

STUDY OF NUMERICAL SIMULATION OF ROTARY AIR-PRE HEATER

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Abstract: In my work, was an analyzed different geometrical condition for 3 cases of the air preheater. The three cases were different by the design of their ducts. Case 1 contains the straight duct as compared to the existing duct design, Case 2 with an inclination of 15 degrees and Case 3 by an inclination of 30 degrees. As always with Computational Fluid Dynamics projects, the three major steps involved in this project are Design, Meshing and Analysis. The design is done using Solid Works software, meshing by Gambit 2.4.6 and analysis by ANSYS Fluent. Since the design of even the straight duct is different from the conventional ducts on industrial air preheaters, we see a slight improvement in the temperature of the gas inside the duct. Since the other two cases follow mostly the same parameters, extensive simulation was done throughout the three cases to find the best optimal improvement for the existing design of the air preheater.

1. Introduction

In this study, thermal behavior of a full-scale rotary air preheater is investigated using three-dimensional approach and solving Circulating air-pre heater with inlet and outlet ducts. So far, no one has done this type of simulation with the inclusion of the ducts Existing simulations of regenerative air pre-heaters are mainly based on rotating matrix where some of the effects of the ducts are neglected. Although this existing one usually gives reasonably acceptable results, it was thought that CFD analysis of such devices including its ducts would result in a better understanding of the process features, such as the effect of duct angles over the heat transferred. It also helps to determine the temperature distribution in air-pre heater with duct and also determines the temperature distribution for different angle of ducts. We can determine the efficiency of air preheater under three different cases of ducts.[1-4]

2. Literary Survey

The Ljungström Air Preheater was a regenerative heat exchanger, and comprises a slowly rotating rotor filled with heat transfer plates. The hot and cold gas ducts were arranged so that half of the rotor was in the flue gas duct and the other half was in the primary air duct which supplies combustion air with the furnace. The hot flue gases heat the part of the rotor in their path, and as the rotor rotates, the hot section.[5-9]

Boilers at that time were not normally fitted with induced draught fans, so the fans were incorporated in the air preheaters. A picture of this arrangement is shown on the cover. Some of the steam-turbine powered locomotives manufactured by the company were also fitted with Ljungström Air Preheaters at the front in order to increase efficiency.[10-15]

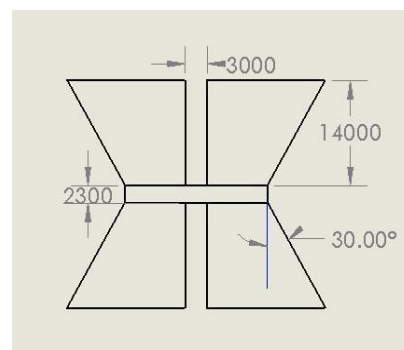


Figure 1. Straight Duct APH with dimensions

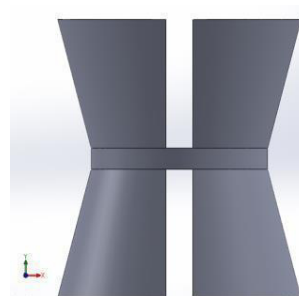
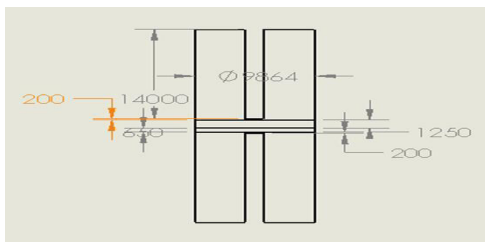
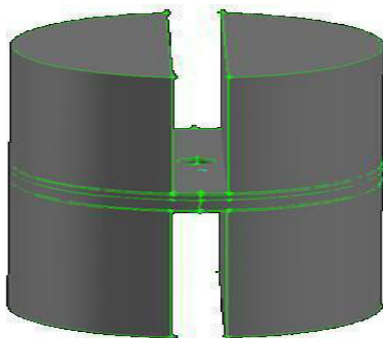
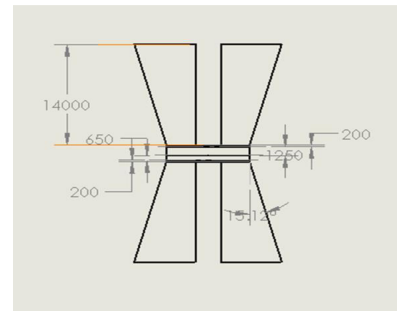
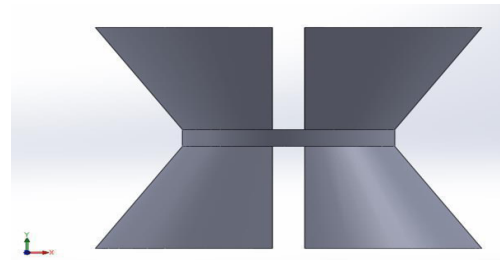


Figure 2. SolidWorks model of Straight Duct APH**Solid Works modeling of APH with 15° duct**

Geometric modelling of the air preheater with duct angle 15 degree are created using SolidWorks. The dimensions are shown in Fig.3.3. The diameter of the rotating matrix is 9.864m. Height of the duct are 14m each for both inlet and outlet. Clearance is 0.2m. Thickness of hot matrix is 1.250m. Thickness of cold matrix is 0.650m. The duct angle is 15 degree. This is shown in Fig 3.4.

**Figure 3.** Dimensions of APH with zero degree duct**Figure 4.** Solid Works model of 15° APH**Solid Works modeling of APH with 30° duct**

Geometric modelling of the air preheater with duct angle zero degree are created using SolidWorks. The dimensions are shown in Fig.3.5. The diameter of the rotating matrix is 9.864m. Height of the duct are 14m each for both inlet and outlet. Clearance is 0.2m. Thickness of hot matrix is 1.250m. Thickness of cold matrix is 0.650m. The duct angle is 30 degree. This is shown in Fig. 3.6.

**Figure 5.** Dimensions of 30° APH**Figure 6.** Solid Works model of 30° APH**3. Gambit Modelling**

GAMBIT stands for GEOMETRY AND MESH BUILDING INTELLIGENT TOOL KIT. GAMBIT is Fluent's geometry and mesh generation software. GAMBIT's single interface for geometry creation and meshing brings together most of Fluent's preprocessing technologies in one environment. Advanced tools for journaling let you edit and conveniently replay model building sessions for parametric studies. GAMBIT's combination of CAD interoperability, geometry cleanup, decomposition and meshing tools results in one of the easiest, fastest and most straightforward preprocessing paths from CAD to quality CFD meshes. Gambit is an mesh generation software used for this analysis. Hexahedral elements are used for meshing the total air-preheater[24-27].

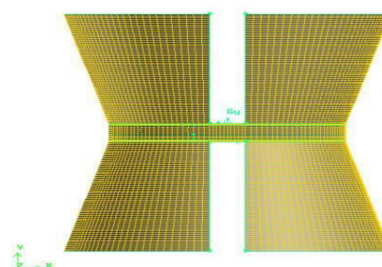
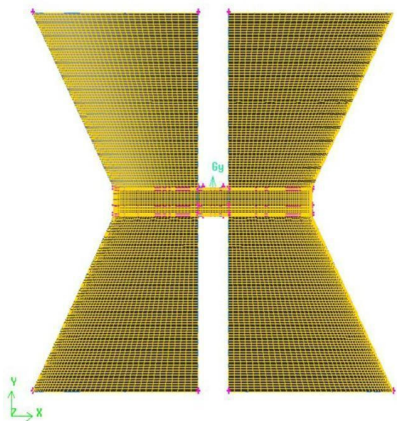
Hexahedral Meshing

Figure 7. APH with 0° duct

Hexahedral elements are used for meshing the total air preheater. There are elements on all corner called the nodal points. Hexahedral meshing are those meshing technique in which hexahedral elements are used. These types of meshing are used to generate high quality of mesh. One disadvantage of hexahedral mesh is they cannot be meshed for complex shapes. Hexahedral element has eight nodal points[28-30].

Gambit modeling for APH with 0° duct

Three dimensional model of air preheater with duct angle zero degree created in SolidWorks are transported to Gambit. In order to create high quality of mesh hexahedral meshing is carried out in the given model. Total domain is split in eight volumes. For multi reference frame hexahedral mesh is preferred. Hexahedral mesh was used with around 2, 88,438 elements. Gambit model for an air preheater with zero degree duct angle are given below.

**Figure 8.** APH with 15° duct

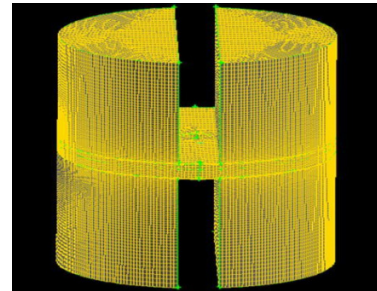
Gambit modeling for APH with 15° duct

Three dimensional model of air preheater with duct angle fifteen degree created in SolidWorks are transported to Gambit. In order to create high quality of mesh hexahedral meshing is carried out in the given model. Total domain is split in eight volumes. For multi reference frame hexahedral mesh is preferred. Hexahedral mesh was used . 4,56,784 elements were used. Gambit model for an air preheater with fifteen degree duct angle are given in Fig. 3.8.

Gambit modeling of APH with 30° duct

Three dimensional model of air preheater with duct angle thirty degree created in SolidWorks are

transported to Gambit. In order to create high quality of mesh hexahedral meshing is carried out in the given model. Total domain is split in eight volumes. For multi reference frame hexahedral mesh is preferred. Hexahedral mesh with. 5, 18,286 elements were used. Gambit model for an air preheater with thirty degree duct angle are given in the Fig.3.9.

**Figure 9.** APH with 30° duct

Analysis By Ansys-Fluent

Three dimensional models and meshed models created are transferred to the ANSYS-FLUENT. Analysis are done using this software. The term Ansys stands for analysis system.

ANSYS Fluent

It is an engineering simulation software or computer-aided engineering developer headquartered south of Pittsburgh in the Southpointe business park in Cecil Township, Pennsylvania, United States. One of its most significant products is ANSYS CFD, a proprietary computational fluid dynamics (CFD) program. ANSYS CFD allows engineers to test systems by simulating fluid flows in a virtual environment, for example, the fluid dynamics of ship hulls; gas turbine engines including the compressors, combustion chamber, turbines and afterburners; aircraft aerodynamics; pumps, fans, HVAC systems, mixing vessels, hydro cyclones, vacuum cleaners, etc. Ansys fluent software contains the broad physical modeling capabilities needed to model flow, heat transfer, turbulence, heat transfer, and reactions for industrial applications ranging from airflow over an aircraft wing to combustion in a furnace, from bubble columns to oil platforms, from blood flow to semiconductor manufacturing, and from clean room design to waste water treatments plants. Today thousands of companies throughout the world benefit from the use of ANSYS fluent software as an integral part of the design and optimization phases of their product development. Advanced solver technology provides fast, accurate CFD results, flexible moving and deforming meshes.

Boundary Conditions

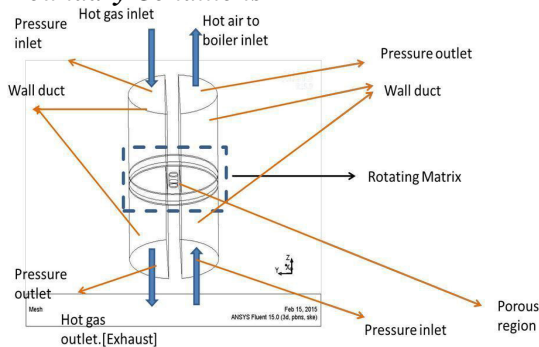


Figure 10. Boundary conditions

The boundary conditions of the rotating air preheater are given in Fig.3.10. There are mainly four types of boundary conditions. These are the inlet, outlet, wall, and porous region conditions. The temperature and pressure values are given at each of the boundary conditions.

Inlet boundary conditions

Temperature and pressure inlet conditions have been used to define the fluid pressure and temperature at the flow inlet. Temperature and pressure values are taken from the base paper. Temperature of the inlet air is 348.9k. Temperature of inlet flue gas is 64.2k. Pressure at the inlet of gas is -1.89kpa. Pressure at the inlet of air is 2.97kpa.

Outlet boundary conditions

Temperature and pressure inlet conditions have been used to define the fluid pressure and temperature at the flow outlet. Temperature and pressure values are taken from the base paper. Pressure at the exit of gas is -3.11kpa. Pressure at the exit of air is 1.65kpa.

Wall boundary conditions

All the inner and outer circumferential walls and the radial dividing walls above and below the porous media have been specified as insulated and stationary walls of steel. Inner and outer circumferential walls of porous media have also been specified as insulated walls of steel but having same rotational speed as that of the porous media.

Porous media conditions

Rotating air preheater has a circulating matrix. This circulating matrix is made of porous materials which can trap heat energy without dissipating to other forms. So porous media approach are used for the analysis of air preheater. The porous media consists of enameled steel as solid. Moving reference frame has

been used to specify the rotational motion to the porous medium. MRF is used to incorporate the effect of rotational speed of the matrix. Speed of rotation of porous media is 2 rpm, with z-axis as the axis of rotation.

Temperature Contours of Aph With 0° Duct

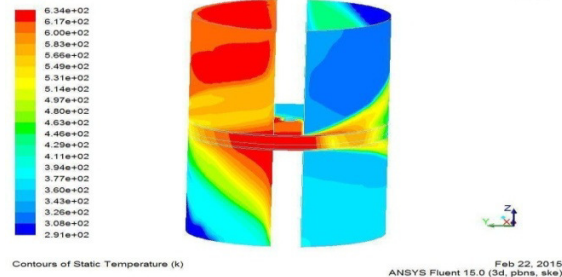


Figure 11. Temperature contours of zero degree duct

Temperature contours across the straight duct air preheater are shown in Fig 4.1., where it clearly shows path of movement of heat from the flue gas duct to the air duct. As you can see, the flue gas with high temperature comes from the combustion chamber at very high temperatures. When the gas reaches the rotating matrix, the heat from the flue gas is absorbed by the hot layer matrix. This is possible because the rotating matrix is made of metal.

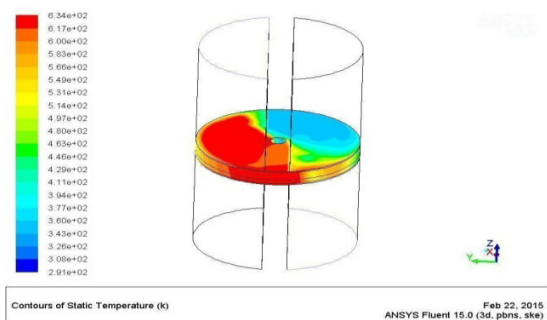


Figure 12. Temperature contours of rotating matrix

As the rotating matrix moves from one end to another, it carries the absorbed heat from the flue gas end of the matrix to the air duct end, thus transferring the heat to the moving air through the duct. In Fig.4.2., you can see the rotating matrix being divided into two. The two divisions are the Hot Layer matrix and the Cold Layer matrix. The rotating matrix is being divided into two so as to efficiently transfer heat from one side of the matrix to another.

If we observe the flue gas duct in the Fig. 4.1 carefully, we can see a certain temperature drop form before the gas reached the rotating matrix. We can see this specific characteristic because when the rotating matrix completes one rotation, the matrix loses all the heat to the air in the air duct. As a result, when the matrix comes back onto the starting point, it is cooler than it usually was. Therefore, the matrix absorbs some heat from the flue gas

beforehand which results in the flue gas being cooler just above the rotating matrix in the above figure.

Pressure Contours Of Aph With 0° Duct

The temperature contours of rotating air preheater with duct angle zero Fig. 4.2. It represents the temperature contours of air preheater including its ducts in an instant time. Red color indicates maximum heat transfer. Yellowish and blue color represents further less heat transfer. The red color crossing the separator frame indicates maximum heat transfer.

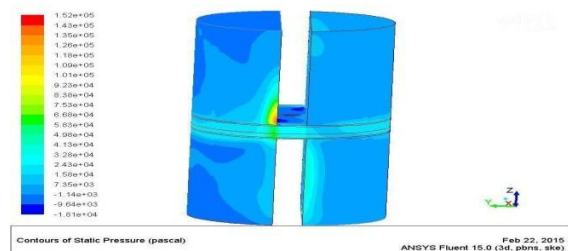


Figure 13. pressure contours of the rotating air preheater with duct angle zero

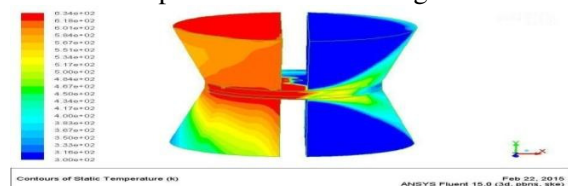
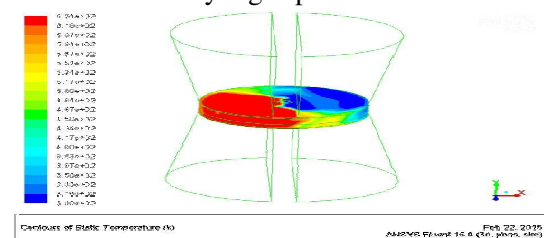


Figure 14. Temperature contours of APH

The pressure contours of the rotating air preheater with duct angle zero are shown in Fig 4.3. It represents the temperature contours of air preheater in an instant time. Inlet and outlet ducts have pressure negative pressure. Negative pressure is due to the draft fan suction. Inlet and outlet ducts of air have positive pressure, since there is no suction. Region closer to the rotating matrix have more pressure than other regions. This is due to the rotating effect of the air preheater. We can also see a slight yellowish spot to the region nearer to the separator frame of the rotating matrix. It indicates the region having high pressure. This is caused due to the action of flue gas over the surface of separator frame when hit by high speed.



5. Conclusion

In this project, we took three different cases of the

rotating APH with the duct angles of 0°, 15° and 30°. We took this approach to this subject in order to observe the difference in the efficiency with the change of the duct angle. In contrary to our expectations, the 0° angle to the duct turned out to be the most efficient of these three cases. The reason for this result is that with the increase of angle to the duct, the volume of the duct also increases proportional to the duct angle. As the volume inside the duct increases, the heat getting transferred from the flue gas duct via the rotating matrix is absorbed by the higher volume of air inside the duct. When the volume is higher, heat is distributed to more air inside the duct and the temperature of air at the end of the duct will be much lesser than that of the 0° duct air preheater.

Therefore, when the efficiency is calculated for all the three cases, the 0° duct turns out to be the most efficient duct design in this project. It should be noted even though the other ducts are not that efficient than the straight duct, they are expected to show more efficiency when compared to the normal duct, which has a square or rectangular cross section of the duct, though this can only be confirmed by further research. As a result, it can be concluded that the straight duct APH has better mixing of heat and an increase in efficiency. In the other two cases, due to the increase in duct angle and volume of the duct, lower mixing takes place. Therefore, choosing the optimum design for the APH is very much essential to achieve the best efficiency in the transfer of heat form the flue gas to the air.

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