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Design Analysis in the Application of Solar Energy for Crossing River HDPE Boat

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Abstract. Solar energy become alternative in the provide power for many transportation modes. It is also growing fast in the sea transportation such as ship and boat. The lack of solar power is relatively low power output instead of the free in prices. In the other hand, to get higher power then such as energy sources need bigger plant area. Therefore, one of the solution that will be explore in this study is using lighter boat material such as HDPE to lowering draft and in consequently should lowering hull resistance. Combined latest solar cell technology and lightest HDPE material may present a better design in term of technical and economic aspects. A double impact for green earth campaign by a good combination of renewable energy and environmentally friendly materials. This work uses a 15 meter crossing river boat as case study. The proposed design analyzed to perform as many owner requirements as possible to serve in the certain crossing river area. Also there will be comparative study with the other ship material commonly used such as fiberglass and aluminum.

INTRODUCTION

Fast growing of citizens in the big city come simultaneously with the problems of traffic congestions. Roads consequently no more accommodate the traffics, in daily, during office times the citizens have culminated into delayed and unpredictable travel times, excessive loss of energy, and loss of veritable man hour [4]. Fortunately, a big city commonly be split by a river. River is main part of the civilization development (*UNESCO*). Many ancients use their river not only for water reservoir but also as a transportation way. In this modern age the river still become a potential water-road in so many big cities around the world. Cities have long been preferentially located on rivers, and rivers have been the cultural and economic heart of most cities over history, an essential living element of the urban landscape [9]. Badly speaking, many big cities in Indonesia, especially in Java Island, are developed without considering river as a part of public transport. Bridges and many others constructions facilities engineered too low. Continue long distance water may not possible, so the river can be utilized for leisure and sport activities only. Crossing short distance river may one opportunity to occupy river transportation system. Crossing by certain incline direction that can bring passengers with their bikes may be an interesting idea. By applying solar panel then the boat can run from one pier to another pier without any cost for fuel. Solar cell technology has mate battery that make possible for the boat to run also in the evening time. The speed of crossing not necessary high but the current of river must be considered under two opposite directions. Using light hull's material such as HDPE will save energy demands. Working with both latest technologies of solar cell and lightest material of HDPE will produce an efficient river-boat.

Shipbuilding Polytechnic in Surabaya was developed a workshops for HDPE (*High Density Polyethylene*) boat since three years ago and the second author is one of the technical consultant in there. Some small crafts built in that environmental friendly material compared with any types of fiberglass technology. The use of HDPE grown globally and accepted even in the oil and gas industry. The density of 0.92 ton/m3 place the HDPE as the lightest ship's hull material. Table 1 shows the differences of hull material used by ship or boat. The HDPE hull's boat technically will not be submerged into the water. The basic material prices between aluminum and fiberglass make the HDPE compete with both of them.

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TABLE 1. Specifications of Ship's Hull Materials

Specifications Data	Aluminum	Fiberglass	Polyethylene (PE)	Wood Grade-1	HDPE (High Density Polyethylene)
Density (ton/m3)	2.74	2.4	0.94	0.98	0.92 ~ 0.94
Yield Strength (MPa)	215	69	~ 10	60	10 ~ 22
Ult. Strength (MPa)	305	138	-	75	21 ~ 35
Elongation (%)	10 ~ 16	4.8	-	-	9
Hardness (Brinell)	85	>35	-	-	64
Thermal Con. (W/m.K)	117	77.9	-	0.14	0.42
Fabrication method	welding	Casting/mold	Casting	Glue/spies	Thermoplastic weld
Material IDR/kg	90.000	21.000	30.000	30.000	45.000
Production IDR/kg	250.000	150.000	100.000	125.000	180.000

Background

Table 1 shows big opportunity to use HDPE to crossing river boat in technically and economic aspects. Operate boat without any costs for fuel is sound attractive. Anyway the owner should take into account the initial and maintenance costs for battery. The main topic of this research work is investigate how much the use of HDPE material can improve the performances of a 15m length solar powered boat that is used here for case study. The analysis will focus on the effect of the density material to the weight balance of the boat.

TECHNICAL REVIEW

Solar cell is one of an effective renewable energy for tropical country such as Indonesia [11]. This potential known well but the applications still limited due to higher capital investments than other energy. Solar energy resulted by absorption of the sun rays to the certain modules then convert to the electrical energy that finally store on batteries or convert mechanically to rotate directly an electrical motor. Motor then drive a car axle in land transportation unit or a propulsion shaft in a boat [8]. To maximize the low power of the solar energy then improving the design of the boat is offers great opportunity to get better sea performances. One design adds underwater foils to maintain lift forces [5], other design use interceptor part to perform even-keel condition [6], and adopt the technology of hydrofoil to a catamaran called as HYSUCATS [3]. Widening the distance of demi-hull can also give benefits to the stability and spacing the deck and even the area to lay up the solar modules [1]. A simple work is using lighter hull's material as studied in this paper.

METHODOLOGY

This paper will examine the application of sun rays as renewable energy for crossing river boat. A 15 meters solar powered catamaran boat has been designed for GIZ SUTIP [8], as shown in Figure 1 will be use as a case study and it modified here by using HDPE material. The vessel is functioned as a passenger boat with maximum capacity of 32 people and it can bring bike and some light motor bikes [2]. In the similar boat particular dimension, the hull and inside structural members will replace with HDPE material, also the superstructure. Technical analysis will re-do for trim and stability conditions, draft measurement, resistance and powering, etc. Limiting space to lay up the solar modules will provide maximum power available. For standard module size of 806 x 1576 mm, there will 52 modules can be stored in the rooftop of the boat. One module consists of 72 cells. Therefore, the maximum total power available is about 52 x 200 Watt-peak = 10.400 Watt-P or 10.4 KW (can be supplied at peak sun rays condition). In the previous design, the power can navigate the boat at the design speed of 5 knots or 9 km/hr.

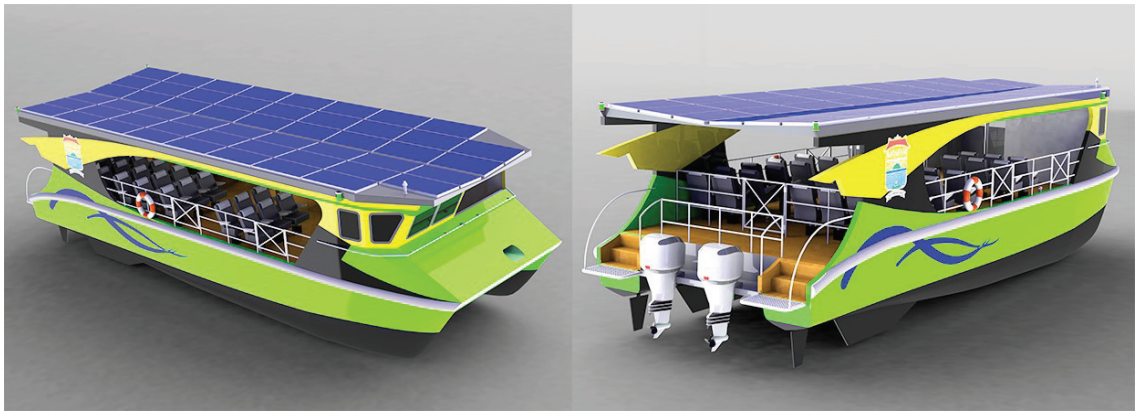

FIGURE 1. Visual design of the 15m solar boat exterior

The principle dimension of the original boat made by aluminium material can be stated as the waterline is 14.28m, the breadth is 4.98m with demi-hull width of 1.23m, the draught is 1m at depth of 2m. The boat designed to be equipped with 2 x 10 KW electric motors with power margin of 48%. 16 unit batteries of 6V-260Ah provide total power of 25 KWh with load factor of 0.8. The batteries are kept as small number as possible because of only these components have shortest life time that give consequences to the operational cost of the boat.

DESIGN ANALYSIS AND DISCUSSION

Table 2 shows the technical comparison of the boat with different hull material. The boat is calculated from the similar basic Lines plan, and the differences are caused by the different density of material used. Three types of material are used where the aluminum is the original one and fiberglass also investigated to enrich the comparative data. The weight of hull calculated progressively with different thickness. Deadweight of the ship is 6.21 ton and the payload of 2.38 ton are keep unchanged. Power efficiency in value of the % of peak power calculated from the calculated power demand divided by the total power supplied by solar panels.

TABLE 2. Technical Comparison of the boat with different Hull Materials

Technical Data	Aluminum	Fiberglass	HDPE (High Density Polyethylene)
Density (ton/m3)	2.74	2.4	0.94
Weight of main hull (ton)	6.04	7.06	4.84
Draught (m)	1.00	1.057	0.9725
Ship Displacement (ton)	16.44	17.47	15.24
Lightweight (ton)	10.23	11.25	9.03
Total Ship Resistance (KN)	1.325	1.839	1.294
Power efficiency (% of peak power)	77.11	107.02	75.29

The boat can serve passengers from pier-1 to another side of the river called as pier-2 without any costs for fuel. Therefore, they can be operated as many trips as possible in regularly without any consideration with the number of the passenger onboard the boats. It is a basic idea of a public transport. Solar panel and most boat parts have long life about 15 years. Only conventional batteries have shorter lifetime about maximum 3 years. Thank to today technology that claim their battery can give 15 years of life [7]. A good scenario for crossing river boat is transporting people from busway terminal at pier-1 to the busway terminal at pier-2. At certain peak time, a busway crossing a bridge may take half an hour or more. Integrated transportation mode can utilize the boat to bring people from pier-1 to pier-2 at about 7 minutes only per 100 m track with the speed of 9 km/hr. The bigger parameters data result more advantages of this scheme. In event such as total congestion on the bridge, the traffic operator has solution not to cross the busway by the bridge. All passengers should use the available boats that scheduled in regular time.

CONCLUSION REMARKS

Solar powered HDPE boat promise highly applicable for crossing river in integrated transportation mode of a big city. The use of HDPE material can reduce 1.2 ton of hull material in progressive calculation. This cheaper boat can be used to increase the number of passenger about 16 people (50% more than the previous design) to achieve the same level of previous safe waterline at maintained speed of 5 knots. There is no significant improvement in the saving power where the efficiency only 1.82% different, then it will not feasible to increase the boat speed. In the other hand, the use of fiberglass material results no benefit technically. Finally, good design of HDPE boat may offer more advantage compare with aluminum boat in term of technical and economic aspects.

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