A Review on Experimental and Numerical Analysis of Thermally Stratified Storage Tank

Sonali Rajendra Pansare[1], Nitin Sali[2]

[1,2] *Department of Mechanical Engg., Government College of Engg., Karad-415124, India.*

Abstract - *Design of solar energy storing tank having obstacles have been considered for minimizing intermixing of cold and hot water such that the water can be supplied at higher temperature. The discharging or charging process of the storage has influence on stratification. Particularly, turbulence which is due to inlet devices can be the important phenomenon which produce intermixing. Thus, optimum design of inlet device for circulating the water in tank may minimize the mixing, which improves the available energy of the water. Vertical mantled hot water tanks are commonly used because they can be easily produce and supply better thermal stratification. Better thermal stratification improves utilization efficiency and performance of system. Stratification can also be affected by design of outlet and inlet ports and the discharge and charge flow rates. Some modifications in the inlet devices and flow rate using CFD tool are done to improve performance of tank. The results which were obtained experimentally were confirmed numerically and was observed that a sintered bronze conical diffuser (SBCD) improves thermal stratification than conventional bronze elbow inlet.*

Key Words: **stratified thermal energy storage (TES), thermal stratification, obstacle, sintered bronze conical diffuser (SBCD), thermocline layer**

1. INTRODUCTION

The economic development resulted in increase in rate of consumption of energy and many environmental problems recently. As solar energy is a major contributor to renewable energy, it has been considered [2]. Energy wastage is a main concern and the solutions provided by stratified thermal energy storage (TES) systems give a boost to cost saving techniques. TES seems to be the only one solution to cope up with the mismatch in between the supply and demand of the energy [8].The principle of stratified TES tank operation is the thermal stratification process. Low temperature heavy water goes down to tank bottom and high temperature water goes up to top of tank due to buoyancy [2], [6].

For vertical mantled tank thermal stratification was studied by fixing 4 different obstacles in the tank at 4 different height from the bottom of tank. Therefore, effect of the obstacle shapes and their position were studied.

For 12 types of obstacles temperature distributions in the tank were obtained using both experimental and numerical results. The type of obstacles which have gap at the center proved to have better thermal stratification as compared to the obstacles which have gap near to the tank wall. The study included to determine the effect of obstacle placing on thermal performance in the horizontal mantled tank. The obstacles were kept normal to flow direction in the tank at various positions. Results of temperature distribution proved that the temperature and volume of stored hot water increases by fixing obstacle in the tank. Lastly, it was found that by obstacle fixing inside the tank the thermal stratification is enhanced.

The study is of comparison between 2 water inlet devices; one is sintered bronze conical diffuser (SBCD) and the other is conventional inlet elbow. The results showed that SBCD helps thermal stratification by both high and low flow.

2. LITERATURE SURVEY

Many researchers contributed for development of technology in the domain under securely.

Dogan Erdemir et al, [1] have done experiment to determine the effect of obstacle fixing on thermal performance of the horizontal mantle water tank. At various positions obstacle were placed normal to the flow within the tank. First, an obstacle was positioned inside the tank at different positions and then 2 obstacles were placed in the tank. The results included the distribution of temperature within the tank, the main output temperature, the mantle output temperature, exergy and energy efficiency. Lastly, it concluded that placing obstacles in the horizontal mantle tank increases thermal performance of the tank and increases the volume and temperature of hot water.

Dogan Erdemir et al. [2] studied thermal stratification of the vertical tank by positioning different obstacles in the tank. At 4 different positions from the bottom of the tank 4 obstacles were placed in the tank. This investigated the effects of the positions and types of obstacles. Lastly, it proved that the obstacle placed in the tank improved thermal stratification. The results included energy storage capacity, temperature distribution, Richardson number, consumption output and mantle output temperature. These all values are enhanced by fixing the obstacle in the tank. The best stratification was obtained between Y = 200 mm and Y = 300 mm and by A type obstacle.

Eugenio García-Marí et al. [3] studied effect of 2 water inlet devices during a thermal loading process: a conventional inlet elbow and SBCD. The temperature, thermocline layer, the number 1-MIX and other parameters (shape, midpoint height and thickness) are recorded for studying stratification. Results showed that SBCD promotes stratification while thermal loading with high and low flow rates. The determination of dimensionless height of midpoint of thermocline layer can be used to determine volume of the water which is affected by mixture created due to turbulence which is generated by flow of water from the inlet device.

Jae Dong Chung et al. [4] have studied the effect of using diffuser on thermal stratification for rectangular water storage tank. In this document, a new diffuser shape is introduced, which exemplifies better performance. 3-D unsteady experiments were conducted for 4 design parameters: 3 design parameters for 3 levels (i.e. Reynolds number 400, 800 and 1200; Froude number 0.5, 1 and 2 ; diffuser to tank c/s area ratio 0.0327, 0.0582 and 0.131) and a two-level design parameter (i.e. diffuser type: radial adjusted plate type and radial plate type).Reynolds number seem to be the dominant parameter in the range of parameters considered. In addition, the shape of the diffuser plays an important role.

Necdet Altuntop et al. [5] have studied the effect of placing various obstacles on thermal stratification in a cylindrical tank numerically. Using numerical and experimental results the numerical method is validated. Temperature distributions are obtained inside the tank for 12 types of obstacle. The observations show that fixing obstacles inside the tank gives improved thermal stratification. The types of obstacles that have a gap at the center seem to have a improved stratification than that which have a gap near to the tank wall. Tanks with obstacles 7 and 11 supply hot water at high temperature. In comparison between obstacle 7 and 11 about hot water temperature indicates that obstacle 11 gives the best thermal stratification.

Ibrahim Dincer [6] this document discusses methods and applications of describing and evaluating thermal energy storage (TES) systems in buildings. Many criteria and aspects for TES systems and applications are discussed, and the environmental impacts and energy-saving techniques of these systems are mainly considered. An exergy and energy analysis of TES systems and their subprocesses is presented for system design and optimization. Especially for solar energy TES can be considered the best way for solving the issue between the supply and demand for thermal energy.
Shu-hong Li et al. [7] have studied that using the solar water heating system reduces a building's conventional energy consumption. A good input to the solar water storage tank can improve stratification and increases thermal storing efficiency as well as discharge efficiency. Experiments were conducted to investigate the unloading behaviour of a rectangular storage tank for different input structures that are direct, slotting and shower inlet. This study provided guidance for optimizing the inlet structure such that the efficiency of the solar water heating system can be further improved. Discharge time and discharge efficiency were considered for evaluating water tank performance. The results proved that the slotting inlet showed the best stratification and enhanced the discharge performance more effectively than the other 2 types of inlets.

A. achar et al. [8] performed numerical analyses to study the temperature and velocity fields within the tank considering different boundary conditions for lower and upper inlet rates. The objective was to determine effect of the different sized plates located opposite to input with a view of increasing thermal stratification. By experimentation the numerical model developed was validated by. 2 initial temperatures were assumed along with 2 layer configuration. The thermocline layer in the middle of tank and in the vicinity of plate were analyzed. In the first case, the diameter of plate showed less impact but when thermocline moved close to plates it showed much effect. It was concluded that larger plates preserved stratification at higher inflow rates also. The effect of diameter of plate for cold inlet was studied with 2 temperature differences between tank and inlet. It showed that distance between plate and top of the tank and diameter of the plate had great impact on thermal stratification of the temperature inside the tank when cold water is allowed to enter at top of the tank.

3. RESEARCH GAP

1. From the above study it is clear that thermal stratification is affected by the number of inlet diffuser and its position, flow rate, type of diffuser used, obstacles fitted in the tank, type of obstacle used, position of the obstacle in the tank.
2. Up till now analysis of thermally stratified storage tank is done on single inlet diffuser and outlet.
3. Also the effect of obstacles of different types and at different positions fitted in the tank is studied.
4. Hence it is required to study the thermally stratified tank with combined effect of various inlet diffuser and outlet configuration with the internal obstacle fitted in the tank.

4. CONCLUSIONS

Above literature survey research papers covers following

1. The inlet structure has significant effect on the thermal stratification.
2. The use of diffuser reduces the velocity of cold inlet water, thus minimizes mixing of hot and cold water layer.
3. The types of obstacle which have gap at center show better stratification than the ones which have gap close to the wall of the tank.
4. For a vertical mantled thermally stratified storage (TES) tank the obstacle placed close to the tank bottom showed best thermal stratification.
5. By using proper obstacles and SBCD efficiency of TES tank can be increased.

REFERENCES

1. Dogan Erdemir, Hakan Atesoglu, Necdet Altuntop, "Experimental investigation on enhancement of thermal performance with obstacle placing in the horizontal hot water tank used in solar domestic hot water system", Renewable Energy 138 (2019) 187-197.
2. Dogan Erdemir, Necdet Altuntop, "Improved thermal stratification with obstacles placed inside the vertical mantled hot water tanks", Applied Thermal Engineering 100 (2016) 20–29.
3. Eugenio García-Marí, María Gasque, Rosa Penélope Gutiérrez-Colomer, Federico Ibáñez, Pablo González-Altozano," A new inlet device that enhances thermal stratification during charging in a hot water storage tank", Applied Thermal Engineering 61 (2013) 663-669.
4. Jae Dong Chung, Sung Hwan Cho, ChoonSeob Tae, Hoseon Yoo, "The effect of diffuser configuration on thermal stratification in a rectangular storage tank", Renewable Energy 33 (2008) 2236–2245.
5. Necdet Altuntop, Mevlut Arslan, Veysel Ozceyhan, Mehmet Kanoglu, "Effect of obstacles on thermal stratification in hot water storage tanks ", Applied Thermal Engineering 25(14)(2005) 2285-2298.
6. Ibrahim Dincer, "On thermal energy storage systems and applications in buildings", Energy and Buildings 34(4) (2002) 377–388.
7. Shu-hongLi , Yong-xin Zhanga, Yang Lib, Xiao-song Zhang, "Experimental Study of Inlet Structure on the Discharging Performance of a Solar Water Storage Tank".
8. A. Zachar, I. Farkas, F. Szlivka, "Numerical analyses of the impact of plates for thermal stratification inside a storage tank with upper and lower inlet flows", Solar Energy 74 (2003) 287–302.