International Journal of Offshore and Coastal Engineering
Vol.7 | No. 1 | pp. 44 – 49 | May 2023
e-ISSN: 2580-0914

Submitted: January 11, 2023 | Revised: March 10, 2023 | Accepted: May 1, 2023

Design Optimization on Seawater Distillation System That Utilizes Exhaust Gas On 300 Gt Fishing Vessel

S A A Sunya[1], A Santoso[1], and M B Zaman[1]

[1)] Department of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia
*Corresponding author: sulfiaanizar@gmail.com

ABSTRACT

In the shipbuilding process, planning and calculations are needed, including the planning of the existing systems on the ship, one of which is the freshwater supply system. In planning the freshwater supply system, it is necessary to calculate the fresh water tank, which depends on several parameters such as; length of sailing time, number of ship passengers, and others. There are two options to supply the large freshwater needs, either providing a large tank capacity or a freshwater production system (seawater treatment). However, providing a large space for freshwater tanks will reduce the payload of the ship. Most of the generators' diesel engine combustion can be used to maximize the heat energy wasted through the generators' diesel engine exhaust gases. The solution that will be pursued is the distillation of seawater into freshwater by utilizing the heat energy of engine exhaust gases, which so far have not been optimally utilized on fishing vessels. In this project, we will discuss the use of exhaust gas for the design optimization of a seawater distillation system that utilizes exhaust gas on a 300 GT fishing vessel.

Keywords: *Design, Distillation, Diesel Generator*

1. INTRODUCTION

Currently, development in the fisheries sector is a major concern for the Government. The policy is directed at preserving fish resources and the environment. It is hoped that the impact of the policies that have been carried out is that the contribution of the fisheries sector will increase. In addition, the role of fishing vessels is to fulfill an adequate contribution to the fisheries sector. In the process of ship manufacture, planning and calculations are important, including the planning of the existing systems on the ship, one of which is the freshwater supply system. In the freshwater supply system process, it is necessary to calculate the freshwater tank, which depends on several parameters such as; the length of time the ship sails, the number of passengers on the ship, and other needs (such as engine cooling, etc). Therefore, the availability of fresh water in large quantities will affect the amount of cargo that can be transported by ships (payload).

There are two options to meet the large freshwater supply needs: to provide a large amount of the tank capacity or provide a freshwater production system (seawater treatment). However, providing a large space for freshwater tanks will reduce the payload of the ship, so in this study, we will discuss the freshwater production system (seawater treatment) as an alternative to fulfill the needs of fresh water on a 300 GT fishing vessel. The process of filtration of seawater into freshwater is called distillation. There are various kinds of heat sources to run this distillation technology: solar panels, steam (boilers), heaters, and many more. The heat of the exhaust gases produced by the diesel engine contains much potential thermal energy that can be utilized because 34-40% of the energy comes from the combustion fuel placed in the engine and is disposed of through the exhaust gases. Using exhaust gas will be advantageous for reducing the price of excessive heat processing, lowering the temperature of flue gas, and reducing environmental air pollution. However, there have been too many studies on the use of exhaust gases in the ship's main engine.

The utilization of exhaust gas on ships can also be sourced from diesel generators. Generators on board are the only source of power generation available, so their existence is very vital for the operation of a ship. In addition, applying a diesel generator will be beneficial for the ship's main engine when turned off. Applying a diesel generator is possible because the diesel generator functions as a backup, while the main supply comes from the main engine of the fishing vessel. Based on the description above, most of the results of diesel generator combustion can be applied to maximize the heat energy waste through exhaust gases. In overcoming this constraint, it is necessary to apply an accurate technology for handling exhaust gas exertion. The solution that will be pursued is the distillation or filtration of seawater into freshwater by utilizing the heat energy of engine exhaust gases, which have not been optimally utilized on fishing vessels.

2. LITERATURE STUDY

2.1 Fishing Vessel Classification

Fishing vessels include the type of boat or ship and other floating equipment used to catch fish, prevent illegal fishing, and support fishing operations, fish processing, fishery training, and fishery research or exploration. Fishing vessels are classified into several types. The type of classification shape of fishing vessels is carried out by several institutions. According to Indonesian Capture Fisheries Statistics, based on the type of fishing gear used, fishing vessels are divided into 2 (two) categories, for example:

1. Non-powered fishing vessel
2. Powered fishing vessel

A simple classification of fishing vessels can be seen in Table 1.

FAO (Food and Agriculture Organization) is an institution under the auspices of the United Nations that issued an international standard for the statistical classification of fishing vessels (International Standard Statistical Classification of Fishing Vessels, ISSCFV – FAO 1985). ISSCFV – FAO 1985, in its elaboration, has 11 (eleven) types of fishing vessels and 7 (seven) other types of fishing vessels. In conclusion, ISSCFV – FAO 1985 divided fishing vessels into 2 (two) types of fishing vessels as follows:

1. Types of fishing boats
2. Type of non-fishing vessel (other fishing vessels)

2.2 Freshwater for Fishing Vessels

In principle, fresh water is a fundamental human need. Therefore, the necessity for freshwater availability is a determinant of the ergonomic value of fishing vessels. In general, the need for freshwater for fishing vessels is equal to the need for fresh water on commercial vessels. Theoretically, human freshwater needs are the same. The need for fresh water on commercial vessels is divided into 3 (three) parts as follows:

1. Fresh water for eating, drinking, and cooking purposes (5-10 liters/person/day)
2. Fresh water for washing and bathing purpose (80-100 liters/person/day)
3. Freshwater equipment for engine coolant (2-5 lt/BHP)

However, there are some differences in the freshwater supplies needed on marine fishing vessels and commercial ships according to the economic aspect, including loading and function efficiency. Economic sectors include the efficiency of non-fish cargo and fish cargo effectiveness, while the functional aspects include the efficiency of the non-fish loading space and the fish loading space. In addition, there are cultural and traditional that require consideration in the freshwater design needs of fishing vessels. Therefore, the supply of fresh water on fishing vessels can be defined as the availability of fresh water for eating, drinking, cooking, and ice flakes making to preserve fish. According to the analysis of the related sector, it can be explained that the availability of freshwater needs on fishing vessels lies in the supply of fresh water for the needs of eating, drinking, cooking, and making ice flakes. Ice flake is fine ice grains with a diameter of 2 mm and a soft texture, generally a little developed. This ice melts faster so that the cooling process occurs faster. However, on the other hand, there will be a large amount of ice meltdown and requiring more ice is needed. Small ice develops the same. The smaller ice, the faster the fish will cool down.

2.3 Seawater Distillation

The distillation method of separating mixtures is based on a different level of volatility (ease of a substance to evaporate) at a certain temperature and pressure [1]. The distillation process is strongly influenced by the characteristics of the liquid to be overflowed. Distillation is divided into two main processes, called the evaporation process and the cooling process (condensation). Distillation processes have widely been used in industrial processes. The separation process contains salt in seawater in seawater to produce fresh water. The evaporation process of seawater compounds precedes the evaporation process of salt content in seawater through an evaporator, followed by the condensation process of freshwater vapor that collects in a separate container through a condenser to produce fresh water.

Table 1. Indonesia Fisheries Statistics Classification Fishing Vessels

No	Category Boat/Ship		
1	Non-powered boat	*Jukung* (Traditional boat)	Small, medium, and big
2	Powered boat	Motorboat	<5 GT (Gross Tonnage), 5-10 GT, 10-20 GT, 20-30 GT, 30-50 GT, 50-100 GT, 100-200 GT, 200-300 GT, 300-500 GT, 500-1000 GT, >=1000 GT

The separation for the main basis by distillation is the difference in the boiling point of the liquid at a certain pressure. The distillation process is mainly a mixture of evaporation followed by a cooling and condensation process. There are several types of distillation, as follows:

1. Simple distillation
   The chemical separation technique separates two or more components with extreme different boiling points.
2. Graded distillation
   Separate two or more components that have slight differences in boiling points.
3. Azeotropic Distillation
   Separating azeotropic mixtures (a mixture of two or more components that are difficult to separate) is usually used in the process of other compounds to break the azeotropic bonds by using high pressure.
4. Steam distillation
   Separate liquid compounds that are insoluble in water and have a fairly high boiling point. The application of steam distillation to extract some natural products such as eucalyptus oil, citrus oil from lemons or oranges, and the extraction of oils from other plants. Steam distillation is a general term for the distillation of a mixture of water with compounds that are insoluble in water.
5. Vacuum distillation
   Separate two components with very high boiling points, using a method to lower the surface pressure lower than 1 atm (a low boiling point). In the process, the temperature used for distillation is not too high.

2.4 Characteristics of Seawater

Seawater, in general, has an average salt content of 34.5%, which means one liter of sea equals 34 grams of salt. The level of salt contained in seawater is called the salinity of seawater. In order to determine salinity, all bromine and iodine must be replaced with equal amounts of chlorine, all carbonates must be transformed into their oxidation state, and all organic compounds must be oxidized. Salinity is calculated as the weight in grams of all solids dissolved in 1 (one) kilogram of seawater. Salinity values expressed in g/kg are generally written in, which means parts per thousand (ppt). The salinity level of seawater greatly determines its density of seawater. Density increases with increasing salinity and decreasing temperature. Meanwhile, the seawater temperature ranges from 18.7^0C to 42^0C. Based on the results of research on the composition of salt in seawater since 1859, Forchhammer explained that seawater has the same salt composition ratio all over the world. In general, seawater has a salinity level of 35 or better known as standard seawater.

3. EXHAUST GAS UTILIZATION FOR THE DISTILLATION SYSTEM

Research by [2] in 2014 utilized the thermal energy in an IC engine's exhaust gas for desalination. The IC engine's thermal energy is absorbed by a horizontal tube evaporator that runs in a straight line. Fresh water is collected after the condenser, which is water-cooled, condenses the steam from the evaporator. The steam from the evaporator is cooled using seawater, which is then collected and will be used again throughout the evaporation process.

Experiments were conducted through an evaporator, condenser cooling water with and without preheating coupled to a 5 HP. Kirloskar produced a single-cylinder diesel engine. We will study the evaporation flow rate under various engine load conditions. Below is a summary of the findings.

1. Compared to water-cooled condensers without preheating, desalinated water production is significantly higher when employing water-cooled condensers with preheating.
2. The seawater works as a cooling medium in the condenser to chill the steam from the evaporator. It is heated to a maximum of 60°C before being kept in a separate, insulated water tank. The same warm water can be used efficiently for various beneficial applications.

Research by [3] in 2007 uses an experimental method in the distillation process by utilizing sub-atmospheric pressure. The arrangement of the system uses exhaust gas from the power plant, besides using exhaust gas allows for increasing the efficiency of freshwater production, which is better than the current technology. The Botticelli concept is also used in this study as the barometric leg. During the experiment, the water from the evaporator was cooled, and the condensed water was warmed. This indicates that the water level in the tank has changed, and the distillation process has occurred.

Research by [4] in 2010 from Japan and Korea indicated that if the amount of heat energy produced by the portable electric generator is fairly low, the heat energy can still be used as an additional heat source for solar stills. In many locations, including isolated areas and islands, where there is a lack of water and energy infrastructure, portable electric generators are frequently used. Since the waste heat energy is insufficient to be successfully used, the waste heat from portable electric generators is typically only dispersed to the environment. However, this waste gas's heat energy can evaporate a heat source to produce fresh water from seawater or contaminated water.

Distillation in this research involves evaporation and condensation processes where heat energy is recycled to increase the productivity of the distillate. It was discovered that 20 kg of fresh water could be produced during a few hours of operation by transferring around half of the energy from exhaust gases to the heated partition of the distillation process. Fresh water used in the distillation process is equal to the daily productivity peak of solar stills as determined by field tests.

Continuous heating of seawater occurs during the distillation process. The surface of the divider has a heat pipe attached to it. As the working fluid, seawater is continuously injected into the heat pipe. In this study, a number of assumptions are made, including:

1. Each division has an even temperature.
2. Convection may not be present because of the tiny spaces between the barriers.
3. There is very little heat transfer from the top, bottom, and side walls.
4. The waste gas pipe's entire outer surface experiences nucleate boiling since the heat pipe has been sufficiently emptied.
5. Both the condensing temperature on the inner surface of the condensing pipes and the boiling temperature on the waste gas pipe's outer surface are uniform.

The flow rate of the exhaust gas from a portable electric generator varies depending on the engine size and the electric generator's operating circumstances. While the temperature of the exhaust pipe wall is nearly constant from the inlet to the exit, the temperature of the exhaust gas reduces exponentially as it travels through the exhaust pipe. This occurs because nucleic boiling has a far higher heat transfer coefficient than convection. In order to boost the productivity of the distillation process, the boiling temperature of the nucleic acid should be raised. This may be done by raising the convection heat transfer coefficient between the exhaust gas and the exhaust gas pipe wall. However, if fins or other equipment are added to improve the heat transfer coefficient, the back pressure may increase, which could affect how well the power generator works.

Research by [5] in 2017, in order for the ship's payload to increase in tandem with the decreased freshwater load, the method for processing fresh water production with the distillation process is discussed. The method of processing is relatively straightforward: some of the seawater that enters the evaporator is evaporated, and the water vapor is subsequently cooled in the condenser. The cooling system and main engine exhaust gas provide the energy needed to evaporate seawater. The energy used in this study, 6074 kW from the cooling system and 3492 kW from the exhaust gas, can create 0.611789 kg/s of fresh water. With this value, the distillation system is able to meet 48.112% of the total demand of 1.2716 kg/s. To produce freshwater of 0.611789 kg/s, a condenser with dimensions of 750 mm long, 750 mm wide, and 1300 mm high is required and an evaporator with dimensions of 800 mm long, 800 mm wide, and 1300 mm high. Regarding equipment procurement, this system does not require too much space, so it can be installed or applied to KM. Labobar.

Research by [6] in 2021 from Vietnam analyzes the impact of the heat exchanger structure on exhaust heat recovery equipment on the effectiveness of heat transfer between exhaust gas and saltwater. This research discusses the process of building a waste heat recovery tube. Ansys Fluent software was used for the research, and experimental data were used to determine the input data. The outcomes show that the heat exchanger's fin structure significantly impacts the efficiency of exhaust heat recovery. Design and manufacture a system that uses both internal combustion engine (ICE) exhaust gases and cooling heat energy to separate fresh water from seawater on fishing boats off the coast of Vietnam.

The experimental procedure demonstrates that the thermal energy emission varies sequentially in response to the ICE mode, directly impacting the efficiency of the heat recovery apparatus as well as the efficiency of the system. This study was able to develop an EHR with a suitable structure and a good heat transfer coefficient by improving the flue gas structure.

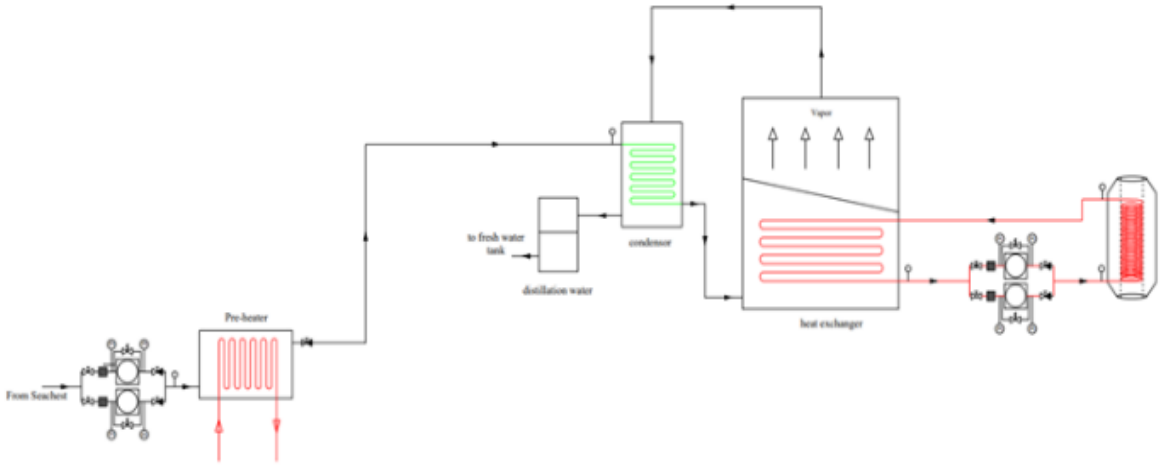

Figure 1 Flow Diagram Process

Research by [7] in 2020 discusses the desalination of seawater on passenger ships using engine exhaust heat is the topic of this study. Three processes—Forward Feed Multiple Effect Evaporation (MEE-FF), Once Through Multi-Stage Flash (MSF-OT), and Brine Circulation Multi Stage Flash—are used to desalinate water (MSF-BC). Desalination plant factors, such as the quantity of fresh water needed and the related total heat transfer area, have been calculated using simulations. A plant that delivers the requisite distillate flow rate with the least amount of heat transfer area is the best option. It has been investigated how numerous factors, such as steam temperature, exhaust temperature, and inlet water flow rate, affect plant selection. The best desalination technique has been chosen for an existing passenger ship utilizing the developed software in order to test the proposed procedure. The advantages in terms of economics, the environment, and technology are quantified in order to evaluate the effectiveness of the proposed strategy. The product cost per unit of fresh water is reduced by about 30% when waste heat recovery is used. This facility lowers annual emissions by about 5,000 tons of CO2, 100 tons of NOx, and 35 tons of SO2. Applying the ideal saltwater desalination design suggested in the case study reduced the average cost of clean water at the port by at least 2.7$/m3. These savings might pay for the plant's capital expenses for a maximum of six years. As of now, the article has demonstrated how effectively cooling water and exhaust gases may be used to create water desalination machines. By examining the effectiveness of additional waste heat sources, such as the air cooler and lubricating oil, the work in this article can be expanded in the future. The report also concentrated on techniques for desalinating water using heat. An extension is the use of hybrid or reverse osmosis technologies for water desalination on ships. Because it is straightforward to use, this method has a significant advantage over other methods in the literature.

4. ANALYSIS AND RECOMMENDATION

After doing a paper review of several studies that have been done, there are several recommendations for distillation systems. Exhaust gas utilization that has been done mostly utilizes exhaust gas from the main engine. However, using diesel generator exhaust gas has not been optimally utilized. The advantages of the diesel generator are able to replace the function of the main engine when it dies. In addition, the exhaust gas heat from the diesel generator is quite high and can be used for the distillation process, which turns seawater into fresh water.

Desalination can be done with water and other low-temperature evaporation systems in the future, including flash evaporation, to boost the desalination rate even further. It is needed to establish a standard for the most energy that can be extracted from exhaust gas without negatively impacting the exhaust gas system. When the dimensions of each component in the distillation system have been determined, it is necessary to calculate the variation of the main engine power so that the calculation is more accurate. Figure 1 is a flow diagram process that will be used in the distillation process for a 300 GT fishing vessel. There are several components in the design, namely:

1. Sea-chest that serves to take seawater with the help of a pump,
2. The pump serves to pump water to the next process,
3. The pre-heater serves to heat seawater with pressure to reach below its boiling point. Seawater temperature should not exceed the boiling point to minimize cracking,
4. Condenser: Light compounds that evaporate first will enter the condenser. In this condenser, the collected vapor will be condensed into a liquid,
5. Heat exchanger, and
6. Exhaust gas from diesel generator.

5. CONCLUSIONS

In particular, for fishing vessels, the purpose of this article is to ascertain how exhaust gas is used for the process of distilling seawater into fresh water. The literature study method shows that there have been many studies using exhaust gases for the distillation process. However, there is no use in using exhaust gas from diesel generators. Most of the results of generator diesel engine combustion can be used to maximize the heat energy wasted through the exhaust gases from a generator diesel engine. Using exhaust gas of diesel generator is a solution that can be used for the distillation of seawater into freshwater, which has not been used optimally on fishing vessels, especially on 300 GT fishing vessels.

REFERENCES

1. Alghifari, W.H.M: Spray dryer design as sea water distillation system arrangement for fishing vessel 100 gt. *Undergraduate Thesis*. Departmen of Marine Engineering, ITS, Surabaya, Indonesia, 2017 (in Bahasa Indonesia)
2. Maheswari, K.S., Kalidasa, M.K., and Esakkimuthu, G.: Thermal desalination using diesel engine exhaust waste heat - an experimental analysis desalination 358 94–100, 2015
3. Brandon A. M. and Eiki M.D.R.: Waste to water: a low energy water distillation method Desalination 248 123–30, 2009
4. Tanaka, H. and Park C.D.: Distillation utilizing waste heat from a portable electric generator Desalination 258 136–42, 2010
5. Fegie Damayandi Harnitya, F.D.: Design of distillation system by utilizing exhaust gas and high temperature cooling system of main engine for fresh water supply on km. labobar. *Undergraduate Thesis*. Departmen of Marine Engineering, ITS, Surabaya, Indonesia, 2017 (in Bahasa Indonesia)
6. Vu Quang K, Duy Tien N, Minh Dien V, Manh Toi L and Dang Duy L: Developing a waste heat recovery tube used in the seawater distillation system Appl Therm Eng 195, 2021
7. Hussein, A. and Kandil, H.: Seawater desalination using waste heat recovery on passenger ship port-said engineering research journal 0 0–0, 2019