ON BOARD EXPERIENCE: PRESSURE DROP AFFECTS THE HEAT TRANSFER RATE IN THE HEAT EXCHANGERS

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Abstract: Heat exchangers are indispensible elements of any engine that reduces the temperature of a medium by transferring temperature of that medium to another, when both the mediums are separated by a solid membrane or wall like structure. Exchanging of heat in a heat exchanger can be in between- liquid and liquid, gas and liquid, liquid and gas etc. For heat transfer basically three patterns of flow are used for construction of a heat exchanger. Onboard ships heat exchanges are used in various segments such as propulsion plant, auxiliary power Generation System, Starting Air System, Fuel injection system, Refrigeration System, air conditioning system, Fresh Water System, Steam Turbine Unit etc. The choice and performance of heat exchangers in the engines of ships on board and engines that run stationary are quite different. This paper provides an insight in to the performance of heat exchangers in onboard ships with special reference to pressure drop that affects the heat transfer rate in the heat exchangers.

***Index Terms* –** Heat exchanger, Marine engineers, Thermodynamic

I. INTRODUCTION

It was observed in my sea career of more than 30 years mainly two types heat exchangers are in use.

1. Shell And Tube type
2. Plate type exchangers were in use.

Actually the plate type has been in use and preferred since more than a decade which was found to be more efficient and economical at low pressure operating conditions. Apart from this the maintenance also is quite simple and easier compared to the shell and tube type. Whenever the seawater temperature dropped to the value less than 20 deg centigrade the temperatures were controlled and maintained reducing the mass flow rate. Another method of maintaining is by using multiple heat exchangers either of same or different capacities.

II. Principles of heat exchangers-Importance of pressure

As a fluid flows through a heat exchanger there will normally be a pressure drop in the direction of the flow (in some special situations where the fluid velocity decreases there may be an increase in pressure). Pressure drops occur in the flow channels, nozzles, manifolds and turning regions in the headers of heat exchangers and each of these pressure drops must be evaluated, unless experience suggests that one or more may be neglected. Having a lower than permissible pressure drop across the heat exchanger implies that improvements could be made:, depending upon the application e.g. a longer heat exchanger would have a higher effectiveness allowing greater heat recovery; changes in the heat exchanger geometry (for example, use of smaller tubes) would result in a more compact design for a particular heat load. Determination of the maximum allowable pressure drop involves practical and thermodynamic considerations. If starting from first principles, it is possible to pursue various strategies to minimize entropy generation within a heat exchanger, remembering that entropy is generated by irreversible pressure drops in the heat exchanger and by heat transfer through a finite temperature difference. From purely thermodynamic considerations, frictional pressure drops should be minimized since they are irreversible, while in principle the work done in accelerating and raising the fluid may be recovered. An entropy analysis is particularly relevant if considering heat exchangers in power or refrigeration plant. For many heat exchangers the inlet and outlet temperatures and flow rate are fixed (e.g. an oil cooler) and the allowable pressure drop is a function of the pumps and fans used. There may, of course, be a trade off in this situation; for example, it may be decided to up rate a fan to permit the use of a more compact or cheaper heat exchanger. In applications involving natural convective circulation the pressure drop and flow rate are determined by the geometry of the convection loop (including the heat exchanger) the properties of the fluids involved and the rate of heat transfer.

Therefore, it is significant to manage the pressure drop during thermal design of the exchanger. If during the course of thermal design, calculated pressure drop is far more than the allowable pressure drop, the pressure drop becomes a limiting factor.

However, there may be situations when the calculated pressure drop is far less than allowable pressure drop, i.e., the pressure drop becomes surplus. The pressure drop should be managed in such a way that the calculated pressure drop is within and as close as possible to the allowable pressure drop. In other words, if the pressure drop is a limiting factor during thermal design, the calculated pressure drop should be reduced such that it is closest possible to the allowable pressure drop without exceeding the same. On the other hand, if pressure drop is surplus during thermal design, the calculated pressure drop should be increased as close as possible to the allowable pressure drop.

III. Factors governing performance of Heat Exchangers on board ships-real time solutions

On board the merchant navy ships normally high powered diesel engines of 5000 B.H.P to 21,000 B.H.P for main propulsion along with 3-4 diesel engines of 750 KW to 1500 KW for electrical power generation are used .The jacket cooling water ,lubricating oil and scavenge air temperatures have to be maintained with in a particular range as per the recommendations by respective makers of the engines. At sea the only cooling media available in abundant and free of cost is Sea water, of course of different temperatures as per the zone and climatic conditions. For example if the vessel sails from Chennai to New York it takes the route of Bay Of Bengal, Indian Ocean, Arabian Sea, Mediterian Sea and Atlantic Ocean and the sailing period is about 20 – 23 days. During this period the sea water temperatures varies from 31 – 3 deg centigrade. Irrespective of these temperatures the engines temperatures have to be maintained within limits as recommended .. This is normally achieved by regulating the flow of either the hot fluid or the cold fluid. In other words the mass flow rate could be adjusted by diverting or by-passing the fluids through 3 way valves or changing over to pumps which circulates and supplies the fluid to different capacity. On certain occasions a thermocouple or a pneumatically operated regulating valves controls and regulates the flow.

Maintaining of the aforesaid temperatures are very imperative for efficient performance of the engines as otherwise there will be an abnormal amount of heat losses which in turn leads reduction in brake horse power for propulsion. Even the thermal efficiency also gets affected due to improper cooling. The cooling system on board the ships as mentioned earlier mainly is of jacket water cooling , lubricating oil cooling and the scavenge air cooling. Improper cooling of the first two would affect the heat balance where as the third one , the scavenge air temperature would affect the combustion itself. The other parameter pressure also influences the heat transfer rate coefficient. Any amount of reduction in working pressure of the above mentioned water, oil and air would make a considerable change in the mass flow rate which affects the heat transfer coefficient .So the pressure has to be maintained strictly as per the manual instructions of the respective machineries.

IV. Conclusions

The heat exchangers of static engines and engines in ships are of extremely different. Hence, a great body of new knowledge and understanding is to be developed by experienced marine engineers. It is also concluded that pressure drop affects the heat transfer rate in the heat exchangers of on board ships.

V. References

1. Yimin Xuan and Qiang Li. 2003. Investigation on Convective Heat Transfer and Flow Features of Nanofluids. J. Heat Transfer 125(1), 151-155
2. Yan, WM et al. 2003. Performance of finned tube heat exchangers operating under frosting conditions. International Journal of Heat and Mass Transfer. Volume 46, Issue 5, February 2003, Pages 871-877
3. Jeom-Yul Yuna and Kwan-SooLeeb. 2000. Influence of design parameters on the heat transfer and flow friction characteristics of the heat exchanger with slit fins. International Journal of Heat and Mass Transfer. Volume 43, Issue 14, July 2000, Pages 2529-2539
4. Ala Hasan and Kai Sirén. 2004. Performance investigation of plain circular and oval tube evaporatively cooled heat exchangers. Applied Thermal Engineering. Volume 24, Issues 5–6, April 2004, Pages 777-790
5. Ramesh K. Shah, Alfred C. Mueller, Dusan P. Sekulic. 2015. Heat Exchangers, 4. Auxiliary Issues in Heat Exchanger Design. Ullmann's Encyclopedia of Industrial Chemistry, pages 1-21.