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# Design of Solar Powered Cooling Engine For Fishing Vessel ≤ 5 GT

Didit Eko Setiawan[1], Budhi Hascaryo[2], Fis Purwangka[2], Vita Rumanti[3], Ari Purbayanto[4], Berbudi Wibowo[5]

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***Abstract* - The fishermen in Sendang Biru, Malang, East Java Province, Indonesia, using boat ≤5 GT, specifically an outrigger boat with 10,6 m Length of Overall (LoA), 1,3 m Breadth (B), and 0,7 m Depth (D), have experienced low priced fish catches for many years caused by low quality of fish handling on board. In this research, the researcher overcomes the problem by designing the solar powered cooling engine (SPCE) to maintain the caught fish quality on boat ≤5 GT, especially the boat with outrigger and size as previously mentioned. Meanwhile, the outrigger boat as mentioned above has limited in term of its space and its capacity on board. The research designed the SPCE that fitted to space and capacity of the outrigger boat. The stability of the boat had been analyzed by using IMO resolution on "IMO A.749 (18) Chapter 3". The result of the analyses showed that the SPCE designed met the IMO criteria applicable to all ships, which has GZ Max 0,492 m at 25.5°, and as the general arrangement of the SPCE on the boat, the SPCE device put in the middle of the boat while in the back part of the boat is fisher working area.**

*Keywords: low quality of fish handling, limited in term of its space and its capacity, IMO resolution*

## I. INTRODUCTION

The good quality of caught fish is one of the determining factors its price. The better the quality of fish, the higher of its price. One of the indicators of the good quality of fish is its freshness, which is stated in the standard for Fish Freshness Standar Nasional Indonesia (SNI) or Indonesia National Standard 2729: 2013. It is stated that fish fresh is fish that have not undergone preservation treatment except chilling.

According to that, it is important for fishers to put ices on boat for chilling process of caught fish. Fish handling process should meet the criteria of good facility and good technique. The good handling technique is a technique of preserving fish after being caught to avoid decay which can result in organoleptic, chemical and physical quality degradation that affects prices [1]. Fish handling is directly proportional to the price. The better the handling, the higher the selling price.

One of the fish landing places in Indonesia is Pondok Dadap Fishery Port which is located in Sendang Biru Village, Malang Regency, East Java province, Indonesia. Pondok Dadap Fishing Port is one of the Fishery Port in Wilayah Pengelolaan Perikanan Negara Republik Indonesia (WPPNRI) 573. According to Minister of Marine and Fisheries Affairs decree no 19 Year 2022 about the Estimation of Resource Potential, Total Allowable Catch and Fish Resource Utilization Rate, there are 354.215 tons of potential resource of tunas, skipjacks and cobs in WPPNRI 573. Especially tunas, there are 3.546,4 tons landed in Pondok Dadap Fishery Port per year [2]. Yet, there are 69% of tunas landed in Pondok dadap Fishery Port only be sold in domestic market. They did not meet the export criteria [3]. The difference price between export product and domestic product is very high. The selling price of tuna for export is Rp55,000.00 at the production level, while tuna sold for domestic market is Rp18,000.00 – Rp25,000.00 per kilogram [3]. The facts shows that the fishers should improve fish handling quality to get better price and meet the export criteria.

Tuna has characteristic its temperature increases fast after got caught. In order to preserve its freshness, the fishers should do two stages of handling as follows [1]: 1) to decreases tuna temperature by putting it into cooled sea water. By applying this method, the entire surface of tuna will be submerged and there will be direct contact with cooled seawater; 2) to move into cold storage after twenty-four hours. These handling methods can be implemented on fishing vessel size more than > 5 gross tonnage (GT) because such fishing vessel can load cold storage on board. This situation is completely different for small fishing vessel especially with size less than ≤ 5 gross tonnage (GT) due to limited capacity and space.

There are about ±300 small fishing vessel less than ≤ 5 gross tonnage (GT) in Sendang Biru village, Malang regency, East Java province, Indonesia. These fishing vessels use outrigger and sized ±10,6 m Length of Overall (LoA), ±1,3 m Breadth (B), and ±0,7 m Depth

Didit Eko Setiawan, Teknologi Perikanan Laut, Fakultas Perikanan dan Ilmu Kelautan IPB University, Bogor, 16680, Indonesia. E-mail: di2t.setiawan@gmail.com
Budhi Hascaryo, Teknologi Perikanan Laut, Fakultas Perikanan dan Ilmu Kelautan IPB University, Bogor, 16680, Indonesia.
Fis Purwangka, Teknologi Perikanan Laut, Fakultas Perikanan dan Ilmu Kelautan IPB University, Bogor, 16680, Indonesia.
Vita Rumanti, Teknologi Perikanan Laut, Fakultas Perikanan dan Ilmu Kelautan IPB University, Bogor, 16680, Indonesia.
Ari Purbayanto, Teknologi Perikanan Laut, Fakultas Perikanan dan Ilmu Kelautan IPB University, Bogor, 16680, Indonesia.
Berbudi Wibowo, Politeknik AUP Jakarta, 12520, Indonesia.

(D). In this research we called outrigger boat. The outrigger boats operate one day fishing only. In order to improve fish handling quality for this kind of vessel, this research designs solar powered cooling engine (SPCE) [4] as the implementation of stage 1 [1] as mentioned above. The problem is, the outrigger boat has limited capacity and space. It means the solar powered cooling engine must fit and suitable for this kind of boat. The addition of these equipment affects the stability of the boat, for that the additional load of the equipment needs to be designed for placement on board and tested for the stability of the boat.

In order to check whether the designed device meet the stability criteria of the vessel, we use the International Maritime Organization (IMO) resolution A.749 (18) Chapter 3 [5].

## II. METHOD

### A. Materials and tools

Materials in this research are cool box, compressor, condenser, evaporator, sea water, solar panel, solar charge controller, battery, and cables. Tools used are meter gauge, small drill, electric welder, pliers, and screwdriver.

### B. Time and Location

The research was conducted on June – December 2023 in Sendang Biru village, Malang Regency, East Java province. The design of Solar Panel Cooling Engine was conducted in Institut Pertanian Bogor (IPB) University.

### C. Design of Solar Powered Cooling Engine

#### 1) Cooling Engine

Furthermore, the design of solar powered cooling engine will separate between the cooling engine and the fish storage box. The fish storage box, which is a fish storage area, will be given seawater [6] as much as half of the capacity of the fish storage box. The sea water, as the load, will be pumped into the cooling engine. The temperature of sea water in the cooling engine will be lowered to 4° C, which refers to Standard Nasional Indonesia (SNI) or Indonesia National Standard 2729:2013. When the cooling machine is fully filled with seawater, then the seawater will be flowed back into the fish storage box. This circulation process is a continuous process. This scheme can be seen at figure 1.

The cooling engine needs electric power and, in this research, the electric power is generated from solar energy. The amount of electrical energy needed actually is the same with the energy of cooling engine to cool the sea water until 4° C. The electric power is calculated by the following formula:

$$Q_t = Q_1 + Q_2 \quad (1)$$

$Q_t$ = total load
$Q_1$ = product load
$Q_2$ = wall heat load

Product load ($Q_1$) can be determined by the following formula:

$$Q_1 = m \times C \times \Delta t \quad (2)$$

Q is the product cooled load, in order to lower sea water temperature from 30° C to 4° C. **m** stands for mass, the amount of seawater in kilogram, C stands for heat specific, and *Δt* is difference of temperature to be changed from normal temperature to certain temperature.

Wall heat load ($Q_2$) is the load that consider the heat comes from outside, like sun exposure, affected the wall of cooling engine. It can be calculated by following formula:

$$Q2 = UA\,(T_a - T_r) \quad (3)$$

U = total heat transfer coefficient (Watt/$m^2$ $^0$C)
A = area of wall ($m^2$)
$T_a$ = temperature outside ($^0$C)
$T_r$ = temperature inside ($^0$C)

$$U = \frac{1}{\frac{1}{ha} + \frac{x1}{k1} + \frac{x2}{k2} + \frac{x3}{k3} + \frac{1}{hb}} \quad (4)$$

ha = coefficient of convection heat transfer of the wall surface (W/$m^2$°C)
hb = coefficient of convection heat transfer of the roof surface (W/$m^2$°C)

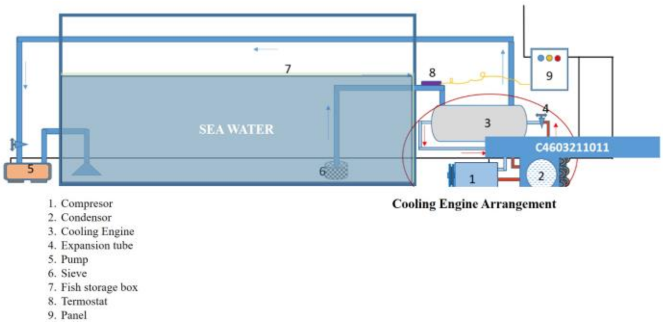


Figure 1.

x = material thickness
k = material conductivity

2) Solar Panel

The electrical energy required to cool the load will be equal to the total amount of the load. In this research, the electrical energy will be generated by solar panel or photo voltaic. One piece of photo voltaic will generate at least 3 or 4 times of energy, it depends on the location. Electrical energy generated from solar energy will be stored in the battery.

Required number of solar panels can be calculated by following formula:

$$\frac{\text{Energy required by electrical load}}{\text{Energy produced by one photo voltaic x peak of solar radiation}} \quad (5)$$

The electrical energy generated by solar panels stored in the battery. The battery capacity should be higher than the load energy due to the Depth of Discharged (DOD) battery only 50% or more depends on the type of battery used.

3) Outrigger boat stability

Design of solar powered cooling engine should be based on: the size of the outrigger boat, fish storage box capacity, the length of fishing time, and the targeted fish. The outrigger boat has ±10,6 m Length of Overall (LoA), ±1,3 m Breadth (B), and ±0,7 m Depth (D) as can be seen in figure 2. The size and capacity of the boat is quite small so that the placement of solar powered cooling engine should be planned and arranged well [7]. The placement of solar powered cooling engine on outrigger boat must pay attention to boat stability, which refers to International Maritime Organization (IMO) resolution A.749 (18) Chapter 3 [8] as follows:

a. The area under the static stability curve to an angle of 30º should not be less than 0.055 meters radians;
b. The area under the static stability curve to an angle of 40º should not be less than 0.09;
c. The area between the 30º to 40º angles should not be less than 0.03 meters radians, where the room on the deck will be submerged with the heel angle;
d. The maximum value of righting lever (GZ) should be achieved at an angle of not less than 30º and
e. The maximum angle of stability should be more than 25º;
f. The initial GM value should not be less than 0.35 meters.

Stability itself is a Stability is the balance of the vessel, is a trait or tendency of a ship to return to its original position after getting the angle (slope) that caused by external forces.

Stability of the outrigger boat will be tested using IMO resolution based on 3 (three) different load condition. First condition is load of: outrigger boat, fisher, fish storage box, fishing gear, ices, propulsion engine, fuel tank, small generator set. Second condition is first condition plus caught fish, and third condition is second condition plus solar powered cooling engine but minus ices.

We need to test 3 (three) load conditions on outrigger boat to get the level of stability of the outrigger boat. The test results for the 3rd load largely determine whether the addition of a solar-powered cooling engine meets the stability criteria required by IMO.

## III. Results and Discussion

### 1. Design of Cooling Engine

Fisher needs fish storage box usually with 200 liters, equivalent with 150 kg capacity, for keeping caught fish during fishing operation. They operate one day fishing from two o'clock in the early morning until at least four o'clock in the afternoon. The trip to fishing ground takes 2 to 3 hours. After reaching fishing ground, the fishers set the fishing gears. One moment later, they begin fishing. This activity takes 8 hours during daylight. They catch tuna, skipjack, and mackerel tuna. It means the designed machine should cover 8 hours operation during fishing to cool the caught fish.

Based on formula (2), seawater specific heat is 4,011 KJ/Kg ºK and the targeted temperature of sea water to be cooled is 4º C. The sea water as the cooling media should be put in the fish storage box which is around equivalent to 75 kg. The sea water temperature is about 30 º C and the targeted temperature of cooled sea water is 4 º C.

Known from the specification above as follows:

TABLE 1. DETERMINATION OF THE NUMBER OF SOLAR PANELS

| | The Size of PV in the market (WP) | Duration of Solar Irradiation in East Java Province (hrs) | Number of PV |
|---|---|---|---|
| 1. | 50 | 4 | 20 |
| 2. | 100 | 4 | 10 |
| 3. | 150 | 4 | 7 |
| 4. | 200 | 4 | 5 |
| 5. | 250 | 4 | 4 |
| 6. | 300 | 4 | 5 |
| 7. | 545 | 4 | 2 |

Energy 3.986,21 Watt

m (sea water) = 75 Kg
c (sea water) = 4,011 KJ/Kg °K
$\Delta t$ = 30 ° C - 4° C = 26° C

then by applying formula (2), the product load ($Q_1$) is 1.558,48 Watt.

The wall heat load of cooling machine has been calculated by applying formula (3). The cooling machine size is 47 cm x 47 cm x 47 cm. The sea water temperature is 30° C and targeted temperature is 4° C. There are 6 walls that are the same size consist of 4 walls on the side, 1 wall on the roof, and 1 wall below.

A (area of wall) = 47 cm x 47 cm = 2.209 $cm^2$
Total six wall (A) = 6 x 2.209 = 13.254 $cm^2$
Δt = 30° C– 4° C = 26° C
ha = 56,942 $w/m^2$ °C
hb = 56,942 $w/m^2$ °C
$x_1$ = fiberglass 12 mm, k = 0,035 W/m2 °C
$x_2$ = polyurethan 12 mm = k = 0,023 W/m °C
By applying formula (3) and (4) so the result is
Q2 = UA ($T_a$-$T_r$)
A = 0.1681 $m^2$, Δt = 26° C

$$U = \frac{1}{\frac{1}{4.628}+\frac{0.6}{0.035}+\frac{1.2}{0.023}+\frac{0.6}{0.035}+\frac{1}{4.628}} = 36{,}007 \text{ Watt}$$

The total load can be counted by formula (1) and the result is 1.558,48 + 36,007 = 1.594,48

2. Solar Panel

According to map of potential of solar energy in East Java, the duration of solar irradiation in East Java Province ranges from 4,4 – 8,9 hours / day and for Malang Regency the potential level of solar energy ranges from 4 – 5 kWh / $m^2$ [9] as figure 2.

Based on previous calculation, the load to be cooled is 1.594,48 Watt. It means the electrical energy generated by solar panel should be more or same with the total load.

As mentioned above, the trip from fishery port to fishing ground takes ±2,5 hours. The energy needed to cool the sea water for 2,5 hours is 3.986,21 Watt. The solar panel, or we call it photo voltaic (PV), needs 3.986,21 Watt to keep it in the battery. By applying formula 5, we can have an option as table 1.

Energy required = 3.986,21 Watt
Optimum power of solar radiation = 4 hours
Per hours need = $\frac{3.986,21}{4}$ = 996,55 watt

The use of photo voltaic should not be much due to lack of space and capacity on outrigger boat, so solar panels are chosen that have a large capacity but the amount needed is small. By choosing photo voltaic 545watt peak, there are only need 2 PVs. The fewer the number of solar panels used, the better for the limited space on board.

As in table 1, the two photo-voltaic, each 545watt peak (WP), are chosen in this design. The total electrical energy generated by using two photo voltaic is 1.090 Watt. According to the map of potency of solar energy in Malang regency, East Java province, the maximum duration solar irradiation is 4 hours. It means the electrical energy generated by two photo voltaic will be 4360 Watt.

Furthermore, the electric power generated by photo voltaic is a direct current (DC), meanwhile the cooling engine uses alternating current (AC) input. So that, we must convert DC to AC electric by using the inverter.The inverter is needed in this design. The Pure Sine Wave (PSW) inverter type is chosen in this research due to efficiency up to 95%. We need to add 5% to the required energy as the loss factor of the inverter.

Energy with loss factor 5% = 3.986,21 + (5% x 3.986,21) = 4.185,52 Watt.

The following step is to determine the number of batteries used. Due to small capacity of outrigger boat, we must choose the battery with high power but take minimum space. In this research we use battery with capacity 48 Volt/100 Ah and its power is 4800 Ah. The number of batteries used is:

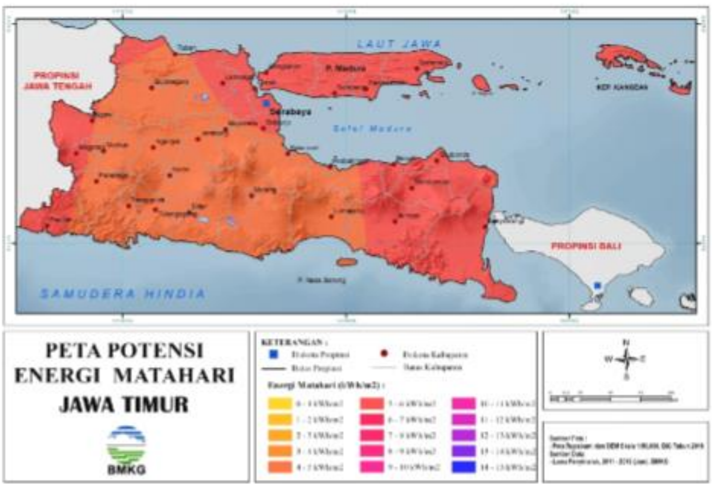

Figure 2. The potency of solar energy in East Java Province

$n = \frac{4.185,52}{4.800}$ = 0,87 battery

There are two types of battery, which are: VRLA (valve regulated lead acid) and LifePo (lithium ferro phosphate). VRLA battery has 50% of Depth of Discharge (DoD) and LifePo has up to 80% of DoD. The depth of discharge (DoD) of a battery indicates the percentage of the battery that has been discharged relative to the overall capacity of the battery.

In this research, we use LifePo battery which is its efficiency up to 80%. The Depth Of Discharge (DOD) LifePO battery can be up to 100% but only up to 80% is recommended.

Number of LifePo battery = $\frac{0,87}{80\%}$ = 1,08~ 1. In this research we use 1 battery LifePo.

The following tool is Solar Charge Controller (SCC), which has function to regulate current flows from photo voltaic to battery, to avoid battery damage due to excess voltage. There are two types of SCC, first is Pulse Width Modulation (PWM) and second is Maximum Power Point Tracking (MPPT). In this research, MPPT is chosen due to efficiency up to 95%.

By using the designed device, the fisher operated his boat that had been equipped with solar-powered cooling devices with the result that seawater could be cooled to a temperature of 4 degrees Celsius within two hours and 30 minutes. The fisher started to operate his boat on 2 o'clock A.M and came back at 4 P.M and there were 60 kg of fish caught with fresh condition.

TABEL 2. LOAD BOAT – FIRST CONDITION

| Item Name | Quantity | Mass (kg) | Total Mass (kg) | Long. Arm m | Trans. Arm m | Vert. Arm m |
|---|---|---|---|---|---|---|
| Lightship | 1 | 700,0 | 700,0 | 6,000 | 0,000 | 0,600 |
| Fisher | 1 | 70,0 | 70,0 | 6,000 | 0,000 | 1,500 |
| Fish storage box | 1 | 10,0 | 10,0 | 5,000 | 0,000 | 1,200 |
| Fishing gears | 1 | 20,0 | 20,0 | 5,500 | 0,000 | 1,000 |
| Ice | 1 | 270,0 | 270,0 | 3,000 | 0,000 | 1,500 |
| Caught fish | 1 | 0,0 | 0,0 | 4,000 | 0,000 | 1,000 |
| Engine 1 | 1 | 20,0 | 20,0 | 1,400 | -0,550 | 1,300 |
| Engine 2 | 1 | 20,0 | 20,0 | 1,400 | 0,550 | 1,300 |
| Genset | 1 | 51,0 | 51,0 | 3,000 | 0,000 | 1,500 |
| Fuel tank | 100% | 22,7 | 22,7 | 1,800 | 0,000 | 0,325 |
| Total Load case | | | 1183,7 | 4,934 | 0,000 | 0,946 |

TABLE 3. STABILITY CRITERIA LOAD CASE 1

| Code | Criteria | Value | Units | Actual | Status | Margin % |
|---|---|---|---|---|---|---|
| A.749(18) Ch3 - Design criteria applicable to all ships | 3.1.2.1: Area 0 to 30 | 3,1513 | m.deg | 13,8856 | Pass | +340,63 |
| | 3.1.2.1: Area 0 to 40 | 5,1566 | m.deg | 22,8338 | Pass | +342,81 |
| | 3.1.2.1: Area 30 to 40 | 1,7189 | m.deg | 8,9482 | Pass | +420,58 |
| | 3.1.2.2: Max GZ at 30 or greater | 0,200 | m | 0,899 | Pass | +349,50 |
| | 3.1.2.3: Angle of maximum GZ | 25,0 | deg | 30,9 | Pass | +23,64 |

3. Outrigger Boat Stability

The addition of solar powered cooling engine should be arranged on small boat, with lack of space, correctly. During catch operation, fisher is in the back area of the boat to drive the boat and start fishing.

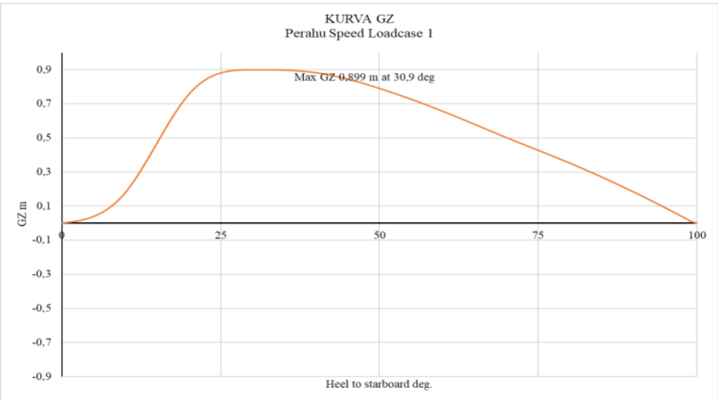


Figure 3. GZ curve load case first condition

When fish are caught, the fisher put the caught fish inside the storage box, which is placed in the middle of the boat. According to this activity, the cooling engine will be placed in the middle of the boat include the solar panel.

The addition of a solar powered cooling engine to outrigger boats will increase the load and it will affect the boat stability. The boat stability will be tested based on three conditions using International Maritime Organization (IMO) resolution A.749 (18) Chapter 3.

a. First Condition

First condition of the load is the load of the boat without caught fish. It was a burden at the time the boat departed for the fishing grounds. Total load for the first condition is 1.183,7 kg as it can be seen at table 2.

According to IMO Criteria, the stability of outrigger boat, without caught fish load, can be seen in table 3. It shows that all criteria pass. It has GZ value 0,2 m at 30° and maximum GZ at angle 25° which can be seen at figure 3. This means the outrigger boat stability meet the criteria on International Maritime Organization (IMO) resolution A.749 (18) Chapter 3.

b. Second Condition

The second condition is the same as the first condition but added the load of fish caught. It was a burden at the time the boat came back from fishing ground. Fish storage box, which fisher carry on outrigger boat, can hold 150 kg of fish, but in the season, fisher can catch up to 400 kg of fish. In this research we consider the figure of 400 kg to be used as the maximum number of fish caught as maximum loaded fish caught.

So that total load of the outrigger boat is 1.583,7 kg as it can be seen at table 4. Under this circumstance, the outrigger boat must be tested based on IMO criteria because there is additional load the fish caught on board.

According to IMO Criteria, the outrigger boat has GZ value 0,2 m at $30^0$ and maximum GZ at angle $25^0$ which can be seen at table 5 and figure 4. It means the second condition, in which there are 400 kg of fish caught, meets the IMO criteria. The stability of the outrigger boat still meets the required standard after they came from fishing.

c. Third Condition

Equal treatment has been done for the third condition. The third condition is the condition where fisher finished fishing and departure from fishing ground to the fishing port. All materials related to cooling engine and solar panel has been put on board which means increasing the weight of the boat. The addition of solar powered cooling engine makes the total load becomes 1.698,7 kg as be seen in table 6. Total load of equipment related solar powered cooling engine is about 106 kg. It is very important to test the third load condition with IMO Criteria. Through this study, it will be tested whether the solar-powered cooling engine made will meet the boat's stability criteria because the boat quite small and lack of space.

TABLE 5. STABILITY CRITERIA LOAD CASE 2 (SECOND CONDITION)

| **Code** | **Criteria** | **Value** | **Units** | **Actual** | **Status** | **Margin %** |
|---|---|---|---|---|---|---|
| A.749(18) Ch3 - Design criteria applicable to all ships | 3.1.2.1: Area 0 to 30 | 3,1513 | m.deg | 9,1806 | Pass | +191,33 |
| | 3.1.2.1: Area 0 to 40 | 5,1566 | m.deg | 14,4047 | Pass | +179,34 |
| | 3.1.2.1: Area 30 to 40 | 1,7189 | m.deg | 5,2241 | Pass | +203,92 |
| | 3.1.2.2: Max GZ at 30 or greater | 0,200 | m | 0,550 | Pass | +175,00 |
| | 3.1.2.3: Angle of maximum GZ | 25,0 | deg | 26,4 | Pass | +5,46 |

TABLE 6. LOAD BOAT THIRD CONDITION

| **Item Name** | **Qty** | **Unit Mass kg** | **Total Mass kg** | **Long. Arm m** | **Trans. Arm m** | **Vert. Arm m** |
|---|---|---|---|---|---|---|
| Second Condition | | | 1583,7 | 5,140 | 0,000 | 0,946 |
| Solar Panel | 1 | 70,0 | 70,0 | 3,000 | 0,000 | 2,000 |
| Cooling box | 1 | 5,0 | 5,0 | 6,000 | 0,000 | 1,500 |
| Frame | 1 | 25,0 | 25,0 | 6,000 | 0,000 | 1,500 |
| Condensor and evaporator | 1 | 20,0 | 20,0 | 6,000 | 0,000 | 1,500 |
| Solar charger controller | 1 | 25,0 | 25,0 | 5,000 | 0,000 | 1,500 |
| Battery | 1 | 20,0 | 20,0 | 5,000 | 0,000 | 1,500 |
| Sea water | 1 | 100,0 | 100,0 | 7,500 | 0,000 | 1,500 |
| Box panel of battery and SCC | 1 | 80,0 | 80,0 | 5,000 | 0,000 | 1,500 |
| Evaporator box | 1 | 40,0 | 40,0 | 6,000 | 0,000 | 1,500 |
| Fuel tank | 100% | 22,7 | 22,7 | 1,800 | 0,000 | 0,325 |
| Total Load case | | | 1698,7 | 5,566 | 0,000 | 0,969 |

TABLE 7. STABILITY CRITERIA LOAD CASE 3 (THIRD CONDITION)

| Code | Criteria | Value | Units | Actual | Status | Margin % |
|---|---|---|---|---|---|---|
| A.749(18) Ch3 - Design criteria applicable to all ships | 3.1.2.1: Area 0 to 30 | 3,1513 | m.deg | 8,1908 | Pass | +159,92 |
| | 3.1.2.1: Area 0 to 40 | 5,1566 | m.deg | 12,8254 | Pass | +148,72 |
| | 3.1.2.1: Area 30 to 40 | 1,7189 | m.deg | 4,6346 | Pass | +169,63 |
| | 3.1.2.2: Max GZ at 30 or greater | 0,200 | m | 0,492 | Pass | +146,00 |
| | 3.1.2.3: Angle of maximum GZ | 25,0 | deg | 25,5 | Pass | +1,82 |

When operating fishing, the fisher is in the position of the back of the boat. Likewise, when starting fishing, the fisher's position is in the same place. The fisher moves to the middle of the boat section to move fish caught from the sea into the fish storage area. When the fish is caught, the fisher moves to the center of the boat to take the fish from the sea and move it into the fish storage box. It means these two places on board, back and middle of the boat, are the working area of fisher.

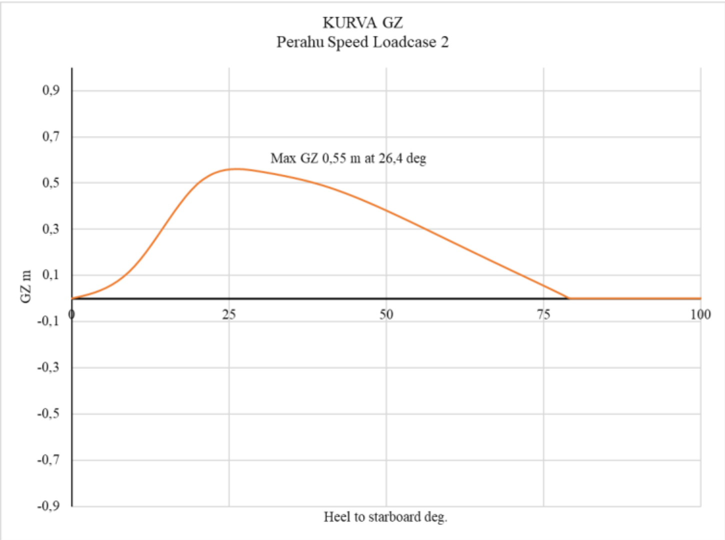


Figure 4. GZ curve load case second condition

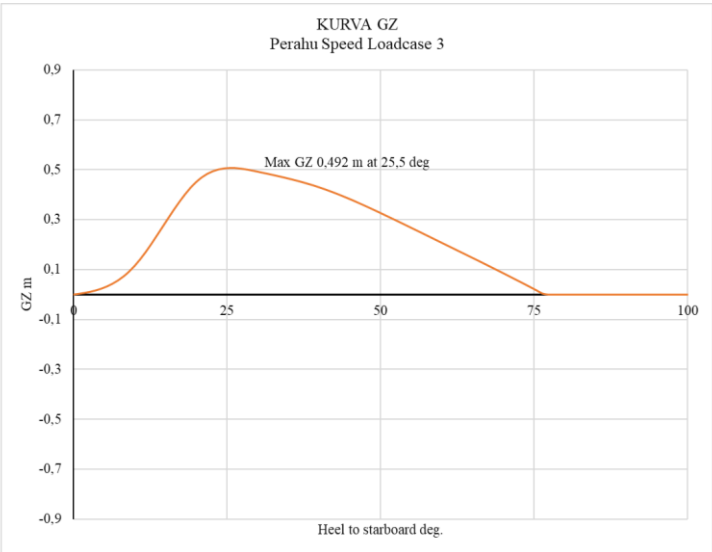


Figure 5. GZ curve load case third condition

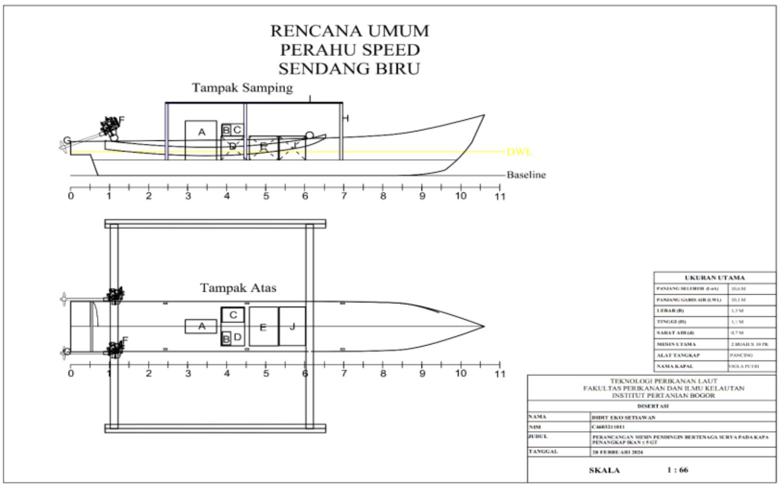


Figure 6. General arrangement of outrigger boat with solar powered cooling engine

Furthermore, according to IMO Criteria, the stability of the boat passes IMO Criteria test which is GZ value 0,2 m at $30^0$ and maximum GZ at angle $25^0$ as be seen in table 7 and figure 5.

In this design, the cooling engine is placed in the middle of the boat together with the fish storage box and two solar panels as a roof on it. This design pays attention to the effectiveness of space on board the boat and also pays attention to the habits of fisher. The general arrangement outrigger boat with solar powered cooling engine can be seen in figure 6.

According to this research, it is possible to put a solar-powered cooling engine on an outrigger vessel measuring ±10,6 m Length of Overall (LoA), ±1,3 m Breadth (B), and ±0,7 m Depth (D) with total load maximum 1.698,7 kg including fisher, caught fish, solar powered cooling engine, outrigger boat itself with two machines, fishing gear and diesel fuel.

The design of a solar-powered cooling engine placed on a ≤5 GT outrigger boat is a novelty of this research.

## IV. Conclusion

Based on the analysis that has been carried out, the research results the solar powered cooling engine on outrigger boat as follows:

a. The solar-powered cooling engine consists of two units of solar panel each 545 WP; 1 unit of battery of LifePo with specification 48 V/100 Ah; 1 unit of inverter SCC type MPPT; 1 unit of cooling engine; 1 unit of fish storage box;

b. The solar powered cooling engine can cool seawater to a temperature of 4 (four) degrees celcius with a duration of 2 (two) hours and 30 minutes;

c. On outrigger boat, measuring ±10,6 m Length of Overall (LoA), ±1,3 m Breadth (B), and ±0,7 m Depth (D), can be given solar-powered cooling engine with weight 285 kg;

d. the addition of load of solar powered cooling engine is still meet the IMO standard requirement related to boat stability; which GZ value is 0,2 m at $30^0$ and maximum GZ at angle $25^0$

e. the general arrangement of the outrigger boat with solar powered cooling engines is as follows:

1) Working area
Fisher works area is in the back and middle part of the boat.
2) Fish storage area
Fish storage box put in the middle part of the boat.
3) Solar powered cooling engine area
Solar powered cooling engine put in the middle part of the boat.

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