Fire-Tube Boiler Flow Characteristics- A Simulation Using ANSYS

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ABSTRACT

In this work, the thermal analysis of fire-tube boilers used in thermal power plants is discussed. A small-scale prototype of the original fire-tube boiler designed using Solid Works is used for simulation purpose. ANSYS Fluent is used to carry out the numerical simulation of the designed model. The initial portion of this paper presents the pressure and temperature variations along the length of the boiler for different water velocities such as 25 m/s, 30 m/s, 35 m/s and 40 m/s. The later section deals with different boiler casing material between steel, brass and stainless steel and studies the pressure and temperature variations at constant water velocity of 30 m/s. After observing the results, the best boiler shell material among these three has been chosen. The result has been obtained from the CFD analysis and is presented in the form of pressure and temperature contours.

Key words: Fire Tube Boiler, Numerical Analysis, ANSYS Fluent, CFD Analysis, Negative Heat Flux, Pressure-Velocity Variation.

1. INTRODUCTION

Boilers are pressure vessels which are used for heating water or generating steam for the heating facility in industries and to generate electricity through steam turbines. A boiler is an enclosed vessel which is used to provide heat for the combustion of the fuel in the thermal power plant [1]. In a fire tube the hot gases or flue gases pass inside the boiler tubes and the water is transferred outside in the shell. Water gets converted into the high temperature by the heat transfer from the gases to water [2]. If the boiler is subjected to the high temperature and high pressure conditions then the walls of boiler are subjected to the high stresses [3]. The main components of a boiler are fabricated by the high-temperature alloys such as steel, cast iron, stainless steel etc. The failure in the boiler generally affects the output of the overall power plant. Identifying the correct failure reason often helps to ensure integrity of the component. There are many reasons due to which boiler failure occurs such as pitting, stress corrosion cracking, stress rupture, creep, erosion and thermal fatigue [4].

In the Pulverized coal-fired boiler, the flue gases temperature can reach up to the 1200˚C and it contains fly ash that induces the erosion [5]. In present, the boilers have to completely isolated from the external environment for the proper functioning. So, methodologies based in the computational simulations have been used to analyze effect of velocity on boiler function. Nowadays, the computation analys is isused instead of prototype.

2. FORMULATION AND SOLUTION METHODOLOGY

The small-scale proto type of the fire-tube boiler was designed using Solid Works. The individual parts, i.e. the boiler shell, water flow domain, fire tubes and exhaust flow domain, were designed individually and then assembled to get the final model. The assembly of the fire-tube boiler was saved as .STEP file to import it in ANSYS Fluent. The boiler consisted of two fire tubes through which hot exhaust gases would flow. The isometric view of the final model is shown in Fig.1 along with the geometrical specifications inTable1.
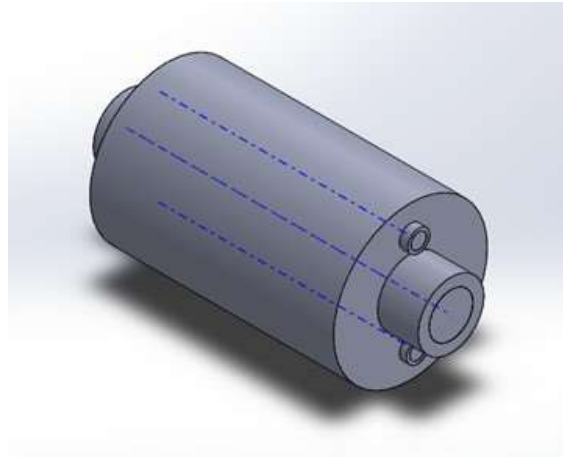

Figure1 Isometric view of the 3D fire-tube boiler

Table1 Geometrical Specifications of 3D fire-tube model

Sr. No.	Feature	Dimension(mm)
1	Length of boiler	550
2	Diameter of boiler casing (inner/outer)	300/350
3	Diameter of fire tube (inner/outer)	35/50

The assembly was imported to ANSYS Fluent and meshing was carried out. The mesh type was set to Automatic, hence we got triangular cells. The cell count of the mesh was1, 36,518. Named selections were created for various part surface. The meshed model is shown
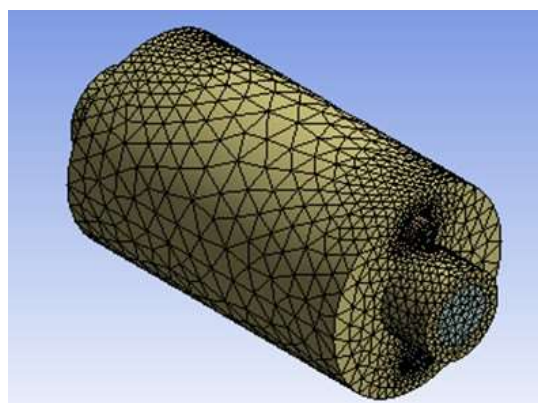
in Fig.2.

Figure2 Meshed fire-tube boiler model

The simulation has been performed using ANSYS Fluent 17.2, 3D double precision, pressure based version and reliable ek–ε has been solved.

The required materials were selected from the fluent data base. The inlets and outlets for the fire tube and boiler were selected as velocity inlet and pressure outlet respectively. Airis

made to flow through both the fire tubes at a velocity of 5 m/s with a temperature of 1500 K. Water is made to pass through the fluid domain with varying velocities (25 m/s, 30 m/s, 35 m/s and40 m/s) at a temperature of 350 K. The boiler shell material and fire tube material is chosen accordingly and convection coefficient is set to 25 W/m^{2}K along the interface. Simulation is run to get the results.

3. RESULTSANDDISCUSSIONS

The inlet velocity of the water into the boiler is varied between 25 m/s, 30 m/s, 35 m/s and 40m/s. The pressure induced inside the boiler is determined by simulation and presented in the form of contours in Fig.3. Fig.4 and Fig.5 represents the variation of minimum and maximum pressure with velocity in the form of graph.
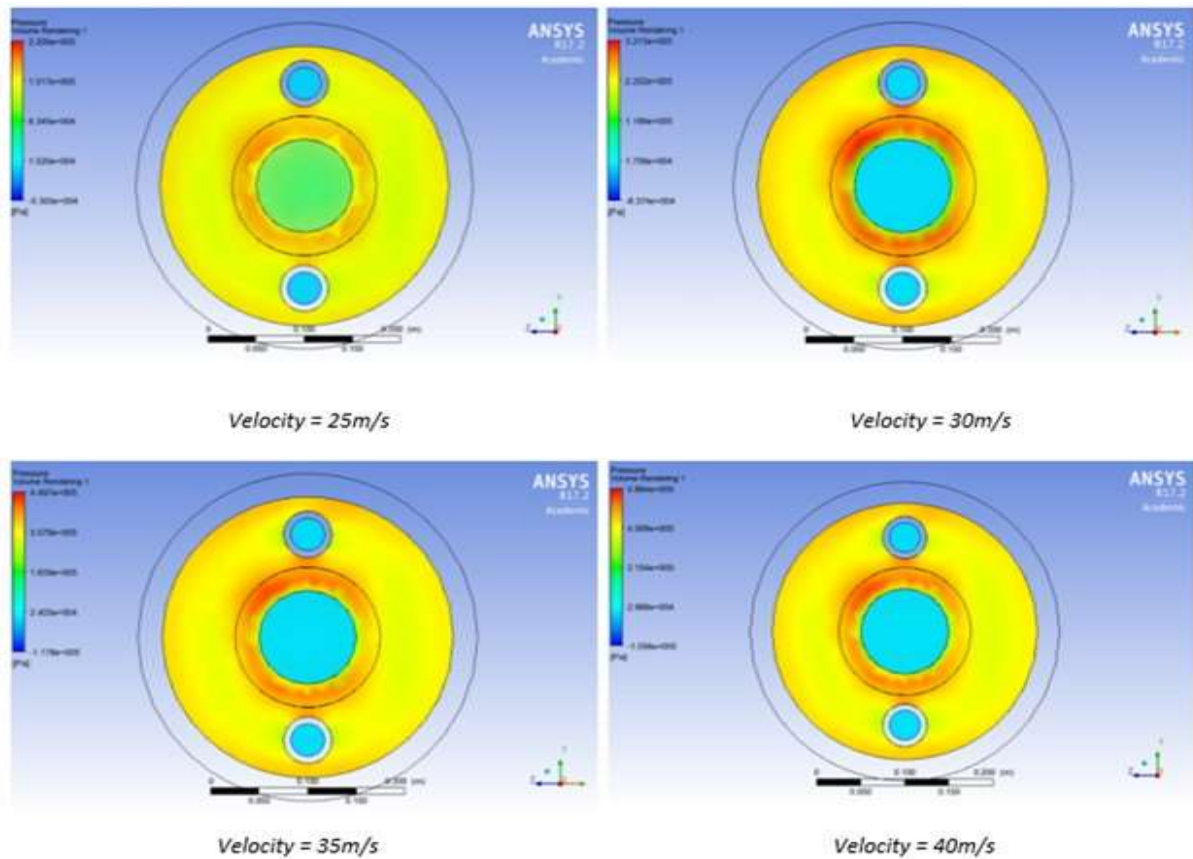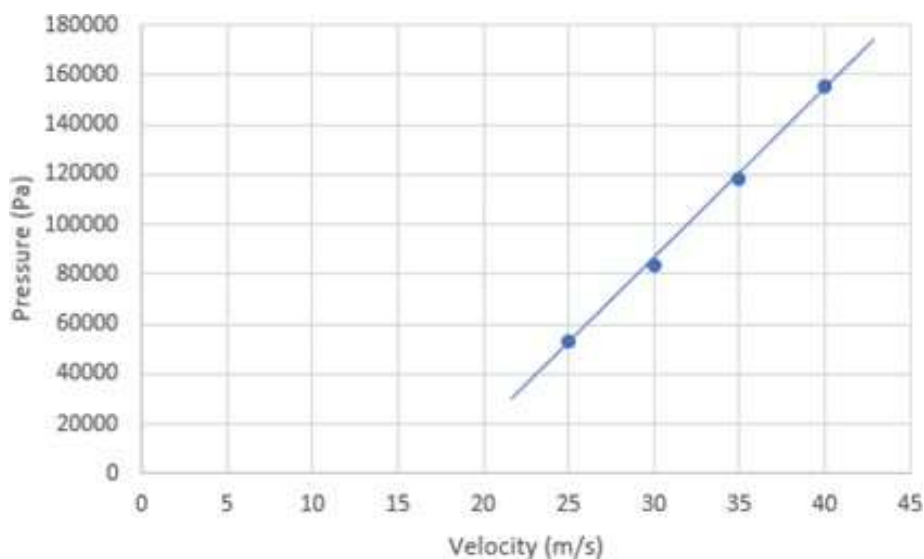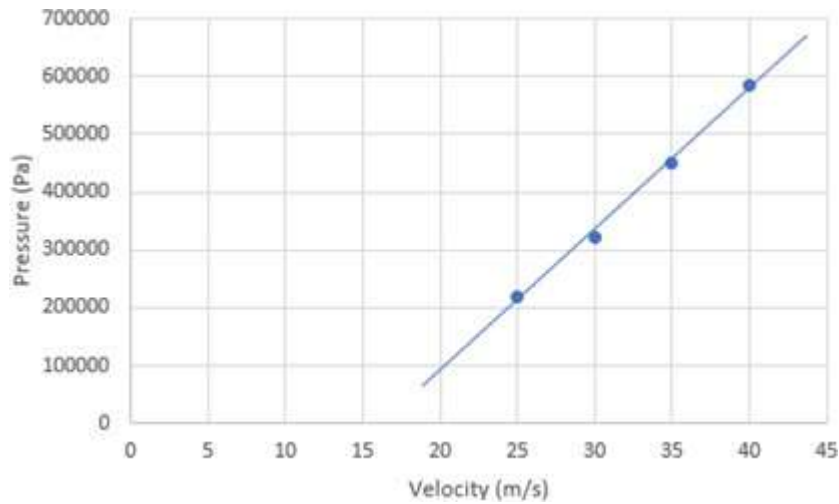

Velocity = 25m/s

Velocity = 30m/s

Velocity = 35m/s

Velocity = 40m/s

**Figure3** Pressure plot for different inlet velocities of water

Figure4 Minimum pressure (vacuum) variation with velocity

Figure5 Maximum pressure variation with velocity

It can be seen from Fig.3, Fig.4 and Fig.5 that as the velocity of water increases inside the boiler, the pressure encountered during the flow also increases. Greater pressure implies greater stresses on the walls of the boiler. Hence, they are more susceptible to failure under high pressure condition. As the velocity of the water increases, lesser heat will be transferred from the hot gases to the water.

On varying the boiler casing material, significant changes can be seen in the amount of heat that is being lost through the boiler shell. Fig.6. represents the heat flux contours, as obtained by varying the boiler casing material. Table2 states the loss of heat flux through the boiler.

Brass   Stainless Steel
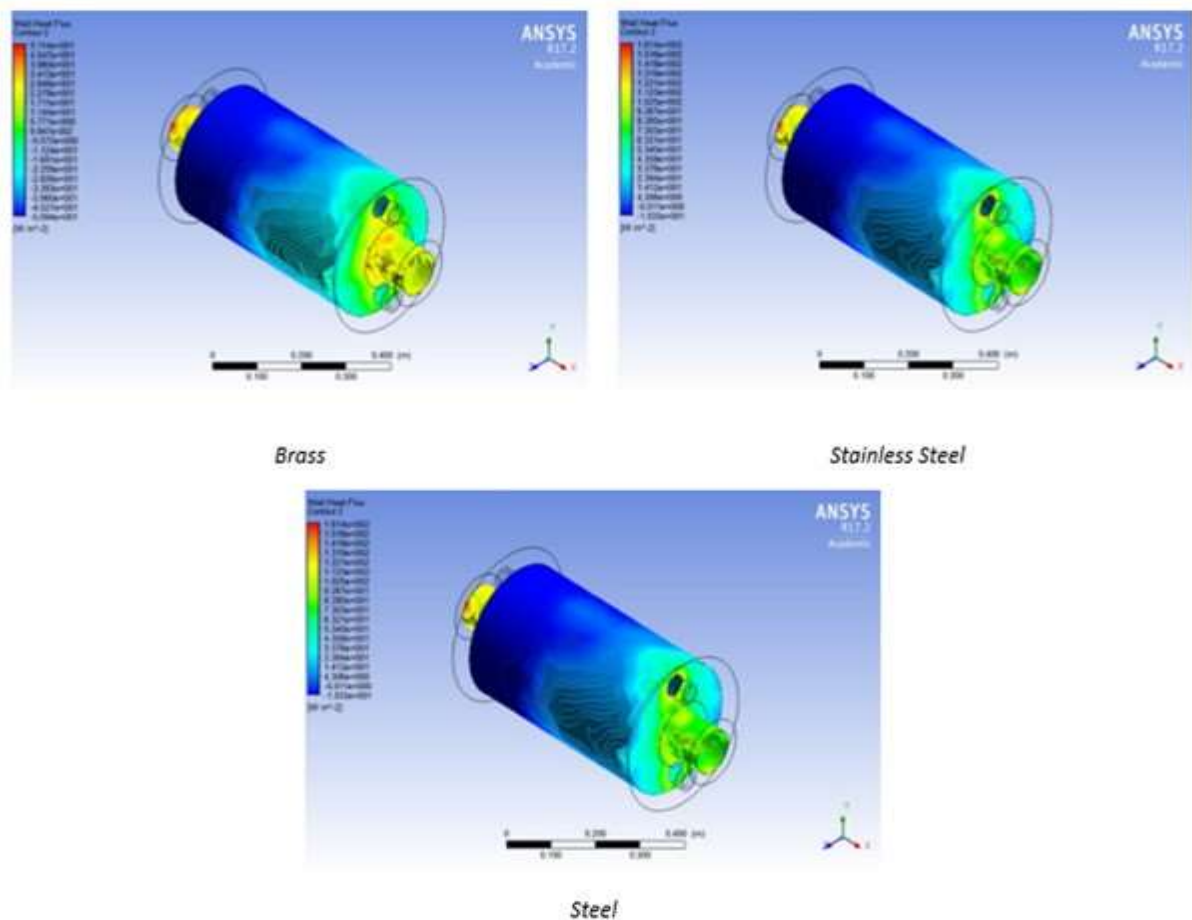
Steel

Figure6 Heat flux variation with boiler casing material

Table2 Heat flux variation with respect to boiler casing material

Boiler Casing Material	Negative Heat Flux (W/m²)
Steel	15.51
Brass	50.94
Stainless Steel	15.32

While selecting the boiler casing material, the key factor is the loss of heat through the boiler casing. Greater the loss of heat, lower is the efficiency of the boiler. Among the three materials tested, brass is having a very high negative heat flux of 50.94 W/m^2. Steel and stainless steel are nearly having the same negative heat flux value. Stainless steel is having the lowest negative heat flux of 15.32 W/m^2.

4. CONCLUSION

Flow of water and hot exhaust gases through the fire-tube boiler has been simulated using ANSYS Fluent. In the first case, the inlet velocity of the water has been varied and the pressure distribution across the boiler shell has been studied. In the second case, the boiler casing material has been varied to identify the loss of heat through the boiler. In order to run the boiler at greater efficiency, the following points needs to be considered.

1. It is recommended to keep the velocity of the water as low as possible to reduce the induced pressure and increase the heat transfer.

2. Among the three boiler casing materials, stainless steel has minimum heat loss from the boiler casing.

3. The preferability order among the three materials is–Stainless Steel >Steel >Brass.

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