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Design of a Biodiesel B30 Fuel Engine System on a People's Ship Made of Composite Wood Material

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ABSTRACT

Indonesia, as an archipelagic country, requires reliable maritime transportation to support economic growth. However, limitations in wood supply and traditional shipbuilding processes, which have not yet advanced in terms of technology, continue to hinder the development of the people's shipbuilding industry. This study emphasizes the application of laminated wood technology as an alternative material for ship construction, along with its integration with propulsion systems recommended by the government. The research methods include collecting primary data through observations and interviews at local shipyards and traditional ports, as well as secondary data from literature and relevant institutions. The analysis focuses on design optimization, construction feasibility based on NCVS standards, and the compatibility of engine performance with operational needs using B30 fuel. The research findings indicate that the main dimensions of the laminated wood vessel are Lpp = 18.05 m, B = 3.58 m, H = 1.80 m, T = 1.19 m, with a speed of 8 knots and an engine power of 46.23 HP. The technical and economic assessments propose a people's shipping vessel model with two alternative propulsion systems: a motor vessel (KM) and a motor-sail combination (KLM). These alternatives are expected to improve efficiency and sustainability within the traditional maritime fleet

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INTRODUCTION

The construction of people's shipping vessels is generally carried out without proper planning, drawings, forms, or dimensional standards, relying only on customer requests. This practice leads to inefficiencies in the use of raw materials, construction dimensions, lightweight ship mass, and work duration.

Indonesia's forest resources, particularly timber, are depleting at a rate of approximately 52 million m^3 per year. According to research by the Corruption Eradication Commission (KPK), from 2003–2014 the total timber production in Indonesia reached between 630.1 and 772.8 million m^3. Forest Watch Indonesia (FWI) warns that Indonesia's natural forests will vanish due to unresolved timber legalization processes. As a result, the country experiences deforestation at an average rate of 1.13 million hectares per year. This phenomenon also affects the traditional shipbuilding industry, since the increasing demand for wood as shipbuilding material has further reduced availability due to massive exploitation of forests to sustain rapid development. At present, the primary timber used for ship construction is increasingly difficult to obtain and expensive. However, with the mission to safeguard community shipping, it is necessary to develop more cost-efficient shipbuilding technologies while improving material quality.

With advances in shipbuilding technology, alternative methods have been discovered for constructing traditional vessels, one of which is the use of laminated wood (composite wood) as the main material. In theory, composite or laminated wood vessels are more effective and efficient compared to other traditional ships in terms of materials, strength, cost, production, and maintenance. This laminated wood technology breakthrough is considered a feasible substitute for scarce timber resources. However, this method is still relatively new for people's shipping vessels and traditional shipbuilders, which calls for further research to determine suitable designs and construction methods tailored to community shipping needs and Indonesian waters in general.

The demand for transportation services continues to diversify in line with the need to improve the mobility of goods and passengers. Many regions remain underserved by conventional transportation facilities. However, limited mastery of advanced technology may negatively affect the quality of ship design and construction. Additionally, traditional shipbuilders typically build vessels without detailed plans, drawings, or reference to classification requirements, making it difficult to ensure the quality of design and construction.

Therefore, the stages of developing people's shipping vessels using laminated wood include designing the vessels through the following steps:

a. Identification and analysis of stakeholders
b. Inventory and identification of existing people's shipping vessels;
c. Inventory and identification of vessel characteristics;
d. Inventory and identification of current operational patterns;
e. Analysis of laminated wood specifications and vessel suitability under local water conditions;
f. Preparation of technical specifications (standards) covering ship material, cargo capacity, speed, dimensions, and construction (hull and superstructure), onboard systems (machinery, electricity, fuel, water,

ventilation, pumps, navigation, and communication), and ship equipment (safety gear and firefighting equipment);

Selection and development of two "quick win" design types for laminated wood vessels based on operational areas, with outputs including:

a. Technical design analysis and drawings (basic design) as required by Non Convention Vessel Standards (NCVS) using original software;
b. Technical design analysis and drawings (key plan) as stipulated by NCVS, approved by the Directorate General of Sea Transportation;
c. Cost estimation and construction master schedule development.

Theoretical foundations include composite materials, wooden vessels, and design studies of community vessels using composite materials. Laminated wood specifications may refer to Table 1 below:

Table 1. Laminated Wood Requirements

Part of the Ship	**Minimum Density kg/cm³**	**MOE (Modulus of Elasticity)* Kg/cm²**	**MOE (Modulus of Elasticity)* Kg/cm²**
Keel, stem and sternpost, floors, frames, stern beam, deck side covering: wood with minimum specific gravity	700	1100–725	650–425
Keel, stem and sternpost, floors, frames, stern beam, deck side covering: wood with minimum specific gravity	450	725–500	425–300
Outer skin, deck beams, floor beams, knees, deck supports, engine beds	560	560	425–300
Deck and bilge floor	450	725–500	425–300
Size of keel beams and deck beams may be reduced by 15% if using laminated beams	–	–	–

(Source: Wooden Ship, BKI 1996)

During the concept design phase, principal particulars are determined using formula-based approaches or comparative vessels. In subsequent phases, calculations, iterations, and optimizations become key determinants, while dimensional limitations and main equipment selection based on owner, regulatory, and builder requirements are decisive factors. At this stage, it is also determined whether owner requirements can be met.

Currently, traditional people's vessels are constructed entirely from solid wood, often using various timber species without clear standards for different structural components such as frames, planking, or other parts. Wood selection depends on material availability and shipbuilder experience. As a result, it is difficult to assess the structural strength and quality of such vessels, since wood quality and dimensions vary significantly and lack standardization. Interestingly, some vessels in Probolinggo use fiberglass finishing on their hulls, which is similar to laminated composite systems where fiberglass is applied as an external layer.

Laminated wood composite construction is unique. Although wood remains the base material, this system does not require solid wood. Instead, most parts are produced from plywood, which is relatively cheaper. In general, laminated composite wood ships and traditional wooden ships have similar final appearances, but laminated wood construction is more complex to build, despite cheaper and more readily available materials. In the long term, laminated composite wood has significant potential because solid timber is becoming increasingly scarce and difficult to maintain. The fiberglass finishing layer also reduces the need for traditional caulking and re-caulking, simplifying maintenance.

LITERATURE REVIEW

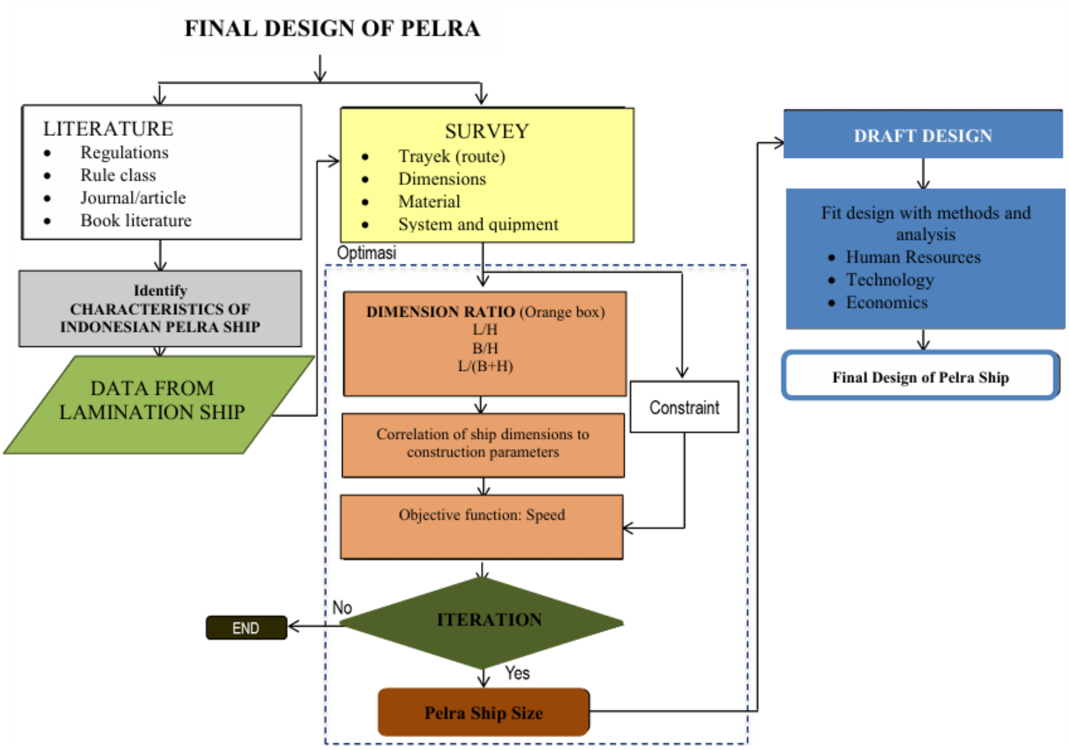
Propulsion and Safety Analysis: Most surveyed vessels use diesel engines as their main propulsion, while some still feature sails, although they are rarely used despite having masts. Engines are typically second-hand truck or generator engines connected to the propeller shaft. These engines, however, are not designed for marine use. Land engines are less resistant to tilting angles, whereas marine engines are designed to operate even at inclinations exceeding 40 degrees. Additionally, marine engines are equipped with seawater cooling systems, while land engines use air cooling. In practice, these engines are modified to run with seawater cooling, which damages materials not designed for saline environments.

Safety equipment on traditional vessels is minimal, with some carrying life jackets but lacking essential requirements such as life rafts or fire extinguishers. In contrast, laminated wood vessels built outside Indonesia generally use marine engines and follow high construction standards, as they are often intended for luxury tourism purposes requiring powerful engines for high speed. From a safety standpoint, these vessels are better equipped, at least with life jackets and portable fire extinguishers, though major equipment such as life rafts and lifeboats is still absent due to relatively small vessel sizes.

Propulsion Systems Used: Survey results show that diesel engines dominate as the main propulsion, with a few vessels also carrying sails. However, sails are rarely utilized despite the presence of masts. Engines are mostly second-hand truck or generator units adapted for marine use. Marine engines, however, are purpose-built with seawater cooling and durability against inclinations, unlike land-based engines. Laminated wood vessels built outside Indonesia are fully equipped with marine engines and constructed to high standards, mainly for luxury tourism needs requiring large, reliable, and powerful propulsion systems.

METHODOLOGY

The research methodology of this study can be presented in the form of a flowchart as shown below:



RESULTS AND DISCUSSION

In this study, field survey data and optimization of the design of small-scale port vessels (kapal pelayaran rakyat / Pelra) were identified and analyzed. The following are the results of the analysis and review carried out in this study:

Optimization Analysis and Preliminary Design of Pelra Vessels

In the optimization and regression process presented in the following chapter, the reference used is L(B/3+H) = 60. The hypothesis assumes there is room for optimization in the frame spacing range of 250–600 mm. Thus, field data obtained were first evaluated and focused on vessels with component parameters L(B/3+H) ≤ 70. This range was slightly extended to include a sufficient upper margin. The available data were re-sorted and analyzed across vessel length variations ranging from 10.5 m to 19.69 m, with deck heights between 1.5 m and 2 m. Meanwhile, construction coefficient values varied from 38.5 to 66.42, still below 70.

Table 2. Flowchart of Pelra Vessel Design Analysis

Ship Name	L	B	H	T	Estimated Displacement	L/H	GT	L/(B+3H)	Port
SEKO	10.50	5.90	1.70	1.32	35.62	6.18	10.20	38.50	SURVEY DATA REMBANG
KMN. BUDARTI	12.10	4.30	2.00	1.32	35.20	6.05	20.30	41.54	SURVEY DATA REMBANG
MEKAR BARU PUTRA	12.50	5.00	1.70	1.12	40.68	7.35	22.60	46.30	SURVEY DATA REMBANG
ARMADA JOYO	12.70	5.40	1.75	1.32	44.55	7.26	24.30	45.20	SURVEY DATA REMBANG
JAYA MAKMUR 05	13.75	5.00	1.60	1.12	39.55	8.59	22.70	49.08	SURVEY DATA REMBANG
MAJU SUKSES 1	13.75	5.20	1.75	1.12	45.69	7.86	26.00	47.42	SURVEY DATA REMBANG
SIDO LANCAR	12.10	6.20	1.75	1.12	49.28	6.91	25.30	39.66	SURVEY DATA REMBANG

HASIL SAMUDRA 2	13.60	6.00	6.00	1.12	47.56	8.50	29.60	47.86	SURVEY DATA REMBANG
SETO-04	12.60	5.60	1.60	1.12	42.86	7.88	24.30	44.36	SURVEY DATA REMBANG
DIANA NDAH	13.15	6.20	1.75	1.12	55.28	7.51	30.00	45.60	SURVEY DATA REMBANG
TUNAS KARYA MNA MNA	14.00	5.60	1.75	1.12	52.18	8.00	30.70	47.62	SURVEY DATA REMBANG
SUMBER LATU RAMBO	13.50	6.00	1.80	1.32	55.35	7.50	30.00	45.36	SURVEY DATA REMBANG
KARYA SEJATI XII	14.35	5.40	1.90	1.32	52.60	7.55	30.00	50.64	SURVEY DATA REMBANG
KEMBANG JOYO	15.80	5.15	1.75	1.32	55.20	9.03	30.00	58.23	SURVEY DATA REMBANG
RIZAL BERKAH MAKMUR	13.85	6.40	1.70	1.32	59.30	8.15	31.20	47.13	SURVEY DATA REMBANG
PUTRA MANDIRI	14.00	6.20	1.80	1.32	61.48	7.78	32.0	47.77	SURVEY DATA REMBANG
MEKAR BARU - 01	15.65	5.70	1.75	1.32	62.38	8.94	34.50	55.45	SURVEY DATA REMBANG
DIANA PUTRIVI	13.75	6.00	1.75	1.32	57.38	7.86	30.60	48.04	SURVEY DATA REMBANG

KARTIKAN	13.90	5.40	1.90	1.32	51.50	7.32	29.60	49.11	SURVEY DATA REMBANG
JAULAH	17.00	4.70	1.90	1.32	51.70	8.95	29.50	66.42	SURVEY DATA REMBANG
PERMATA BD	15.50	5.00	1.90	1.32	51.40	8.16	30.00	58.71	SURVEY DATA REMBANG
SRIPAHALA - 3	14.70	5.10	1.80	1.32	49.50	8.17	30.00	54.33	SURVEY DATA REMBANG
NEW MANGGALA	14.60	5.70	1.90	1.32	56.40	7.68	32.00	52.85	SURVEY DATA TUBAN
KAMANDANU 1	15.75	5.50	1.85	1.32	56.00	8.51	33.00	57.76	SURVEY DATA REMBANG
PURNAMA II	16.00	5.60	1.90	1.32	60.00	8.42	35.00	57.14	SURVEY DATA REMBANG
UNGGUL BARU	15.80	5.70	1.90	1.32	61.50	8.31	36.00	56.39	SURVEY DATA REMBANG
FAJAR SAKTI	16.00	6.00	1.90	1.32	64.00	8.42	37.00	54.24	SURVEY DATA REMBANG
BAROKAH JAYA	17.18	5.74	1.85	1.32	64.90	9.30	40.00	60.51	SURVEY DATA REMBANG
MAYOR	19.69	6.35	2.00	1.32	63.38	9.84	33.60	66.42	SURVEY DATA REMBANG

From the data above, a regression graph was generated to examine the statistical relationship between the vessel's principal dimensions and the component L(B/3+H), in order to identify which dimension has the strongest influence.

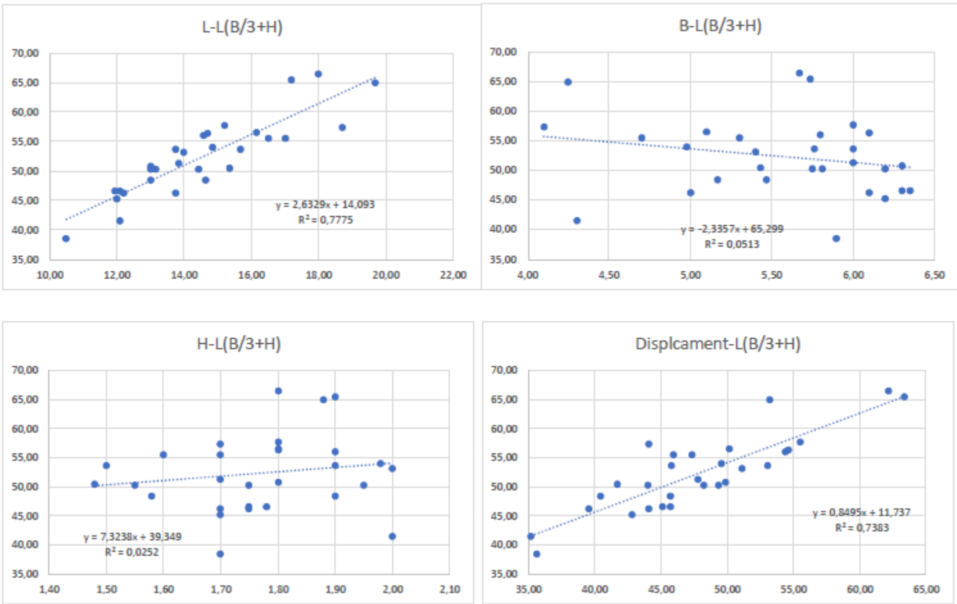


Figure 3. Regression Graph Testing the Statistical Relationship of Vessel Main Dimensions

Based on the graphs, it can be concluded that the relationship between L vs L(B/3+H) shows a strong pattern, as indicated by an R^2 value of 0.7775. From this, the correlation function between L vs L(B/3+H) is adopted as the initial benchmark to determine the vessel's length, targeting L vs L(B/3+H) = 60.

$$y = 2{,}6329x + 14{,}093$$
$$R^2 = 0{,}7775$$

From this formula, to obtain L(B/3+H) = 60, the required vessel length is 17.44 m. This dimension is then used as the basis for determining other main dimensions, such as breadth, height, and draft.

The following are the optimized dimensions of Pelra vessels for both KLM and Non-KLM types, based on the analysis:

PRINCIPAL PARTICULARS

LENGTH OVERALL	20.25	M
LENGTH W.L	18.14	M
BEAM MOULDED	3.80	M
DEPTH MOULDED	1.80	M
DRAFT DESIGNED	1.20	M

PERFORMANCES

CARGO CAPACITY	20.00	TON
SPEED	8.00	KNOT
COMPLEMENT	4	PERSON

PRINCIPAL PARTICULARS

LENGTH OVERALL	20.25	M
LENGTH W.L	18.14	M
BEAM MOULDED	3.80	M
DEPTH MOULDED	1.80	M
DRAFT DESIGNED	1.20	M

PERFORMANCES

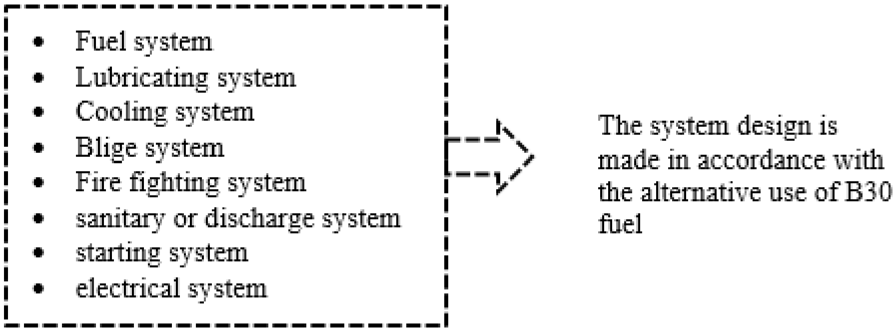
CARGO CAPACITY	20.00	TON
SPEED	8.00	KNOT
COMPLEMENT	4	PERSON

Figure 4. Principal Particulars and Performance of KLM & Non-KLM

Ship System Design Fuel System: Does not require pumps or transfer manifolds, operating entirely by gravity. Bilge, Ballast, and Firefighting Systems: Equipped with a bypass system, enabling all pumps to serve as backups if one fails.

Main Engine Cooling System: Supplied directly from the seacock to the engine's heat exchanger, with an emergency cooling system using the general service pump.

Domestic System: Freshwater tanks for sanitation are located behind the wheelhouse.



Effect of B30 Fuel Use on Vessel Design and Construction

a. Fuel Tank Volume – For the same voyage range, B30 consumption is higher than MFO but lower than HSD. Hence, tank volume design may increase or decrease.
b. Fuel Tank Layout and Supporting Systems – Supporting systems such as piping, heating requirements, pumping systems, valves, and fuel-checking mechanisms will change accordingly.
c. Volume and Layout Around the Fuel Tank and Engine Room – Tank size changes will affect surrounding space and system layouts.

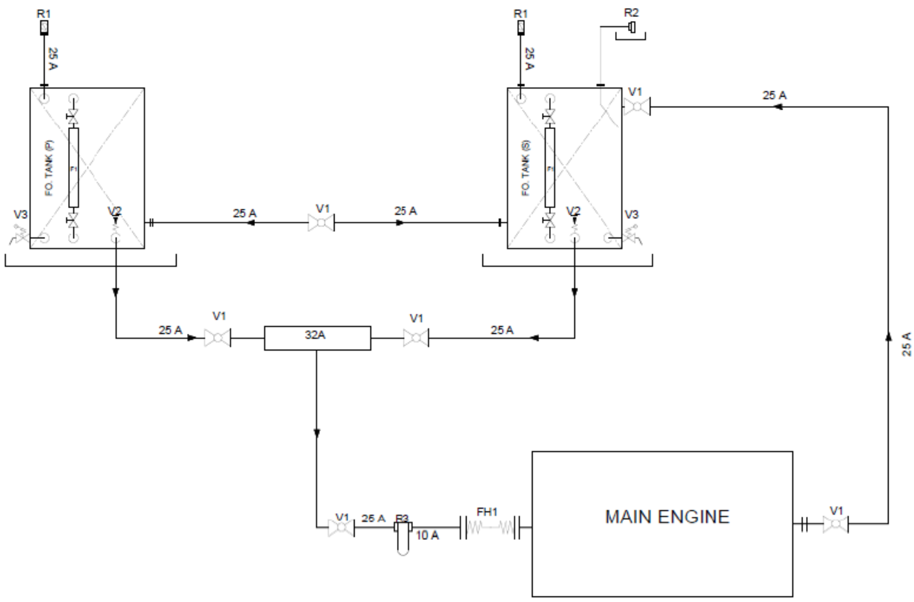


Figure 5. Fuel System Diagram

Bilge, Ballast, and Fire Fighting Systems; The bilge and ballast systems are arranged according to existing safety regulations. There is a bypass system that allows all pumps to substitute for each other in case of a malfunction.

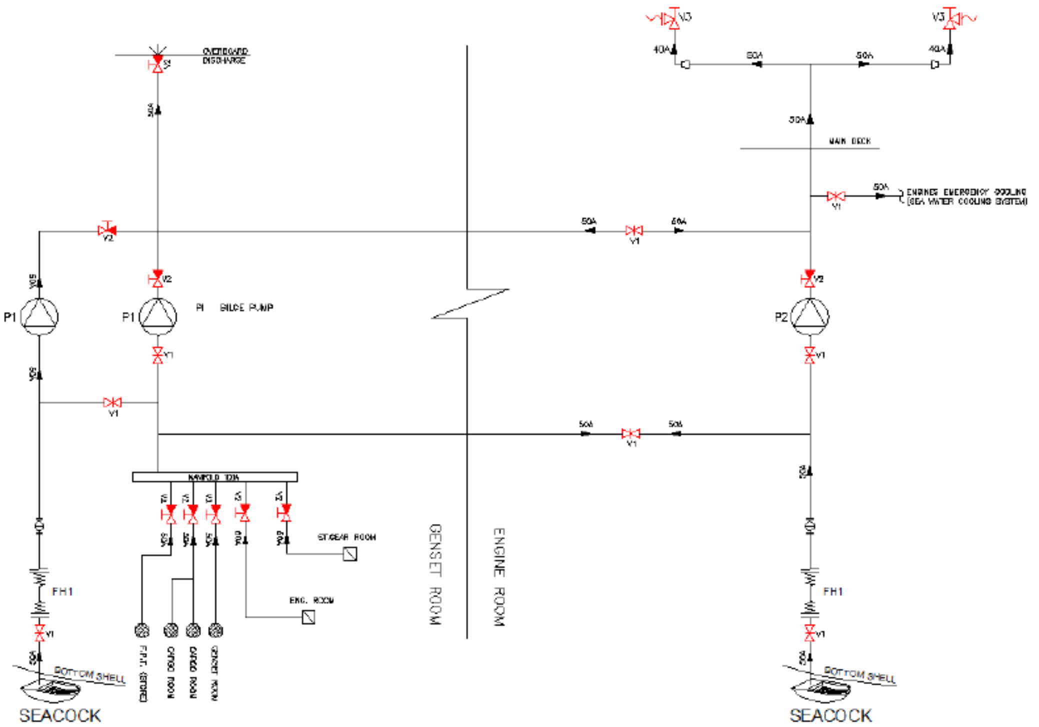


Figure 6. General Service System

The general service system on board functions as a backup for other systems in case of failure, and it also supplies the ship's fire-fighting system. On ships, this system is generally mandatory; however, unfortunately, in traditional public shipping vessels (pelayaran rakyat), this system is often absent. This condition is highly dangerous for ship safety, especially in the event of a fire. The crew has no choice but to extinguish the fire with makeshift equipment, and not infrequently they are forced to abandon the ship when such efforts fail.

Meanwhile, the main function of the bilge system is to remove or drain water in case of leakage, whether due to grounding or collision. Its secondary function is to drain or dry water that enters the cargo hold as a result of sea waves, bad weather or rain, minor leaks caused by cracks, or condensation. The bilge system operates by discharging water collected in the bilge well.

The main engine cooling system is supplied directly from the seacock to the engine heat exchanger. In addition to the main cooling system, there is also an emergency cooling system using the general service pump, with the schematic as follows.

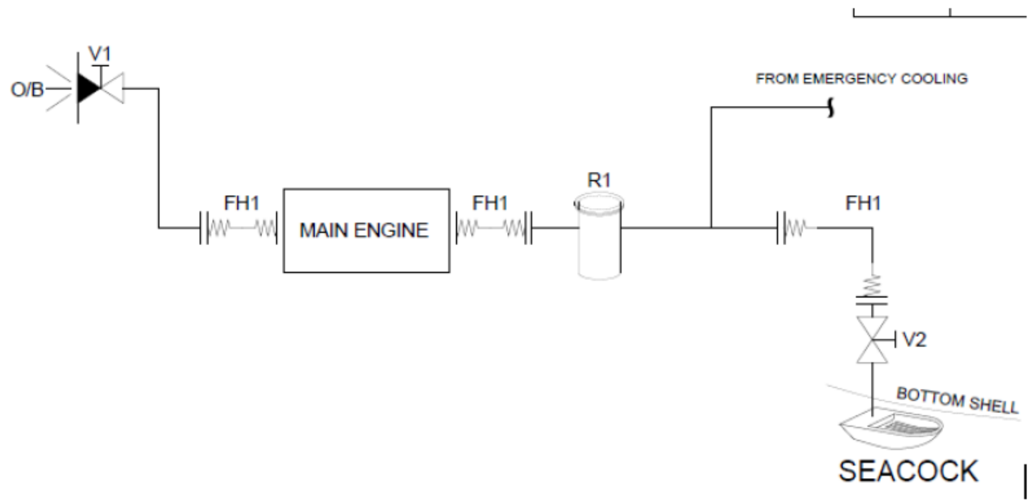


Figure 7. Cooling System

The domestic system; The domestic system for fresh water requirements—such as crew sanitation and galley needs—is supplied with fresh water stored behind the ship’s wheelhouse. The arrangement is shown in the following diagram.

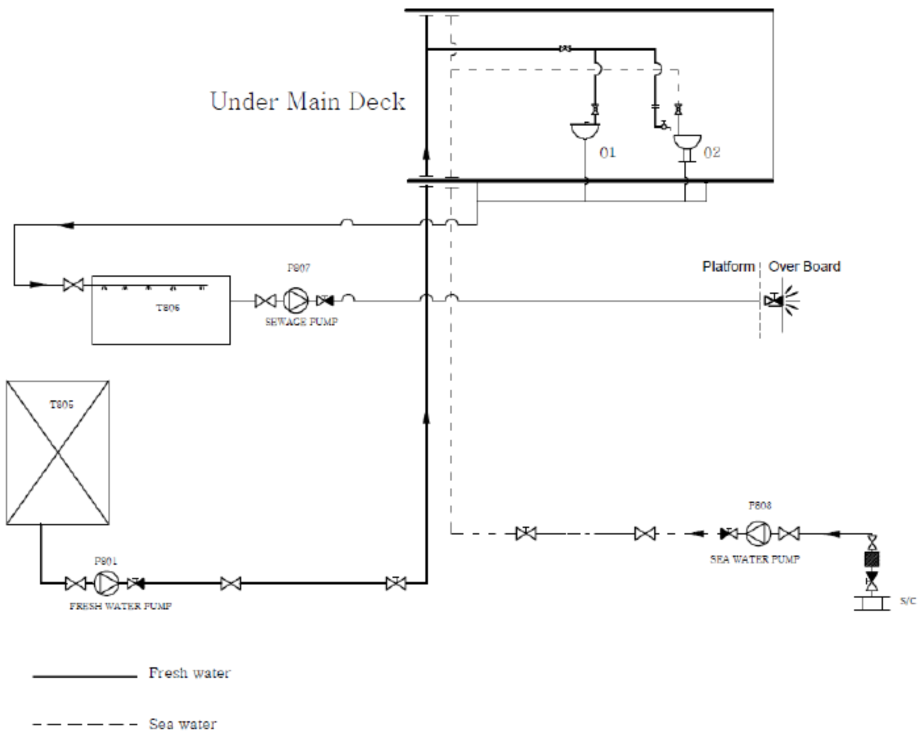


Figure 8. Domestic System

This system is better known as the system that regulates the clean water supply on board as well as the wastewater disposal system. On traditional public shipping vessels (pelayaran rakyat), the clean water system is usually operated in the same way as a household system, using a pressure set and connected through pipes to the bathroom or galley. As for wastewater disposal, it is usually discharged directly into the sea. This practice is certainly very harmful to the environment and causes significant marine pollution.

Pelra Vessel Specifications

Table 2. Pelra Vessel Specifications (1)

No	Specification	Identity
1	Fuel Capacity	2 × 200 Liters
2	F.W. Tank	700 Liters
3	Crews	4 persons
4	Classification	BKI
5	Room	Fore Peak Tank
6		Engine Room
7		Generator Room
8		Cargo Hold
9		Accommodation Room
10		Engine Room
11	Material an Hul Structure	Steering Gear Room
12	Material	Plywood with FRP Coating
13	Side Shell	45.8 × 52 mm
14	Bottom	45 mm
15	Deck	36 mm
16	Bulkheads	12 mm
17	Transom	45.8 × 52 mm
18	Superstructure Deck Outfitting	36 mm
19	Engine Hatch	1 pc – Flush hatches for removal of engine
20	Cargo Hatch	1 lot – Wooden Hatch
21	Engine Hatch Coaming	4 pcs – Watertight
21	Watertight Door	1 unit – Watertight Door
22	Windows	1 lot – Toughened Glass
22	Windows	8 mm – For Front Windows
22	Windows	6 mm – For Side Windows
22	Bollard	6 pcs – Single-bitt Bollards
23	Mast Machinery Equipment	1 pcs – Aluminum mast for navigation lights and flags
24	Main Engine	Class Type Approval
25	Gearbox, Alternator, Sea Water Cooling Pump	Coupled with Main Engine
26	Engine Equipment	Manual & Part Book, Engine Accessories, Engine Indicator Panel, Minimum Stock Engine's Spare Part

27	Exhaust Pipe	Pipe and fittings with expansion joint, silencer, heat insulation
	Propulsion System	
28	Conventional Fix Propeller 1 unit	Material Ni-Al-Bz or Ni-Mn-Bz, power steering using helm pump

Table 3. Pelra Vessel Specifications (2)

No	Specification	Identity
30	**Electrical Equipment** Genset	1 marine type set according to class requirements, min 8 kW with 1 phase AC/50 Hz
31	Output	
32	Battery (Accu)	2 units (200 Ah, 12 Volt DC)
33	Battery charging with shore power connection socket	Battery charging with shore power connection socket
34	**Piping and Pumping System** Pipe installation system	BKI Class
35	Bilge Pump	Electric Bilge Pump
36	Fire Pump	Manual Fire Pump
38	**Steering Gear Equipment** Steering Wheel	1 unit
39	Helm Pump	1 set
40	Steering Gear System	1 set
41	**Navigation and Communication Equipment** Navigation Light	2 side lights
42		1 stern light
43		1 masthead light
44		1 anchor light
45	Search Light	1 unit search light 500 W
46	Flood Light	2 units flood light 100 W
47	Cabin Light	x units (to be confirmed)
48	Electric Horn	1 unit Electric Horn with TA
49	Compass	1 marine type
50	Binocular	1 lot Binocular
51	GPS	GPS chart plotter
52	VHF/MF Radio Telephone	
53	VHF/MF Portable Radio	
54	AIS Type B	1 set
55	National Flag (Red & White)	
56	**Safety Equipment** Lifebuoys	4 units According to SOLAS
57	First Aid Kit	2 sets According to SOLAS
58	Lifejackets	15 sets According to SOLAS
59	Life Raft	1 unit According to SOLAS

60	Parachute Signal	1 unit According to SOLAS
61	Hand Flare	6 units According to SOLAS
62	Smoke Signal	2 units According to SOLAS
63	Heat and Smoke Detector	1 unit According to SOLAS
64	Portable CO_2	2 units According to SOLAS

Source: Pelra Vessel Design Study Consultant Analysis (Puslitbang LLASDP, 2020)

After designing the ship systems for traditional passenger vessels (pelayaran rakyat) using composite wood material, the following systems can be applied to realize this design:

1. Fuel System – The fuel system used follows the design that has been made. In general, there is no significant difference between the fuel system of this vessel and that of other pelayaran rakyat ships. However, it should be noted that fuel consumption may be slightly lower or higher, as the use of composite wood material affects the friction between the fluid and the hull, which in turn impacts resistance and fuel consumption. Further studies are needed in order to produce a vessel with low fuel consumption.
2. Lubrication System – The designed lubrication system can already be applied to this vessel. Our note is that routine maintenance must be carried out on both the system and the ship's engine, so that the engine's ability to generate thrust remains consistent with the design.
3. Cooling System – The designed cooling system is sufficient for cooling the engine on this composite wood vessel.
4. Bilge System – The designed bilge system is adequate to accommodate liquid inside the vessel, which can then be stored or discharged.
5. Fire-Fighting System – The designed fire-fighting system meets the requirements for ship and passenger safety.
6. Sanitary/Disposal System – The designed sanitary system is adequate to accommodate passenger needs.
7. Starting System – The designed starting system can already be used for the propulsion engine of this composite wood vessel.
8. Electrical System – The designed electrical system meets the standard requirements for both passengers and the composite wood vessel.

In addition, as part of the innovation in using B30 biofuel as fuel for traditional passenger ships made of composite wood, the following can be noted: B30 can be used on this vessel with the assumption of an engine power of 80 HP or equivalent to 58 kW. The SFOC (Specific Fuel Oil Consumption) when using HSD (High-Speed Diesel) is 0.162927, whereas with B30 it is 0.137527. This indicates that the use of B30 is more efficient compared to HSD for the same engine power. However, to obtain more realistic results for laminated pelayaran rakyat vessels, it is necessary to conduct experiments on ships with the same or nearly similar engine power, hull form, and tonnage as those used in traditional passenger vessels.

CONCLUSION AND RECOMMENDATION

The study shows that the hard chine hull design offers advantages in ease of construction, cargo space efficiency, reduced resistance, and the possibility of incorporating a sail system as an alternative propulsion method. The use of laminated composite wood has proven to be more economical compared to conventional wood, with costs at about half and added maintenance benefits through fiberglass coating. The application of B30 fuel is feasible, although it requires more complex handling. From an operational perspective, sail utilization is effective under wind conditions up to 19.2 knots, with an estimated utilization potential of about 58% annually. The potential combination of engine propulsion and sail systems opens opportunities for fuel efficiency as well as improved vessel speed. Based on these findings, it is recommended that the use of sails on traditional passenger vessels (pelayaran rakyat) be limited to weather conditions with wind speeds of up to 19.2 knots, in accordance with study results in the Tuban and Jakarta regions. Furthermore, the adoption of the motor sailing vessel (KLM) type is highly recommended, as it provides greater benefits with relatively minor differences in construction costs. Further studies on optimizing the combination of engine thrust and sail power should be conducted to improve operational efficiency, support sustainability, and add value to Indonesia's pelayaran rakyat fleet.

FUTHER STUDY

This research still has delays, so it is necessary to conduct further research related to the topic Design of a Biodiesel B30 Fuel Engine System on a People's Ship Made of Composite Wood Material in order to improve this research and add insight for readers.

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