ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

CFD Analysis of Shell and Tube Heat Exchanger With and Without Fins for Waste Heat Recovery Applications

D.Panduranga
Student,
Mechanical Engineering,
Mallareddy College of Engineering,
Maisammaguda, Dhulapally, Ranga Reddy Dist,
Telangana State, India.

B.C.Raghu Kumar Reddy
Assistant Professor,
Mechanical Engineering,
Mallareddy College of Engineering,
Maisammaguda, Dhulapally, Ranga Reddy Dist,
Telangana State, India.

Abstract:

The energy available in the exit stream of many energy conversion device such as I.C. Engine gas turbine etc. goes as waste, if not utilize properly. The present work has been carried out with a view to predicting the performance of a shell and finned tube heat exchanger in light of waste heat recovery application. The performance of the heat exchanger have been evaluated by using the CFD package ANSYS 15.0. An attempt has been made to predict the performance in terms of heat flux available with and without fins with different heat transfer fluids and the results so obtained have been compared. The performance parameters pertaining to heat exchanger such as heat flux from Tube internal side fluid and tube external side fluids, heat transfer coefficient from both the fluids.

Keywords: Waste heat recovery, Heat transfer Fluid, finned tube with baffles heat exchanger, Diesel engine exhaust

1. Introduction:

The process of heat exchanger between two fluids that are at different temperatures and separated by a solid wall occurs in may engineering applications the device used to implement this exchange is termed a heat exchanger, and specific applications may be found in space heating and air conditioning, power production, waste heat recovery, chemical processing. Waste heat is by necessity produced both by machines that do work and in other processes that use energy. The need for many systems to reject heat as a by-product of their operation is fundamental to the law of thermodynamics. Sources of waste heat include all manner of human activities, natural systems, and all organisms. Rejection of unneeded cold (as from a heat pump) is also a form of waste heat (i.e. the medium has heat, but at a lower temperature than is considered warm). Waste heat is heat, which is generated in a process by way of fuel combustion or chemical reaction, and then “dumped” into the environment even though it could still be reused for some useful and economic purpose. The essential quality of heat is not the amount but rather its “value”. The strategy of how to recover this heat depends in part on the temperature of the waste heat gases and the economics involved. Large quantity of hot flue gases is generated from boilers, kilns, ovens and furnaces. If some of this waste heat could be recovered, a considerable amount of primary fuel could be saved. The energy lost in waste gases cannot be fully recovered.

At present scenario the rapid industrial growth is the main reason for the crisis of energy and also for pollution. Diesel engine are now widely used device in all industrial application starting from gas turbine power plant .Nearly about 2/3 rd. of energy are now wasted through the exhaust gas which is indirectly cause of global warming and overall energy requirement. Depending on the temperature level of exhaust stream and proposed application, different heat exchanger devices, heat pipes combustion equipment’s has been employed to facilitate the use of recovered heat. Previously Shell and tube heat exchanger was widely used as industrial heat transfer equipment’s. Here both plain tube and with fins are been analyzed. But now a day’s modified tube are using for proper

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

exchanging of heat just like finned tube. Transformer oil is a one type of Polychlorinated biphenyls (PCBS) which formed from "Askarel", "Inerteen", "Aroclor" and many others. Finned tube heat exchanger has selected as it has high compactness. Extended surfaces has provide for better heat transfer rate in the exchanger. The present work is been done with view to predicting the performance of a shell and tube heat exchanges with and without fins by using waste heat.

2. Literature Survey

Technologies and resources

Sparrow and Reifschneider (1986) conducted experiments on the effect of inter baffle spacing on heat transfer. Huadong Li and Volker Kott Ke (1998) conducted experiments on the Effect of leakage on pressure drop and local heat transfer in shell and tube heat exchangers for staggered has slight contribution to the local heat transfer at the surfaces of the external tubes of the tube bundle, but reduces greatly the per-compartment average heat transfer. Qiao He and Wennan Zhang (2001) presented a theoretical analysis and an experimental test on a shell and tube latent heat storage exchanger. The prediction by the mathematical model on the performance of the heat storage exchanger is reasonable and in agreement with experimental measurements. The experimental outcome confirms that helically corrugated tubes are particularly effective in enhancing convective heat transfer for generalized Reynolds number ranging from about 800 to the limit of the transitional flow regime. Hosseini et al (2007), they experimentally obtained the heat transfer coefficient and pressure drop on the shell side of a shell and tube heat exchanger for three different types of copper tubes (smooth, corrugated and with micro-fins). Corrugated and micro fin tubes have shown degradation of performance at a Reynolds number below a certain value (NRe < 400). At a higher Reynolds number the performance of the heat exchanger greatly improved for micro finned tubes.Tan and Fok (2006) developed an educational computer aided design tool for shell and tube heat exchanger that integrates thermo hydraulics analysis with mechanical design.

Dirkse et al (2006) has modeled a shell and tube heat exchanger based on natural convection using computational fluid dynamics. The CFD models have made it possible to analyze the impact of many different changes of the geometry.

3 Geometric Modeling and Data Input

The geometry of shell and tube heat exchanger and fins &baffles have been modeled on CATIA V5R20 software and ANSYS design modeler.

3.1 Geometric modeling

Table 3.1 Geometric modeling details

Shell outer diameter (D_o)	168.30 mm
Shell thickness (t_s)	18.30mm
Fin thickness (t_f)	1mm
Fin height (h_f)	8mm
Tube outer diameter (d_o)	19.1 mm
Tube thickness (t_T)	3.302mm
Length of the shell (L_s)	600 mm
No. of tubes inside the shell (n)	7
Transverse pitch(S_T)	38.971 mm
Longitudinal pitch(S_L)	22.5 mm
Total no .of baffles inside the shell (N_b)	6
No. of C type baffles inside the shell(N_{cb})	3
No. of D type baffles inside the shell(N_{db})	3
Baffles thickness(**Cut Segmental**) (t_b)	4 mm
Baffles arc(**Cut**	75 mm

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Segmental) (b_a)	
Baffles horizontal length (B_{hl})	145.616 mm
Distance between baffles D to C (B_{dc})	81.5 mm
Distance between baffles D to D (B_{dd})	167.5mm
Distance between 1 finned tube to another finned tube (S_D)	45 mm

The shell and baffles material, fin and tube material is insulated, and copper respectively. In this analysis tetrahedral mesh is used.

3.2 IMPLEMENTATION:

Figure 3.2 Heat exchanger in D.M AND ANSYS MESH WITH AND WITHOUT FIN

After the fluid body has been created we will import the fluid body into the meshing area and do meshing for the Heat exchanger by doing some of the typical meshing operations, and same as with fin heat exchanger and the final view of the meshing is as shown in the figure 3.2. After the meshing has been created we have to check the quality of the meshing and give the naming for the inlet, outlet, tubes, baffles ,transformer oil, exhaust gas, after all these operations has done the quality of the meshing is 0.82(without fin) and 0.84(with fin). The total no of elements used is 3.9 lacks without fins and 7.93 lacks with fins. As per the meshing rules the quality of the meshing must be below 0.9 which is acceptable. the shell side exhaust is exhaust gas which is coming from 15HP exhaust having temperature 400k the tube side fluid is taken 308K for both fluids keeping shell side fluid velocity constant (2m/s) those are turbulent flow and only varying the tube side velocity at varies condition like a (0.04,0.06,0.09) those are laminar flow analysis has been done

3.3 Properties of Working Fluid

Table 3.3 Properties of Working Fluid

Fluid	Properties	Values
Shell side (Exhaust Gas) at inlet temperature 400 k	Density	0.871 Kg/m^3
	Specific Heat	1014 j/kg-k
	Thermal conductivity	0.0336 w/m-k
	Viscosity	0.000023 kg/m-s
Tube side(transformer oil) at inlet temperature 308 k	Density	890 Kg/m^3
	Specific Heat	2060 j/kg-k
	Thermal conductivity	0.12 w/m-k
	Viscosity	0.01664 kg/m-s

4. Result and discussion and Tables and graphs

After the exporting the model into analysis has done in two steps. In first step fluent analysis of without fin for the Shell and tube heat exchanger at three different fluid velocities is taken into consideration. All the analysis has been done. In same as with fin for the Shell and tube heat exchanger.

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

4.1.Fluent analysis of without fin for the heat exchanger

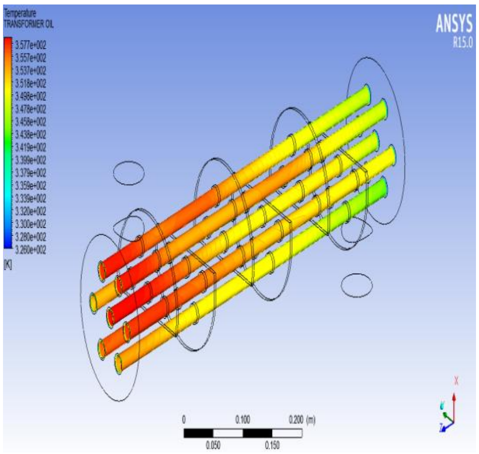

Figure.4.1a: Temperature distribution for the Transformer oil without fin at tube inlet velocity is 0.04m/s

Temperature at the inlet is suddenly increasing after passing through some distance temperature is got constant almost so we will get jump in respective graph. show in the figure 4.1a

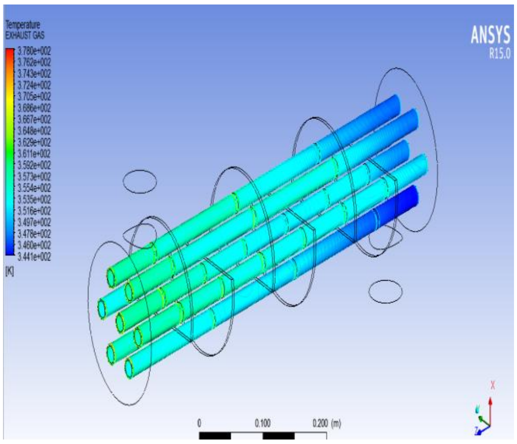

Figure 4.1 b: Temperature distribution for the Exhaust gas without fin at tube inlet velocity is 0.04m/s

On the other hand, temperature of exhaust gas is decreasing rapidly there are two reasons for this first is exhaust is continuously expanding and other is because tubes are absorbing heat from gas. show in the figure 4.1 b

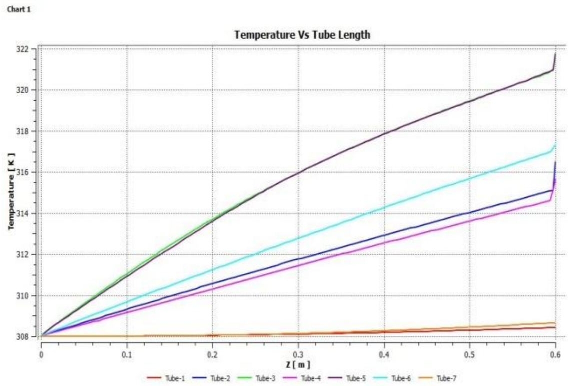

Figure 4.1c :Temperature Vs tube length without fin at tube inlet velocity 0.04 m/s

As transformer oil is flowing from inlet to outlet temperature is increased by 14 K, sudden rise is not observe because turbulence is less in this design. show the figure 4.1 c

4.2.Fluent analysis of with fin for the heat exchanger

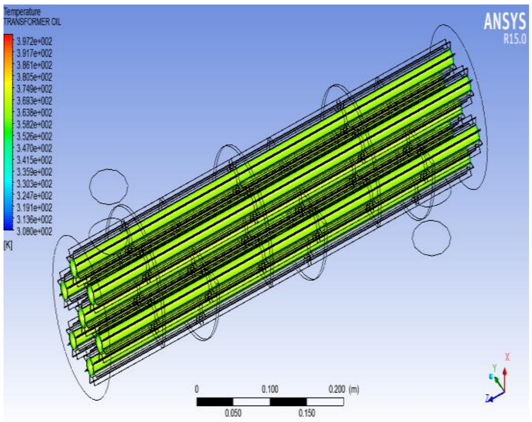

Figure 4.2a:Temperature distribution for the Transformer oil with fin at tube inlet velocity is 0.04m/s

Initially surface temperature of tubes will be high but inside tube there is little change is happening, as flow goes on developing temperature is increasing as per the intension behind addition of extended surfaces. show the figure 4.2 a

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

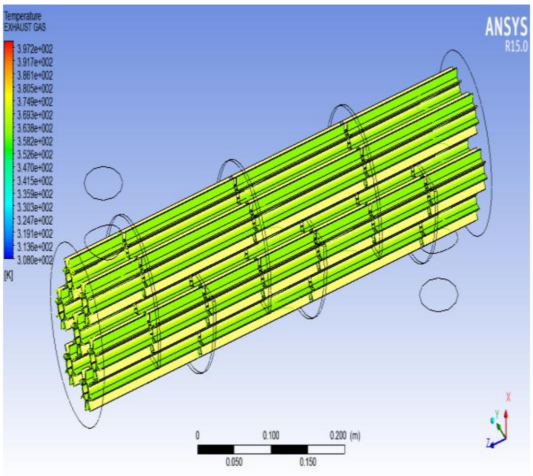

Figure4.2b: Temperature distribution for the Exhaust gas with fin at tube inlet velocity is 0.04m/s

Temperature is affected by addition of the fins at tips of the fins temperature observed is higher as compare to model without fins. Concentrated on tips then drawn inside the tube. show the figure 4.2b

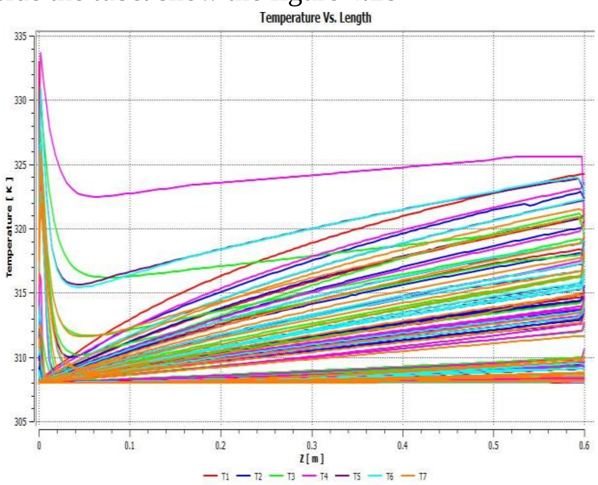

Figure 4.2c :Temperature Vs tube length with fin at tube inlet velocity 0.04m/s

As transformer oil is flowing from inlet to outlet temperature is increased by 17 K, sudden rise is observe because turbulence is more in this design. show the figure 4.2 c

4.3 Final Annulment:

4.3.1 Without Fin

As tube side inlet velocity increases from 0.04m/s by keeping shell side velocity constant the temperature at the outlet of tubes is decreasing and pressure is almost same. As velocity is increased total time for contacting surface to tubes will be decreasing and gas will goes on simply expanding. Similarly velocity 0.06, 0.09 is simulated and desired results are found and then statements are concluded.

4.3.2 With fin

As tube side inlet velocity increases from 0.04m/s by keeping shell side velocity constant the temperature at the outlet of tubes is decreasing because of additional surfaces of fins there is more turbulence this is because less decrement in temperature and pressure is varying for each simulation (0.04, 0.06, 0.09). As velocity is increased total time for contacting surface to tubes will be decreasing in this case fins are impeding gas flow so less heat is wasted compare to without fin design. Similarly velocity 0.06, 0.09 is simulated and desired results are found and then statements are concluded.

Note: In tables values are mass averaged at particular mentioned surfaces, and on graphs stream line vertex maximum values are mentioned

4.4.CFD analysis of shell and tube heat exchanger output without fins

Table 4.4a Heat exchanger without fin at tube inlet velocity 0.04m/s, 0.06m/s, 0.09 m/s comparison of Average temperature (K), pressure (pa), velocity (m/sec)

Velocity m/s	0.04	0.06	0.09
	Oil	Oil	Oil
Shell inlet K	400	400	400
Shell outlet K	362.226	361.698	361.707
Tube inlet K	308	308	308

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

Tube outlet k	315.5917	313.475	311.871
Shell inlet (pa)	8.27938	8.27938	8.27938
Shell outlet (pa)	0	0	0
Tube inlet (pa)	50.798	70.7029	116.2084
Tube outlet (pa)	0	0	0
Shell inlet (m/sec)	2	2	2
Shell outlet (m/sec)	2.10456	2.10652	2.13378
Tube inlet (m/sec)	0.04	0.06	0.09
Tube outlet (m/sec)	0.04969	0.07454	0.111813

Table 4.4b Heat exchanger Without fin at tube inlet velocity 0.04m/s, 0.06m/sec, 0.09m/sec comparison of Average of heat flux and Average of heat transfer coefficient

Velocity m/sec	0.04	0.06	0.09
	Oil	Oil	Oil
Average of Internal side heat transfer coefficient (hi) [W m^-2 K^-1]	118.84	118.84	118.84
Average of External side heat transfer coefficient(he)[W m^-2 K^1]	91.27	91.2792	91.209
Average of Internal side heat flux (qi) [W m^-2]	3584.98	3874.64	4105.56
Average of External side heat flux(qe) [W m^-2]	-651.170	-651.170	-678.717

Shell side temperature at outlet is almost same in all three case of velocity but at the outlet of tubes the temperature is decreasing, mass average pressure increasing from inlet to outlet. Mass flow averaged velocity is increasing with same rate in all three cases by 24.255% for 0.04 m/s, 24.23% for 0.06 m/s, 24.236% for 0.09 m/s. Internal and external heat transfer coefficient is almost constant irrespective velocities at inlet of the tubes. Increasing velocity causing increase in internal heat flux. Conversely, External heat flux is decreasing as inlet velocity increasing CFD analysis of shell and tube heat exchanger output with fins.

4.5 CFD analysis of shell and tube heat exchanger output with fins

Table 4.5 a Heat exchanger With fin at tube inlet velocity 0.04m/s ,0.06m/s ,0.09m/s comparison of average temperature, pressure, velocity

Velocity m/s	0.04	0.06	0.09
	Oil	Oil	Oil
Shell inlet K	400	400	400
Shell outlet K	360.2 25	360.8 34	361.7 79
Tube inlet K	308	308	308
Tube outlet k	316.7 45	314.3 19	312.7 20
Shell inlet (pa)	12.0 301	15.4 93	8.06 938
Shell outlet	0	0	0

ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

(pa)			
Tube inlet (pa)	50.7 039	76.7 214	116. 2084
Tube outlet (pa)	0	0	0
Shell inlet (m/sec)	2	2	2
Shell outlet (m/sec)	2.070 55	2.046 75	2.054 66
Tube inlet (m/sec)	0.04	0.06	0.09
Tube outlet (m/sec)	0.050 55	0.075 827	0.113 7358

Table 4.5 b Heat exchanger With fin at tube inlet velocity 0.04m/s,0.06m/sec, 0.09m/sec comparison of average heat flux and average heat transfer coefficient

Velocity m/sec	0.04	0.06	0.09
	Oil	Oil	Oil
Average of Internal side heat transfer coefficient (hi) [W m^-2 K^-1]	128.104	128.104	128.104
Average of External side heat transfer coefficient(he)[W m^-2 K^1]	127.6022	127.683 7	127.683142 9
Average of Internal side heat flux (qi) [W m^-2]	4151.147 1	4500.49	5038.81
Average of External side heat flux(qe) [W m^-2]	-99.9305	- 207.195	-186.98

Shell side temperature at outlet is almost same in all three case of velocity but at the outlet of tubes the temperature is decreasing but comparing without fins design temperature at outlet is always higher, mass average pressure increasing from inlet to outlet with same rate with and without fins. Mass flow averaged velocity is increasing with same rate in all three cases by 26.375% for 0.04 m/s, 26.3783% for 0.06 m/s, 26.3731% for 0.09 m/s. Internal and external heat transfer coefficient is almost constant irrespective velocities at inlet of the tubes. Increasing velocity causing increase in internal heat flux comparing this with design of heat exchanger without fins it has increased by 15.79% at 0.04 m/s, 16.15 % at 0.06 m/s, 22.7% at 0.09 m/s. Conversely, External heat flux is decreasing as inlet velocity increasing and comparing this values with design of heat exchanger without fins, the value is 6.5162 times more than value of same for design heat exchanger without fins at velocity 0.04 m/s, for 0.06 m/s it is 3.22 times more, for 0.09 m/s it is 3.6298 times more

5. Conclusion and Future Scope:

From CFD Simulation we can observe that the temperature of transformer oil is height for tube inlet velocity 0.04m/s for with fin design. Transformer oil, as the velocity inlet of tube side fluid increases the heat flux is increasing consequences of that is temperature at outlet for tubes is less (refer table 4.4 a , 4.4 b and 4.5 a ,4.5 b to see reduction in temperature as tube side fluid velocity increases) we found that the highest temperature is getting for velocity 0.04 m/s with fin model of heat exchanger and that is because we are increasing surface area to increase the heat transfer rate. Values from graph and tables are mean to the results, graph values are taken as vertex strength stream lines and table values are mass averaged temperature at outlet or any surface where we want to calculate the temperature. Maximum deference in temperature we are getting is 3 Kelvin or 3 C (compare both the graph Temperature vs. Tube length for velocity 0.04m/s). In contrast we saw as velocity increases temperature at outlet is decreases because of the time for which fluid is contacting to tubes is less i.e. nothing but convection rate is decreasing because of inertia of flow.

Future Scope:

1)We can check the different types of fins to increase more efficiency of heat exchanger by adding some perforation on fins that will increase in computational efforts but it will increase the effectiveness of heat exchanger further.
2)CFD provide alternative to cost effectiveness speedy solution to heat exchanger optimization. Conventional methods used for the design and development of heat exchanger are expensive. CFD results are the integral part of the design process and has eliminated the CFD is still a developing art in prediction of erosion/ corrosion due to lack of suitable mathematical models to represent physical process. New flow modeling strategies can be developed for flow simulation in shell and tube heat exchanger

6. ACKNOWLEDGEMENT

We would like to thank all the authors of different research papers referred during writing this paper. It was very knowledge gaining and helpful for the further research to be done in future.

REFERENCES

[1]Kreith, F.; Boehm, R.F.; et. al. "Heat and Mass Transfer" Mechanical Engineering Handbook Ed. Frank Kreith Boca Raton: CRC Press LLC, 1999

[2]Transformer oils by sah petroleum's limited and www.dieselnet.com tech diesel exhaust

[3] Standards of the Tubular Exchanger Manufacturers Association. 9th ed. Gaddis D, Ed. Tarrytown, N.Y.: TEMA Inc.; 2007

[4]Gay B, Mackley NV, Jenkins JD. Shell-side heat transfer in baffled cylindrical shell- and-tube exchangers - an electrochemical mass transfer modelling technique. Int J Heat Mass Tran 1976;19:995-1002.

[5]V.H.M Orcos," performance of shell and dimpled tube heat exchanger for waste heat recovery ", Heat recovery systems and CHP volume 8, issue 4, 1988, page 299308

[6]A Text book of Fundamentals of Engineering Heat and mass transfer by R.C Sachdeva ,Fourth edition and new age international publishers

[7]ANSYS Fluent version 15.0 Fluent 15.0 User's Guide. ANSYS Inc

[8]Taborek J. Thermal and hydraulic design of heat exchangers. In: Heat Exchangers Design Handbook. Vol 3. (eds) Hewitt GF. New York: Begell House Inc; 2002.