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HULL REDESIGN AND ITS EFFECT ON THE RESISTANCE OF MANADO PROTOTYPE SMALL PURSE SEINER

Rancang Ulang Desain Lambung dan Pengaruhnya terhadap Tahanan Gerak Kapal Pukat Cincin Kecil Manado

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ABSTRACT

This research aims to determine the effect of redesigning the hull of a small purse seine ship on its motion resistance. The research was carried out using a small purse seine ship prototype in Manado by changing the length-breadth-depth ratio based on the ship's main dimensions, resulting in three new hull designs coded K-0 (prototype), K-1, K-2, and K- 3. Maxsurf modeler and Maxsurf resistance were used to run a simulation set of three loading conditions (light, half, full) and speed (low, medium, high). The research results show that changes in ship hull design affect the resistance and thrust of the ship. There is a difference in resistance between the ship with the redesigned hull and the prototype, where K-3 shows the smallest difference. In addition to changes in hull design, changes in ship loading conditions, Froude number, and ship speed lead to increased ship resistance and thrust. Based on the average allowance (sea margin or service margin) in shipping lanes, the need for propulsion power and the number of propulsion power vessels K-0 (prototype) and K-3 are still better than K-1 and K-2.

Keywords: *purse-seiner, ship resistance, ship speed, ship engine propulsion*

ABSTRAK

Penelitian ini bertujuan untuk mengetahui pengaruh desain ulang lambung kapal purse seine kecil terhadap tahanan geraknya. Penelitian dilakukan menggunakan prototipe kapal purse seine kecil di Manado dengan mengubah rasio panjang-lebar-kedalaman berdasarkan dimensi utama kapal, sehingga diperoleh tiga desain lambung baru yang diberi kode K-0 (prototipe), K-1, K-2 , dan K-3. *Maxsurf modeler* dan *Maxsurf resistance* digunakan untuk menjalankan set simulasi tiga kondisi pembebanan (ringan, setengah, penuh) dan kecepatan (rendah, sedang, tinggi). Hasil penelitian menunjukkan bahwa perubahan desain lambung kapal mempengaruhi hambatan dan daya dorong kapal. Terdapat perbedaan hambatan antara kapal dengan lambung yang didesain ulang dan prototipenya, dimana perbedaan paling kecil ditunjukkan oleh K-3. Selain perubahan pada desain lambung, perubahan kondisi pemuatan kapal, bilangan *Froude*, dan kecepatan kapal menyebabkan peningkatan hambatan dan daya dorong kapal. Berdasarkan rata-rata kelonggaran (*sea margin* atau *service margin*) pada alur pelayaran, kebutuhan tenaga penggerak dan jumlah tenaga penggerak kapal K-0 (*prototype*) dan K-3 masih lebih baik dibandingkan dengan K-1 dan K- 2.

Kata kunci: kapal pukat-cincin, resistensi kapal, kecepatan kapal, daya dorong mesin kapal.

INTRODUCTION

Ships are a means of transportation to bring goods and or passengers from one locality to another on the water and are built according to their respective interests (Suriadin and Putra 2021). Fishing boats, fishing gear, and fishermen are three factors supporting the success of a fishing operation (Soeboer *et al.* 2018). Fishing vessels in Indonesia have a variety of shapes (Putra *et al*. 2020). The vessel shape is significantly affected by fishing grounds and operations (Niam and Hasanudin 2017).

Purse-seiners are fishing vessels widely used by fishermen in small pelagic fishing activities. According to Azis *et al.* (2017), purse seiners belong to a type of fishing vessel targeting the schooling fish by encircling the fish schools. They have a variety of distinctive shapes with the locality where the ships are made. Despite their different shapes, they all intend to support the ship's activities in operating purse seines. Indonesian fishing boats, including purse-seiner, are made of wood, have a relatively small size, under 25 m long, and are generally planned and made traditionally (Mulyanto *et al*. 2019), with an easier and simpler manufacturing procedure than steel vessels (Liu *et al*. 2019; Chrismianto *et al*. 2020).

Purse seine fisheries in North Sulawesi Province are located in several different localities, including Bitung, Molibagu, Belang, and Manado, each with its typical shape and different technical capability. A previous study (Pamikiran *et al*. 2017) found that the purse seine vessel of Manado has a better technical capability than other areas. Based on this study, the original type of Manado purse-seiner has a better resistance value than vessels from other purse seine fisheries-based areas in North Sulawesi. Nevertheless, the hull line needs to be redesigned in relation to the ship capacity development, particularly the ship resistance, and power.

The ratio of length (L), width (B), and depth (D) are a significant component that will indirectly provide an idea of the ship's shape and influence its performance, such as resistance, stability, loading ability, and motion. It is in agreement with Putra *et al.* (2020) that different ship shapes will give different technical capabilities of the ship, such as resistance, movements, and stability.

Ship resistance is a fluid force that acts on a ship in such a way that counteracts the movement of a ship in which the resistance is equal to the component of the fluid force acting parallel to the axis of the ship’s motion (Harvald 1992). In general, ships moving in the water at a certain speed will experience resistance forces opposite to their direction. This resistance must be overcome by the thrust of the ship's propulsor. Information on the ship's resistance is essential in relation to the ship's speed and propulsion, which will affect the propulsion engine's thrust needs and fuel oil use. The interaction between the ship resistance and velocity needs to be balanced to make use of power efficiency (Diaz-Ojeda et al. 2023). There are several definitions of power often used in estimating the power requirements of the ship propulsion systems, including adequate power, i.e., the amount of power needed to overcome the inhibitory force of the ship's body (hull) so that the ship can move from one place to another at the service speed (Vs). Thrust is the amount of power generated by the work of the ship's propulsor to push the ship's body.

For the average condition of sailing service, an additional leeway should be given on the resistance and effective force caused by wind, erosion, and fouling of the ship's body. The addition of this leeway depends mainly on the cruise line. The average allowance for resistance or planned effectiveness for East Asian shipping lines is 15-20% (Harvald 1992). It means that designing the ship's effective power requires an addition of 15-20% to avoid power deficiency in poor weather conditions.

This study is aimed at knowing the resistance of the redesigned vessel, including the prototype as basic information to set the ship power added with the service margin.

METHODS

The redesign and data analysis were carried out in the drawing room of the Shipmenship Laboratory, Fisheries Resources Utilization Study Program, the Faculty of Fisheries and Marine Sciences, Sam Ratulangi University, Manado. This study was carried out from July 2019 to January 2020.

Research procedure

Data collection covered the technical data of the prototype ship in the form of the size and hull line of the ship from Manado City (Pamikiran *et al.* 2017). The prototype ship is the original purse seiner of Manado, which has better technical capability than the ships from other areas. This ship shape was adopted as a standard measure.

The redesign of the Manado prototype ship in the form of a hull line was carried out by changing the ratio of breadth (B) and depth (D) of the ship. The change in the ratio between the principle dimensions of Length (L), Breadth (B), and Depth (D) is carried out based on the standard ratio of the principle dimensions of purse-seiner proposed by Fyson (1985) as follows: L/B = 3.10 - 4.30, B/D = 2.10 – 5.00, and L/D = 9.50 - 11.00. From the middle value of the scale of the primary size, three new hull line forms were obtained, and together with the prototype ship, the following abbreviation codes were given: K-0 (prototype), K-1, K-2, and K-3. The redesign was conducted by altering the ratio scale of the primary dimension; namely, the hull-line structure was altered in two directions, the width and the height, whereas the ship length did not change. The change in hull-line structure was done automatically through *transform scale vector* and simulation of *transverse axis* and *vertical axis values, while the longitudinal axis* value was maintained. Thus, this redesigning only alters the ratio of the principle dimension and the hull-line structure, whereas the block coefficient (Cb) and prismatic coefficient Cp) remain the same; the change only occurs when the submerged part changes from loading conditions (I=light condition, II=half condition, and III=full condition) (Table 1). The implementation of the draft values on three immersion conditions of the ship operation were 13% for light condition, mid-draft (half-submerged), and 18% from the half-draft to the full-load condition. The ship's offset body plan data, buttock line data, and hull-line image are presented in Tables 2 – 5 and Figures 1 – 4.

Table 1 Principle dimension, draft, Cb, and Cp in various loading conditions.

Ship and loading condition	Technical parameters					
	Length (m)	Breadth (m)	Depth (m)	Draft (m)	Cb	Cp
K-0 I	20.50	4.75	1.63	0.475	0.393	0.630
K-1 I	20.50	5.54	2.10	0.612	0.393	0.630
K-2 I	20.50	4.75	2.10	0.612	0.393	0.630
K-3 I	20.50	5.54	1.63	0.475	0.393	0.630
K-0 II	20.50	4.75	1.63	0.545	0.418	0.642
K-1 II	20.50	5.54	2.10	0.702	0.418	0.642
K-2 II	20.50	4.75	2.10	0.702	0.418	0.642
K-3 II	20,50	5.54	1.63	0.545	0.418	0.642
K-0 III	20.50	4.75	1.63	0.644	0.446	0.657
K-1 III	20.50	5.54	2.10	0.829	0.446	0.657
K-2 III	20.50	4.75	2.10	0.829	0.446	0.657
K-3 III	20.50	5.541	1.63	0.644	0.446	0.657

Table 2 Body plan and buttock line offset data of K-0 (prototype of Manado small purse seiner, Indonesia)

BODY PLAN (Meter)

ST	WL 0	WL 1	WL 2	WL 3	WL 4	WL 5	WL 6	WL 7	WL 8	WL 9
0	-	-	-	-	1.84	2.04	-	-	-	-
1a	-	-	-	-	2.00	2.05	-	-	-	-
1b	0.10	0.10	1.43	1.84	2.03	2.12	-	-	-	-
2	0.10	0.10	1.52	1.93	2.07	2.19	-	-	-	-
3	0.10	0.10	1.59	1.98	2.15	2.25	-	-	-	-
4	0.10	0.10	1.71	2.03	2.20	2.31	-	-	-	-
5	0.10	0.10	1.78	2.05	2.22	2.34	-	-	-	-
6	0.10	0.10	1.43	1.86	2.10	2.27	-	-	-	-
7	0.10	0.10	0.84	1.36	1.73	2.01	2.26	-	-	-
8	0.10	0.10	0.38	0.70	1.05	1.40	1.77	-	-	-
9	0.10	0.10	0.10	0.18	0.30	0.45	0.69	1.02	-	-
10	-	-	-	-	-	-	-	-	-	0.10

BUTTOCK LINE (Meter)

BL	ST 0	ST 1a	ST 1b	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8	ST 9	ST 10
1	-	-	0.14	0.13	0.12	0.12	0.12	0.14	0.20	0.44	1.38	-
2	-	-	0.20	0.18	0.15	0.13	0.13	0.20	0.37	0.81	1.89	-
3	-	-	0.27	0.25	0.21	0.16	0.16	0.28	0.59	1.16	2.26	-
4	-	-	0.43	0.38	0.35	0.27	0.25	0.44	0.84	1.53	-	-
5	-	-	0.70	0.61	0.56	0.48	0.42	0.69	1.18	1.86	-	-
6	-	0.47	1.39	1.19	1.03	0.92	0.88	1.15	1.63	-	-	-

Where: ST (Station), WL (*Water Line*), and BL (*Buttock Line*)
ST 0 (0), ST 1a (2.05), ST 1b (2.75), ST 2 (4.10), ST 3 (6.15), ST 4 (8.20), ST 5 (10.25), ST 6 (12.30), ST 7 (14.35), ST 8 (16.40), ST 9 (18.45), and ST 10 (20.50)
WL 0 (0), WL 1 (0.10), WL 2 (0.46), WL 3 (0.82), WL 4 (1.17), WL 5 (1.53), WL 6 (1.89), WL 7 (2.25), and WL 8 (2.61)
BL 1 (0.35), BL 2 (0.64), BL 3 (1.04), BL 4 (1.39), BL 5 (1.74), and BL 6 (2.09)

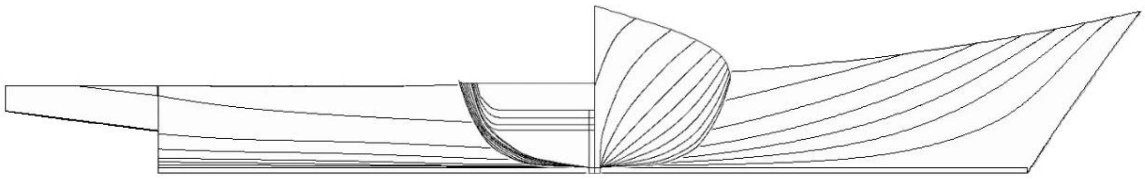

Figure 1 K-0 Hull Line (prototype of Manado small purse seiner, Indonesia)

Table 3 Body plan and buttock line offset data of K-1 (first redesign of Manado small purse seiner prototype, Indonesia)

BODY PLAN (meter)										
ST	WL 0	WL 1	WL 2	WL 3	WL 4	WL 5	WL 6	WL 7	WL 8	WL 9
0	-	-	-	-	2.15	2.38	-	-	-	-
1a	-	-	-	-	2.33	2.46	-	-	-	-
1b	0.12	0.12	1.67	2.15	2.37	2.48	-	-	-	-
2	0.12	0.12	1.77	2.26	2.41	2.55	-	-	-	-
3	0.12	0.12	1.86	2.31	2.51	2.63	-	-	-	-
4	0.12	0.12	2.00	2.37	2.56	2.71	-	-	-	-
5	0.12	0.12	2.08	2.40	2.59	2.73	-	-	-	-
6	0.12	0.12	1.67	2.17	2.45	2.65	-	-	-	-
7	0.12	0.12	0.98	1.59	2.02	2.64	2.64	-	-	-
8	0.12	0.12	0.44	0.82	1.23	1.63	2.07	-	-	-
9	0.12	0.12	0.12	0.21	0.35	0.52	0.81	1.20	-	-
10	-	-	-	-	-	-	-	-	-	0.12

BUTTOCK LINE (meter)												
BL	ST 0	ST 1a	ST 1b	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8	ST 9	ST 10
1	-	-	0.17	0.17	0.16	0.15	0.15	0.18	0.26	0.54	1.66	-
2	-	-	0.25	0.23	0.20	0.17	0.17	0.26	0.48	1.04	2.44	-
3	-	-	0.35	0.32	0.28	0.21	0.20	0.36	0.76	1.50	2.91	-
4	-	-	0.55	0.49	0.45	0.35	0.32	0.56	1.08	1.97	-	-
5	-	-	0.90	0.78	0.72	0.61	0.55	0.88	1.52	2.39	-	-
6	-	0.90	1.79	1.53	1.32	1.19	1.13	1.48	2.10	-	-	-

Where: ST (Station), WL (*Water Line*), and BL (*Buttock Line*)
ST 0 (0), ST 1a (2.05), ST 1b (2.75), ST 2 (4.10), ST 3 (6.15), ST 4 (8.20), ST 5 (10.25), ST 6 (12.30), ST 7 (14.35), ST 8 (16.40), ST 9 (18.45), and ST 10 (20.50)
WL 0 (0), WL 1 (0.12), WL 2 (0.59), WL 3 (1.05), WL 4 (1.51), WL 5 (1.97), WL 6 (2.43), WL 7 (2.89), and WL 8 (3.35)
BL 1 (0.41), BL 2 (0.81), BL 3 (1.22), BL 4 (1.62), BL 5 (2.03), and BL 6 (2.44)

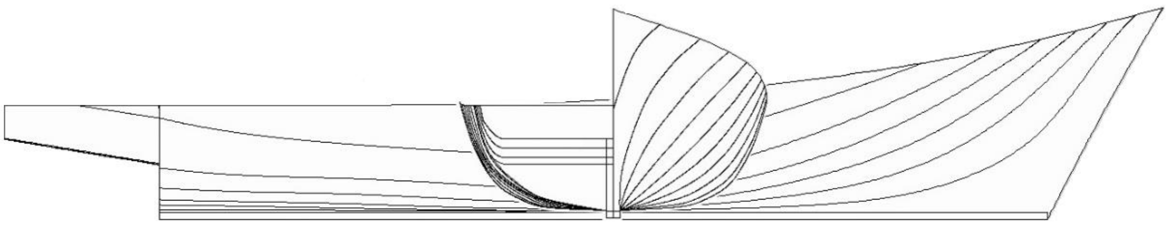

Figure 2 K-1 Hull Line (first redesign of Manado small purse seiner prototype, Indonesia)

Table 4 Body plan and buttock line offset data of K-2 (second redesign of Manado small purse seiner prototype, Indonesia)

BODY PLAN (meter)										
ST	WL 0	WL 1	WL 2	WL 3	WL 4	WL 5	WL 6	WL 7	WL 8	WL 9
0	-	-	-	-	1.84	2.04	-	-	-	-
1a	-	-	-	-	2.00	2.10	-	-	-	-
1b	0.12	0.12	1.43	1.84	2.03	2.12	-	-	-	-
2	0.12	0.12	1.52	1.93	2.08	2.18	-	-	-	-
3	0.12	0.12	1.59	1.98	2.15	2.25	-	-	-	-
4	0.12	0.12	1.71	2.03	2.20	2.31	-	-	-	-
5	0.12	0.12	1.78	2.05	2.22	2.34	-	-	-	-
6	0.12	0.12	1.43	1.86	2.10	2.27	-	-	-	-
7	0.12	0.12	0.84	1.36	1.73	2.01	2.26	-	-	-
8	0.12	0.12	0.38	0.70	1.05	1.40	1.39	-	-	-
9	0.12	0.12	0.12	0.17	0.29	0.45	0.69	1.03	-	-
10	-	-	-	-	-	-	-	-	-	0.12

Table 4 Body plan and buttock line offset data of K-2 (second redesign of Manado small purse seiner prototype, Indonesia) (continued)

BUTTOCK LINE (meter)												
BL	ST 0	ST 1a	ST-1b	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8	ST 9	ST 0
1	-	-	0.17	0.17	0.16	0.15	0.15	0.18	0.26	0.54	1.66	-
2	-	-	0.25	0.23	0.20	0.17	0.17	0.26	0.48	1.04	2.44	-
3	-	-	0.35	0.32	0.28	0.21	0.20	0.36	0.76	1.50	2.91	-
4	-	-	0.55	0.49	0.45	0.35	0.32	0.56	1.08	1.97	-	-
5	-	-	0.90	0.78	0.72	0.61	0.55	0.88	1.52	2.39	-	-
6	-	1.89	1.79	1.53	1.32	1.19	1.13	1.48	2.10	-	-	-

Where: ST (Station), WL (*Water Line*), and BL (*Buttock Line*)
ST 0 (0), ST 1a (2.05), ST 1b (2.75), ST 2 (4.10), ST 3 (6.15), ST 4 (8.20), ST 5 (10.25), ST 6 (12.30), ST 7 (14.35), ST 8 (16.40), ST 9 (18.45), and ST 10 (20.50)
WL 0 (0), WL 1 (0.12), WL 2 (0.59), WL 3 (1.05), WL 4 (1.51), WL 5 (1.97), WL 6 (2.43), WL 7 (2.89), and WL 8 (3.35)
BL 1 (0.35), BL 2 (0.70), BL 3 (1.04), BL 4 (1.39), BL 5 (1.74), and BL 6 (2.09).

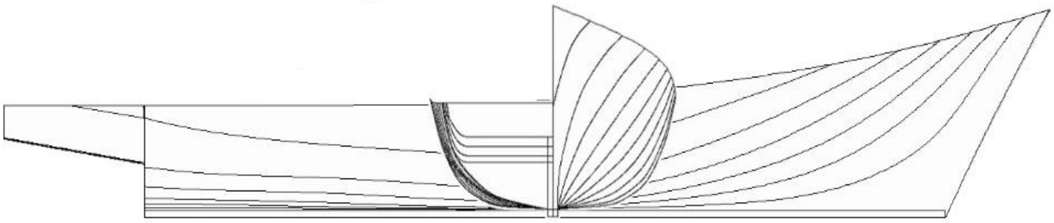

Figure 3 K-2 Hull Line (second redesign of Manado small purse seiner prototype, Indonesia)

Table 5 Body plan and Buttock Line offset data of K-3 (third redesign of Manado small purse seiner prototype, Indonesia)

BODY PLAN (meter)										
ST	WL 0	WL 1	WL 2	WL 3	WL 4	WL 5	WL 6	WL 7	WL 8	WL 9
0	-	-	-	-	2.15	2.38	-	-	-	-
1a	-	-	-	-	2.33	2.46	-	-	-	-
1b	0.10	0.10	1.67	2.15	2.37	2.48	-	-	-	-
2	0.10	0.10	1.77	2.26	2.41	2.55	-	-	-	-
3	0.10	0.10	1.86	2.31	2.51	2.63	-	-	-	-
4	0.10	0.10	2.00	2.37	2.56	2.71	-	-	-	-
5	0.10	0.10	2.08	2.40	2.59	2.73	-	-	-	-
6	0.10	0.10	1.67	2.17	2.45	2.65	-	-	-	-
7	0.10	0.10	0.98	1.59	2.02	2.64	2.64	-	-	-
8	0.10	0.10	0.44	0.82	1.23	1.63	2.07	-	-	-
9	0.10	0.10	0.12	0.21	0.35	0.52	0.81	1.20	-	-
10	-	-	-	-	-	-	-	-	-	0.12

BUTTOCK LINE (meter)												
BL	ST 0	ST 1a	ST 1b	ST 2	ST 3	ST 4	ST 5	ST 6	ST 7	ST 8	ST 9	ST 10
1	-	-	0.14	0.13	0.12	0.12	0.12	0.14	0.20	0.42	1.29	-
2	-	-	0.20	0.19	0.15	0.13	0.13	0.20	0.37	0.81	1.90	-
3	-	-	0.27	0.25	0.21	0.16	0.16	0.28	0.59	1.16	2.26	-
4	-	-	0.43	0.38	0.35	0.27	0.25	0.44	0.84	1.53	-	-
5	-	-	0.70	0.61	0.56	0.48	0.42	0.69	1.18	1.86	-	-
6	-	1.47	1.39	1.19	1.03	0.92	0.88	1.15	1.63	-	-	-

Where: ST (Station), WL (*Water Line*), and BL (*Buttock Line*)
ST 0 (0), ST 1a (2.05), ST 1b (2.75), ST 2 (4.10), ST 3 (6.15), ST 4 (8.20), ST 5 (10.25), ST 6 (12.30), ST 7 (14.35), ST 8 (16.40), ST 9 (18.45), and ST 10 (20.50)
WL 0 (0), WL 1 (0.10), WL 2 (0.46), WL 3 (0.82), WL 4 (1.17), WL 5 (1.53), WL 6 (1.89), WL 7 (2.25), and WL 8 (2.61)
BL 1 (0.41), BL 2 (0.81), BL 3 (1.22), BL 4 (1.62), BL 5 (2.03), and BL 6 (2.44)

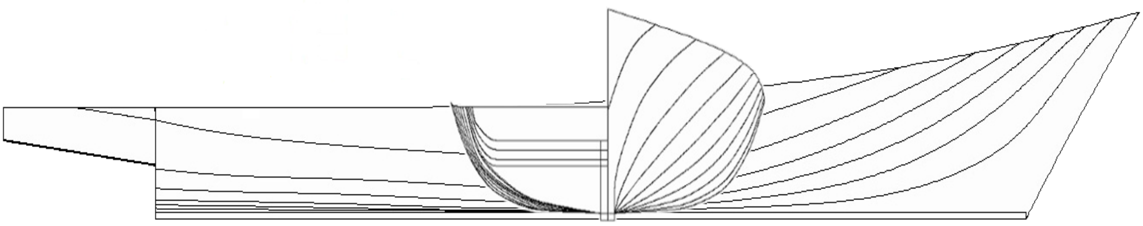

Figure 4 K-3 Hull Line (third redesign of Manado small purse seiner prototype, Indonesia)

Data Analysis

The hull line data were inputted into the free-ship plus application. The data format was then adjusted to the application by exporting the data from free-ship plus and importing them into the Maxsurf Modeler Advanced application. This application changed the hull line data format to a format corresponding to the Maxsurf Resistance Enterprise. Maxsurf application, including Maxsurf Resistance, was also used for data analysis by taking advantage of free Maxsurf Enterprise V8i (SELECTSeries 3) 20.00.02.31. The Froude number was used to obtain the value of ship speed in various categories, namely low, medium, and high speeds, using the formula below (Harvald 1992):

Froude Number = $V/\sqrt{g.L}$ .... (1)

where V is ship speed (m/s.), g is the acceleration of gravity (9.8 m/sec^2), and L is ship length (m).

In this study, the calculation of ship resistance used the Wyman method. The ship's total resistance data consisted of friction, auxiliary, air, and residual resistance. The friction resistance and coefficient were calculated following the formulation of the International Towing Tank Conference (ITTC) 1957. The formulations used in the analysis are as follows:

$$R_f = ½.\rho.V^2. (1+k)\, C_f.\, S \quad (2)$$

$$C_f = 0.075/(\log R_n - 2)^2 \quad (3)$$

$$R_n = (VxLWL)/v \quad (4)$$

$$1 + k1 = C_{13}\,(0.93 + C_{12}\,(B/L_R)^{0.92497}\,(0.95\text{-}Cp)^{-0.521448}(1\text{-}Cp+0{,}025 \times \%\,LCB)^{0{,}6906} \quad (5)$$

$$C_{12} = (T/LWL)^{0{,}2228446} \quad (6)$$

$$C_{13} = 1 + 0.003 \times C_{stern} \quad (7)$$

$$L_R = L\,(1 + Cp + \frac{0.06 \times Cp \times \%LCB}{4Cp-1}) \quad (8)$$

$$S = LWL\,(2T+B)\sqrt{C_M}\,(0.4530+0.4425C_B-0.2862C_M - 0.003467\,B/T+ 0.3693\,C_W) + 2.38\,A_{BT}/Cb \quad (9)$$

where A_{BT} is bulb area because the fish boat does not have a bulbous bow, then ABT = 0, B is the breadth, Cb is block coefficient, Cf is the frictional coefficient, Cm is midship coefficient, Cp is the prismatic coefficient, Cw is water area coefficient, LWL is the length of waterline (m), R_f is total frictional resistance (N), S is wet surface area of the vessel (m^2), T is draft (m), V is ship speed (m/s), ρ is density of seawater (1.025 kg/m^3), and v is kinematic viscosity of seawater 0.94252 x 10^{-6} m^2/s (at the temperature of 25^o C).

Additional ship resistance (R_{APP}) is determined based on additional part factors (1 + k2), which is determined by the following formulation:

$$(1 + k2) = \sum E2 / \sum E1 \quad (10)$$

where ∑ E1 is the value of the presence or absence of additional parts and

∑ E2 is the multiplication of the value of the presence or absence of additional parts and the value of the factor:

$$R_{APP} = (1 + k2) \times Cf \times 0.5 \times \rho \times As \times V \quad (11)$$

where C_F is the coefficient of friction, 1 + k2 is additional part factor values, ρ is seawater density, 1025 kg/m3, As is the area of additional fields, and V is variation in ship speed in m/s.

The power needed to respond to the ship's resistance to various speeds was obtained by converting the ship resistance value in Newton's (N) unit to the horsepower (HP). The conversion was calculated as follows:

HP = Rf (N) x V (m/s)

Where 1 N. m/s = 0.001 kW, and 1 kW = 1.34102 HP.

RESULTS

Based on the redesign of K-1, the dimension needed to add the ship breadth and depth, the K-2 ship only needed to add the depth size, and the K-3 ship needed to add the width size, whereas the prototype ship of K-0 (prototype) did not change. This condition causes the hull-line structure change, influencing the ship submergence, wet surface area, and half angle of entrance (Table 6).

The relationship between the Froude Number and the ship's resistance, as well as the ship's speed and power in three load conditions, namely light condition (I), half condition (II), and full condition (III), are presented in the form of a two-dimensional curve (Figures 5 –10).

Table 6 Submergence parameters in 3 loading conditions for prototype and redesign of Manado small purse seiner, Indonesia.

Ship/ Condition	Ship's submerging parameters					
	LWL (m)	BWL (m)	Draft (m)	Disp. (m^3)	W.area (m^2)	½ angle-e.(^{0})
K-0 (I)	16.02	3.61	0.48	10.78	46.42	7.5
K-1 (I)	16.02	4.21	0.61	16.22	55.28	8.8
K-2 (I)	16.02	3.61	0.61	13.90	49.08	7.5
K-3 (I)	16.02	4.21	0.48	12.59	52.76	8.8
K-0 (II)	16.08	3.79	0.58	15.18	51.71	9.5
K-1 (II)	16.08	4.43	0.75	22.81	61.73	11.3
K-2 (II)	16.08	3.79	0.75	19.55	55.05	9.7
K-3 (II)	16.08	4.43	0.58	17.71	58.58	11.1
K-0 (III)	16.15	3.93	0.68	19.48	56.11	11.4
K-1 (III)	16.15	4.59	0.87	29.26	67.13	13.0
K-2 (III)	16.15	3.93	0.87	25.07	60.11	11.2
K-3 (III)	16.15	4.59	0.68	22.74	63.36	13.2

Notes: I (light condition), II (half condition), and III (full condition); LWL (Length of water line); BWL (Breadth of water line); Draft; Disp. (Displacement/); W.area (wet surface area); ½ angle- of entrance)

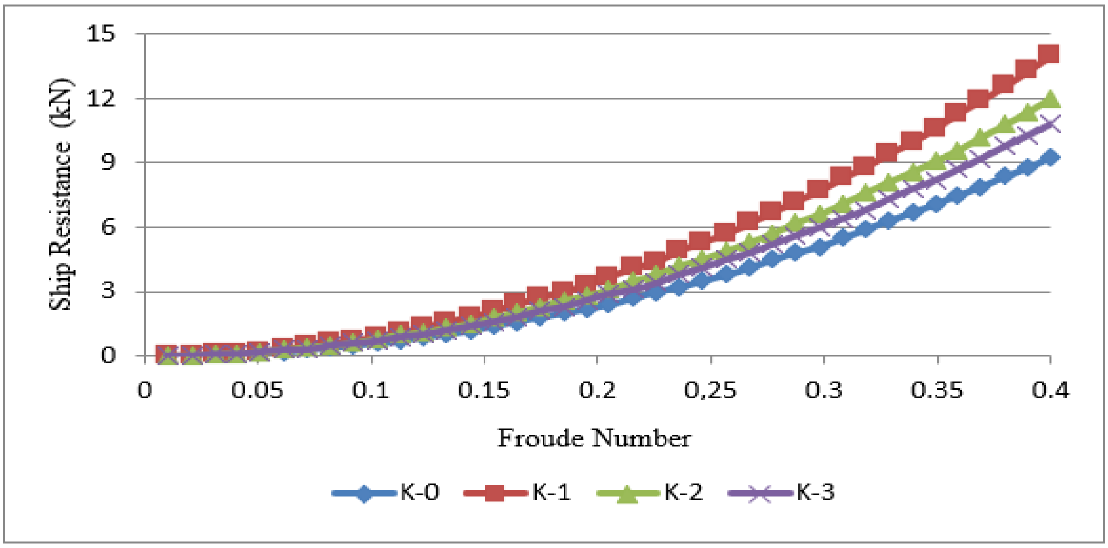

Figure 5 Froude number curve and ship resistance on light condition (I) for prototype and redesign of Manado small purse seiner, Indonesia.

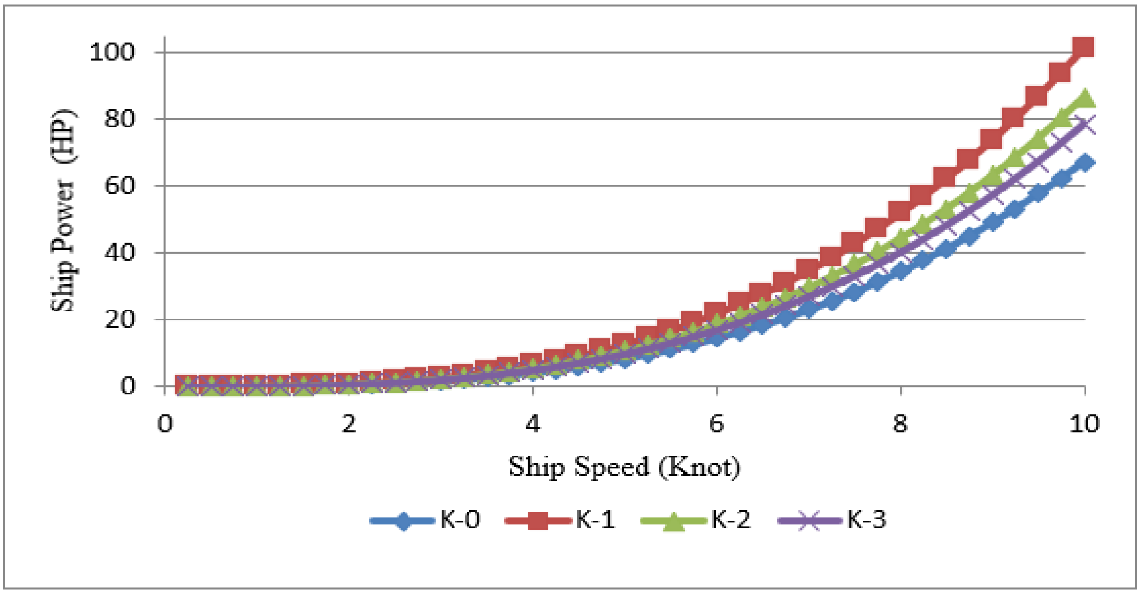

Figure 6 Speed curve and ship power on light conditions (I) for prototype and redesign of Manado small purse seiner, Indonesia.

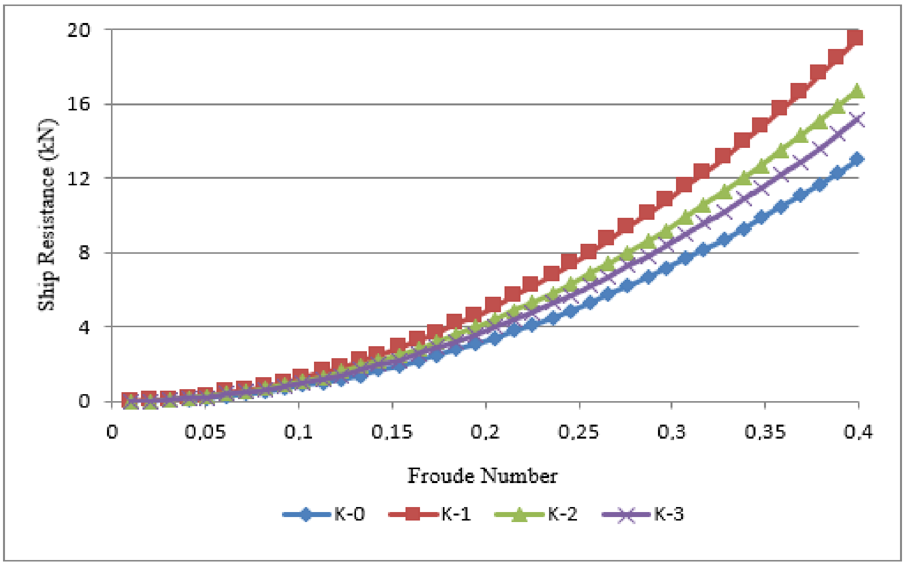

Figure 7 Froude number curve and ship resistance on half condition (II) for prototype and redesign of Manado small purse seiner, Indonesia.

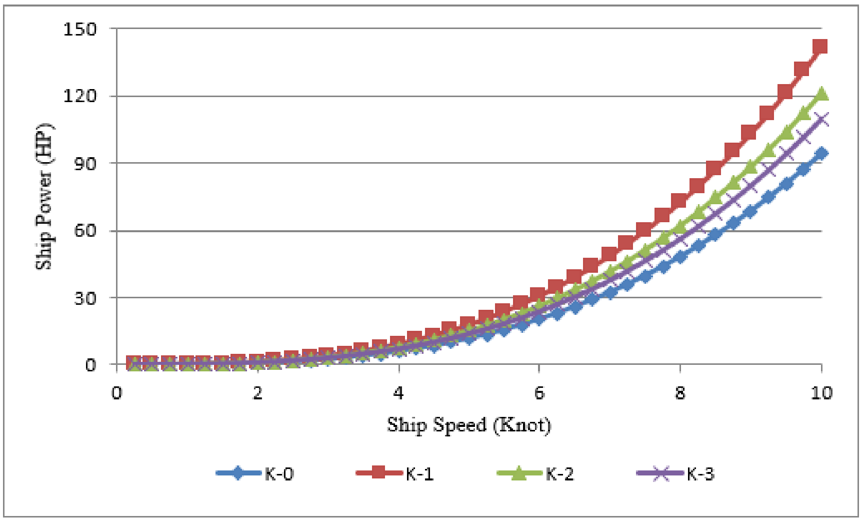

Figure 8 Speed curve and ship power on half conditions (II) for prototype and redesign of Manado small purse seiner, Indonesia.

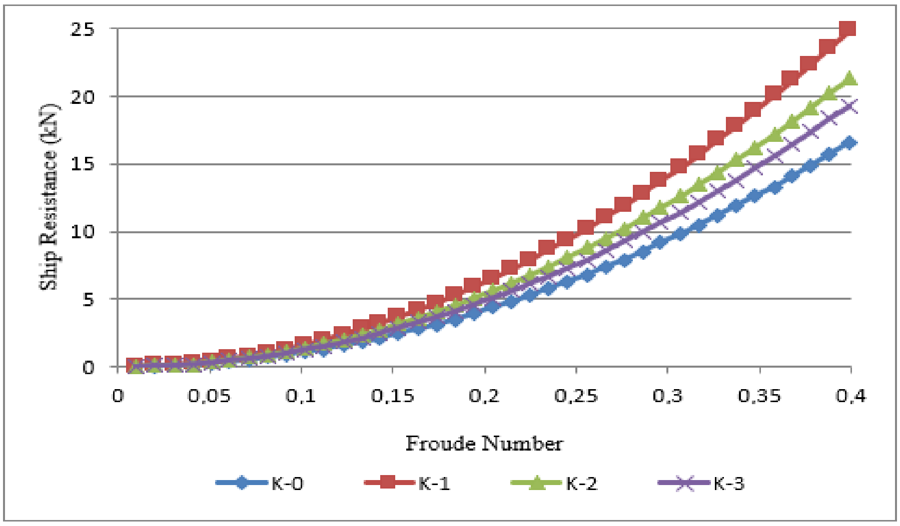

Figure 9 Froude number curve and ship resistance on full condition (III) for prototype and redesign of Manado small purse seiner, Indonesia.

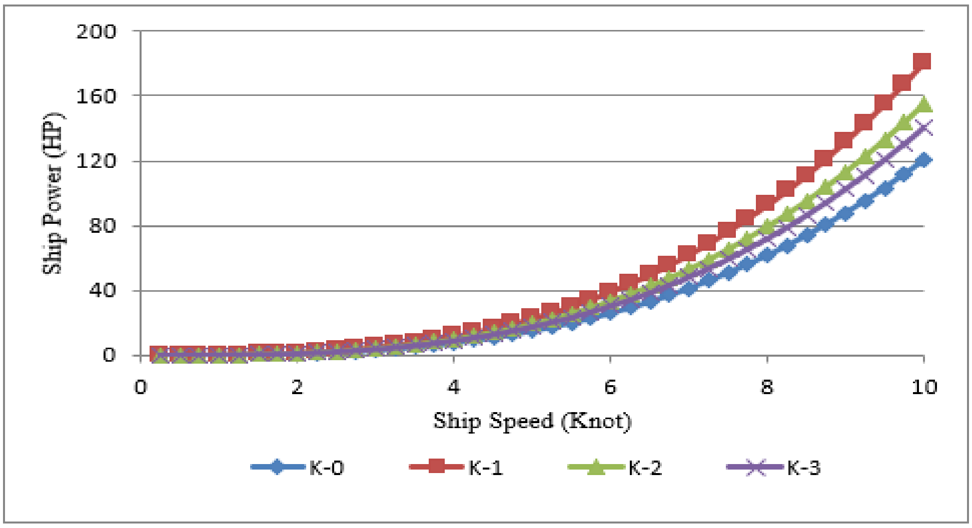

Figure 10 Speed curve and propulsion of the ship on full conditions (III) for prototype and redesign of Manado small purse seiner, Indonesia.

DISCUSSION

Figures 5 – 10 show the effect of the increase in the Froude Number on the value of resistance and the speed of the ship's propulsion on each ship's impact. The change in the ship's impact from the light condition, half condition, and full condition, as well as changes in Froude Numbers and ship speed, led to an increase in the ship's resistance and power as following what was stated by Rosmani *et al*. (2013) that the magnitude of the ship's resistance is strongly influenced by speed of the ship (Vs), the weight of the water displaced by the ship's body immersed in water (displacement), and the shape of the ship's body (hull form). In this case, the shape of the ship's block coefficient and prismatic coefficient, wet surface area, and angle of entry of the ship's bow affect the ship's resistance (Simajuntak *et al*. 2018).

The estimated values (Table 7) show that the resistance values of four ships under various conditions of impact and ship speed have the same trend (Figures 5, 7, 9). Therefore, as a comparison between ships, only values at the full condition were taken at the maximum speed. The maximum resistance was 12.77 kN for ship K-0, 19.19 kN for K-1, 16.45 kN for K-2, and 14.90 kN for K-3, respectively, whereas the maximum power was 75.45 HP for K-0, 113.33 HP for K-1, 97.11 HP for K-2, and 88.05 HP for K-3, respectively. If the resistance and the power values of K-0 are taken as a standard, 12.77 kN and 75.45 HP, respectively, these values have increased by 50.27% and 50.21% for K-1, 28.82% and 28.71% for K-2, and 16.68% and 16.69% for K-3. It indicates that the resistance and propulsion of the K-0 ship (prototype) and the K-3 ship are similar. In ship planning and designing, the resistance and propulsion should be relatively small so that the ship operations could be more fuel-efficient (Sunardi *et al*. 2015).

Table 7 Resistance value and power based on load conditions (I, II and III) and speed categories of the ship.

Ship/ Condition	Low speed (V1) (4,891 knots)		Medium speed (V2) (6,726 knots)		High-speed (V3) (8,560 knots)	
	Resistance (kN)	Power (HP)	Resistance (kN)	Power (HP)	Resistance (kN)	Power (HP)
K-0 (I)	2.34	7.89	4.43	20.51	7.17	42.29
K-1 (I)	3.53	11.86	6.65	30.85	10.77	63.59
K-2 (I)	3.01	10.17	5.70	26.44	9.24	54.49
K-3 (I)	2.73	9.21	5.16	23.94	8.35	49.35
K-0 (II)	3.27	11.03	6.18	28.68	10.02	59.13
K-1 (II)	4.92	16.58	9.30	43.11	15.04	88.87
K-2 (II)	4.22	14.21	7.96	36.94	12.90	76.15
K-3 (II)	3.82	12.87	7.22	33.47	11.68	69.00
K-0 (III)	4.17	14.08	7.89	36.60	12.77	75.45
K-1 (III)	6.26	21.14	11.84	54.98	19.19	113.33
K-2 (III)	5.38	18.12	10.16	47.11	16.45	97.11
K-3 (III)	4.87	16.43	9.20	42.72	14.90	88.05

The changes after the redesign and the submerge condition applications (Table 2) could be the reason for the highest resistance and power of the K-1 and the lowest resistance of the K-0 compared with those of K-2 and K-3. The addition of the ship draft (K-1 and K-2), submersion (K-1, K-2, and K3), and half angle of entrance highly influenced the ship's resistance and power. The resistance and power values of K-0 and K-3 are not significantly different, but these are different from those of K-1 and K-2. In general, it could result from the difference and addition of displacement value, wet surface area, and half angle of entrance. However, there is a privilege and advantage of the K-3 ship; even though this ship has a larger wet surface area and half entrance angle than the K-2, the K-3 has lower resistance value and power.

The estimated power values of the four ships at full condition and high speed (V3) are presented in Table 7. If the mean looseness of the sea margin (service margin) for adequate power is considered (Harvald 1992), then the propulsion required will be 90.54 HP for the ship K-0, 135.99 HP for the ship K-1, 116.53 for K-2, and 105.66 HP for K-3, respectively. In the field, prototype ships usually use four outboard motor units with a power of 40 HP for each outboard motor, meaning that the total driving power is 160 HP. The amount of propulsion required for the service margin of the K-3 ship is very close to that of K-0, only 16.70% (15.12 HP), whereas that of K-1 and K-2 have higher service margins. Based on the ship resistance, power, and power needs to meet the margin service, the K-0 and K-3 ships tend to be similar. However, K-3 has a larger loading capacity than K-0 (prototype) because of the breadth and the rise in submergence, as shown in Tables 1 and 6. In addition, K-3 also has better stability than the previous finding (Pamikiran *et al*. 2020).

CONCLUSION

Redesigning the Manado prototype purse seiner has altered the ship's hull-line structure onto the transverse and vertical axes by maintaining the longitudinal axis.

Changes in the ship's impact from light conditions, half condition, and full load, as well as changes in Froude numbers and ship speed, led to an increase in the ship's resistance and thrust values. Changes in the shape of the hull line caused changes in the value of the ship's resistance and thrust, in which, based on the average allowance (sea margin or service margin) on the ship's shipping lane, the need for propulsion and the use of the amount of propulsion for K-0 ships (prototypes) and K-3 ships is still better than that of K-1 ships and K-2 ships. Besides, the K-3 ship has a higher capability in shipping services.

SUGGESTIONS

The findings have shown that the K-3 ship design yields higher resistance than the prototype, but the percent service margin was lower than the allowable sea margin added for sea safety. The redesigned K-3 ship has a more extensive hull line than the prototypes, which helps increase the ship's stability on the water. Therefore, the redesigned hull line of the K-3 purse seine vessel could be considered for small purse seiners in Manado and North Sulawesi. A safe range of hull line development is also crucial to be established. Nevertheless, further studies are needed to carefully decide on a possible ship design development for other purposes.

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