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Effective Utilization of Different Types of Heat Exchangers for Onboard Ships

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Abstract: A heat exchanger is an equipment which transfers energy from a hot medium to cold medium when both the mediums are separated by a wall like structure. It is critical for heating and cooling a variety of media during the operation of many onboard services and systems. This study represents different types of heat exchangers used in ships. Here, it has been given emphasis on the shell, tube and plate type of exchangers along with literary reviews and onboard ship. The applicability of various types of heat exchangers at different situations and environmental conditions has been explained. This study, thus, provides an overview of different types of heat exchangers with special reference to onboard ships.

Key words: Ships, heat exchangers, types, energy, environmental conditions, equipment

INTRODUCTION

Technically, heat exchangers are instruments used to reduce 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 (Florides and Kalogirou, 2007; Stehlik, 2011). The medium to be regulated for temperature may be between liquid and liquid, gas and liquid, liquid and gas etc. To make the heat exchanging process more efficient, there are several factors being considered. Of which the chief most is surface area. It can be maximized, so, as to reduce the flow resistance of the fluid there by enhances the efficiency of the process (Vohra *et al*., 2013; Florides and Kalogirou, 2007).

Though marine heat exchangers are technically similar to that of non-marine heat exchanger, the major factor which distinguishes them is the former is being operated in a highly changing marine environment where one can experience highest fluctuations in temperature, salinity, etc. These marine heat exchangers are operated in ships where the prevailing situation warrants the effective use of different types of heat exchanges (Li *et al*., 2011). There are many types of heat exchangers used on board ships.

Major types:

- Shell and tube type exchangers
- Plate type exchnagers

MATERIALS AND METHODS

Types of exchangers used onboard: Different types of heat exchangers are used on board ship depending on the application and requirement as shown in Fig. 1. They are used throughout many system including lube oil, jacket water, steam systems and main sea water. These systems are often interconnected by heat exchangers to remove heat generated from running equipment from the engine room (Venkateshan and Eswaramoorthi, 2015). They are used in propulsion plant, fuel injection system, refrigeration system, fresh water system and steam turbine unit. They are mainly defined by the construction and are as follows:

Shell and tube type exchanger: This is the most popular type design with a shell accompanying several tubes and the flow of liquid to be cooled is mainly through tubes as shown in Fig. 2 whereas the secondary liquid flows over the tube inside shell (Vohra *et al*., 2013). Shell and tube type heat exchanger is extremely economical to install and easy to clean: however, the maintenance costs is very high.

Plate type heat exchanger: Plate type exchanger consists of thin corrugated plates joined parallel together as shown in Fig. 3, creating cavity for fluid flow inside it. Alternate sides of the plate carries two different liquids between which heat transfer is carried out. The installation of this type of heat exchanger is expensive than other types but the maintenance cost is much lower. Efficiency of plate type is higher than shell and tube type for same size of unit and withstand high pressure.

Concepts of heat exchangers

Parallel flow: Parallel flow exists when both the tube side fluid and the shell side fluid flow in the same direction. The two fluids enter the heat exchanger from the same end

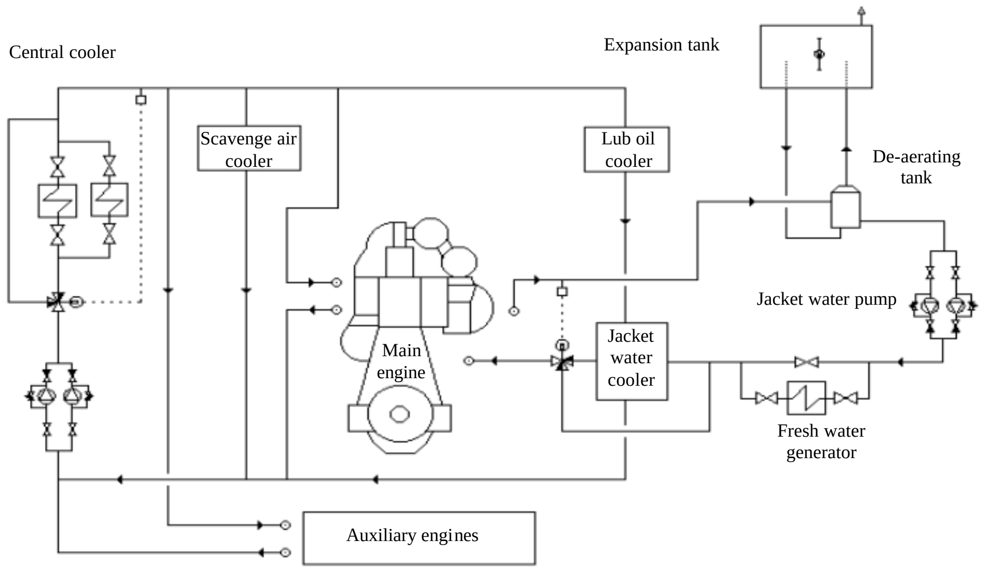

Fig. 1: Central cooling system onboard ships

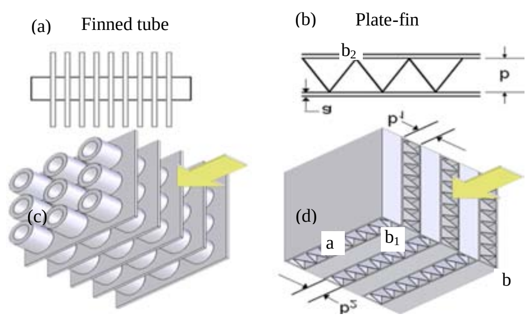

Fig. 2: a, b) Plate and tube exchangers

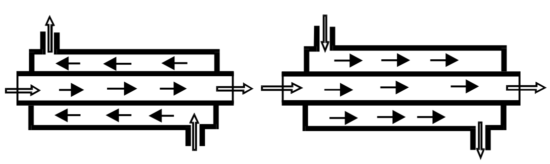

Fig 3: Parallel flow

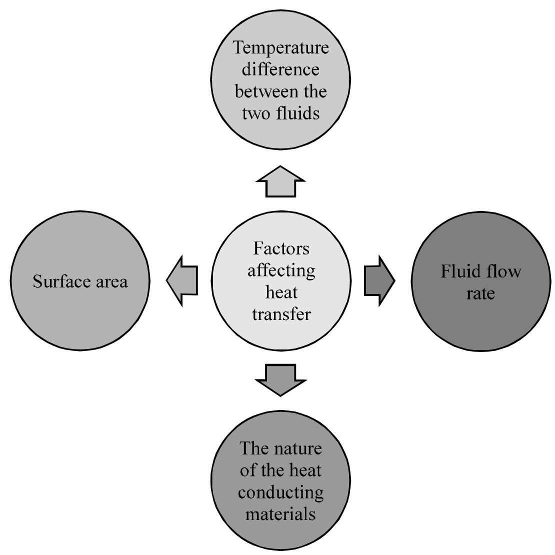

Fig. 4: Factors affecting the performance of heat exchangers

with a large temperature difference. As the fluids transfer heat, hotter to cooler the temperatures of the two fluids approach each other. It is to be noted that the hottest cold fluid temperature is always less than the coldest hot fluid temperature.

Counter flow: Counter flow exists when both the tube side fluid and the shell side fluid flow in the opposite direction. The two fluids enter the heat exchanger from the opposite end with a large temperature difference. As the fluids transfer heat, hotter to cooler the temperatures of the two fluids approach each other. It is to be noted that the hottest cold fluid temperature is always greater than the coldest hot fluid temperature. It is the most efficient type exchanger.

Factors affecting the performance of heat transfer: There have been several factors which could affect the heat transfer in a heat exchanger (Venkateshan and Eswaramoorthi, 2015; Stehlika, 2011). It has been summarized in the Fig. 4.

Temperature difference (T) between the two fluids: This is the driving force in heat exchange principles. The greater the T, the greater the heat transfer rate.

Fluid flow rate: Increasing flow rate will increase heat transfer rate. High speeds increase the thermal transfer coefficient but they are associated with pressure drop instead. Speed should be so high that could prevent from particles deposition on the one hand and on the other hand; it should not be so high that it would cause tube corrosion itself. Because high speeds reduce tube fouling. A plastic cover is often applied to the tube input to reduce corrosion rate in this place. However, high speed prevents from particles deposition or tube fouling and increases thermal transfer coefficient as well. On the other hand, it also increases pumping costs. Thus, speed would be determined considering pumping cost, tube longevity and cleaning cost against thermal load score.

The nature of the heat conducting materials: Some materials have a high conductivity while others don't. This factor is 'built-in' in the design of the exchanger and choice of materials. It is governed by the design engineers before manufacture.

Surface area: The larger the surface area of the conducting interfaces, the greater the heat transfer rate. The surface area, again, is controlled by the design and manufacture of the exchanger. The more tubes contained in the bundle, the greater the surface area. The tube length will also affect heat transfer as will the outside diameter and metal thickness of the tubes.

RESULTS AND DISCUSSION

The main problems encountered with heat exchangers (Fig. 5).

Fouling: This is caused by deposits of scale, dirt, sand and/or other solid deposits on the conducting surfaces. Coke formation in furnace tubes and other causes of semi-blockage of tubes will drastically decrease efficiency in an exchanger. Such problems will result in shutdown for cleaning and possible tube replacements. Many of these problems can be avoided by proper operation and fluid treatment filtration, corrosion inhibition, furnace firing control etc.

Air pockets: The formation of air pockets in exchanges due to improper venting at start up or build of gas from light materials will affect the heat transfer rate. This can be avoided by venting all air or gas out at start up and periodically venting gases as required.

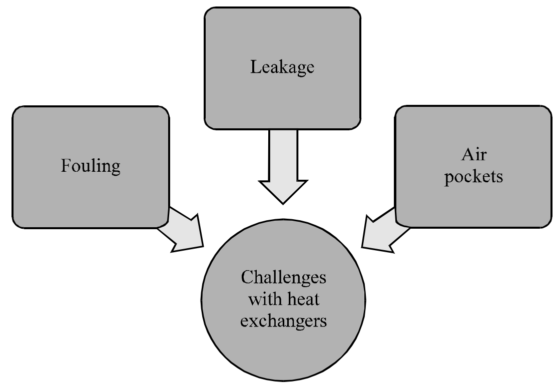

Fig. 5: Challenges encountered by heat exchangers

Leakage: Most leakages occur due to gasket failure replacement of gaskets will be necessary. Internal leakage due to tube failure will cause contamination of the lower pressure fluid by the ingress of higher pressure fluid. This will require tube 'plugging' or replacement. Tube failure generally occurs due to corrosion, excessive pressure or by failure of the welded or rolled fitting of the tubes into the tube-sheets.

The overall heat transfer coefficient is inversely proportional to the total Resistance Rtot to the heat flow. The latter is the sum of Resistance Rconv, h to convective heat transfer from the hot fluid to the partition between the fluids, Resistance Rp to thermal conduction through the partition and Resistance Rconv, c to convective heat transfer from the partition to the cold fluid.

Logarithmic Mean Temperature Difference (LMTD) method: If heat capacity rates of the cold and hot fluids are the same and the heat exchanger is operated in the counter flow regime then ΔT is independent of position in the heat exchanger. However, LMTD method can be extended to more complex heat-exchanger designs (e.g., multi-pass and cross-flow systems) using a correction factor.

Effectiveness-NTU method: LMTD method is useful for determining the overall heat transfer coefficient U based on experimental values of the inlet and outlet temperatures and the fluid flow rates. However, this method is not very convenient for prediction of outlet temperatures if the inlet temperatures and U are known. This solution requires application of an iterative approach.

A more convenient method for predicting the outlet temperatures is the effectiveness-NTU method. This method can be derived from the LMTD method without introducing any additional assumptions. Therefore, the effectiveness-NTU and LMTD methods are equivalent. An advantage of the effectiveness-NTU method is its ability to predict the outlet temperatures without resorting to a numerical iterative solution of a system of non-linear equations.

Temperature control scheme by thermocouple: In heat exchangers mixing does not but energy transfer takes place between the two liquids. The hot liquid pass through the shell of the exchanger while the cold liquid enters through the tube of the exchanger. The hot process liquid transfer the heat to the cold process liquid, thus, increasing the temperature. However, the elevated temperature of the cold liquid is controlled by the temperature control valve, the thermocouple.

Advantages of compact heat exchangers: Due to their compact size, Plate Heat Exchangers (PHEs) are widely used in industrial processes. They have higher heat-transfer performance, lower temperature gradient, higher turbulence and easier maintenance in comparison with shell and tube heat exchangers. For minimizing material consumption and space requirements compact models have been developed over the last years. By using thin plates forming a small gap, these compact models impress with larger heat transfer coefficients and thus, smaller required heat transfer area (Li *et al.*, 2011). The advantages of compact heat exchangers (Li *et al.*, 2011) over shell and tube ones at a glance:

- Larger heat transfer coefficients
- Smaller heat transfer surfaces required
- Lower fouling due to high fluid turbulences (self-cleaning effect)
- Significantly smaller required installation and maintenance space
- Lighter weight
- Simplified cleanability, especially, for GPHE
- Lower investment costs
- Closer temperature approach
- Pure counter-flow operation for GPHE

CONCLUSION

Heat exchangers are important elements of almost all types of engines. There are several types of heat exchangers used with varying performance. There are different applications for different heat exchangers. Based on the need and other factors, different types of heat exchangers may be used onboard ships.

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