Chapter 4
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Use of Ship Main Engine Cooling Water for the Design of Micro Hydro Power Plants

Danny Faturachman [a*], Endang Tri Pujiastuti [b] and Fridolini [c]

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ABSTRACT

The present study highlights the use of Ship Main Engine Cooling Water for the Design of Micro Hydro Power Plants. Renewable energy is non-fossil energy that is derived from nature and is sustainable. If resources are managed effectively, they can also run out. By using the cooling water flow pressure machine ships as a water turbine impeller manufactured in such a way so it may create electricity, he uses the cooling water disposal on his boat as an environmentally friendly energy-producing method. Commercial ships typically use large-capacity cooling systems and large-sized machinery, therefore the cooling water flow capacity will be considerably higher. This prompted the opportunity to create an instrument for utilizing renewable energy flow of cooling water disposed in vain to rotate the propeller has been drafted into a micro hydro. And expected results can help reduce the workload of the auxiliary engines which will also have an impact on the reduction of fuel consumption. The proposed water turbine will rotate as a result of fluid flowing by the pump, producing electrical energy. When the ship sail, the lighting definitely need in each room, by using the electrical energy produced by the auxiliary engine, this water turbine can be applied then the fuel that had been used or consumed by the auxiliary engine can be replaced by the electric energy generated by the water turbines for light ships. Testing of the prototype for a micro hydro generator aboard a ship yielded a 40% efficiency. Thus, it can be said that this ship's micro hydro power system can reduce energy consumption by up to 40%.

Keywords: *Ship main engine; cooling water; micro hydro power plants; electric energy; renewable energy.*

1. INTRODUCTION

Energy is a very important role in the life of mankind and the energy needs in particular renewable energy not contrary to be available in nature. Because of

[a] Marine Engineering Department, Faculty of Marine Technology, Darma Persada University, Indonesia.
[b] Management Department, Faculty of Economy, Darma Persada University, Indonesia.
[c] English Language and Culture Department, Faculty of Letters, Darma Persada University, Indonesia.
**Corresponding author: E-mail: fdanny30@yahoo.com;*

the dependence of human life, especially the modern man of enormous energy, then the energy sources used today have been experiencing a crisis. The overwhelming reliance on fossil fuels, in particular, threatens to alter the Earth's climate to an extent that could have grave consequences for the integrity of both natural systems and vital human systems. At the same time, access to energy continues to divide the 'haves' from the 'have-nots.' Globally, a large fraction of the world's population—more than two billion people by some estimates—still lacks access to one or several types of basic energy services, including electricity, clean cooking fuel and an adequate means of transportation [1-3]. Energy that is not renewable was created over the course of millions of years by using natural resources. Petroleum was one of the more well-known non-renewable energy examples. People's continued euphoria against energy usage as witnessed via manufactured machines caused energy use to occur on a massive scale. Energy sources that cannot be regenerated are still being explored and exploited. The impact on the global economy has been driven by the energy crisis. A source of primary energy and the source of foreign exchange of the country is known as Fossil energy especially petroleum. Limited crisis of petroleum recently showed that alternates fossil energy especially in Indonesia is indicated by the fact that energy consumption continues to increase in line with the pace of economic growth and the increase of population. The need for the development of renewable energy and energy conservation, called the green energy development is caused by the limited fossil energy sources. The definition of renewable energy here is a non-fossil energy that comes from nature and can be renewed. When managed properly, resources that will not be exhausted. Power plants need to maintain high operating performance, generation, availability, and reliability, in addition to reducing fuel costs and, at the same time, maintain low carbon emissions into the atmosphere. The specific consumption measure—the ratio between power and kilograms of fuel—is an indicator of thermal efficiency, but there is also another important measure that will be addressed in this work: the energy consumption of auxiliary equipment [4,5].

Many companies machine seek and examined to get development of their products in having fuel efficiency large and reduce fuel requirements. One of them performed by a plant origin Finland namely Wartsila who innovates make machine with mixing two fuel between gas and fuel oil, and also use turbo charger. But this business not maximum because of fuel used in combustion only 35 % -40 % could be work.

Shipping world growth in Indonesia is increasing rapidly and will continue to evolve, all that we can see from the many ships that traffic in the trading world, thus making the development and construction of world shipping in Indonesia continued to grow. If growth shipbuilding goes up and automatically energy use not renewable increases also to meet the fuel machines vessel is.

2. LITERATURE STUDY

A water turbines are basically fairly simple systems that have components as follows:

- **Intake shaft:** A tube that connects to the piping or penstock which brings the water into the turbine.
- **Water nozzle:** A nozzle which shoots a jet of water (impulse type of turbines only).
- **Runner:** A wheel which catches the water as it flows in causing the wheel to turn.
- **Generator shaft:** A steel shaft that connects the runner to the generator
- **Generator:** A small electric generator that creates the electricity.
- **Exit valve:** A tube that returns the water to the stream it came from.
- **Powerhouse:** A small shed or enclosure to protect the water turbine and generator from the elements.

Water turbines are also often classified as being either *impulse* turbines or *reaction* turbines. In a reaction turbine the runners are fully immersed in water and are enclosed in a pressure casing. The runner blades are angled so that pressure differences across them create lift forces, like those on aircraft wings, and the lift forces cause the runner to rotate. In an impulse turbine the runner operates in air, and is turned by one or multiple jets of water which make contract with the blade. A nozzle which is aligned so that it provides maximum force on the blades, converts the pressurized low velocity water into a high speed jet much like you might use with a garden hose nozzle [6].

2.1 Types of Turbines

Many kinds of micro hydro turbine designs have outputs of 10 kilowatts (kW) or less and can generate either DC or AC current that depends on the design. It is often heard that water turbines referred to as either Pelton or Turgo turbines which have terms that have to do with the structure of the water wheel which is placed inside the turbine [7].

2.1.1 Turgo turbines

In Fig. 1, there is a picture of a Turgo turbine which is an impulse type of turbine in which a jet of water strikes the turbine blades. The structure of a Turgo wheel is surrounded by a series of curved vanes that catch the water as it flows through the turbine causing the hub and shaft to turn. Designed for higher speeds than Pelton turbines, Turgo Turbines usually have smaller diameters [8].

Fig. 1. Turgo turbine

Fig. 2. Pelton turbine

2.1.2 Pelton turbines

In Fig. 2, a series of cups or buckets which catch the water surrounds this type of turbine the hub. To avoid the central area act as a dead spot incapable of deflecting water away from the oncoming jet, the buckets are split into two halves. The cutaway on the lower lips allows the following bucket to move further before it cuts off the jet propelling and permits a smoother entrance of the bucket into the water jet [8].

2.1.3 Cross-flow turbines

In Fig. 3, a cross-flow turbine which is called a Michell-Banki turbine taken from the name of the manufacturer is a turbine that uses a drum shaped runner like the wheel on an old paddle wheel steamboat. This type of turbine uses a vertical rectangular nozzle to drive a jet of water along the full length of the runner [8].

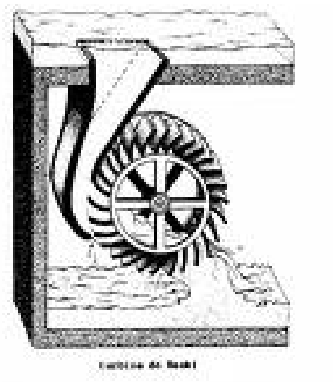

Fig. 3. Cross flow turbine

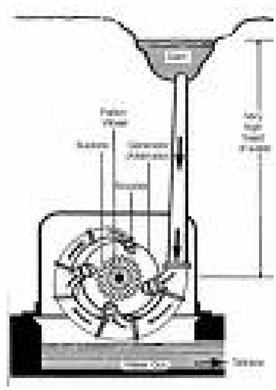

Fig. 4. Franscis turbine

2.1.4 Francis turbine

In Fig. 4, the type of this turbine is a reaction type of turbine because Francis Turbine's wheel assembly is immersed in water and surrounded by a spiral shaped pressure casing which is tapered to distribute water uniformly around the entire perimeter of the runner. Guide vanes is used to ensure that water is fed into the runners at the correct angle [8].

2.1.5 Propeller turbine

In Fig. 5, a runner shaped is used in Propeller Turbine, just like a boat propeller to turn the generator. There are six vanes in Propeller Turbine. Propeller turbine's variation is the Kaplan turbine. The pitch of the propeller blades is adjustable. Large hydroelectric plants often use this type of turbine. Propeller type of turbines has an advantage that they can be used in very low head conditions provided as long as there is enough flow [8].

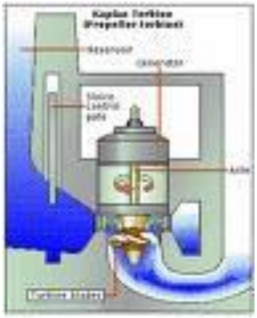

Fig. 5. Propeller Turbine

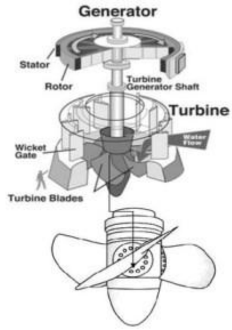

Fig. 6. Kaplan Turbine

2.1.6 Kaplan turbine

In Fig. 6, the Kaplan turbine is a propeller-type water turbine that has adjustable blades. Austrian professor Viktor Kaplan developed The Kaplan Turbine on 1913. He automatically adjusted propeller blades with automatically adjusted wicket gates in order to achieve efficiency over a wide range of flow and water level. As an evolution of the Francis turbine, its invention allowed low-head applications of efficient power production that was impossible with Francis turbines [8].

3. MICRO HYDRO PLANNING ON A SHIP

To transmit rotational force generated by turbines to generators, it uses Gear and chain as a device. Micro hydro turbine transmission system used this comparison between the turbine and the generator on gear, a comparison drawn 3: 1. In order to obtain an optimal round or rounds larger generators, it uses the gear on the turbine that has a size of 16 cm and the generator that has a size of 8 cm. To work to revamp the kinetic energy of motion into electricity, generators are expected to produce the desired electrical power on a round shaft that is low and fast. Magnitude of rotation of the turbine shaft is transmitted by a shaft to the generator determine how power produced. From comparison between gear on the turbine and gear on generator, quantity rounds are able to be determined. If it has been obtained as a result of power, then it can be defined as the distribution of electricity produced by the generator to electronic tools, lamps or if possible pumps on a vessel can make use of the results of these micro hydro generators for the electricity cases.

Fig. 7. Micro hydro design diagram

3.1 Design of Turbine for Micro hydro

The turbine is a Pelton turbine with this type of turbine vanes follow type of windmills Sagebien water wheel. Data turbine planned: turbine: diameter 10 cm wide turbine: 9.00 cm amount of Turbine Vanes: 9 pieces.

The pump is used as a water transmitter, tools and pumps was as the main character in this research, because this micro hydro planned could be function as alternative power plants on the ship by utilizing the wastewater cooling machine. However, in this experiment pump used in relation to 1: 2.5 from the pump into a reference point of observation on the dredger KM. Timor, which cooling pumps use the head of 25 meter.

Specifications dredgers as follows: Name: KM. Timor, principal dimensions: DWT: 4002,41 tons, LOA: 95 m, LPP: 89,17 m, Sea Water Cooling Pump data: Quantity: 3, Capacity: 320 m^3/h = 0.88 m^3/s, Head: 25 m, Power: 30 kW.
When the ship operations only one pump is working. Fresh Water Cooling Pump data: Quantity: 1, Capacity: 90 m^3/h = 0.025 m^3/s, Head: 25 m.

3.2 The Tools for Micro hydro

Pump Specifications: brand Sanyo PH-261, Power: 250 Watt, Head: 9 m. Paralon pipe serves as a liaison between the container of water to the pump and turbine, used pipe diameter of 1.27 cm or inch. Nozzle is a device that can change water pressure in supply by pumps become larger.

Lights and fan as a means of electricity distribution and as a determiner how big electric can produce electricity and turned on the lights and fan. Electrical power AC has been turned by diode be current DC will be directed to turn the light and fan arranged according to power each lights and fan [9].

Tachometer is a testing tool that is designed to measure the speed of rotation of an object, such as a car in a gauge that measures the revolutions per minute (rpm) of the crankshaft of the engine. The word derives from the word Greece tachos which means speed and metron, meaning measure. This device was previously created with the dial, the needle that indicates the current readings and signs which indicate the level of safe and dangerous. At the time have now been produced digital tachometer which gives readings precise and accurate numerical comparison using the dial and needle.

Multi tester is an electrical gauge are often known as VOM (Volt-Ohm Meter) which can measure the voltages (Voltmeter), resistance (Ohm-meter), as well as the current (Ampere meter). There are two categories: digital multi meter or multi meter DMM (Digital Multi Meter) for a new and more accurate measurement results, and the analog multi meter. Each category can measure AC power or DC power. A multi meter is a hand-held device that is helpful for finding errors and the work of the field, as well as devices that can measure with a very high degree of accuracy.

3.3 Step for Testing

Test preparation:

- Ensure all available testing equipment ranging from piping systems, pump, turbine and generator.
- Ensuring piping systems are ready to use or no longer part of the leak. - Ensure the connecting system of the pump to a turbine is attached properly.
- Ensure equipment for loading on the generator is available on site.
- Make sure the electrical system on the experiment can work well.

Test execution:

- Measure the speed of rotation of the gear on the turbine tachometer with the tools.
- Measuring the speed round gear on the tachometer generators with the tools.
- Measuring results of electricity produced by the generator with multi tester.

The test procedure is carried out in several stages including:

1. Measure the rotation of the turbine and generator with a tachometer.
2. Measure the voltage and current DC generators with a multi tester with several stages including:

    a. Measure the voltage T1 carefree aims to get maximum spin on micro hydro turbines and generators so it can be taken into account also the maximum voltage of the generator.
    b. Measure the voltage T2 to the load of 1 LED and fan CPU aims to get round a turbine and generator as well as the efficiency of the turbine and the generator on load 1 LED of the 1 CPU fan.
    c. Measure the voltage T3 across the load of 2 LEDs and 1 fan CPU aims to get round a turbine and generator as well as the efficiency of the turbine and the generator on load 2 LEDs and 1 CPU fan.
    d. Measuring voltage T4 load of 2 lights and fan of LED and 1 CPU fan and aim to get round a turbine and generator as well as the efficiency of the turbine and the generator on load 2 LEDs and 1 CPU fan.
    e. Measuring voltage T5 load 2 lights and fan of LED and 2 CPU fans and aim to get round a turbine and generator as well as the efficiency of the turbine and the generator on load 2 LEDs and 2 CPU fans.

4. PROBLEM IDENTIFICATION

4.1 Data and Analysis of Testing Power Generator

From the measurement results using a multi tester and tachometer on micro hydro retrieved data as follows:

1. For lamp obtained without load: Generator spin (n1): 1299 rpm, Rotation of the turbine (n2): 433 rpm, Generator voltage: 24 Volt.
2. For T2 with weight 1 LED light is obtained: Generator spin (n1): 1076 rpm, Rotation of the turbine (n2): 358.6 rpm, Generator voltage: 19 Volt, Generator current: 0.069 Ampere.

From the results of data retrieval in field which consists of the turbine, the voltage and current is generated by a generator, can be taken into account at each load generator power. Using the formula: P = I × V where: P: power (Watts) I: current (Ampere) v: Voltage (Volt) and found in Table 1.

Table 1. Experiment result data

No.	Generator spin (rpm)	Rotation of turbine n2 (Rpm)	Voltage(V)	Current (A)	Power (Watt)
1.	1076	358.6	19	0.069	1.311
2.	884.7	295	16	0.108	1.728
3.	717.3	239	15	0.17	2.55
4.	583	194.3	10	0.31	3.1

4.2 The Results of Twist Moment

The twist occurs at the moment of the generator and turbines at each addition of load, as follows:

$T = 9{,}47 \times 10^5$ (P/n) where: T = Torque Twist (kg.mm) P = Power Generator (kW) n = Round Generator and Turbine (rpm) and results of the analysis calculation of the twist moment on generator above can be created in a table as follows:

Table 2. Twist moment

Number of Loads	Power(Watt)	Generator spin(rpm)	Rotation of Turbine(rpm)	Twist Moment of Generator(kg.mm)	Twist Moment of Turbine(kg.mm)
1	1.311	1076	358.6	1.186	3.560
2	1.728	884.7	295	1.902	5.705
3	2.55	717.3	239	3.462	10.392
4	3.10	583	194.3	5.179	15.539

4.3 Turbine Shaft Efficiency and Shaft Generator Efficiency

The efficiency of the turbine and generator shafts are taken to determine the performance of turbines and generators are designed and analysed the turbine and the generator can work properly and in accordance with the calculation of the design of the turbine.

4.3.1 Turbine shaft efficiency

Before determining the efficiency of the turbine and generator, must be in advance estimate as follows:

1. Turbine Power Calculation:

a. Power Turbine Shaft time without Load (P1pt):

$$P1_{pt} = \frac{\frac{1}{8} m_{pt} {D_{pt}}^2 (\omega_{pt})^2}{t} \tag{1}$$

where,

m_{pt} = Turbine Mass $= 3\text{Kg}$
D_{pg} = Diameter of Turbine Shaft $= 12 \text{ mm} = 0.012$
n_{pg} = Turbine Shaft Rotation $= 358.6\text{rpm}$

From equation:

t = Time 1 minute $= 60$ second

$$\omega = \frac{\theta_{pt}}{t} \tag{2}$$

$$\theta_{pt} = 2\pi n_{pt} \tag{3}$$

where,

ω = the turbine shaft angular speed (rad/s)
θ_{pt} = amount of the angle (rad) SO:

Obtained:

$$\omega = \frac{2\pi n_{pt}}{t} = \frac{2x3{,}14x(433)}{60} = 45{,}32\text{rad/s}$$

$$P1_{pt} = \frac{\frac{1}{8} m_{pt} D_{pt}^2 (\omega_{pt})^2}{t}$$

$$P1_{pt} = \frac{\left(\frac{1}{8}x3\right)x(0{,}012^2)x(45{,}32^2)}{60} = 0{,}0018\text{watt}$$

b. Power Turbine Shaft with Load 1 LED light $(\mathbf{P2_{pt}})$:

With the same formula:

$$P2_{pt} = \frac{\left(\frac{1}{8}x3\right)x(0{,}012^2)x(37{,}533^2)}{60} = 0{,}00126\text{watt}$$

c. Power Turbine Shaft with Load 2 LED lights $(\mathbf{P3_{pt}})$:

With the same formula:

$$P3_{pt} = \frac{\left(\frac{1}{8}x3\right)x(0{,}012^2)x(30{,}876^2)}{60} = 0{,}000858\text{watt}$$

d. Power Turbine Shaft with 2 LED lamps and 1 fan $(P4_{pt})$:

With the same formula:

$$P4_{pt} = \frac{\left(\frac{1}{8}x3\right)x(0{,}012^2)x(25{,}000^2)}{60} = 0{,}00056\text{watt}$$

e. Power Turbine Shaft with 2LED lamps and 2 fans $\text{CPU}(\text{P5}_{\text{pt}})$:

With the same formula:

$$P5_{pt} = \frac{\left(\frac{1}{8}x3\right)x(0{,}012^2)x(20{,}336^2)}{60} = 0{,}000372\text{watt}$$

2. Calculation of the Shaft Power Generator:

a. Power Shaft Generator Without Load:

$$P1_{pg} = \frac{\frac{1}{8}m_{pg}{D_{pg}}^2(\omega_{pg})^2}{t} \tag{4}$$

Where:

$$\begin{aligned}
m_{pg} &= \text{TurbineMass} = 0{,}3\text{Kg}\\
D_{pg} &= \text{DiameterofTurbineShaft} = 10\text{ mm} = 0{,}010\\
n_{pg} &= \text{TurbineShaftRotation} = 1299\text{rpm}\\
t &= \text{Time1minute} = 60\text{second}\\
\omega &= \frac{2\pi n_{pg}}{t} = \frac{2x3{,}14\times(1299)}{60} = 136\text{rad/s}
\end{aligned}$$

Obtained:

$$\begin{aligned}
P1_{pg} &= \frac{\frac{1}{8}m_{pg}{D_{pg}}^2(\omega_{pg})^2}{t}\\
P1_{pg} &= \frac{\left(\frac{1}{8}x0{,}3\right)x(0{,}010^2)x(136^2)}{60} = 0{,}0011\text{watt}
\end{aligned}$$

b. Shaft Power Generator with Load 1 LED light 2_{pg} :

With the same formula:

$$P2_{pg} = \frac{\left(\frac{1}{8}x0{,}3\right)x(0{,}010^2)x(112{,}621^2)}{60} = 0{,}000792\text{watt}$$

c. Shaft Power Generator with Load 2 LED lights 3_{pg} :

With the same formula:

$$P3_{pg} = \frac{\left(\frac{1}{8}x0,3\right)x(0,010^2)x(92,60^2)}{60} = 0,00053\text{watt}$$

d. Shaft Power Generator with Load 2 LED lights and 1 fan CPU P4 4_{pg} :

With the same formula:

$$P4_{pg} = \frac{\left(\frac{1}{8}x0,3\right)x(0,010^2)x(75,077^2)}{60} = 0,00035\text{watt}$$

e. Shaft Power Generator with Load 1 LED lights 5_{pg} :

With the same formula:

$$P5_{pg} = \frac{\left(\frac{1}{8}\times 0,3\right)x(0,010^2)x(61^2)}{60} = 0,00023\text{watt}$$

From the above calculation can be obtained appropriate turbine efficiency turbine rounds on each of the given load on the generator as follows:

1. Efficiency turbine without loads is:

$$\eta_T = \frac{P_{pg}}{P_{pt}} \times 100\%$$
$$\eta_T = \frac{0,0011}{0,0018} \times 100\% = 61\%$$

2. Efficiency of the turbine with a Load of 1 LED light is:

$$\eta_T = \frac{0,000792}{0,00126} \times 100\% = 62,85\%$$

3. Efficiency of the turbine with a load of 2 LED lights are:

$$\eta_T = \frac{0,00053}{0,00085} \times 100\% = 62,35\%$$

4. Efficiency of the turbine with Load 1 LED lights and 1 CPU Fan are:

$$\eta_T = \frac{0,00035}{0,00056} \times 100\% = 62,50\%$$

5.Efficiency of the turbine with Load 1 LED lights is:

$$\eta_T = \frac{0,00023}{0,00037} \times 100\% = 62,16\%$$

4.4 Efficiency the end of a Generator

$$\eta_G = \frac{I_G}{I_{Max}} \times 100\%$$

where,

I_G = the resulting current of generator when experiment (0.32 Ampere)
I_{Max} = the maximum current that can be generated by the generator (0.80 Ampere)

$$\eta_T = \frac{0,32}{0,80} \times 100\% = 40\%$$

So the obtained efficiency at generator by 40%, the generated power is electric power and can help savings and performance of auxiliary engines on ships.

4.4 The Planned Micro Hydro System

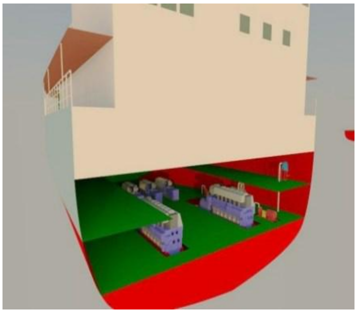

Fig. 8. 3D Form with Sketch up

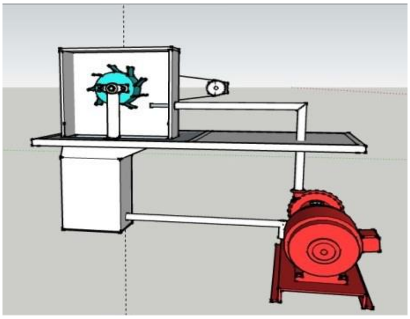

Fig. 9. Micro hydro System with 3D Sketch up

5. CONCLUSION

Electricity produced by the generator on the prototype on the ship for a micro hydro is 0.31 Ampere maximum electrical current from the results that can be generated by the generator of 0.80 Ampere. Testing of the prototype on the ship for a micro hydro efficiency is gained by 61%. Testing of the prototype on the ship for a micro hydro generator efficiency is obtained by 40%. Thus it can be stated that by using this ship micro hydro power can save energy up to 40%.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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