Paper Reference ID: UMT/FMSM/MARTEC/MTP-90

EFFICIENT AND POLLUTION FREE ELECTRIC CATAMARAN FERRY FOR KUALA TERENGGANU RIVER

Ferry M.[1*], Wan Nik W. B.[1], Fitriadhy A.[1], Amaheka S.[2] and Muzathik A. M.[3]

[1]Universiti Malaysia Terengganu, 21030 Kuala Terengganu, Terengganu Malaysia
[2]Pattimura University, Ambon, Indonesia
[3] Institute of Technology University of Moratuwa, Sri Lanka
*E mail: ferry.m@umt.edu.my

ABSTRACT

Catamaran floats on two demihulls where the cross-sections are slimmer and shallower than the single hull of an equivalent capacity so it has less weight, small draught, much more deck area for passengers and more stable. Due to these features catamaran may be powered by electric energy thus make it more economical. Electric motors as the prime mover maintains high efficiency over a wide range of loads and speeds, has a small weight and need very low maintenance and repair cost compared with diesel engines or outboard motors. Battery is used as energy storage that enables the catamaran operates as ferry for transportation at rivers or between closed islands which is more efficiently due to its low operational cost, besides that it is pollution free hence environmental friendly. The obstacle of this transport system is that the distance to be traveled is limited and depends on the capacity of the battery. Recharging the battery should be done through an electric charger with capacity 60-80Amp per hour connected to the electricity line exist at the jetty. The monthly operational cost of catamaran boat is more less compare to the monohull diesel boat. Such type of ferry is effective for connecting two closed places on rivers or as a means of transportation for tourism along rivers, canals or small lakes with limited sailing time.
In this case the route is taken for Kuala Terengganu River at Kuala Terengganu, Malaysia from “Seberang Takir” to the central market “Pasar Payang” with a distance of 500m.

Keywords: Catamaran, electric motor, pollution free, inland waterways.

1. INTRODUCTION

Kuala Terengganu city is the capital of Terengganu State in Malaysia. It is located at the eastern coast of Malaysia facing to the South China Sea. The river Kuala Terengganu splits the city into two parts the northern and southern parts. In the past people crossing the river by canoes, raft or sailing canoes, but since there were bridges most people traveling to the center of the city by car, however nowadays people still using boats/ferries to cross the river. At Figure 1 can be seen that until today traditional monohull boat are still used to carry passengers (10-15 passengers) crossing the river. The distance between jetty at “Seberang Takir” (Fig. 2, 3) and jetty close to the central market “Pasar Payang”(Fig. 1, 2) is about 500 m

Almost all boats that now are traveling along the river are monohull boats powered by outboard or inboard engines using fossil fuels where the exhaust gasses causing measurable negative effects on the earth’s atmosphere so called as the carbon emission. Beside that increasing of oil price will increase the operational cost of the boats/ferries especially when there is small number of passengers using the ferries hence will not making profit but lossy. Electric boat will not produce any pollution during its operation; no carbon emission, no waste engine cooling water and no noise [1].

The engine cooling water and the bilge wastewater which are pumped out into the river from the diesel boats that nowadays traveling at the river contains an amount of oil and fuel which will pollute the river and the sea water also the exhaust gasses will pollute the air although at low rate, but after years if the number of the boats increases due to the increasing of the population and the number local/international tourists hence the need of fossil fuels will increase and that will increase the air pollution rate too [2]. Yearly accumulations of the polluted components increase the level of the pollution of the river, sea and air.
So it is wisely if there will be an effort to begin to reduce the pollution by transferring fossil fuel step by step to the green energies.

Figure 1 Passenger boats at Kuala Terengganu river

Figure 2 Map of Kuala Terengganu

Figure 3 Jetty at seberang Takir

Figure 4 Monohull boats at Jetty

2. BOAT DATA, RESISTANCE AND POWER SYSTEM

2.1 Monohull boat

The design of a ship typically begins with analysis of the existing ships according to all of the requirements which are important to obtain general information on the type of particular boat that is the passenger boat. If the fulfilled of requirements with the successful design exists, the design might proceed using this boat as the basis boat and, thus, involve scaling its characteristics for changes intended in the design. It is necessary bringing the design calculations and analysis of monohull which then fulfilled the requirement as a passenger's boat. Also evaluate the performance including the hydrostatic, speed, resistance, and power estimation by maxsurf software.

The small passengers boat that nowadays connect Seberang Takir and central market "Pasar Payang" are monohull boats that each could carry 10-15 seated passengers running 10 trips daily with service speed 10 knots. These boats were made by famous local boat builders at Kuala Terengganu without using drawings, made from hard wood and the boat shape is not changed much over the years.

Using maxsurf software with input data taken manually from the boat during the boat was on maintenance at the river bank is determined the body plan view of the boat at Fig.5 and the main dimensions at Table 1.

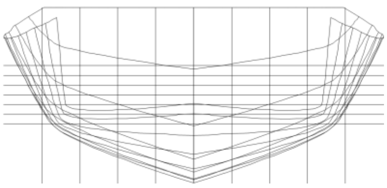

Figure 5 Body plan view

Based on the boat dimension, is determined that passenger space has length 6m and width 1.8m, is revealed that the deck space for the passengers is very limited. Total passengers space is 10.8m^2 minus 1.5m2 area of the engine casing, then space for one passenger is only about 0.65m^2.

Table 1 Main dimension of monohull boat

Displacement	2.007	tonne
Volume	1.958	m^3
Draft to Baseline	0.388	m
Immersed depth	0.388	m
Lwl	7.603	m
Beam wl	1.874	m
WSA	13.149	m^2
Waterplane area	12.301	m^2
Cp	0.622	
Cb	0.354	
Cm	0.57	
Cwp	0.863	
KB	0.277	m
GMt	1.447	m

Table 2 Monohull boat resistance and power versus speed

Speed, kts	Resistance, kN	Power,
0	0	0
1	0.01	0.01
2	0.04	0.04
3	0.08	0.12
4	0.15	0.3
5	0.29	0.74
6	0.48	1.48
7	0.9	3.25
8	1.29	5.3
9	1.69	7.8
10	1.99	10.22

2.1.1 Water Resistance and Engine Power

Water resistance of a ship could be determined by various method of resistance calculation, Formula of total water resistance of a ship is: $R_T = ½\ C_T*\rho*V^2*S$,

Where : R_T – Total Resistance (kN)
C_T – Total resistance coefficient
P – Seawater density (t/m^3)
V – Ship speed (m/sec)
S – Wetted surface area (m^2)

Table 2 shows the result of resistance and power prediction with Holtrop method at the maxsurf software, where at speed 10 knots the resistance is 1.99kN and the power is 10.22kW ≈ 11kW, that is in accordance with the power of the engine using at the boat analyzed in this study.

2.1.2 Diesel Power system

Diesel power system where diesel engine is the main engine where its rpm is reduced by the gearbox when reach the propeller shaft. The speed controller is located in front of the engine which is regulated by the boat driver (see Fig. 6). Commonly brake specific fuel consumption (BSFC) of diesel engine is expressed in units of grams per kilowatt-hour (g/(kW·h)). The engine power is 11 kW, BSFC = 0.25 g/(kW.h), daily engine operating hours is 1.67 hours, daily fuel consumption is 5.8 litres [3].

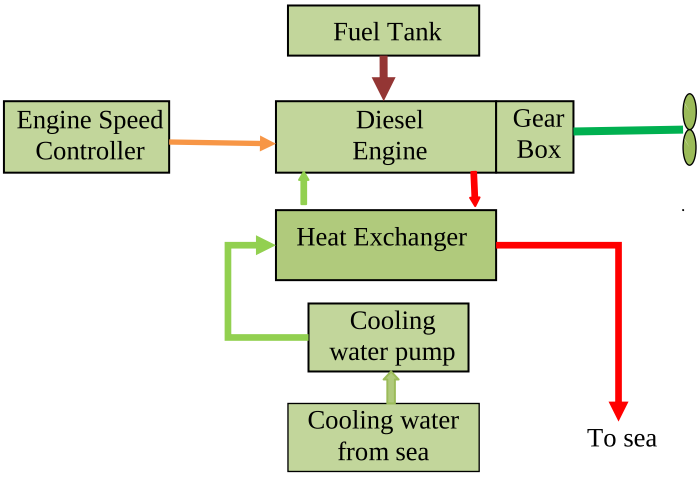

Figure 6 Diesel boat engine/propulsion system

2.2 Catamaran ferry

Catamaran is a boat that floats on two demihulls (Fig.6 & Fig.7), which has more deck area compare with a monohull boat. Water resistance of catamaran and monohull calculation results with maxsurf are stated at Table 2 and Table 4, where the resistance of catamaran is 20% less than the resistance of monohull, hence the power is also less 20%.

According to the main dimension of the catamaran at Table 3, the deck space for one passenger is determined about 1.6m^2, so it is more convenient for the passengers.

Figure 6 Small passenger catamaran

Figure 7 Body plan view of catamaran

Table 3: Main dimension of catamaran boat

Displacement	2.088	tonne
Volume	2.037	m^3
Draft to Baseline	0.383	m
Immersed depth	0.383	m
Lwl	9.174	m
Beam wl	3.85	m
WSA	17.085	m^2
Max cross sect area	0.292	m^2
Waterplane area	6.42	m^2
Cp	0.762	
Cb	0.638	
Cm	0.838	
Cwp	0.77	

Table 4: Resistance, power versus speed

Speed, kts	Resistance, kN	Power, kW
0	0	0
1	0.04	0.02
2	0.11	0.12
3	0.21	0.33
4	0.38	0.83
5	0.54	1.41
6	0.71	2.20
7	0.97	3.58
8	1.17	4.90
9	1.39	6.43
10	1.67	8.78

2.2.1 Catamaran Resistance and Power

Table 4 shows the result of water resistance and power prediction of the catamaran predicted with Holtrop method at maxsurf software.

2.2.2 Electric Power System

AC/DC electrical charger placed on the jetty using public electricity line as electrical source then stored the electricity in the batteries placed on board as the electric source to run the brushless electric motor as prime mover of the boat. This system is more economical compare with the diesel engine at same capacity which is used at mono-hull boat compare Table 4 and Table 2.

The equipments used at the electric catamaran boat are:

Electric charger (at jetty) capacity : 220V AC , 60A DC 48 V
Battery capacity : 500 AH, 48 V
Capacity of the electric Motors : 9 kW, 48 V DC

The patterns of the electric motor-propeller system of the electric boat at Fig. 8 shows that the electric charger will charge the batteries then the dc current from the batteries through the speed controllers will control the speed of the

electric motor which runs the propeller. Electric motor as prime mover has following advantages: easy and low cost of maintenance and repair, no use of fuel hence reduce the operational cost and the carbon dioxide emission.
Electric motor has long life time service and has high efficiency about 93 %. Besides that this system does not need thrust bearing because the electric motor delivers the propeller thrust directly to the boat hull [4].

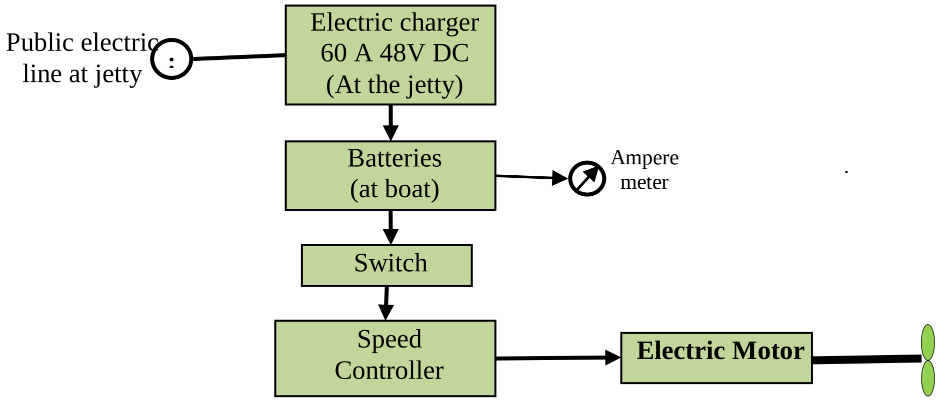

Figure 8 Electric Boat propulsion system

Electric motors maintain high efficiency over a wide range of loads and speed, they run up to 48 volts which generate power until 10 KW ≈ 13 HP with low shaft speed and high torque they are enable to use a simple, cheap and efficient transmission system in most application. These motors enable us to get the best possible performance from the batteries. High efficiency gives longer running time and less frequent battery replacement [5].

3. RESULT AND DISCUSSION

3.1 Resistance, power and passenger space

This study is focused on implementing the electric small ferry boats crossing the Kuala Terengganu River on place of the traditional monohull boats powering by engines using fossil fuels.

From the result of resistance and power calculation using maxsurf software is determined that the resistance of catamaran at speed 10 knots is 1.67kN, monohull boat is 1.99kN, about 20% more, hence the engine power is also 20% more by monohull.

Besides that the deck area for one passenger at monohull boat is 0.65 m^2 and the passengers sit facing each other, but at catamaran boat each passenger can use 1.6 m^2 so they sit more conveniently, heading to the front of the boat and could have a view to the surroundings.

3.2 Income

The income of the boat depends on the daily average passengers number which is assumed 8 passengers for oneway trip during the whole 10 trips daily. Based on the collected data the boats operate 12 hours a day. The total operating days per year is 300 days. Ticket price is MYR1 for one way travelling so the projected monthly income for both boat types will be the same (Fig. 9).

3.3 Operational Cost (Fig. 9)

The monthly operational cost of a boat with outboard, inboard engine or electric motor depends on the following items:

- Number of daily trips and operational hours
- Main engine power
- Operational cost
- Maintenance and repair cost [6] and [7]

3.4 Profit

Each boat is considered carrying average 8 passengers daily for one way trip, based on that is determined the monthly profit of each type of boat which is shown at Fig. 9.

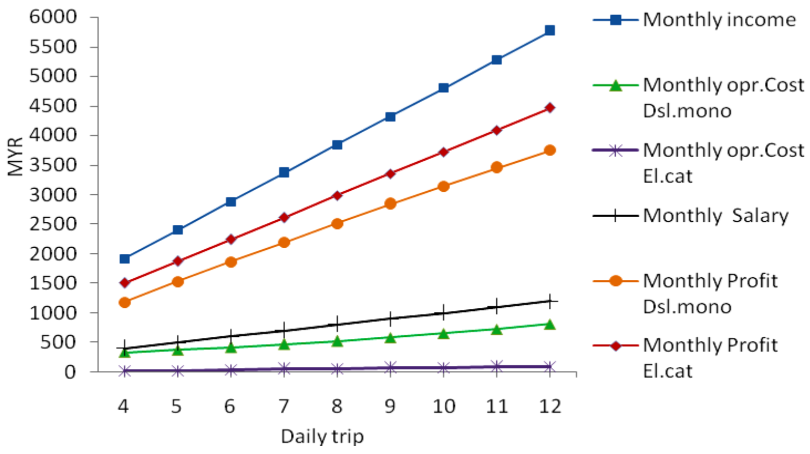

Figure 9 Income, cost and profit

3.5 Carbon Emission, Sound and Waste Water

The carbon emission exhausting by the engines using fossil fuels into the air is one liter petrol sends 2.3kg CO_2 into the air and 1 liter diesel fuel will send 2.7kg CO_2[6]. Specific fuel consumption of small diesel engine is 0.25 g/kW.h. Daily fuel consumption is 5.8litres, yearly 300x5.8x0.=1740litres Yearly exhausted CO2 will be 1740 x 2.7 x 0.4 = 696 kg CO_2. If there will be 30 boats sailing along the Kuala Terengganu river daily so 20880kg of CO_2 will be exhausted into the air.
The river will be polluted by the engine cooling water and bilge wastewater which is directly thrown into the river. On the other side the electrical catamaran has no carbon emission, no bilge wastewater contained with oil and fuel and no sound pollution where during the travelling the passengers can talk to each other without disturbance by the engine sound as at the diesel boat[8]. Besides that electric boats have no smell of fuel or exhaust gas.

4. CONCLUSION

Based on the predicted resistance, power, main dimension and monthly profit of both boats reveal that electric catamaran is pollution free and more efficient than diesel monohull boat, where:

- Electric catamaran boat has less resistance and power.
- Passengers are more convenient due to more space, good sight to the surroundings; talk to each other without engine noise interference.
- More profit.
- No carbon emission, no waste water.

REFERENCES

[1]. EPA. USA, Greenhouse Gas Emission from U.S. Transportation Sector, 2006 H. Suzuki, E.
[2]. Dragan Ljevaja1Impact of Emissions of Marine Diesel Engines to Air Pollution on the Example of the Yugoslav River Shipping. World Transport Overseas., Milutina Milankovića 25b, 11000 Belgrade, Serbia Received 19 May 2011; accepted 15 July 2011
[3]. P. J. Shayler, J. P. Chick and D. Eade, "A Method of Predicting Brake Specific Fuel Consumption Maps", SAE 1999-01-0556
[4]. James Lambden, (2012), Hundred Reasons for Electrical Boats, Marine Industry Standards and Technical Education Journal.
[5]. Kevin Jeffery, (2006), Independent Energy Guide-electric Power for Home, Boat & RV.
[6]. Harry Benford, (1984), "Ships' Capital Costs: The Approaches of Economists, Naval Architects and Business Managers," Ships' Costs Conference, Cardiff, Wales.
[7]. Harry Benford, (1991), A Naval Architect's Guide to Practical Economics," Report No. 319, Department of Naval Architecture and Marine Engineering, University of Michigan.
[8]. Hamada, K. Saito, Y. Maniwa and Y. Shirai, (1980), The Influence of Sound on The Environment. Journal of Navigation, 33:pp. 291-295.

NOMENCLATURE

C_b	Block coefficient
C_m	Midship coefficient
C_p	Prismatic coefficient
C_{wp}	Waterplane coefficient
GM_t	Transverse metacenter height (m)
KB	Height of center of buoyancy (m)
L_{WL}	Length of waterline (m)
WSA	Wetted surface area (m^2)