Electric Waste Collecting Vessel (EWOV) – Citarum River

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Abstract—**This waste collecting vessel is specifically designed to assist with the clean up of the 300km Citarum River, the longest and largest river in Indonesia. This vessel has the capacity of cleaning at least 5.4 tons of waste per day. In a country highly dependent on cheap fossil fuel, Indonesia has yet to ride on the wave of clean energy revolution due to its high initial cost of investment. The vessel uses rechargeable batteries as a source of energy for propulsion and to reduce impact on the environment in contrast to using combustion engine. The method used for this design is The Parrent Vessel Approach. The main dimension of the vessel is determined to be L_{OA} = 8 m, B = 3 m, T = 0.2 m, H = 0.7 m, B_1 = 0.7 m, Cb = 0.977, with 3 knots service speed and operating duration of at least 1.3 hours, motor power requirement to be 0.756 kW with 2.685 Wh per battery capacity. The payload capacity is 1.8 tons per round of waste collection. Garbage's density in general is 481 kg/m^3.**

Keywords—**Citarum, Electrical Energy, Parent Vessel Approach.**

I. INTRODUCTION

FOSSIL fuel consumption and pollution emission have become a serious concern to researches and policy makers. Changes in climate and global warming have affected both humans and the environment [1]. The consumption of energy in Indonesia has been dominated by the use of fossil fuel and the Indonesia government subsidized 700 to 1000 rupiah for every liter of petrol to keep fuel price stable. In July 2018, the government of Indonesia declared that there will be a presidential decree to increase biodiesel fuel usage and to slash $5.5 billion of crude oil import annually. Therefore, it is imperative that reliance of fossil fuel as the primary energy source must be curtailed or at least be reduced by alternative means through the use of biodiesel fuel or the use of rechargeable batteries that has lesser impact on the environment.

The use of rechargeable batteries and electric motor can be an alternative to combustion engine and this idea was mooted by Tesla Technologies (USA). Furthermore, global leaders have been calling to reduce global carbon dioxide emissions and also to reduce the reliance of fossil fuel. This project replaces the use of fossil fuel as the source of energy and combustion engines with rechargeable batteries and electric driven motors. There are several advantages of using electric propulsion system namely: (1) Simplification of the propulsion system that includes reduction of gears used to generate thrust, (2)

Reduction of maintenance and repair costs including total life cycle costs, (3) Reduction in noise and environmental pollution that are attributed to combustion engines [2].

Degradation of Citarum River water quality in Indonesia is increasing year by year due to ever increasing load of untreated waste with nearly 20,000 tons of rubbish being released into the 300km long river every day. To combat rubbish and environmental pollution, an electric waste collecting vessel was designed to collect rubbish waste with the use of affordable and practical green technology that had little impact on the environment during the collection process.

II. LITERATURE

A. Ship Design Theory

A ship designing process is a repeated process where it begins with initial requirements. These are usually specified by ship owner, who based their decisions upon current and future market scenario and expectations, defines the parameter and features of the ship. The design process can be further elaborated with a spiral design. The design consist of 4 stages which are (a.) Concept Design, where the key objective is to arrive at the feasibility of the project which includes the fundamental dimensions, (b.) Preliminary Design, where the key objective is to plan the project which includes improving and elaborating major ship characteristics which affects the cost and performance, (c.) Contract Design, where the key objective is to arrive at the cost of project which describes the features precisely based on the model testing, (d.) Detailed Design, where the key objective is to construct the vessel [3].

B. Ship Design Method

There are various methods used in ship design and they are further elaborated; (a.) Parent Design Approach, where by using an existing vessel as a reference which has the same characterisitic for comparison. (b.) Trend Curve Apporach, or commonly known as statistical method, uses linear regression analysis of several similar vessels to determine the dimension of the vessel. (c.) Iterative Design Approach, a method of designing vessels that are based on the cycle process of prototyping, testing and analysing. (d.) Optimization Design Approach, used to determine the optimum size of the main vessel, optimum design is sought by finding a design that will minimize economic cost.

C. Catamaran

A catamaran is a hulled watercraft featuring two parallel hulls of equal size. It is a geometry-stabilized craft, deriving its stability from its wide beam, rather than from a ballasted keel as with a mono-hull sailboat.

Catamarans typically have less hull volume, higher displacement, and shallower draft (draught) than mono-hulls of comparable length. The two hulls combined also often have a smaller hydrodynamic resistance than mono-hulls, requiring less propulsive power from either sails or motors. The catamaran's wider stance on the water can reduce both heeling and wave-induced motion, as compared with a mono-hull, and can give reduced wakes [4].

Catamarans range in size from small (sailing or rowing vessels) to large (naval ships and car ferries). The structure connecting a catamaran's two hulls ranges from a simple frame strung with webbing to support the crew to a bridging superstructure incorporating extensive cabin and/or cargo space.

D. Battery

The battery serves as a storage place for electrical energy. The battery has three important components, namely anode (positive pole), cathode (negative pole) and electrolyte as the transmitter.

Battery capacity is stated in ampere hours (Ah = current strength / Ampere x time / hour), meaning that the battery can supply / supply a number of contents on average before each cell touches the drop voltage. However, the actual storage capacity of battery energy can vary significantly from "nominal" rated capacity, where there are three factors that determine the size of the battery capacity, namely the amount of active ingredients, temperature, and time and expenditure flow.

To calculate battery energy that can be installed using the Battery Energy formula [5].

$$E_{batt} = \frac{V_{batt} . C_{batt} \cdot x_2}{1000 . \eta_d} \quad (1)$$

Where V_{batt} is the nominal voltage of the battery in volts and Cbatt is the battery capacity in Ampere-hours, ηd is the efficiency of battery usage which states the loss of energy during the energy usage process, and x_2 is the number of batteries to be used.

E. Location

Citarum (Sundanese: Walungan Citarum) is the longest and largest river in West Java, Indonesia. It stretches over 269 km and its geographic location is located at 106°5 1’36” - 107°51’BT and 7°10’ - 6°24’ LS. The River begins from Mount Wayang, pasing through Kabupaten Bandung/West Bandung, Kabupaten Cianjur, Kabupaten Purwakarta and Kabupaten Karawang Purwakarta, and ends at Muara Gembong, Jawa Sea.

There are 3 reservoirs that exist along Citarum River and they are Saguling Dam (2,750 million cubic meter), Cirata (3.9 million cubic meter), and Jatiluhur Dam (9.1 million cubic meter). Citarum River has an important role in the life of the people of West Java, as it supports agriculture, water supply, fishery, industry, sewerage, and electricity. It is listed as one of the most polluted rivers in the world since 2009 [6].

The river flows in the northwest area of Java with a predominantly tropical monsoon climate. The annual average temperature in the area is 24°C. The warmest month is May, when the average temperature is around 26°C, and the coldest is January, at 22°C. The average annual rainfall is 2646 mm. The wettest month is January, with an average of 668 mm rainfall, and the driest is September, with 14 mm rainfall.

Since 2008, Citarum River has been known to be one of the most polluted in the world and the government has indeed step up to deal with the situation. Recently in February 2018, Indonesia’s President stated that the river should be drinkable within seven years and the latest cleanup involved police, military, government departments, organizations and the public.

Figure 1. Citarum River Basin [7].

III. METHODOLOGY

A. Data Collection

The data collection is not taken directly from the source, secondary data. The collected data is then used as a reference and a parameter in the ship designing process. The required data are as follows:

a. The payload (the amount of waste to be harvested)
b. Condition of Citarum River
c. Parent vessel data

B. Analysis Data

The objective of this analysis is to determine the vessel’s payload value based on the data collected from both Citarum River and parent vessel.

C. Ship Main Dimension

The vessel’s dimension is determined by using Parent Vessel Approach as a reference for analysis.

D. Technical Analysis

The technical analysis that is carried out consist of coefficient calculations, resistance, power, electric propulsion, plate thickness, weight, displacement, freeboard and stability.

E. Model Design

This planning stage is done based on the reference from the parent vessel. The focus of the design is on the load and the stability of the vessel. The planning is then accomplished as follows:

a. Lines Plan
b. General Arrangement
c. Safety Plan
d. 3D

F. Analysis Result

The results taken from the initial analysis are then used as a reference for the following technical analysis.

IV. TECHNICAL ANALYSIS

A. Determine Payload

The initial steps for designing a vessel would be to determine the payload. In this final project, it is based on the amount of estimated trash in which the vessel will be able to harvest at a minimal energy for maximum output.

Using the data above and the characteristics of the river, and a parent vessel approach, it would deem that a vessel of a medium or a large sized would be inapplicable due to the width and the depth of the river. A small specialized vessel would be the most suitable in this situation as it would be manoeuvrable and small enough to passage through the river. However, the payload that it will carry will be small due to the size of the vessel. Moreover, the aim of the vessel is not only to harvest as much garbage as possible but also to maintain the river cleanliness even after the river has been cleaned.

B. Initial Dimensions

The initial dimensions are obtained using the Parent Design Approach and a sketch due to the fact it is a specialized vessel, it does not have vessels with similar dimensions to be compared and contrast. However, there are 2 other similar design that is similar to the selected Parent Design and the only difference was the length of the vessel. The author then compare the 3 vessels to determine his Parent Design. Thus, the following is the table for the comparisons.

Table 1.
Similar vessels data

Comparison 6m, 7m, 8m			
Length (m)	5.83	7	8
Breadth (m)	2.3	2.5	2.5
Depth (m)	0.7	0.7	0.7
Operating Draft (m)	0.2	0.2	0.2
Max. Cargo (kg)	900	1000	1800
Speed (knots)	2 (operating speed) - 7 knots (max)	2 (operating speed) - 7.5 knots (max)	2 (operating speed) - 9 knots (max)

Therefore, the 8m Buddy has been determined to be the Parent Vessel due to the capability to collect a large amount of trash to challenge the waste situation along the Citarum River. However, the author has do a slight adjustment to its breadth to an additional 0.5 m for his analysis.

There were several factors in determining the reference vessel. The dimensions, payload, manoeuvrability, and its function. The parent vessel 8m Buddy has the following advantages:

1. Versatile
2. Simple to operate

Moreover, the use of Insel & Molland has also been used to approximate that the vessel's dimensions are within suitable means [8].

Table 2.
Insel & Molland

Constrait (Insel & Molland)				
L/B1	11.43	Sahoo, Browne & Salas (2004)	→	7.55<L/B1<13.55
B/H	4.29	Insel & Molland 1992	→	0.7<B/H<4.1
S/L	0.29	Insel & Molland 1992	→	0.19<S/L<0.51
S/B1	2.57	Insel & Molland 1992	→	0.9<S/B<4.1
B1/T	3.5	Insel & Molland 1992	→	0.9/B1/T<3.1
B1/B	0.23	Multi Hull Ships, pg 61	→	0.15<B1/B<0.3
CB	0.98	Insel & Molland 1992	→	0.3<CB<0.59

In addition to the above, the speed allocated to the vessel is at a minimum of 3 knots and a maximum of 7 knots. The speed of 3 knots will allow the vessel to work for at a minimum of 8 hours while 7 knots will lead to a reduction to 1 hour 10 minutes.

C. Vessel's hull model

The vessel's hull model is made from scratch based on the parent vessel as it does not have any initial similarities for other existing vessels. The hull of the vessel is rectangular-shaped hull as you can see from below.

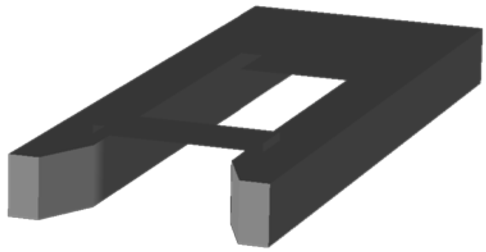

Figure 2. Hull Model

The dimensions applied to the vessel's models are: L = 8 m; B = 3 m; H = 0.7 m; T = 0.2 m; Lwl = 8 m; B1 = 0.7 m, S = 1.8 m. After which, the CB and the CP will then be determined.

Usually, the first step to re-drawing the lines-plan is to insert a reference image into the program with the import image background command and the focus display on the Maxsurf program set to look like a body-plan. Next, determine the reference point (zero pint) and reference point (reference point), in this case the reference point is half the width of the vessel so that the lines- plan reference image will be scaled by the program.

D. Initial Calculations

After obtaining the main dimension of the vessel and the design of the lines plan, the next step is to do the initial calculation. The initial calculation includes the calculation of the Froud number, calculation of the coefficients (Cb, Cm, Cp, and Cwp), the displacement and volume displacement. This initial calculation is done as a first step in technical calculations, one of which is to calculate the resistance value and ship propulsion.

E. Resistance Calculations and Comparison

For resistance calculation for a special vessel with less than 10 m with velocity of 3 knots is nearly unnecessary, however, it is still mandatory to show that resistance exist surrounding the vessel. With a flat hull and a special vessel at that, it would be difficult to use a singular method to determine the resistance of the vessel. Thus, the following methods mentioned below have been used to determine the resistance of the vessel as to compare and contrast. They are as such, Slender Body Method and Hard chine method [9]. The resistance value obtained by using Slender Body Method is within the range of 0.55 kN – 0.6 kN, while Hard Chine Method's value is 0.6206 kN.

The thrust power is determined by using the propulsion formula [10], which results in 0.756 kW. The electric propulsion selected provides a thrust power of 7.83 kW. It is known that the thrust power given is so much greater than the required thrust, however, the aim of the power is to generate more than enough power to enable maximum operation.

F. Battery Capacity and Operation

A one day operation would require an amount of electric energy for its propulsion. For a single propeller, it only require 4 kW power input with an output of 2,2 KW, efficiency of 56%. A single battery capacity is 2,685 Wh, however 2 batteries are fitted. The total capacity will allow the vessel to operate at a minimum of 1 hour at 3 knots. The charging rate of the battery takes about 1.2 hours. 2 – 4 spare batteries are recommended on land to enable a continuous operation. The energy of the batteries are determined by the following formula.

$$E_{batt} = \frac{V_{batt}.C_{batt}.X_2}{1000\,.\eta_d} \quad (2)$$

G. Hull Plate Thickness

The thickness of the hull plate use aluminum where the calculation for high speed vessels made from aluminum uses BKI (Bureau of Indonesian Classification) Volume VII Part 3, Rules for Small Vessel up to 24 m 2013 edition [11].

Calculate the load on the base and leather sides. Each load is calculated in parts 4 0.4 L ÷ fore and at <0.4 L ÷ aft. Then calculate the correction factor because of the speed, the correction factor calculated for the base skin area and the side skin.

Correction factors and the amount of load used in calculating the total aluminum weight (g/m^2) states the weight of aluminum per unit area. The total aluminum weight is calculated on the shell bottom and shell side. The thickness of the upper hull is assumed to be thinner than the shell bottom and shell side. The results obtained from the calculation as described in Table 3 below.

Table 3.
Plate Thickness

Thickness	
.1 The thickness [mm] required for the purposes of resistance to design pressure, is given by the formula: $t = 22{,}4 \cdot \mu \cdot s \cdot \sqrt{\frac{p}{\sigma_{am}}}$ [mm]	
Minimum Thickness of Btm > 0.4L	1.132 mm
Minimum Thickness of Btm <0.4L	1.012 mm
Minimum Thickness of Side > 0.4L	1.009 mm
Minimum Thickness of Side < 0.4L	0.930 mm

Element	Minimum thickness [mm]
Shell plating:	
– Bottom shell plating	$1{,}35 \cdot L^{1/3} \geq 2{,}5$
– Side shell plating and wet deck plating	$1{,}15 \cdot L^{1/3} \geq 2{,}5$
Deck plating	2,5
Bulkhead plating	2,5
Deckhouse side shell plating	2,5

The Thickness calculated is too small thus taken the minimum thickness set by BKI special Vessel 2016, rules for high speed vessel, and based on the Parent vessel, the thickness is 4mm. Thus, thickness to be taken is 4mm.

H. Weight

The weight of the ship is divided into two parts, namely parts DWT (Dead Weight Tonnage) and LWT (Light Weight Tonnage). The total amount of LWT and DWT will not exceed the displacement margin, where the margin displacement is 0-5%.

Table 4.
Displacement

Limitation based on Archimides			
No	**Components**	**Value**	**Unit**
1	Displacement	2.24	Ton
2	DWT	1.28	Ton
3	LWT	8.74	Ton
4	DWT + LWT	2.154	Ton
	Difference	85.03	Ton
		3.8	%

Therefore, based on Table 4, the resulted value is **3.8**% which is within the accepted range.

I. Freeboard

This vessel is less than 24 m. Thus, do not use the International Convention on Load Lines ICLL 1966. Therefore, this vessels use laws from Non-Convention Vessel Standart (NCVS) Indonesian Flagged as a reference [12]. Markings used for ships with a length of ≤ 15 meters are set directly at the amount of: freeboard should not be less than 250 mm for vessels sailing in limited seas. The vessel's freeboard is noted at 0.5 m.

J. Stability

Stability is one of the requirements that must be fulfilled in the ship design process. In this design stability analysis uses the help of Maxsurf Stability Enterprise software. The stability criteria used are the stability criteria for general type vessels and catamaran ships referring to HSC Code 2000 Annex 7 Multi-hull Intact [13].

The Maxsurf Stability Enterprise software uses the 3-dimensional model of the ship's hull. The model that has been created in Maxsurf Modeler Advanced is stored and opened using the Maxsurf Stability Enterprise program. After the model is opened, then the calculation process for stability and trim can be done. In the analysis of this stability calculation several criteria for loading conditions are used (Loadcase) to determine the balance of the ship transversely or shaky in each condition.

Based on the stability criteria by HSC Code 2000 Annex 7, for the criteria that is to be fulfilled can be seen at Table 5.

K. Trim

The trim of the vessel is obtained via Maxsurf Stability Enterprise program. The state of Equilibrium is selected and with each loadcases, the following trim is then obtained via the result window. However, there is limitation set by NVCS 2009 rule Chapter 2 Sect 37.8.1 where the trim has to be less than Lpp/50 for Lpp less than 35m.

L. Lines Plan

This Lines Plan is a picture of a body plan, prolonged (sheer plan), and horizontally elongated (half breadth plan). This line plan is used as the basis for determining the distribution of space on the ship, determining the load capacity of the ship, and calculating and checking the ability to operate the vessel during operation.

Table 5.
Stability Criteria

No	Criteria	Condition	Value (F.C)	Value (U.C)	Value (E.C)	Value (B.C)	Unit	Status
1	Area 0 to 30 deg	Value ≥ 6.9332 m deg	12.49	10.26	10.6	10.7	m deg	Pass
2	Angle of Max GZ (intact)	Value ≥ 10°	17.3	13.6	13.6	13.6	°	Pass
3	Area between GZ and HTL	Value ≥ 1.604 m deg	10.02	11.7	12.1	12.23	m deg	Pass
4	Angle of Equilibrium	Value <10°	0	0	0.1	0.1	°	Pass

Table 6.
Trim

No.	Load Condition	Criteria	Value (m)	Actual (m)
1	Full Load of 1.8 ton	Lpp/50	0.160	-0.31
2	Unladen Load of 1.2 ton	Lpp/50	0.160	-0.0176
3	Empty Load Condition	Lpp/50	0.160	0.57
4	Berth Condition	Lpp/50	0.160	0.37

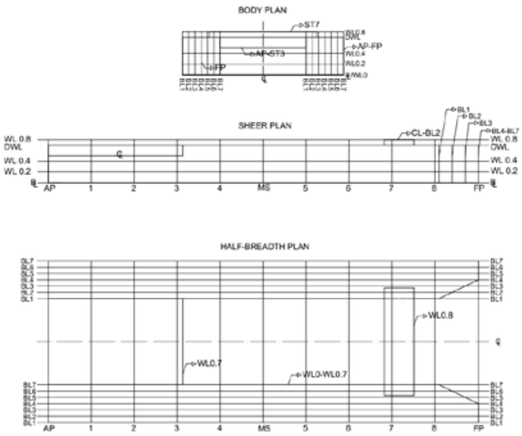

Figure 3. Lines Plan

M. General Arrangement

From the Lines Plan image that has been made, General Arrangement images can also be made. General Arrangement is defined as planning the space needed in accordance with the functions and equipment of the ship. Making General Arrangement is done with the help of CAD software [14].

The arrangement of the vessel space layout can be seen in Figure 5.

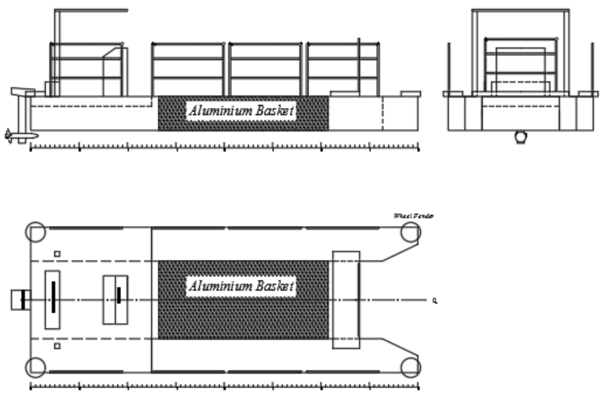

Figure 4. General Arrangement

N. Safety Plan

From the General Arrangement image that has been made, you can also make a Safety Plan Arrangement image from the vessel. Safety Plan Arrangement is defined as safety planning with the functions and equipment on the vessel. Safety on the vessel including its equipment is very much considered, for this reason the rules regarding safety at sea are regulated in Chapter IV of the Non-Convention Vessel Standard (NCVS) [16] regarding safety equipment.

O. 3D Design

The Model 3D design is designed using 3D Rhinoceros program. It it based on the determined dimensions. The initial steps taken in doing the 3D, requires the forming of the hull and the outlook from General Arrangement. The 3D includes the outfitting, main deck and the canopy as well. The centre is where the aluminum basket will be placed to collect the trash.

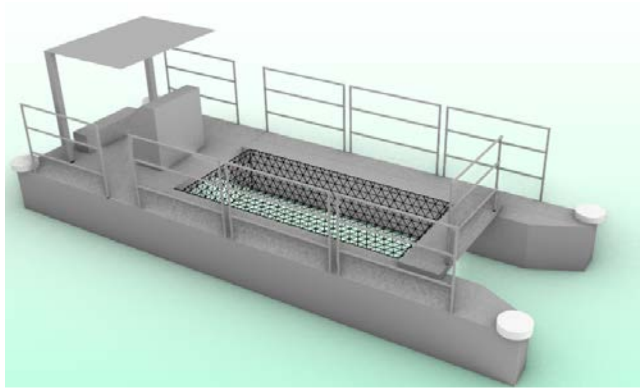

Figure 6. 3D Design

To note:

Based on the 3D designs, it may seem that the designed vessel may seem similar to the parent design, however, the several modifications has been made to avoid plagiarism. The vessel (EVOW) has no transom to facilitate with the battery placement, wider breadth and this vessel is generally made to collect waste only. The parent vessel is a multi-purposed vessel where it can transport goods and as well other forms of uses.

V. CONCLUSION

From this analysis and the technical calculations done on the following special vessel:

- The resulted design of the electric waste-collecting vessel are based on the dimensions given below:
  - LOA = 8 m
  - Lwl = 8 m
  - B = 3 m
  - T = 0.2 m
  - H = 0.7 m
  - B1 = 0.7 m
  - S = 1.8 m
  - Vs = 3 knots = 1.54 m/s
  - Δ = 2.24 ton
- Lines Plan design, General Arrangement, 3D design.
- Battery Capacit at 2,685 Wh.

An estimation by Stephens Waring Yacht Design estimates that diesel propulsion costs $657 for every 1000 miles while electric propulsion only cost $360 for every 1000 miles. Therefore, a properly designed all-electric vessel can offer an enormous savings if done right.

To Note:

To effectively remove the rubbish and to clean up the river, it will take more than 4,000 of these **E**lectric **W**aste c**O**llecting **V**essels (EWOV) to work along the 300km rivers every day. Both local and national policy are required to stop 20,000 tonnes of rubbish being thrown into the Citarum River or any river if the people of Indonesia is determined to have a clean river for their next generation. Huge amount of investment would be required to relocate factories away from the river and build dedicated recycling plants to remove these industrial waste. For the people living along the river, there must be an established proper rubbish collection route and dumping ground with an established recycling plant along the river. Laws must be established and available to prosecute anyone polluting the rivers. This will provide a boost and job opportunities in the local shipping industry to build this vessel, open up a new rechargeable battery industry as well as job opportunities for the man on the street to work on this vessel collecting rubbish every day. Rubbished collected will be converted to cash at the recycling plants providing the worker with an extra income and the recycling plants a constant stream of recycling materials. With the river cleaned up for the next generation, more visitors arrival will be expected and a boom for the local tourism industry.

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