rate and temperature gradient is not given amongst which heat transfer rate found by performing on site experiment.

Given data of experimental damper-

Material of Construction- SS304

Thermal conductivity, k = 35 w/mk

Thickness of flapper, dx = 8 mm

Temperature at left side of flapper (T 1) = 813 K (540°C)

Temperature at right side of flapper (T2) = 313 K (40°C) .... atmospheric

Temperature gradient (dT) = T1 -T2 = 813 - 313 = 500 K

Area of exposure (A4) = Al + A3

Area exposed to hot gases at left side (A1) = 0.51 * 0.51 = 0.26 m^2

Area exposed to atmosphere at right side (A2) = 0.4*0.4 = 0.16 m^2

Area exposed to hot gases at right side (A3) = A1 - A2 = 0.26 - 0. 1 6 = 10 m^2

Area of exposure (A) = 0.26 (A1) + 0. 10(A3) = 0.36 m^2

Assuming convective heat transfer rate of hot gases = convective heat transfer rate of air h= 12w/m^2 K

Resistance to convective heat transfer (R1) = $\frac{1}{hA}$......................[14]

$$= \frac{1}{12*0.36} = 0.213 \text{ k/w}$$

Resistance to conductive heat transfer (R2) = $\frac{dx}{kA}$……………….[14]

$$= \frac{0.008}{35*0.16} = 1.42*10^3 \text{k/w}$$

Heat transfer rate (Q) = $\frac{dT}{R1+R2}$

$$= \frac{500}{0.2314+1.42*10^{\wedge}-3} = 2.01 \text{ Kw}$$

"So, by experimentation heat transfer rate = 2.01 Kw"

From this we can find thickness of flapper

Assuming, convective heat transfer rate of hot gases convective heat transfer rate of air

Hence, h = 12 w/m²K

Resistance to convective heat transfer (R1) = $\frac{1}{hA}$

$$= \frac{1}{12*0.31} = 0.26 \text{ k/w}$$

Resistance to conductive heat transfer (R2) = $\frac{dx}{kA} = \frac{dx}{34.5*0.09}$

Heat transfer rate (Q) = $\frac{dT}{R1+R2}$

$$2.01*10^{\wedge}3 = \frac{530}{0.26+(\frac{dx}{34.5*0.09})} = 0.008\text{m} = 8\text{mm}$$

Therefore, Thickness of Flap is 8 mm

The main problem associated with existing design of single flap is, the flap does not perfectly rest on the duct. Due to this, gas may leak through minute openings.

To avoid this, three flap assemblies with spring and stud is used as shown in fig. Spring ensures perfect resting of duct on side duct. Three flaps avoid the necessary of stiffener.

Modified Design Calculations-

Due to unavailability of standard shaft size (ID 32 and OD 44), we switched over to the shaft (ID 38 and OD 48mm) which is available at company.

If we take do = 48 mm

$$\therefore di^4 = do^4 - (do*d^3)$$

$= (48)^4 — (48*32^3)$ ..... (d = 32 mm)

$di^4 = 3735552$ mm

.'.di = 43 mm ...... (Minimum required ID)

In order to increase F.O.S, thickness can be increased

Therefore, Final dimensions-

ID=38 mm

OD=48mm

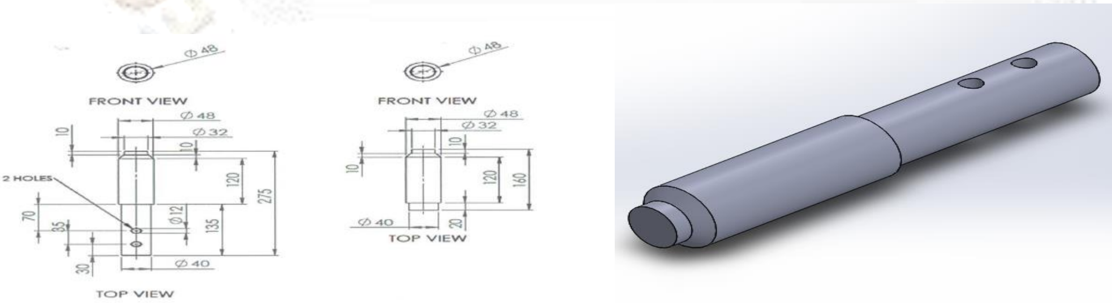
In order to disassemble every part and reduce the weight of the shaft, it is made in three parts. i.e, two solid shafts at both the ends and one hollow shaft at the middle.

The design of hollow shaft is shown in fig. In case of solid shaft, all the diameters are greater than 32 mm, which is minimum required diameter to transmit given torque. Hence it is assumed to be safe.

Hollow Shaft

Fig. 4.4 Hollow Shaft

Solid Shaft



5.5 Design of Fin Tube-

$T=350*10^3$ N-mm

$J = \frac{t}{32}(50^4 - 40^4) = 362.26 * 10^3 \text{ mm}^4$

R = 25mm

$$\therefore \frac{350*10^3}{365.256*10^3} = \frac{\tau}{25}$$

$$\therefore \tau = 24.15 \text{ N/mm}^2$$

Fin Tube

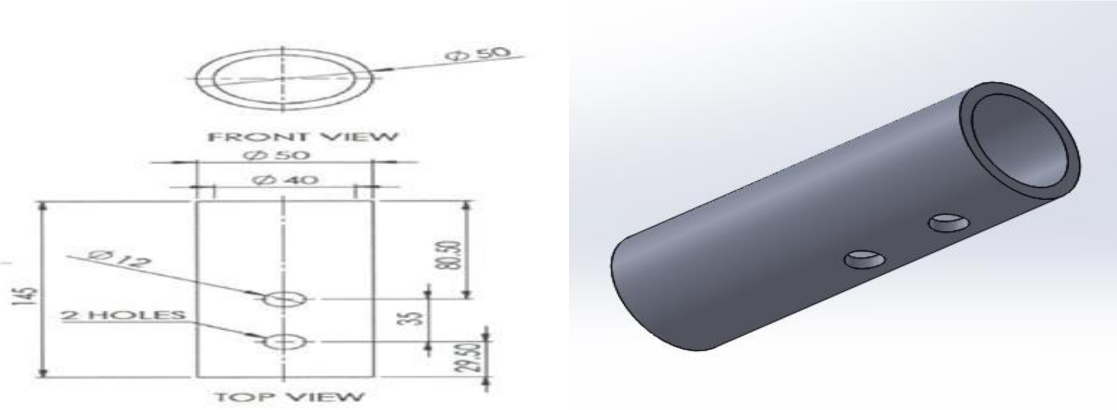


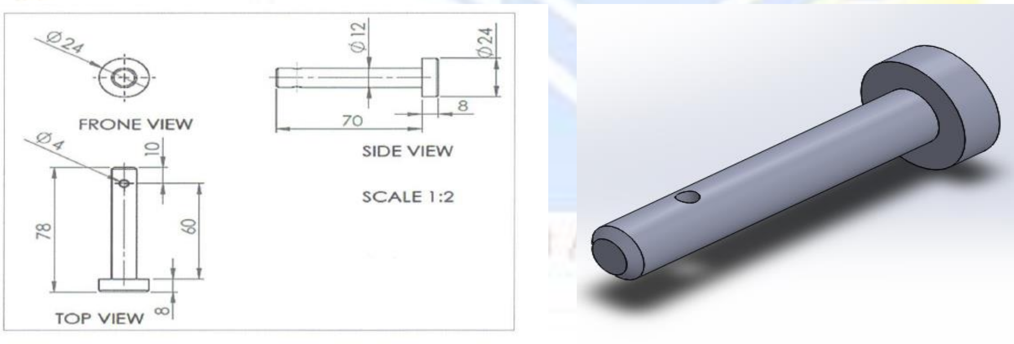
Fig. 4.6 Fin Tube

5.6 Design of Fin Tube Pin-

Load = 2000 N; Assume diameter of pin = 12 mm ; N=2

$$= \frac{2000}{\frac{\pi}{4}(10)^2 2}$$ = 12.73 N/mm² Induced all (Hence design is safe)

Fin Tube Pin



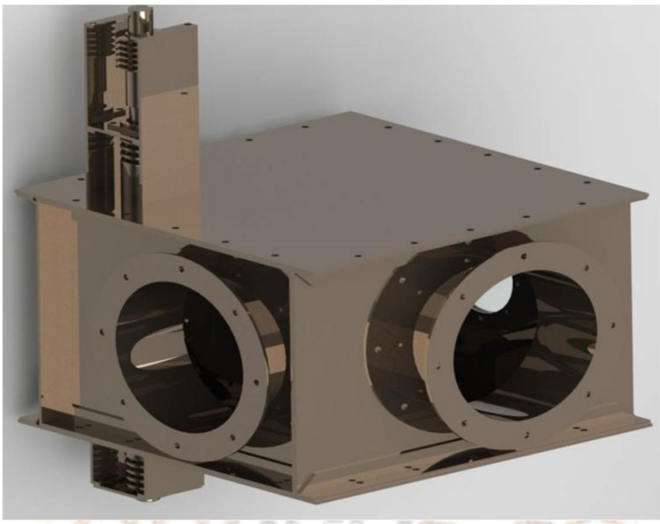


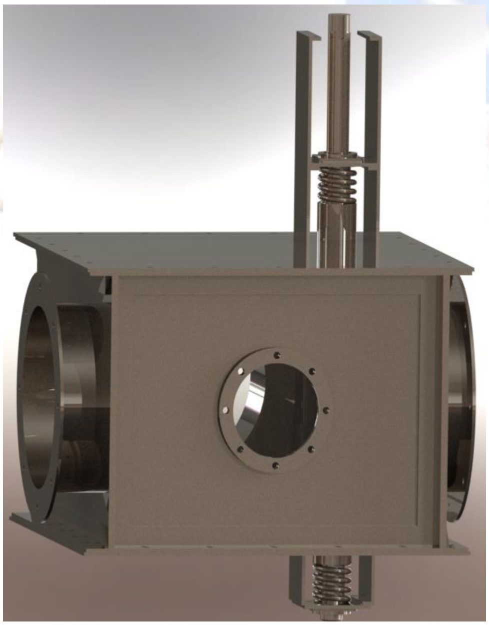
Fig. 5.7 Modified Design Model

6. CAD MODELING AND ANALYSIS

Modeling is the construction of physical, conceptual or mathematical simulation of real world. Models help to show relationship between processes and may be used to predict effects of forces and conditions. All the components of Box type diverter damper are being modeled by using SOLID WORKS.

The SOLIDWORKS is a solid modeling computer aided design (CAD) and computer aided engineering (CAE) software program. It focuses on integrated 3D design environment that covers all the aspects of product development and helps maximize your design and engineering productivity.

The design procedure for components remains the same for both the models, for old design and new design of diverter damper. As we have added only the fin tube and fin assembly as an attachment to the new model. In this chapter we shall see models of all the components of diverter damper. These models are further used in analysis process. The components of Box type diverter damper are as follows:



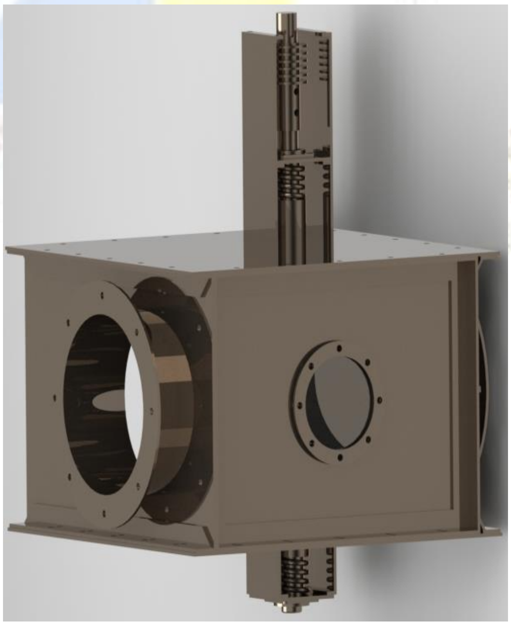


Fig. 6.1 Assembly Model of Box type diverter Damper: a. Old design b. New design

7. CONCLUSION

Earlier the flue gases coming out of the exhaust of a boiler were allowed to be expelled out to atmosphere. However, the heat content wasted in it and the adverse effects of the exhaust on ecosystem led the engineers to reuse it this was achieved with the help of a simple diverter valve placed in the exhaust system.

The traditional dampers do not meet the requirement of 100% leak proof. From the design and modeling the Box type diverter damper is 100% leak proof on paper and this damper also enables on site assembly provision. After conducting the various tests mentioned earlier leakages can be detected if any. If the Box type diverter damper is becomes fully leak proof this will become a revolution in itself. There will be huge boost for waste heat recovery.

The thermal analysis and comparison between the results of numerical solutions for the earlier case and the new fin-linkage design proved that the new design found successful in retarding the heat transferred from damper to actuator. This numerical solution is validated through experimental analysis by manufacturing the damper as well as new linkage and the actual temperatures measured by using pyrometer on-site. The results of comparison are found satisfactory.

Future Scope of the Project

- This damper can be used at higher temperature
- 100% Leak-proof makes it possible for the maintenance of boiler without stopping the entire plant.
- Use of damper reduces pollution as the hot flue gases are utilized.
- Easy maintenance.

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