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A REVIEW OF VARIOUS HEAT EXCHANGER ABOARD AUTONOMOUS SHIP

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ABSTRACT

Heat exchanger is one of the important device aboard the ship to reduce heat and prevent the overheating as overheating in the ship could damage the machinery used in the ship. There are parameters to be considered in the design, and operating the heat exchanger, especially in the autonomous ship. In this paper, a general review is provided of developments and improvements on heat exchanger and its relevance in an autonomous ship. Based on the finding, the design and heat exchanger typing should be adapted well to the applications in which they are used. As the usage in an autonomous ship, an risk and reliability assessment of heat exchanger have to be analyzed. Lastly, the development of heat transfer usage in an autonomous ship is still in the stage of monitoring and measuring the operating parameter. The maintenace and correction of the failures still need human presence.

Keyword: autonomous ship, heat exchanger, heat transfer

1. Introducing

In the operation of the ship, the machinery aboard the ship might generate excesive heat as they operated. The undesirable heat generated from the operation of machinery aboard ship such as main engine, starting air compressor, auxiliary engine, and air conditioning and chiller plan is one of the parameter to be considered. This undesired heat might initiate the damage of the machinery. To prevent this from happening, it is needed to control the heat within the acceptable temperature. To control the undesired heat, a heat exchanger is widely used aboard ship. The heat exchanger has an important role in various application aboard ship. Not only for the cooling system, but also heat exchanger is used in heat recovery system.

In many studies, controlling the engine temperature is necessary due to the change in engine thermal condition could affect the engine performance and its emission, hence, it have to be considered [1, 2]. The cooling system plays an important role in controlling the thermal load, heat balance, and performance of a diesel engine[3]. [4] Stated that the most frequent problem reported in repair report of the ship is overheating problem due to the sea chest blockages and scaling of heat exchanger tube which cause reduction of heat transfer efficiency.

An autonomous ship is a ship that the operating system on the ship have the ability to make decisions and determine action by itself. The trend of autonomous vehicle seems to be accepted by the marine community. The main reason of the development of autonomous vehicle is economic reasons [5]. Although the urge of cost reducing in ship operation, we couldn't ignored the safety of operating devices. As stated before, the overheating problem still become the most frequent problem in ship operation. This potential problem is increased as it's used in an aoutonomous ship if it's not handled properly. In this paper, we will summarize the heat exchanger application on board ship and the relevance of it's usage in autonomous ship.

2. Method

This paper review is carried out by following the procedure as shown in the figure 1.

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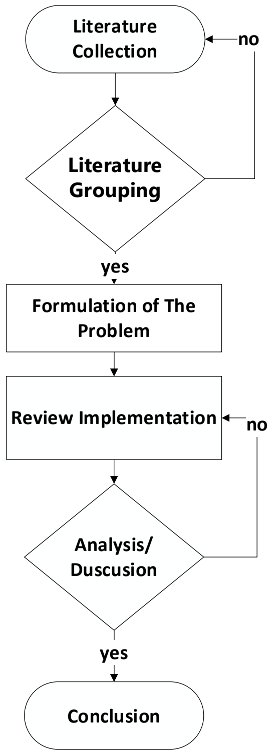

Fugure 1. Review Procedure

The review process is carried out in several stages starting from collecting research papers on heat exchangers, then grouping them according to the type used on the ship. Then formulate the problem according to the subject of discussion. Papers that have been included in the discussion group are analyzed and discussed to determine a conclusion.

3. Results And Discussion

3.1 Heat Exchanger

Heat exchanger is a device used to transfer heat from higher temperature medium to lower temperature medium. The media used in heat exchanger is fluid such as liquid, gas, or combination of liquid and gas. The two medium in heat exchanger are separated by a thin film of metal to prevent the medium to be mixed. In another cases, the medium could be mixed in direct contact. The construction of heat exchanger mostly not include any moving parts. This construction led the heat exchanger greatly reduce the frictional effects and leakage. However, in some cases, heat exchanger can include moving parts, for example in the scraped surface heat exchanger [6]. The applications of heat exchanger are various. It could be applicated in refrigeration system, power plans, HVAC, heat recovery, and other application that needs a heat transfer proces. In marine sector, heat exchanger is used as engine cooler, oil cooler, refrigeration system, HVAC system, and heat recovery system.

3.2 Heat Exchanger Type

Heat exchanger can be categorised according to flow arrangement and construction. According to flow arrangement, heat transfer can be classified into parallel flow, counter flow, and cross flow heat exchanger. According to its construction, generally it can be classified into two type, shell and tube heat exchanger and compact heat exchanger [7]. Researcher also categorised heat exchanger further into many ways. They classified the heat exchanger based on its construction, the phase compactness, working fluid, arrangement of the fluid flow, transfer processses, pass arrangements, and heat transfer mechanism [8, 9]. The most widely used heat exchanger type is the shell and tube heat exchanger [10-12].

Shell and tube heat exchanger is a heat exchanger that consist of tube and shell. The simples shell and tube heat exchanger is built by only one shell and one tube arranged in concentric. The more complex heat exchanger design is built with lots of tube in a shell with various flow arrangement. In the shell and tube heat exchanger, baffles are usually used and installed in the heat exchanger to increase heat transfer area and convective coefficient of the fluid. Beside that, baffles also support the tube construction physically. This led to reduction of vibration. The construction of shell and tube heat exchanger can be seen in figure 2

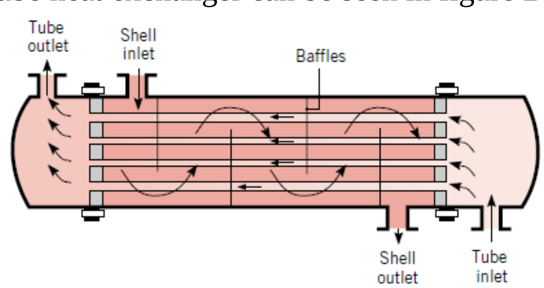

Figure 2. Shell and tube heat exchanger

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The flow arrangement on shell and tube heat exchanger could be classified as parallel flow and counter flow. In the counter flow arrangement, the hot fluid flows from the one side and the cold fluid flows from the other side. The output of cold fluid in this arrangement may exceed the output temperature of the hot fluid.

In the parallel flow arrangement, the hot fluid and the cold fluid flow from the same one side. The output of cold fluid in this arrangement may not exceed the output temperature of the hot fluid.

Compact heat exchanger is a heat exchanger which have significant ratio of area to volume. The difference of area and the volume in this heat exchanger is high. The operating fluid for this heat exchanger could be gas to gas, gas to liquid. or liquid to liquid. For gas to gas and gas to liquid heat exchanger, the value of area to volume ratio is greater than or equal to 500 m2 /m3 or 700 m2 /m3 , while for liquid to liquid type, this ratio is greater than or equal to 200 m2 /m3 or 400 m2 /m3. Compact heat exchanger could be classified as plate heat exchanger, plate fin heat exchanger, printed circuit exchanger, spiral exchangers, shell and tube etc. The compact heat exchanger are widely used in various sector of industries such as refrigeration, power, automotive, waste gas heat recovery, seawater applications, and petrochemical industries.

Choosing the heat exchanger type is not an easy task. Heat exchangers are devices that necessary for all thermal systems. The good designs of heat exchanger should be adapted well to the applications in which they are used. If the design doesn't properly calculated, their performances will be deceiving and their costs excessive.

3.3 Recent Development of Heat Exchanger

In the operation of heat exchanger, leakage, pressure drop, and scaling are few problems that typically became a challenging problem to be solved as long as with the enhanchement of heat transfer coefficient. Researchers have already conducted researches to reduce the heat exchanger problem and enhance its performance. Simin Wang et.al. conducted an experimental investigation to enhance shell and tube heat exchanger performance. They compared two heat exchanger. The one is conventional shell and tube heat exchanger and the other is enhanced heat exchanger using sealers. They found out that the improved heat exchanger could increase the overall heat transfer coefficient.

In the improved heat exchanger, the sealers block the baffle-shell gap. This configuration allowed the original short-circuit flow to participate in heat exchange. This design makes the shell-side circulation area decreases and the shell-side flow rate increases. Thus the overall heat transfer coefficient of the shell-side is effectively enhanced.

The effect of sealer in this heat exchanger on pressure drop also examined. In this heat exchanger, the pressure drop increases with the shell-side flux. When shell-side flux is 150 L/min, the shell-side pressure drop is 7.8 mmHg before the configuration improvement and 11 mmHg after. The pressure drop increased by about 44.8%. When flux increases to 306 L/min, the pressure drop increases from 25.7 mmHg of conventional heat exchanger to 37.2 mmHg of improved with sealers, which increases by 48.8%. Within the operating conditions, the pressure drops increase by 44.6–48.8%.

The advance of compact heat exchanger innovation, some researcher developed heat exchanger design to achieve high effective heat transfer performance, moderate pressure drop and less pumping power. There are some finding from literatures such as discrete, wavy and corrugated fins could yield higher transfer performance compared with flat plate fins. However, at certain condition (very low fin spacing and Re number), this strength might not be achieved. Heat transfer rate inlouver fins is higher than plain fins, offset-strip fins and slit fins at same RE number [17]. Awais et. al. also find that the heat transfer rate and pressure drop in convex louver fins are highly effective than louver and plane fins. Beside the fins design, the arrangement of tube also contribute in the heat exchanger performance. The heat transfer performance of staggered alignment is higher than the inline alignment. But the drawback of the staggered alignment is the pressure drop become large.

Incorporated fin in the heat exchanger design was proved to be an effective way to enhance heat transfer rate. This also seen in the research conducted by Barokah et. al. [18]. They propose an improved baffles design using fin.

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They simulated the design and found that the average fluid heat flow in the proposed design (Fin Baffle- Shell and Tube Heat Exchanger) is greater than the regular baffle shell and tube heat exchanger. This result is caused by the greater turbulance produced by the fin baffle shell and tube heat exchanger. The heat transfer coefficient of the fin baffle shell and tube heat exchanger is smaller due to an addition of fin that makes the surface area of the baffle increases.

From the finding above, fin thickness, baffle height, tube row number, fin spacing, alignment and pattern of fins and tubes have significant influence on thermo-hydraulic performance of heat exchangers.

3.4 Heat Exchanger Relevance on Autonomous Ship

Although autonomous ships could reduce an operating cost of the ship and are projected to change the maritime industry. The safety and reliability of the machinery aboard the ship couldn’t be neglected. Removing human from the ship might reduce the operating cost, but it aslo make another issues to be solved. Its not an easy task to be achieved. The problem rises from this improvement is the reliability and the failures handling at the sea without the present of crew. The failures in the ship still likely happen too often and the repair of this failures still unlikely to be handled without the present of crew [19].

Some researcher conducted an investigation about the possibility of an atutonomous ship in the future. Stig Eriksen et.al. [20] proposed an aproach for assessing reliability challenges of unmanned cargo ship. They indentified each system in the ship and compared the reliability between manned ship and unmanned ship. The case study they used is the case in oil cooler system. The identified system only consists of three different equipment unit types: pumps, heat exchangers and thermostatic regulation valves. All equipment units are critical, as the failure of any of them affect the entire system.

Using the RCM method, Stig Eriksen et. al. [20] proposed three scenario to be analyzed. The first is Preventive maintenance only, the second is preventive and corrective maintenance and the third is system redesign. The results of the assessment of risk for the three scenarios are presented in Figure 3.

		Scenario 1: Preventive maintenance only			Scenario 2: Preventive and corrective maintenance								
					Manned			UMS Short			UMS Long		
Failure Mode		C	P	R	C	P	R	C	P	R	C	P	R
Insufficient heat transfer	Critical	4	2	H	3	2	M	4	2	H	4	2	H
External leakage - process medium	Critical	4	3	H	3	3	M	4	3	H	4	3	H
External leakage - utility medium	Critical	4	3	H	3	3	M	4	3	H	4	3	H
Internal leakage	Critical	4	3	H	3	3	M	4	3	H	4	3	H
External leakage - process medium	Degraded	4	3	H	1	3	L	1	3	L	4	3	H
External leakage - utility medium	Degraded	4	3	H	1	3	L	1	3	L	4	3	H
Internal leakage	Degraded	4	3	H	1	3	L	1	3	L	1	3	L
Plugged/Chocked	Critical	4	3	H	3	3	M	4	3	H	4	3	H
Structural deficiency	Critical	4	3	H	3	3	M	4	3	H	4	3	H
Structural deficiency	Degraded	2	3	M	1	3	L	2	3	M	2	3	M

	Scenario 3.1: System redesign *Redundancy of heat exchangers*									Scenario 3.2: System redesign *Redundancy of heat exchangers & Double-wall heat exchangers*								
	Manned			UMS Short			UMS Long			Manned			UMS Short			UMS Long		
Failure Mode	C	P	R	C	P	R	C	P	R	C	P	R	C	P	R	C	P	R
Insufficient heat transfer	2	2	M	2	2	M	2	2	M	2	2	M	2	2	M	2	2	M
External leakage - process medium	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M
External leakage - utility medium	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M
Internal leakage	3	3	M	4	3	H	4	3	H	3	1	M	4	1	M	4	1	M
External leakage - process medium	1	3	L	2	3	M	2	3	M	1	3	L	2	3	M	2	3	M
External leakage - utility medium	1	3	L	2	3	M	2	3	M	1	3	L	2	3	M	2	3	M
Internal leakage	1	3	L	2	3	M	2	3	M	1	3	L	2	3	M	2	3	M
Plugged/Chocked	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M
Structural deficiency	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M	2	3	M
Structural deficiency	1	3	L	2	3	M	2	3	M	1	3	L	2	3	M	2	3	M

C = Consequence *L = Low*
P = Probability *M = Medium*
R = Risk *H = High*

Figure 3. Risk assessment of heat exchange

In the case of autonomous ship, failure detection only detect failures or potential failures. It could not prevent failures. Indeed, it still became an advantages to minimise damage in the equipment and avoid unnecessary maintenance. This certainly could reduce the operating and maintenance cost due to the cost of failure is high. If this monitoring method is used properly, the unnecessary failure can be eliminated. Failure indicator and other parameter from the autonomous ship could continuously measured and transmitted to a shore control centre and some operational check may be carried out remotely. However, the human presence still needed in some condition such as such as thermography or electrical resistance testing, not to mention inspections by human sensory inputs.

4. Conclusion

Heat exchanger is an important device to prevent the overheating problem aboard the ship. The type, design, sizing of the heat exchanger could be various and should be adapted well to the applications in which they are used. If the design doesn't properly calculated, their performances will be deceiving and their costs excessive. The most widely used heat exchanger aboard the ship is shell and tube heat exchanger. To improve the performance of heat exchanger, various enhancement could be done such as addition of seal, fin, and the use of nano fluid. The usage of heat exchanger in an autonomous ship needs to consider the risk assessment of heat exchanger. Right now, although the monitoring and continuous measuring could be done remotely, the presence of human still needed.

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