ANALYSIS ON UNSTEADY HEAT TRANSFER AND FLUID FLOW THROUGH SENSIBLE HEAT STORAGESYSTEM

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Abstract**—**Developing efficient and inexpensive energy storage device is as important as developing new source of energy storage of thermal energy is going to be decisive factor for the future problem of managing energy. The storage system which is used to store the available form of energy depends on this conversion. The conversion of solar radiations into thermal energy is the easiest way to store solar energy. Thermal energy storage system is very useful and easier in which energy gain of the fluid from the collector is transferred to the storage medium seasons. Therefore, an energy storage unit is essentially required for storing the energy (solar radiations) that falls on it in the absence of solar radiations. Apart from solar energy, thermal energy storage system can use to recover waste heat from industrial processes or geothermal energy as a source. Cored brick heater is used as thermal energy storage system in solar air heaters, storage heaters for hypersonic wind tunnels, regenerators etc**.**

Keywords—*Energy storage, thermal energy, conversion, cored brick heater* (key words)

I. INTRODUCTION

Energy is one of the most important factors in social and economic development of a country. The amount of energy consumption per capita of a country is measure of nation's economic development and it has become an important parameter for sustainable development throughout the world. Conventionally energy is being extracted from petroleum products and fossil fuels like coal, oil and gas etc. but the oil crisis in the world in early 80's forced to think about some other alternate sources of energy. The fast depletion rate of petroleum products and their high prices creates a huge impediment in fulfilling the high energy demands of massive population. In addition to the problem of fast depletion and high prices, several environmental impacts like GHG emissions, acid rain are associated with conventional energy sources. The above impediments of conventional energy sources are creating a great need of exploring new alternatives for fulfilling high energy demands.

Renewable energy sources are appropriate solutions of all the problems associated with conventional sources of energy. As compared to the conventional energy sources, renewable energy sources are more promising for sustainable development. Renewable energy resources like solar, wind, tidal energy etc. are renewed by nature and their supply will not be affected by the rate of consumption. Among all renewable energy sources, solar energy is the most promising source due to quantitative abundance and availability of it. Solar energy is intermittent in nature and having low density. The average intensity of solar radiation of world is about 2500 kWh/m^2 and India's average intensity is approximately 2000 kWh/m^2. Solar collectors are commonly used to capture solar radiations and then solar air heaters and solar water heaters are used to transform the radiations into heat energy. Although solar energy is ambiguous yet it is not continuous at all places. It is highly time dependent and varies according to the location of a particular place. In most of the parts of the earth solar radiations are available for only 10-12 hours in a day which limits the continuous solar energy consumption. In addition to this, solar radiations are not available during rainy and winter seasons.

Therefore, an energy storage unit is essentially required for storing the energy (solar radiations) that falls on it in the absence of solar radiations. The direct storage of solar radiations is very difficult therefore an energy conversion has to be carried out first.

II. RELATED WORK

Developing efficient and inexpensive energy storage device is as important as developing new source of energy storage of thermal energy is going to be decisive factor for the future problem of managing energy. The storage system which is used to store the available form of energy depends on this conversion. The conversion of solar radiations into thermal energy is the easiest way to store solar energy. Thermal energy storage system is very useful and easier in which energy gain of the fluid from the collector is transferred to the storage medium seasons. Therefore, an energy storage unit is essentially required for storing the energy (solar radiations) that falls on it in the absence of solar radiations. Apart from solar energy, thermal energy storage system can use to recover waste heat from industrial processes or geothermal energy as a source. Cored brick heater is used as thermal energy storage system in solar air heaters, storage heaters for hypersonic wind tunnels, regenerators etc.

Many research works have been carried out in large size cored brick heater for their performance analysis during charging and discharging cycle reported in literature review and there is a lack of research work on small size cored brick heater, when alumina is considered as storage material. Hence, in the present work, the hydrodynamic and thermal behaviors of small size cored brick heater during charging and discharging cycle is investigated numerically for various hole diameter, porosity, and inlet velocities.

III. OBJECTIVES

The main objective of this project work is

- To simulate the fluid flow (air) and heat transfer in cored brick during charging and discharging process using CFD to compute Pressure drop, Velocity distribution, axial temperature distribution and energy storage capacity.
- Investigate the effect of hole diameter, porosity and inlet heat transfer fluid (HTF) velocity on storage system performance.

IV. CFD MODELING ANDSIMULATION

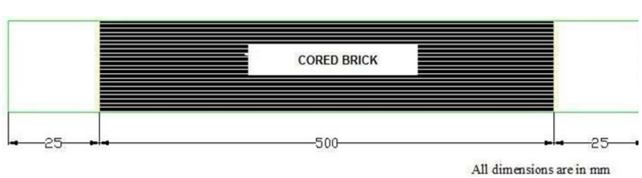
In this study, Geometry creation and mesh was done by GAMBIT 2.4.6 and solved by using commercial CFD software package FLUENT, to solve the equations by numerical method for the geometries constructed using Gambit.

ModelDescription

In this present study, three dimensional geometries of cored brick storage system have been created by using GAMBIT software, the pre-processor used to construct the flow geometry, along with the mesh generation for solving the equations of motion and continuity.

Specifications

2D view with dimensions



Specification of geometry

Total length of pipe(L)	550mm
Diameter (D)	43mm
Inlet length	25mm
Length of cored brick	500mm
Outlet length	25mm
Diameter of hole (d)	5-7mm

Meshing ofGeometry

Mesh was done by using GAMBIT tool. The geometry was meshed with unstructured tet/hybrid T-grid of mesh size 1.5 for whole geometry. Then the grid has been exported as a mesh file from GAMBIT to be used in FLUENT for solution.

Initial And BoundaryConditions

These following conditions were applied for cored brick storage system, which are asfollows:

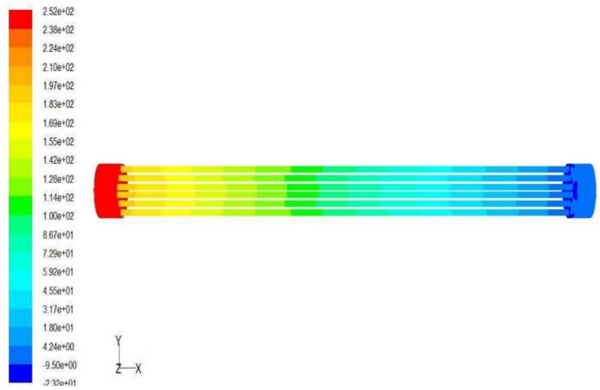
- Initially, all the domains were at assumed to be at a constant temperature of 300K.
- Inlet was specified as velocity inlet, which was set as uniform air velocity with appropriate temperature.
- Outlet was specified as pressure outlet, which fixes static pressure as $1.013x10^5$Pa.
- Outer surface of storage system was specified as convective wall (h=5 W/m2K, ambient temperature = 300oC).
- The hole surfaces were specified as interface to coupled the solid and fluid phases.
- The symmetric plane was specified as symmetry, which used the both flow and thermal solution are symmetric about a plane to reduce computational domain.used the both flow and thermal solution are symmetric about a plane to reduce computational domain.

V. RESULTS AND DISCUSSION

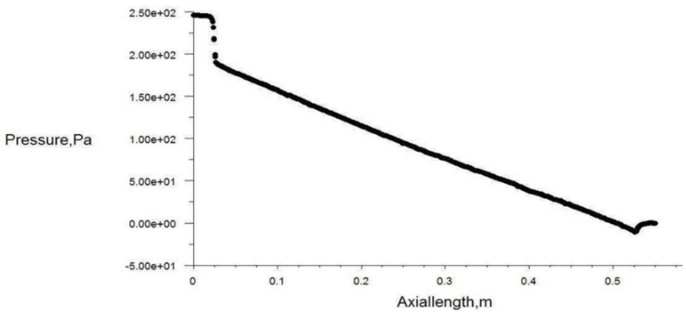
CHARGING PROCESS

Pressure Drop

In this study, the pressure drop across the cored brick storage system was investigated by varying the parameters such as superficial velocity, porosity and diameter of holes, and then the results were compared.
Fluent simulation of 5mm hole size(Porosity-0.3) with initialization of velocity 2 m/s and temperature of 465K, was carried out as per the methodology explained in previous chapter 4 and post processing of the results was done. The variation of pressure drop along the length of cored brick storage system as shown



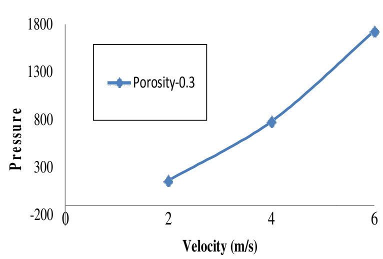
Pressure contour



Variation of pressure drop along the axial length

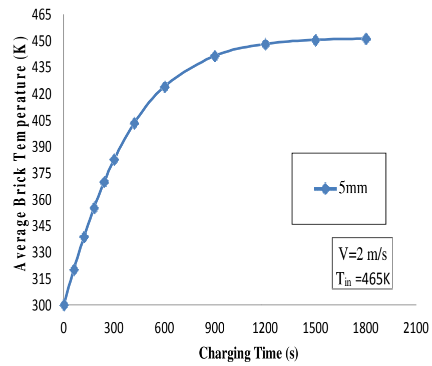
Effect of Velocity

The simulation was carried out on storage system of 5mm hole size for different porosity with initialization of different velocity and constant inlet temperature of 465K. From the comparison of pressure drop variation along the storage system with different porosity for various velocities, increasing the inlet velocities of HTF fluid for storage system during the charging process cause pressure drop also increased along the length of the system and the results are shown



Effect of velocity in pressure drop variation

Figure shows the volume average temperature of storage system for different holesize, the charging time of 5mm hole size storage system- porosity (0.3) was less than that of other system having same storage volume but different size such as 6mm and 7mm. Because the pressure drop across the storage system having 5mm hole size-porosity (0.3) has been higher comparing to other storage system of same porosity with different hole diameters.



Average brick temperature Vs charging time for different hole size

Effect Of HTF Velocity On Charging Time

Increasing the HTF velocity increases the overall heat transfer coefficient enabling faster exchange of heat which reduces the charging time. The simulation results of storage system having different porosity for various velocities are 2m/s, 4m/s and 6m/s as shown in Figure below.

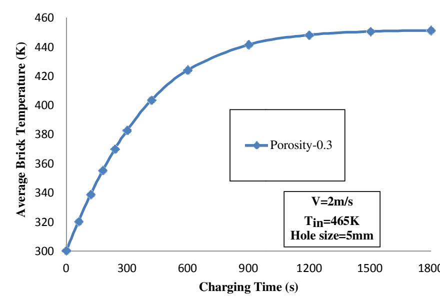


Figure 5.17 Average brick temperature Vs charging time for velocity = 2m/s

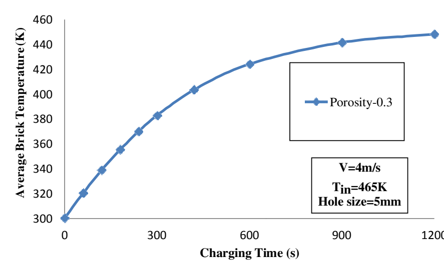


Figure 5.18 Average brick temperature Vs charging time for velocity = 4m/s

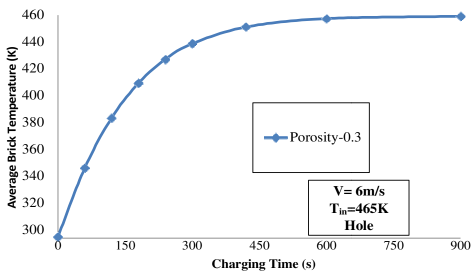


Figure 5.19 Average brick temperature Vs charging time for velocity = 6m/s

Energy Stored

The amount of thermal energy stored in the storage materials at their respective charging times was calculated by using volume integral option in FLUENT 6.3.26 software. The thermal energy storage rate for cored brick storage system having different porosity and hole size

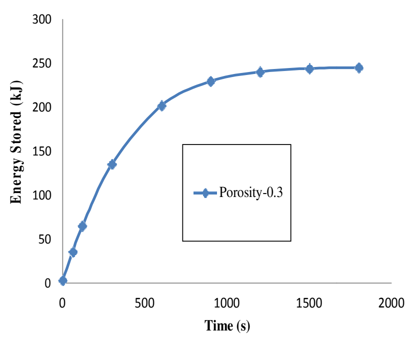
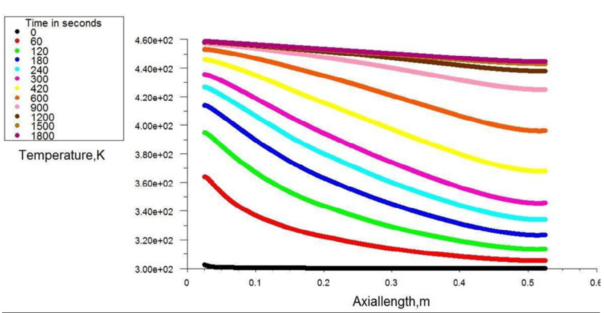


Figure 5.21 Energy storage capacity Vs Time for different porosity

Axial Temperature Distribution

The cored brick storage system was charged by supplying HTF at temperature of 465K through the holes. The temperature distribution across the bed varies with time and space. Initially, the heat transfer rate of cored brick storage system was rapid and then it decreases with time. The simulation was carried out on storage system of 5mm hole size- porosity (0.3) with initialization of velocity 2 m/s and temperature of 465K.



Axial temperature variation of cored brick storage system during charging process

DISCHARGING PROCESS

Effect Of HTF Velocity On Discharging Time

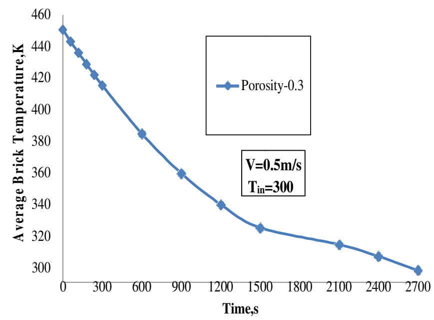
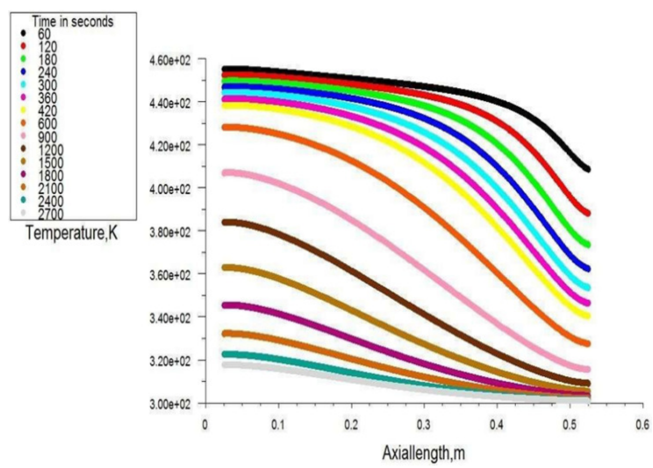


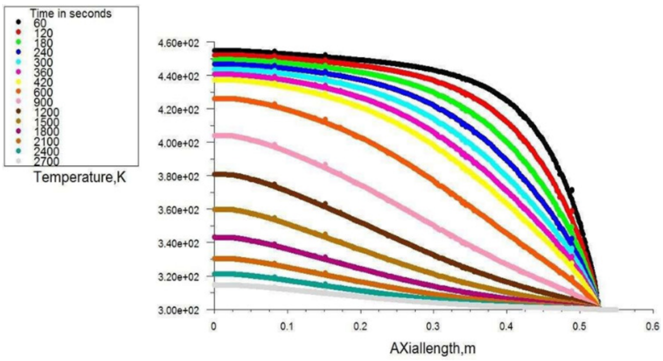
Figure 5.35 Average brick temperature Vs Discharging time for velocity = 0.5m/s

Axial Temperature Distribution

Discharging of charged storage system was initialized by passing HTF in opposite direction at lower temperature (T_{in} =300K); HTF receives the heat from the charged storage system. Therefore, the charged storage system temperature decreases gradually and also the HTF temperature increased along the storage system. The simulation was carried out on storage system of 5mm hole size-porosity (0.3) with initialization of velocity 0.5m/s and temperature of 300K, the discharging process goes on till obtained the volume average brick temperature of 300K.



Axial temperature variation of cored brick storage system during discharging process



Axial temperature variation of HTF along the storage system during discharging process

VI. CONCLUSION AND FUTURE SCOPE

The thermal model of cored brick storage system has been developed to investigate the charging and discharging characteristics of the system. The hydrodynamic and thermal behavior of the storage system have been studied by varying parameter such as hole diameter, porosity and inlet velocity.

During charging process, the following conclusions were made.

- Reducing the hole diameter, increases the pressure drop across the system and also reduced the charging time of the storage system. The energy storage capacity of storage system was also increased.
- Reducing the porosity, the number of holes present in the storage system had reduced but pressure drop was increased. The charging time and energy storage capacity of the storage system was also increased.
- Increasing the HTF inlet velocity, the pressure drop was increased but reduced the charging time required.

During discharging process, the following conclusions were made.

- Reducing the porosity, the discharging time was increased.
- Discharging time decreased by increasing the HTF inlet velocity.

The obtained results from CFD simulation give a good estimation of solid media as sensible thermal energy storage system during charging and discharging processes. It can be concluded that presented work could provide a better guideline to understand the hydrodynamic characteristics and thermal performance, and also design optimization of the solid media as sensible thermal energy storage unit.

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