Preliminary design of small semi-displacement passenger ships for the archipelago regions

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Abstract. The development of rapid passenger transport in Indonesian archipelago regions is so fast in recent years. The previous survey conducted by the authors found the typical passenger boats with the capacity of 12 or 20 persons. Those small boats have the difficulties in operating at worse sea conditions. In addition, there are semi-displacement vessels with the capacity of 150 to 350 persons operated from certain seaports. In fact, there is a gap for the vessels with the capacity of 40 to 100 passengers. The purpose of the research is to provide small semi-displacement passenger vessels which may be operated from local small ports provided by the local government. The vessels were designed to follow standard procedure in ship design. The designed ship are small semi-displacement passenger vessels with the capacity of 40, 69 and 103 passengers. The design process was started by input design parameters due to ship missions and continued by design process up to determination of specification at preliminary design stage. The results of research are design specification of three vessels according to their dimensions and configuration. The results of this research should be followed by future detail design in order to provide the documents for the stakeholders.

Keywords: Ship Design, Semi-Displacement Ship

1. Introduction

The need of fast passenger transport in Indonesian waters, particularly in the Eastern Indonesian Archipelago region develops rapidly in accordance with the local area development. In other side, the operation of passenger vessels have lower load factor due to little passenger numbers in these regions. Transport passenger in these regions are handled by two types of passenger ships i.e. small boats with the capacity of 12 or 20 persons and semi-displacement ships with the capacity of 150 to 350 persons. The small boats are operated from local ports with or without jetty while the semi-displacement ships are operated from middle size jetty located at certain sea port in the island. Passenger travel with semi-displacement ships needs land transportation which takes time and additional cost. In addition, semi-displacement ships operate with low payload due to small number of passengers from little or medium islands. On the other hand, the local authorities have provided small jetties in villages or certain spots that can be used to operate small or middle-size boats.

The research provides small/medium class of passenger ships. Those ships will be operated from the local sea ports. The size of the ships are designed to fulfil the payload of local passenger transport. The ships are designed to fit the range between 40 to 100 passengers. Three ship class are designed in this purpose which could be used depend on number of passenger or pay load at local sea ports.
2. Literature Review

2.1. The Characteristic of Small Passenger Ships

Sea transportation by small speed ships in the Indonesian archipelago regions is the main requirements nowadays. The capacity of passenger are 12 passengers or 25 passengers. Those boats are operated from the local beaches or ports as showed in the following Figure 1. The operation of small fast passenger boats are favourable due to small pay loads from the local ports. Meanwhile, there are kinds of semi-displacement passenger ships, capacity 150 to 350 passengers [1], operated Indonesian waters which as well as parts of the world as presented at Figure 2.

![Small speed boats at local ports](image1)

Figure 1. Small speed boats at local ports

![Semi-Displacement passenger ships](image2)

Figure 2. Semi-Displacement passenger ships

2.2. Semi-Displacement Passenger Ships

Semi-displacement ships are designed to serve the passenger transport in short routes. Their speeds are ranging from 19 to 25 knots or Froude Number, \( F_n \) are 0.55 to 1.0 [2]. According to the definition by IMO-HSC [3, 4], such ships are classified as HSC. With these range of Froude number, they are classified as semi-displacement ships as stated by Molland [2] and Nicolaysen [5]. Due to their operational ranges, those ships are also classified as short-sea ferries, as their speeds generally do not exceed 25 knots [6]. The application of lighter hull material of Aluminium or composite (FRP) gives the benefits for such ships. Such kind of ships are showed in Figure 2. Larsson [7] defined the intermediate region \( (0.5 < F_n < 1.0) \) is called the semi planing speed range as shown in Figure 3. According to Nicolaysen [5], the speed range of ships can be classified into four regions corresponding to the forces acting on the ship hull where the ranges of Froude number for semi-displacement ships are \( 0.5 < F_n < 0.75 \) and for pre-planing ships are \( 0.75 < F_n < 1.0 \).
Figure 3. Approximate speed ranges for the ships [2]

2.3. Design of Small Semi-Displacement Passenger Ships
Ship design is an iterative process where the number of iterations are needed to reach a satisfactory solution [8, 9]. The results of iteration process should be evaluated, analysed and modified until the design process satisfies the objectives and requirements. All requirements and rules imposed for the ship design were strictly adhered to during design process. The objective of designing ship is to find the proper ship dimensions, geometrical hull forms and other parameters that satisfy the design requirements. Particularly in designing a passenger ship, several important key factors such as: spaces, access, service rooms, arrangement, accommodation, passengers safety, services and facilities should be concerned. Also scantling, weights and centres, stability, safety and sea keeping are important parameters for the ship operation [10, 11, 12]. Some details such as lightweight, deadweight, liquids and their centres were required to compute intact stability parameters. The stability parameters were computed with Maxsurf. Two loading conditions (full load departure and arrival) were examined for the ships as required by existing regulation (IMO Resolution weather criterion / 2008 IS Code). During the design process some existing speed boats [13] and semi-displacement passenger ships [14, 15] which is out of design range were taken as reference. Hull material of the ship is Fibreglass Reinforced Plastic (FRP). The structure elements of designed ships are computed based on Biro Klasifikasi Indonesia [16].

3. Methodology
In this research three semi-displacement ships were designed where the size of ships are separated into the capacity of 40, 69 and 103 passengers. The process of design was described as follows:

1. Collecting data base. The data base of small passenger boats and semi-displacement ships were taken into account for design purpose. The database are out of design range which are less than 40 passengers for speed boats and greater than 100 passenger for semi-displacement ships. This database may be used as reference in design procedure.

2. Design phase. In this phase, the design process was executed following the standard procedure of ship design. Ship design parameters were determined and evaluated during an iterative process. Some design considerations concerning new concepts were introduced during the process. This concept was introduced in order to gain an added design value.

3. Developing the ship hull. The hull form of the fishing boats were developed by using Maxsurf software.

4. Computation ship’s parameters. Other ship’s parameters were computed and analysed to define the end of design process.

5. Ship specification. Specification of three designed ships are presented as results of this research.
4. Result and Discussion

4.1. Results of Ship Design
The process of ship design terminates when four main ship parameter are fulfilled at preliminary design phase as stated by Gale [8]. Four main parameters are identified as volume, weight, stability and powering. The design results of three semi-displacement ships fulfilled those main parameters. Meanwhile, all ship’s drawing are provided in this work. The results of three semi-displacement ships are presented in Figures 4 and 5 and Tables 1 and 2.

4.2. Discussion.
Total volume of those three ships are:
- Class 40-P is 121 m³ or 30 GT
- Class 69-P is 171 m³ or 53 GT
- Class 103-P is 246 m³ or 73 GT
It is concluded that the size of ships are available for the passengers and crews room and all services rooms.

The total weights of ships are counterbalanced by weight displacement resulted by ship’s size and geometrical form.

The stability parameters satisfy the IMO rules which are proved that the ships are safe from the stability perspective.

The installed power of prime mover was determined based on the existing method, propulsive properties and other considerations to ensure the installed power fulfil the required speed. The ship Class 40-P has outboard engine configuration while two other Class 69-P and Class 103-P has inboard configuration. This decision is based on the existing engine configuration in the market and the arrangement on board.

The dimensions of structure elements of ships are determined based on the Indonesian Classification Bureau (BKI) which is confirmed that the ships are safe from the structure perspective. Ship stability parameters in departure and arrival conditions are satisfy IMO rules as showed in Table 2.

Other ship parameters are determined during design process and satisfy all rules and requirements. The results of ship designed are determined for preliminary design phase other works concerning optimization, sea keeping, cost and other issue would be explored further.

(a). Class 40-Passengers  (b). Class 69-Passengers  (c). Class 103-Passengers
Figure 4. General Arrangement
Table 1. Design Specification

| Parameters | Units | Class 40-P | Class 69-P | Class 103-P |
|------------|-------|------------|------------|-------------|
| **A. Principal Dimensions** |       |            |            |             |
| 1. Length Overall, $L_{OA}$ | m     | 14.22      | 23.50      | 27.50       |
| 2. Length of Waterline, $L_{WL}$ | m     | 13.23      | 21.99      | 26.00       |
| 3. Beam, $B$ | m     | 3.70       | 4.05       | 5.10        |
| 4. Draft, $d$ | m     | 0.928      | 1.154      | 1.06        |
| 5. Deck height, $D$ | m     | 1.38       | 2.82       | 2.30        |
| 6. Frame space, $a_0$ | m     | 0.50       | 0.50       | 0.50        |
| 7. Passenger number | pax | 40         | 69         | 103         |
| 8. Crew number | pax | 4          | 4          | 5           |
| 9. Speed, $V_s$ | knot | 15.50      | 15.50      | 16          |
| 10. Froude number $F_n = V/\sqrt{g \cdot L_{WL}}$ | -     | 0.70       | 0.543      | 0.521       |
| 11. Total volume of ship | m$^3$ | 121.4      | 170.9      | 245.6       |
| 12. Gross tonnage, GT | tonnes | 30         | 53         | 73          |
| **B. Propulsion** |       |            |            |             |
| 1. Total resistance | kN | 28.70      | 27.70      | 31.10       |
| 2. Propulsion efficiency | % | 58         | 58         | 58          |
| 3. Propulsion power, BHP NCR | hp | 529        | 510        | 593         |
| 4. Propulsion power, BHP MCR | hp | 582        | 562        | 692         |
| 5. Installed engine power 1 unit | hp | 300        | 300        | 350         |
| 6. Number of engine | 2    | 2          | 2          |             |
| **C. Hydrostatics’ Properties** |       |            |            |             |
| 1. Displacement | tonnes | 23.95      | 41.54      | 49.29       |
| 2. Waterplane area | m$^2$ | 37.58      | 70.31      | 92.94       |
| 3. Prismatic coefficient |  | 0.721      | 0.603      | 0.565       |
| 4. Block coefficient |  | 0.481      | 0.375      | 0.326       |
| 5. Midship coefficient |  | 0.674      | 0.633      | 0.590       |
| 6. Waterplane area coefficient |  | 0.796      | 0.822      | 0.749       |
| 7. KB from base line | m | 0.585      | 0.773      | 0.720       |
| 8. BMt | m | 1.482      | 1.865      | 3.05        |
| 9. Immersion (TPC) | tonne/cm | 0.385      | 0.721      | 0.953       |
| **D. Stability Loadcase** |       |            |            |             |
| 1. Total ship weight | tonnes | 23.95      | 41.51      | 49.63       |
| 2. Longitudinal, LCG (from AP) | m | 5.63       | 10.78      | 12.82       |
| 3. Transverse, TCG (from CL) | m | 0.00       | 0.00       | 0.00        |
4. Vertical, VCG (from BL) m 1.241 1.573 1.946

Remarks:
1. Ship type: Semi-displacement with hull material of Fibreglass Reinforced Plastics (FRP)
2. Rules: Biro Klasifikasi Indonesia for FRP Ships
3. Engine type of Class 40-P: outboard engine Yamaha F300 Offshore @ 300 hp
   Class 69-P: Inboard engine MTU Diesel Engine S60 (1A) @ 300 hp
   Class 103P: Inboard engine MTU Diesel Engine S60 (1A) @ 350 hp
4. Resistance method: Savitsky Pre-Planing and Savitsky Planing

Table 2. Evaluation of Stability Parameter of Three Semi-Displacement Ships

| Rules: HSC 2000 Anex 8 Monohull Intact | HSC 2000 Ch2 Part B: Passenger Craft Intact |
|----------------------------------------|--------------------------------------------|
| Criteria | Value | Unit | Class 40-P | Class 69-P | Class 103-P |
|-----------|-------|------|------------|------------|------------|
| Weather Criterion from IMO A.749(18) |      |      | Actual     | Status     | Actual     | Status     | Actual     | Status     |
| 1. Angle of steady hell (<=) | 16 | deg | 6.70 | pass | 6.30 | pass | 3.90 | pass |
| 2. Angle of steady hell/Margin |     |      |      |      |      |      |      |      |
| line immersion (<) | 80 | % | 27.97 | pass | 21.67 | pass | 13.13 | pass |
| 3. Area1 / Area2 (>=) | 100 | % | 114.4 | pass | 101.96 | pass | 101 | pass |
| HSC 2000 Annex 8 Monohull Intact | | | | | | | | |
| 1. Area 0 to 30 or GZ max | 3.15 | m.deg | 6.27 | pass | 6.68 | pass | 9.94 | pass |
| 2. Area 30 to 40 | 1.72 | m.deg | 3.72 | pass | 3.96 | pass | 4.92 | pass |
| 3. Max GZ at 30 or greater | 0.2 | m | 0.375 | pass | 0.41 | pass | 0.50 | pass |
| 4. Angle of maximum GZ | 15 | deg | 34.50 | pass | 40.0 | pass | 36.40 | pass |
| 5. Initial GMt | 0.15 | m | 0.824 | pass | 1.07 | pass | 1.85 | pass |
| HSC 2000 Ch2 Part B Passenger Craft Intact | | | | | | | | |
| 1. Angle of equilibrium-Passenger | | | | | | | | |
| Crowding heeling arm | 10 | deg | 5.10 | pass | 7.0 | pass | 4.80 | pass |
| 2. High speed turning (Ht) | 8 | deg | 9.00 | pass | 4.8 | pass | 2.10 | pass |

5. Conclusion and Recommendation
The results of design process of three semi-displacement passenger ships are presented in this paper. During the design process all ships’ parameters are set to satisfy the rules and requirements. Some conclusions of the research work may be concluded as follows:
1. Four main ship parameters which are volume, weight, stability, engine power as well as other design parameters are satisfied in this preliminary design phase which means that the design results are accepted.
2. The design specifications of three semi-displacement passenger ships are may be used as reference in early design phase of similar ships. The class 40-P ship has dimension of length overall is 14.22 m and beam is 3.70 where the boat can carry 40 passengers with installed power of 2 x 300 hp outboard can reach the service speed of 15.50 knots. The class 69-P ship has dimension of length overall is 23.50 m and beam is 4.05 can carry 69 passengers with installed power of 2 x 300 hp inboard with can reach the service speed of 15.50 knots. The class 103-P ship has dimension of length overall is 27.50 m and beam is 5.10 can carry 103 passengers with installed power of 2 x 350 hp inboard with can reach the service speed of 16.00 knots.
3. Those ships may be selected to be operated from the local sea port according to appropriate passenger number or payload.

*It is recommended that:*
1. Future works would be conducted particularly optimization purpose based on the objective targets.
2. The results of ship design may be used as reference for future detailed design phase.

**Acknowledgement**
Special thanks is appreciated to Ship Design Team, Department of Naval Architecture Faculty of Engineering, Pattimura University for their hard work.

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