DESIGN & DEVELOPMENT OF DIVERTER DAMPER WITH IMPROVED HEAT DISSIPATION

Prabhakar S. Chilwante[1], S. C. Patil[2]
[1]M.E. Scholar, Shri. Shivaji Institute of Engg. and Management Studies, Parbhani 431401, India
[2] Assistant Professor, Shri. Shivaji Institute of Engg. and Management Studies, Parbhani 431401, India
[1]chilwanteps@gmail.com
[2] surendrapatil305@gmail.com

Abstract: *Diverter dampers are used in process industries to divert the hot flue gases from the source to the boiler or to the atmosphere through the chimney during the boiler maintenance. Diverter dampers were invented decades ago and are used widely in present era. This project is related to 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 is more reliable, economical to construct compared to a T-type damper. A Box type diverter damper can replace the low pressure shut off valves in the future. In this project 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.*

Keywords: **Damper, box type diverter damper, reduce heat transfer, linkage with fins, CAD, CAE, solidworks.**

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. 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.

Fig. 1.1 Box Type Diverter 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 radiative 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- foolproof, low cost solution to minimize the heat flow from the turbine housing assembly to the actuator, while increasing the robustness of the assembly.

Objectives

1. To utilize the hot flue gases.
2. To minimize the heat transfer from the box to actuator.
3. To design the box so, that on site assembly can be done.
4. Design all the parts as per the requirement.
5. Analyze the Box and Flap using suitable Analysis Software for safety.

Scope of the Project

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

Methodology

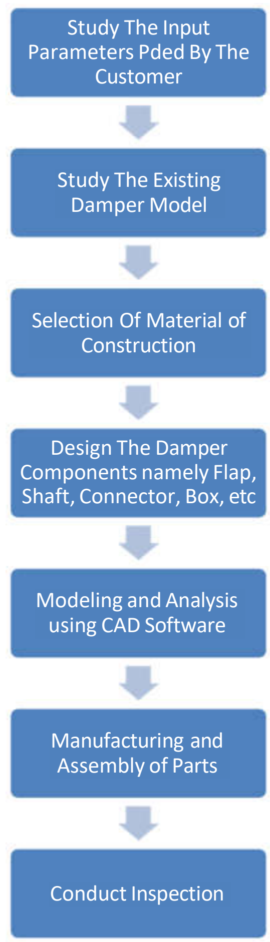


Chart No. 1. Proposed Methodology

2. LITERATURE SURVEY

Literature provides numerous publications on study of Diverter Damper. The following some of this is presented from previous work of researchers who have attempted application of Diverter Dampers.

Diverter damper is intermediate between gas source, heat recovery boiler system and bypass system. There is flow of flue gases from gas source to the waste heat recovery boiler and the combine cycle is operated. Flue gases are diverted to the bypass system in case there is maintenance in the waste heat recovery boiler system. There is need of diverter damper because if such case occurs, we have to stop the whole system of gas source and waste heat

recovery boiler in absence of diverter damper.
So there is diverter damper to direct the flue gases directly to the bypass stack or exhaust if waste heat recovery boiler system is not working.

S. Kachore in his Journal on Recent and Innovation Trends in Computing and Communication reported that- Diverter valves are processing valves designed to direct flow from an inlet to one of two or more outlets. They can also be used for flow control and to converge two lines into one. Diverter valves are primarily used to handle powders, dry solids and slurries, although some types are available that can handle liquid service. They are ideal for applications where the conveying or pumping of materials to multiple vessels or silos is needed.

In industries like steel mills, rolling mills, cement plant the exhaust of the engine is not utilized. Unused heat is lost. Waste heat recovery boiler system is used to recover the heat from engine exhaust. Diverter damper is a box having flap for diverting flue gases from engine to the waste heat recovery boiler system and bypass system. Valves can be replaced by the dampers if the working medium is gases where working pressure is low and cent percent sealing is not required. Diverter is an important component in waste heat recovery boiler system. Diverter damper is shut off or on off type damper. Diverter damper is used to divert the flue gases from engine to waste heat recovery boiler system or bypass stack with the help of flap which operates with 90 degree rotation [10].

Diverter damper is a box having flap for operating the opening of either waste heat recovery boiler system or bypass system. Since most industrial systems cannot be shut down for normal periodic maintenance, diverter damper is designed to facilitate the easy maintenance while the system is operational. Diverter damper is operated by the electrical actuator of suitable size. If in case supply to actuator is stopped it can be operated by the handle provided.

Types of Damper:

1. Butterfly damper
   i. Y- type Damper
   ii. T- type Damper
2. Guillotine dampers
3. Louver damper
4. Stack damper

Butterfly dampers

We can build our butterfly dampers integrally into a "T" or "Y" duct section with an operator mounted to one damper and a slave linkage to other damper. The linkage can be arranged so that as one damper opens, the other damper will close, these are widely used for process air or gas diversion applications. The complete pre-assembled and adjusted unit is shipped to the job site for easy installations, saving time and cost.

a) Y- Type Diverter Damper

Y type dampers shall be butterfly type consisting of circular blade, mounted on axle within formed flanged frame.

Fig. No.2.2.1 (a) Y-Type Diverter Damper

Frames shall be constructed of 304 Stainless Steel or any other material specification channel and shall have full circumstance blade stop located in air stream.

Damper shaft shall be continuous, solid cold rolled stainless steel extending through the entire diameter of damper and beyond damper bearing a minimum of six inches or higher depending on the application. Axel shall be supported and sealed, re-lubricable ball bearings mounted to damper frame. Press fit bearings are not advisable. Damper frame and blades shall be fabricated from Stainless steel or any other material.

b) T-Type Diverter Damper

"T" diverter dampers are commonly used when an application requires diversion of gas to flow to another direction. This damper is normally arranged as a dual damper and resembles a Pipe-T. The individual dampers are mechanically linked externally so that when one is open, the other is closed.

Fig. No.2.2.1 (b) T-Type Diverter Damper [12]

By adding a modulation actuator, this damper will allow diversion or modulation to either outlet. Standard 90^0 and 45° T-damper assemblies are available as round and rectangular/square configurations.

Guillotine dampers

Guillotine damper are generally used when space limitations don't allow for longer damper casings. As stand-alone solutions, this damper type will often be used in coal fired power plants, where high ash accumulation has to be handled. Almost the full cross-section of the duct is available once the guillotine blade is fully retracted, causing a very low pressure drop.

Fig. No.2.2.2 Guillotine Damper [13]

Louver damper

The louver type of damper consists of several blades mounted parallel across a duct, with centrally pivoted shafts extending out through a frame and driven by a linkage. Louver dampers are versatile, able in theory to handle any

application in the power plant.
The drives for Louver are simple, needing only 900 of motion. The torque requirement can vary widely over damper life; if corrosion and thermal effects are sever. Electric motors, air cylinders, and oil cylinders are able to actuate louver dampers with little difficulty.

Louver dampers are best applied to balance or control flow. Leakage performance of a louver damper depends on ratio of flowing to shutoff pressure, design temperature, number of blades, and blade edge treatment.

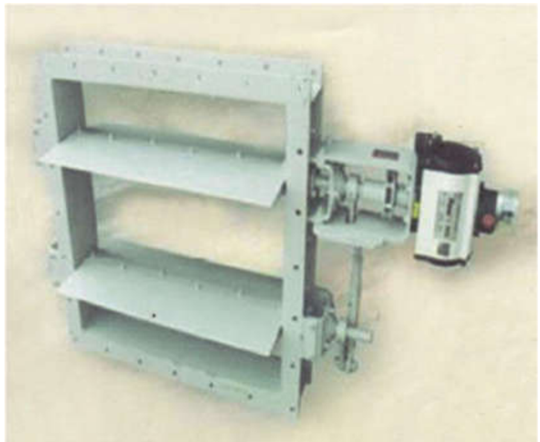


Fig. No.2.2.3 Louver Damper [13]

Stack damper

These dampers are used for two main purposes: Saving energy by closing the stack and reduction of cooling down by natural draft during short boiler stops. Weather protection and rain water drainage for stack silencer and boiler. Stack dampers are commonly used in a wide range of gas turbine power plant applications

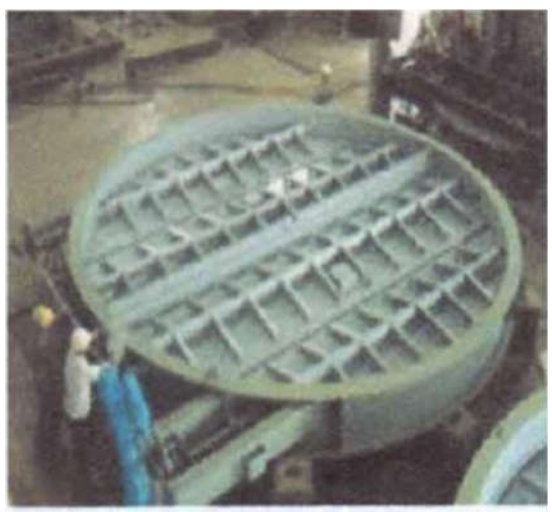


Fig. No.2.2.4 Stack Damper [13]

Camfil diverter dampers [12], Raumag Janich[13], are leaders in damper technologies. We used their brochure for study purpose. We studied different types of dampers. In the early stage of project their sealing type was studied to be used but due to certain limitations we cancelled that.

H.S. Gopalakrishna, et al presented a finite element approach for analyzing the thermal-structural coupling effects of the viscoelastic dampers subjected to steady-state excitation. Nonlinear viscoelastic properties due to temperature rise in the viscoelastic material are considered in the analysis. Examples given in the paper illustrate that the Þnite element approach can properly predict the temperature distribution in the damper and can be used as a practical design tool. A method for analyzing the thermal & structural coupling effects of the viscoelastic damper subjected to steady-state excitations is presented. The method is veriÞed with an experimental damper. It is shown that the strain in the VEM, thickness of the VEM, the extension of steel plates beyond the VEM, and the ambient temperature can affect the temperature distribution in the damper significantly and need to be considered in design. Future work should concentrate on a thorough parametric study to provide detailed information for damper design. In this study, only steady-state excitations are considered [5].

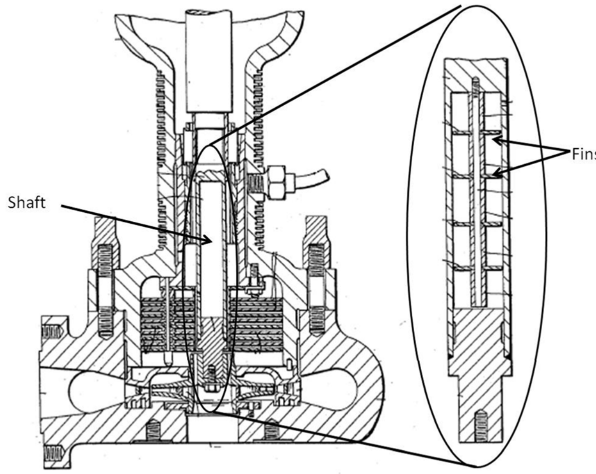
P.S. Els a, et al, performed mathematical modeling of the spring characteristic by solving the energy equation for a gas in a closed container using the thermal time constant approach. The Benedict-Webb-Rubin equation of state is used for real gas behavior. The mathematical model is verified against experimental data and good correlation is achieved. It is shown that hydro-pneumatic suspension systems have a significant amount of inherent damping due to heat transfer which produces no net temperature change or heat build-up. The effect of heat build-up in the damper on the spring force characteristic is determined by laboratory tests. It is shown that heat generation in the damper, accompanied by a rise in gas temperature, has a detrimental effect on the spring force characteristic. Tests performed on experimental hydro-pneumatic spring and damper systems fitted to a test vehicle indicate that the effect is smaller in practice than anticipated. Heat build-up is strongly influenced by terrain roughness, vehicle speed, mission profile and damping levels [6].

M. Baris dogruoz, et al, developed a theoretical model incorporating a lumped system approach for the prediction of both the temperature rise and the corresponding peak force values for MRF dampers subjected to a sinusoidal input motion. The predictions based on the theoretical model were compared with the experimental results obtained from the prototype finned and unfinned MRF dampers. Results show that the theoretical model slightly overestimates the temperature rise during the operation of the damper. The discrepancy between the theoretical and experimental results increased with increasing input peak velocity, but did not vary with input current. Installation of the fins on the damper enhances the heat transfer from the device and, therefore, mitigating the decrease in the peak force, especially for high peak velocities and input currents. If the damper is subjected to motions with large peak velocities, even though the fins make a great contribution to removal of heat from the damper, decrease in the peak force is still large. The dramatic peak force decrease due to temperature rise shows that the temperature effects should be seriously taken into account while designing MRF dampers. Large peak velocities coupled with long working periods produce large temperature increases, which may result in the loss of fluid stability and component failure [7].

John Kaiser Calautit, et al, compared the effect of evaporative cooling and heat transfer devices on the thermal performance of the passive ventilation device. The proposed cooling system was capable of reducing the air temperatures by 12-15 K, depending on the configuration and operating conditions. A geometrical representation of a full scale wind tower configuration, micro-climate and macro-climate was modeled. Computational Fluid Dynamics (CFD) was used to develop a numerical model of a new wind tower system and simulate the air flow pattern and pressure coefficients around and through the wind tower to the test room. Results have indicated that the average internal airflow rate was reduced following the integration of the vertical and horizontal heat transfer device configuration, reductions of 4.11 % and 8.21 % was obtained from the achieved numerical models [8].

John Kaiser Calautit, et al, incorporated heat transfer devices in a wind tower to meet the internal comfort criteria in extreme external conditions. Computational Fluid Dynamics (CFD) was used to develop a numerical model of a new wind tower design and simulate the air flow pattern and pressure coefficients around and through the wind tower to a test room. Results have indicated that the average internal airflow rate was reduced following the integration of the vertical and horizontal heat transfer device configuration, reductions of 7% and 10% was obtained from the achieved numerical models. The work compared the effect of evaporative cooling and heat transfer devices on the thermal performance of the passive ventilation device. The proposed cooling system was capable of reducing the air temperatures up to 15 K, depending on the configuration and operating conditions. Furthermore, the study also highlighted that the proposed system was able to provide the recommended rates of fresh supply even at relatively low external wind speeds. The technology presented here is subject to IP protection under the QNRF funding guidelines [9].

V. Ivanoff, in his patent means for reducing heat transfer along shafts and relates particularly to the prevention of heat transfer along the shaft of centrifugal pumps which may have to operate at high or variable temperatures. The apparatus comprising a shaft along which heat tends to be transferred, said shaft being hollow over at least a portion of its length, a body of liquid in the hollow interior of said shaft, and a plurality of individual transverse baffles spaced along said shaft in the hollow interior thereof with their circumferential edges close to the inner periphery of said shaft so as to reduce heat transfer by thermal convection longitudinally of said shaft.



3. DESIGN OF DAMPER

Design of flap is done according to the area of exposure of flap to the flue gases. The heat transfer rate (2.01kW) is calculated by experiment on-site [3] and accordingly we got thickness of flapper, dx = 8 mm

Torque Calculation for actuator

When flap is to be rotated, total torque required to operate the flap consists,

- i Torque due to self-weight of shaft and flapper.
- ii Torque due to bearing friction.
- iii Torque corresponding to pressure head & velocity head.
- iv Torque due to jet of hot gases. [2]

Total Torque = 235.2 N-m
Considering Factor of Safety as 1.5
∴ Total Torque = 350N-m

4. CAD MODELING AND ANALYSIS

Modeling is the construction of physical, conceptual or mathematical simulation of real world. All the components of Box type diverter damper are modeled by using Solidworks.

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.

Existing diverter damper is modeled using solidworks for simulation and thermal analysis. [15]

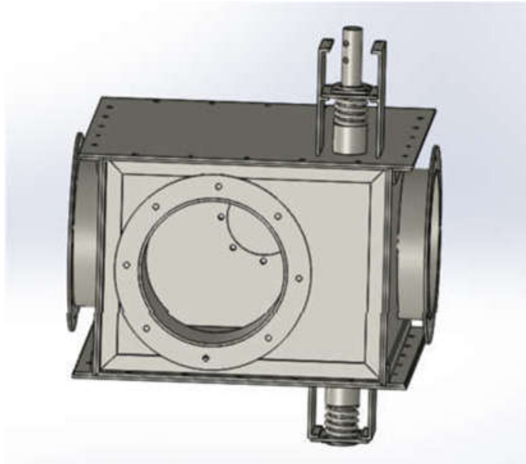


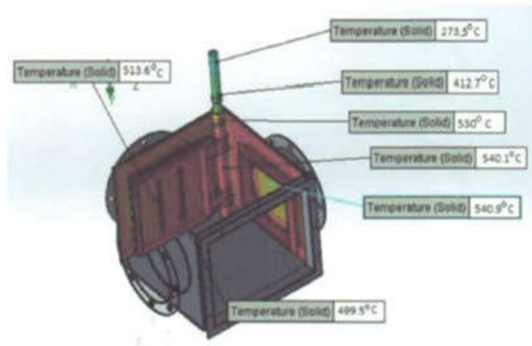
Fig. 5.1 Assembly Model of Box type diverter

Extended circular fins are designed to increase the heat transfer rate through convection. These fins are to be attached over the shaft of damper. The new design is also modeled using solidworks for analysis. [15]

Fig. 5.2 Assembly Model of new Box type diverter Damper with linkage

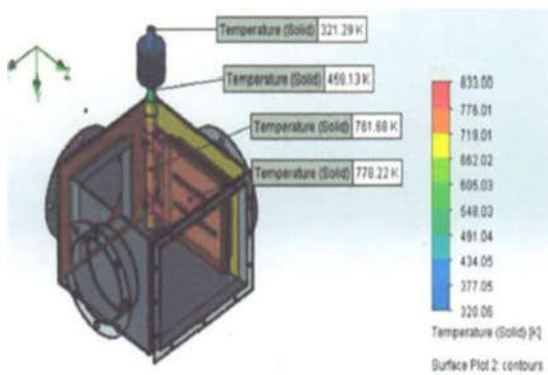
Analysis of Damper

Analysis of damper model with normal shaft extending out of the box



From the above analysis it can be seen that the temperature at the top end is very high (273.5C) which will burn the actuator components. It reduces the life of the components due to continuous exposure to high temperature.

Analysis of damper with provision of fins for heat dissipation.
The below given analysis is done on the new design of the damper. That includes the provision of fins for the heat dissipation purpose.



From this analysis it can be seen that the heat transferred to the top of the shaft is very less compared to previous models i.e. 48.29C. The resulting temperature is found to be within the operating range of actuator (27C – 80C). This reduces the chances of damaging the actuator.

5. TESTS AND CONCLUSION

The experimental model manufactured is tested at different point for temperature variations and compared to the existing model of box type diverter damper.

The temperature is measured by means of a pyrometer and the temperatures are noted down for different points.
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.

6. FUTURE SCOPE

The fins attached to the linkage for reducing temperature to the actuator can be optimized in future for different parameters.

a. Number of fins
b. Area of fins
c. Material of fins
d. Thickness of fins

REFERENCES

[1] "Design of machine elements," by V.B.bhandari, 3d edition, Mc graw hill education publication

[2] "Machine design," by R.S. Khurmi and J. K. Gupta, 14 edition , S. Chand publishing house
[3] "Heat and mass transfer," by Yunus A. Cengal — annexure, 4e special indian edition
[4] "Means for reducing heat transfer along shafts," V. Ivanoff, U.S. Patents, 2,601,146, june 17, 1952.
[5] "Finite element heat transfer analysis of viscoelastic damper for wind applications," H.S. Gopalakrishna, M.L. Lai, Journal of wind engineering and industrial aerodynamics 77&78 (1998) 283-295.
[6] "Heat transfer effects on hydropneumatic suspension systems," P.S. Els, B. Grobbelaar, Journal of terramechanics 36 (1999), 197-205.
[7] "Augmenting heat transfer from fail-safe magneto-rheological fluid dampers using fins," M. B. Dogruoz, Eric Wang, Faramarz Gordaninejad and Arthur J. Stipanovic, Journal of intelligent material systems and structures, vol. 14, no. 2, 79-86, 2003.
[8] "Numerical investigation of the integration of heat transfer devices into a wind tower," John K Calautit et al, International conference on applied energy, 5-8 July 2012, suzhou, china, http://eprints.whiterose.ac.uk/81712.
[9] "CFD analysis of a heat transfer device integrated wind tower system for hot and dry climate," John K. Calautit et al, Journal of applied energy (2013), http://dx.doi.org/10.1016/j.apenergy.2013.01.021
[10] "Diverter damper for waste heat recovery boiler system," international journal on recent and innovation trends in computing and communication issn: 2321-8169, volume: 3 issue: 2, 185— 187 by Swapnil S. Kachore & M.S.Tufail
[11] "Thermal analysis of components of diverter damper used in waste heat recovery boiler system," IJSRD - international journal for scientific research & development| vol. 3, issue 02, 2015 | ISSN (online): 2321-0613 by Swapnil S. Kachore & M.S.Tufail
[12] Camfil diverter dampers, Industrial catalogue
[13] Raumag janich brochure, Industrial catalogue
[14] http://www.sudeengg.com - Company website
[15] Student's Guide to Learning SolidWorks® software, www.solidworks.in

Author Profile

Prabhakar S. Chilwante is currently student of M.E. (M/D) at SSIEMS, Parbhani. He has completed his graduation in Mechanical Engineering in 2007from DBAMU Aurangabad, Maharashtra, India.

S. C. Patil is an Assistant Professor in SSIEMS, Parbhani