IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 1 Issue 9, November 2014.

www.ijiset.com

ISSN 2348 – 7968

A Review: Heat Transfer Enhancement in Boiler Tube Using Different Geometry

Prateek Negi[1], Dr. Anirudh Gupta[2], Vinod Kumar[3]

[1] PG Scholar, Department of Mechanical Engineering, BTKIT Dwarahat

[2] Associate Professor, Departmental of Mechanical Engineering, BTKIT Dwarahat

[3] Assistant Professor, Departmental of Mechanical Engineering, BTKIT Dwarahat

Abstract

This review summarizes the previous works on corrugated geometry for boiler tubes in a water tube boiler to enhance the heat transfer rate and also to increase the boiler efficiency. This review will help the researchers to find the suitable encapsulation to enhance heat transfer in boiler tubes also to give a good idea about previous and recent designs. The recent researches focused on the geometry of the boiler tube, because the geometry (corrugated) of the boiler tube is more efficient than normal boiler tube. Multi refiled tubes, helical ridging or transverse ribbing are widely used and enhance heat transfer rate, and many ways explained were used to improve the heat transfer coefficient.

Keywords: Boiler tube, Heat transfer, corrugated geometry, Multi-refiled tube, helical tube

1. Introduction

Boiler provides the major source in industries to burn fuel to generate process steam and electric power. It is the main device of power plant to generate steam by efficiently burning available fuels used to generation of power. There are mainly two types of boiler, water tube boiler and fire tube boiler. Water tube boiler are those types in which water flows inside the boiler tube and flue gases flows outside to heat up the water to generate steam. Most industrial purpose uses water tube boiler as it is more efficient than fire tube boiler. Today the main concern is to increase the efficiency of water tube boiler by enhancing the heat transfer rate in the boiler tube. Due to economic and environment demand, engineers must continuously focus on improving the efficiency of the boiler and reducing emission.

In real condition the boiler water tube are plane walled, due to this the flow inside the tube is laminar. The introduction of corrugated geometry obtained with roughened surface like internal helical ridging or transverse ribbing or multi refiled tubes to enhance the heat transfer in tubes. Many studies have focused on turbulent flow, the laminar range is of particular interest in wide variety of engineering situations, including heat exchangers for viscous liquids in chemical process and food industry. The use of smooth surface inside the tubes gives poor performances and new geometries are needed to enhance the rate of heat transfer in tubes.

2. Temperature distribution studies in a water tube boiler

Saripally et al. (2005) conducted a computational fluid dynamics simulation of thermal flow in an industrial boiler. Simulation has been done to understand the thermal flow inside the boiler tube to resolve the operational problem and search for optimal solution. The thermal flow behavior inside the boiler is studied to make the boiler more efficient, less emissive and less prone to tube rupture. The study of simulation provided that due to excessive heating the rupture of super heater tube may lead to boiler shutdown. The CFD analysis provided fluid velocity, pressure, temperature, and species concentration throughout the solution domain. During the analysis, the geometry of the system and boundary conditions such as inlet velocities and flow rate was changed to view their effect on thermal flow patterns or species concentration distribution.

Masoud et al. (2006) reported the reasons for tube damage in super heater platen section of the 320MW Bisotoun power plant. A three dimensional modeling was performed using CFD code in order to explore the reasons for the damage of the superheater tubes that occurred in a series of elbows belonging to long tubes. The main aim of the modeling was to find out the reason for the tube rupture inside the boiler. The study largely focused on heat transfer to the boiler tube and the temperature field inside the boiler by incorporating combustion models.

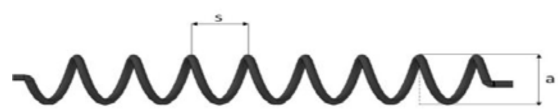
McKenty et al. (1995) successfully simulated various different types of industrial boilers with different types of fuels. They compared with measurements taken at various outlets show good agreement with the predicted values. Wardle (2000) used ultrasonic Nondestructive Oxide Thickness Inspection System (NOTIS) to nondestructively assess a large number of tubes in a relatively short time. Prior to the development of this system, the only method was through the destructive removal of tube samples. Srikanth et al. (2003) analyzed the failures of boiler tube due to fireside corrosion in a waste heat recovery boiler utilizing the exhaust gas of a gas turbine fired with high-speed diesel. It was reported that the high corrosion propensity and consequent failures in the low temperature sections of the boiler were found to be directly related to the formation of hydrated ferric sulfate in these regions. Romeo and Gareta (2006) represented the methodology of neural network design and application for a biomass boiler monitoring stating the advantages of neural network in these situations.

Chaudhuri (2006) showed that the failure takes place due to short-term overheating in the final super-heater tubes. It is also reported that the un-failed reheater tubes exhibit higher tensile properties than that of the platen super-heater tubes. Ranjbar (2007) investigated the analysis on the failure and shut down of boiler cold and hot reheater tubes by chemical analysis of sediments and metallographic examinations. It was concluded that the bad maintenance and feed water chemistry are the main causes of failure, leading to various types of corrosion mechanisms. Rahman and Sukahar (2008) presented the application of finite element method to analyze the tube temperature distribution in a water tube boiler. Two-dimensional finite element models were developed and axi-symmetric triangular elements for the tube cross section area were employed. The results showed that the temperature distribution at the tube wall decreases with increased mass flow rate of steam and increased scale thickness.

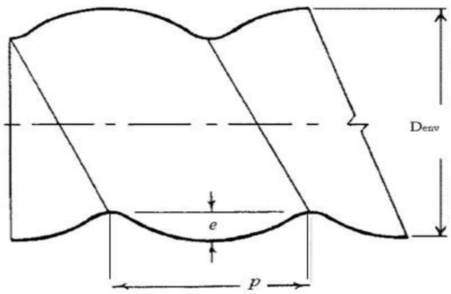
Korytnyi et al. (2008) developed an engineering tool by which the combustion behavior of coals in coal-fired utility boilers can be predicted. It was reported that the computational fluid dynamic codes can successfully predict performance of full-scale pulverized-coal utility boilers of various types, provided that the model parameters required for the simulation are chosen and validated. Purbolaksono et al. (2009) presented investigation study on the failed re-heater tube by finite element modeling.one of the major contributions to the tube failure was the scale formation developed on internal surface of the boiler tubes which reduces the heat transfer rate across the tubes.

3. Heat transfer and pressure drop augmentation studies for laminar flow in a spirally enhanced tubes

Rainieri et al. experimentally investigate the study of the combined effect of the wall curvature and of the wall corrugation as shown in figure 1, in the thermal entrance region for highly viscous fluids by forced convective heat transfer in smooth and corrugated helical coiled tubes in the Reynolds and Dean number ranges from 50-1200 and 12-295 respectively, by adopting Ethylene Glycol as working fluid. The investigation was done under the uniform heat flux boundary condition on two coiled tubes with a curvature ratio of about 0.06, one with smooth wall and the other with spirally corrugated wall. They conclude that, in the Reynolds number range analyzed, both the curvature and corrugation enhance the heat transfer rate. For low Dean number (less than 120), the wall curvature effect prevails and heat transfer enhancement approaches Nusselt number that are approximately 2-3 times higher than the straight smooth section for both corrugated and smooth coiled tubes. For the greater Dean number the wall corrugation instead prevails, the corrugated coiled tubes reaches Nusselt number values which are upto 8 times higher than the ones expected for the smooth straight tubes. The smooth coiled tube shows instead thermal performances at maximum 3.6 times over the straight section.



(a)



(b)

Figure 1. Tube's geometry (a) helical coil parameters (b) wall corrugation profile

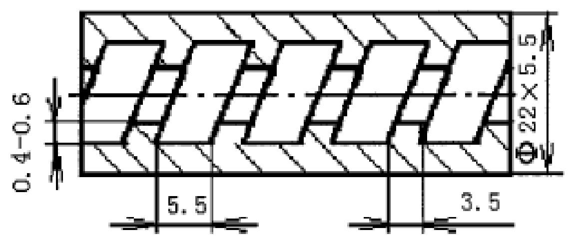


Figure 2. Schematic diagram of spirally internally ribbed tube

4. Flow boiling heat transfer studies in a vertical spirally internally ribbed tube

Lixin (2001) conducted an experiment on flow boiling heat transfer in a vertical spirally internally ribbed tube. Experiment were conducted on flow boiling heat transfer and two-phase flow frictional pressure drop in a spirally internally ribbed tube (ϕ 22 × 5.5 mm) and a smooth tube (ϕ 19 × 2 mm) respectively as shown in figure 2, under the condition of 6 × 105 Pa (absolute atmospheric pressure). The heated length of test section was 2500 mm and the mass flus were selected, respectively, at 410, 610, and 810 kg/m2 s. The maximum heat flus was controlled according to exit quality, which was no more than 0.3 in each test run. The experimental results in the spirally internally ribbed tube were compared with that in the smooth tube. The conclusions were made depends upon the experimental setup that the flow boiling heat transfer coefficient in the spirally internally ribbed tube are improved by a factor of 1.4-2 as compared with that in the smooth tube. It was recorded that the super heat temperature difference in case of spirally internally ribbed tube are also smaller than that in smooth tube. In comparison with the smooth tube, the two-phase frictional pressure drop in the spirally internally ribbed tube also increases as a factor of 1.6-2. They also concluded that the effects of diameters on the flow boiling heat transfer is very little and the increase of mass flux increases the flow boiling heat transfer coefficient.

5. Heat transfer studies in multi lead rifled (MLR) boiler tubes

Thomachan et al. (2013) investigated the heat transfer in a multi lead refiled (MLR) tube in a vertical water tube boiler using computational fluid dynamics (CFD) tool. Simulation was done by varying its influence geometrical parameters like number of refiling, height of refiling, and length of pitch of refiling for a particular length. The influence geometrical parameters depend upon the operating conditions like operating pressure, temperature, mass flow rate, etc. The analysis of a multi refiled tube was done on a real operating conditions of coal fired boiler. In the real condition the boiler water tubes are plane walled. So the performance of optimized refiled geometry was compared with the performance of inner plane walled tube, the result shows the enhancement in heat transfer in a multi refiled tube geometry over normal boiler tube also the enthalpy and the temperature increases with flow as compared to normal boiler tube.

6. Conclusions

A review of corrugated geometry of boiler tubes, heat transfer studies for different geometries and other various designs are carried out. We conclude from this study, the recent researches focused on designs and geometry of the boiler tube that enhance the heat transfer in the tube, reduce emission and also to increase efficiency. The researcher's designs going to the integration between the geometry and flow through the tube to reduce heat loss and system costs.

References

[1] Raja Saripally, Ting Wang and Benjamin Day. (2005) Simulation of combustion and thermal flow in an industrial boiler, proceedings of 27th Industrial Energy Technology Conference, New Orleans, Louisiana.

ISSN 2348 – 7968

[2] Rahimi Masoud, Abbas Khoshhal and Syed Mehdi Shariati, (2006) CFD modeling of boiler tubes rupture. Journal of Applied Thermal Engineering, 26, 2192-2200

[3] Mckenty. F., Gravel L., and Camarero. R. (1999) Numerical simulation of industrial boiler. Korean Journal of Chemical Engineering 16 (4) 482-488.

[4] Srikanth S, ravikumar B, Swapan K. Das, Gopalkrishna K., Nandakumar K., and Vijayan P. (2003) Analysis of failures in boiler tubes due to fireside corrosion in a waste heat recovery boiler -Engineeging Failure Analysis., 10, 56-66

[5] Luis M. Romeoand Raquel Gareta, (2006). Neural network for evaluating boiler behaviour. Journal of Applied Thernal Engineering, 26, 1530-1536

[6] Satyabrata Chaudhuri, (2006). Some aspects of metallurgical assessment of boiler tubes- Basic principles and case studies. Journal of Material science and Engineering, A 432, 90-99

[7] Khalil Ranjbar, (2007). Failure analysis of boiler cold and hot reheater tubes. Journal of Engineering Failure Analysis, 14,620-625

[8] M.M. Rahman and Sukhar, (2008). Tube temperature distribution in water tube boiler - A parametric study by finite element method. International Conference on Construction and Building Technology, ICCBT-2008, 14, 157-170.

[9] Efim Korytnyi, Roman Saveliev, Miron Parelman and Boris Chudnovsky (2008) Computational Flid dynamics simulation of coal fired utility boilers: An emerging tool, Fuel, Elsevier.

[10] Purbolaksono, J., Khinani A, Ali A.A., Rashid A.Z., and Nordin.N.F (2009) Iterative technique and finite element simulation for supplemental condition monitoring of water-tube boiler. Journal of Simulation Modeling Practice and Theory, 17, 897-910.

[11] Sara Rainieri, Angelo Farina e Giorgio Pagliarini, Experimental Investigation of Heat Transfer and Pressure Drop Augmentation for Laminar Flow in Spirally Enhanced Tubes, Department of Industrial Engineering,University of Parma.

[12] Lixin Cheng, Tingkuan Chen, (2001) Flow Boiling Heat Transfer in a Vertical Spirally Internally Ribbed Tube, Heat and Mass Transfer, 37 (2001) 229-236, Springer-Verlag.

[13] Dr T C mohankumar, Nice Thomachan, (2013) CFD Studies on Multi Lead Rifled Boiler Tubes, Int. Journal of Engineering Research and Applications, Vol. 3, Issue 5, pp. 24-26.