Technical Suitability and Static Stability of *Sungkur* Fishing Boats for Fish and Shrimp Catching

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Abstract. Sungkur fishing gear is operated actively on one the side of fishing boat, which requires technical suitability and fishing gear stability to ensure success in fish catching. This is a case study which aimed to analyze some technical issues related to the boat, boat's hydrostatic parameters, and the boat's stability. The data were collected though observation, measuring the boat to obtain the offset table. The data were analyzed numerically and descriptively. The data were processed with technical formula, Microsoft Office's Excel software, graphic display, minitab, statistical data processing, and maxsurf program. The research results showed that: (1) the sungkur fishing boat dimensional ratio L/B (6.47 – 7.00); L/D (10.90 – 11.20) and B/D (1.60 – 1.668) is within the range value of Indonesian fishing boats suitable to operate the fishing gear by towing or dragging. However, during fish catching operation, there have been problems in a hydrodynamic force due to the fishing gear movement, which affect the fish catching efficiency. (2) The boat's coefficient of fineness is in the fine type shape; the displacement on each waterline has increased; the loads of the boat are getting larger following the increase of waterline from one to five; this is also shown from the increasing midship area value. Ton per centimeter immersion to change wl 1 by 1 cm needs 0.04 tons of weight. (3) Sungkur fishing boat have a good static stability, which is proven by the positive value of angle of maximum GZ by 79.1 – 83.6. In other words, the boat has the ability to return to its original position after tilting; however, stability dynamics happens because fishing gear operation are located on just one side of boat.

1. Introduction

1.1. Research Background

The Sungkur fishermen community in Tanah Laut make their own design for their fishing gear. Judging by the material, the fishing gear can only be classified as traditional fishing boats, which may not be found in regular commercial market. These Sungkur boats are more suitable for fishing in shallow coast with sandy mud and relatively flat surface. These boats are traditionally manufactured by Barito Kuala Regency [10]

Sungkur as a fishery unit, which consists of fishing boat, fishing gear, fisherman, and fishery resources, requires a balanced unity of mutual support for ensuring a successful catch. As a supporting facility, Sungkur boats should fulfill particular prerequisite to operate well. The Sungkur Fisheries are Active fishing gears are operated actively to catch fish as the object [10]. The Sungkur fisheries located in Tanah Laut Regency have an abundance of tools and properties which are feared to be disturbing the hydrostatic pressure. Therefore, it is important to calculate the hydrostatic parameter.

During the operation, Sungkur fish catcher is put on one side of the boat. The inside part of the fish catcher consist of shoes, tanjuran, net, and ballast. With these properties, the boat should fulfill certain criteria to operate well. The boats built in South Kalimantan usually are still traditional; the bottom part of the body still depends on the supply of woods cut in half, heated, and made into the boat main foundation, which they call it as kell. The boat manufacture has so far only considered the work load and funding from the buyer. Therefore, the boats are often times transversally not symmetrical when it is launched to the water surface. The boat commonly makers anticipated it by adding ballast on one side of the boat to make it stable. This action, however, increases the weight of the boat and thus increases the boat movement.

Along with the development and modernization of fishing boats, the structure design has been done through some approaches. The first approach in boat designing is measuring the technical suitability based on the characteristics suggested by [5]; that is by comparing the boat's main dimensions. [18] suggested that ratio of boats' main dimensions of traditional fishing boats in Indonesia has several parameter value differences in the body compared to the boats produced by Japan. Japanese boats' parameter value is bigger than that of Indonesian. According to [11] the smaller the value of L/B is, the more the ratio value will affect the ship speed; the bigger L/D value is, the weaker the boat power to longitudinal stretch s. Meanwhile, the bigger the value of B/D is, the more stabile the boat is; however, the worse the propulsive ability gets.

As one of sea ships/boats, fishing boat should also fulfill the requirement to be a sea boat. [17] explained that general requirements for a ship can sail safely in any sea circumstance, having stable shape and enough buoyancy, and efficient regarding size, power, cost, manufacture, and activities. The requirements should be fulfilled to make sure that the boat is ready to sail. Sungkur specialty, in this case, requires a specific boat that can accommodate the fish catcher used; it is, therefore, necessary to learn the technical suitability and static stability of Sungkur boat.

1.2. Research Purpose

This research aims in specific to analyze: (1) the technical suitability of Sungkur boat which consists of general arrangement, lines plan, and main dimension ratio, (2) hydrostatic parameter and (3) static suitability of Sungkur boat. This research is expected to be able to give comprehensive definition of the problems and weaknesses of Sungkur boat and the refinement of its design. Practically, this research can be a consideration to perfect the structure design of the fishing boat and increase its productivity and economical profit in the long terms.

2. Methodology

2.1. Study Sites

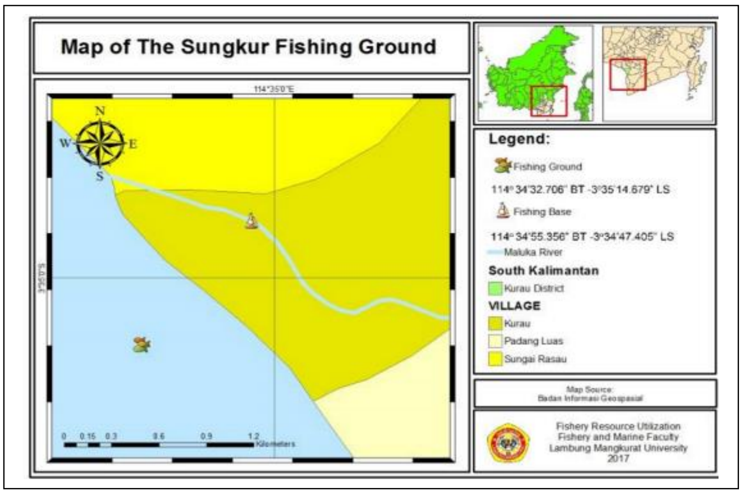

Figure 1. Map of Fishing Ground for Fish and Shrimp Catching with Sungkur Fishery in South Kalimantan Waters Scale Bar 1: 15000

This research was conducted from January to June 2017. This research was done at two sites: at the dry-dock of Sewangi, where Sungkur boats were made, and at the sea waterwork, where Sungkur fish catcher was operating in Tanah Laut regency, South Kalimantan province. Below is the Fishing Ground map of Sungkur catching (see Figure 1)

2.2. *Method*

The method of this research is descriptive and numerical case study. This research is conducted by learning certain particular case and limited object [15]. The research objects are the boats and Sungkur fish catcher. The data are collected through direct observation of the symptoms of the subjects observed during the catching operation, either in real situation or with special aid [1]. The ship is measured directly both at the dry-dock or at the quay in Tanah Laut regency, South Kalimantan province.

The tools used are meter roll, water pass, mast ruler, flexible curve, pendulum, small nail, and drawing table. Next, the tools are put in the field offset table. The soft tools used are Microsoft Excel, Software Maxsurf, and Notepad.

2.3. *Data Analysis*

Data from offset table are then made into picture in the form of general arrangement and Lines plan. The picture of boat line plan is the picture of each water line and ordinate manifested in three pictures: profile plan, half breadth plan, and body plan. The hydrostatic boat parameter is analyzed numerically based on the data resulted from geometrical measurement of boat shape using naval architecture calculation [5]

Newton Law II is used to assume the relationship between hydrodynamic (water resistance) and boat speed. The resistance calculation of Sungkur fish catcher is obtained by recalculating all resistances and wing opener of Sungkur which show the number of resistances from all net body and net pocket/bag as well as the components of fishing aid tools (shoes, surungan, all kinds of rope)

Suitability Analysis: L/B Ratio = Ratio between the length and width affects the boat resistance; L/H Ratio = Ratio between the length and the width affects the longitudinal strength of the ship; B/H Ratio= Ratio between the width and the length affects the boat stability. As a comparison, the standard ratio estimation in Nomura and Yamazaki (1977) is also used.

The Simpson Formula is used to count the midship area (A□), water area (Aw), and displacement volume, Ton Per Centimeter immersion (TPC), moment to change trim 1 cm (MCT 1cm). For calculating coefficient, these formula are used: Coefficient block (Cb), Coefficient prismatic (Cp), Coefficient vertical prismatic (Cvp), Coefficient midship (Cm), and Coefficient waterplan (Cw). The hydrostatic parameter is obtained by using the naval architecture formula [6][28].

To measure the ship stability, several formula is used to calculate the boat metacenter location: floating center location above basic line (KB), metacenter above floating center (BM), longitudinal metacenter above floating center (BM_L).

The static stability parameter is analyzed through static stability curve GZ using Atwood formula method [7]. This method analyzes static boat stability at an angle of heel 0^0-90^0. The calculation is below: GZ = BR – BT in which BR is the horizontal buoyancy center. At this moment, at shade area:

$$v \times hh_1 = BR \times \nabla$$

$$BR = \frac{v \times hh1}{\nabla}$$

in which: v is shade volume.
Hh_1 is horizontal change of shade area.
∇ is boat displacement volume.

Therefore, $GZ = \frac{v \times hh1}{\nabla} - BG \sin \theta$

This method analyzes the static boat stability at angle of heel 0^0-90^0. The static stability curve GZ describes the height of Righting arm GZ at angle of heel 0^0-80^0. Based on GZ curve, an analysis then is conducted on several heeling angles. The stability calculation result is then compared with the standard boat stability released by kingdom regulation the fishing vessels
(Safety Provisional) [7] at Torremolinos International Convention For the Fishing Vessels Regulation 28 (1977) through curve GZ [5]

3. Results

3.1. Description of Fishing Unit

3.1.1. Fishing gear

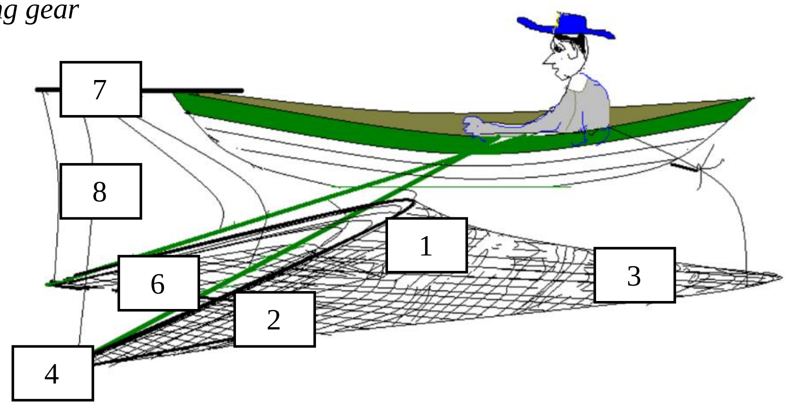

Figure 2. Components of Sungkur Design Model Information

No	Component	Information	Material	Resistance (Kgf)
1	: Webbing	Locking up fish/shrimp. 6 m, mesh size 3 m	PE	11,8426
2	: Wing	Shrimp leader net. 7 m length, mesh size 3 cm	PE	16,3437
3	: Cod end	Shrimp/Fish. 1, 10 m length and 2 cm	PE	1,3282
4	: Shoes	Preventing surungan from embedding at the sea bottom. 45, 0 cm length and 14,0 cm width inside or 2,5 cm thickness.	Wood	3,2421
5	: Surungan	Wing opener of net. 10, 63 m length	Bamboo	18,0406
6	: Sinker	Maintaining the position of wing at the bottom position, 12 item/meter; 3 cm length, 1,2 cm diameter	Rock	438,8204
7	: Tanjuran	A tool to hung ropes to determine the deepness of Sungkur position in the water	Bamboo	0
8	: Ropes	To open net, lift the fish cached, and manage the deepness during the operation	See Table 1	0

Sungkur is a fish catching tool with transversal wing opener forming triangle with a bag at the back. Its bottom part does not have any hull. For further details, the Sungkur fish catching tool is displayed below. The technological technical review on Sungkur fish catcher has been done by applying resistance calculation formula on all components. The biggest resistance is on sinker; the second biggest resistance is on surungan, and the third is on wing. Tanjuran is located at the upper part of the boat; therefore, it does not affect the boat resistance. Beside tanjuran, the ropes also do not affect the resistance. Several kinds of ropes used for Sungkur fish catcher can be viewed in Table 1.

Table 1. Several Rope Sizes at Sungkur Boat

Name of the Rope	Material	Length (m)	Diameter (mm)
Right Tanjuran	PE	12	12
Left Tanjuran	PE	7,3	7,3
Right Surungan	PE	3	20
Opener	PE	24	24
Kamong	PE	5,7	5,7
Upper Ris	PE	5,7	5,7
Lower Ris	PE	3,18	7,37
Sinker	PE	7,21	3,45

The bigger the fish catcher resistance is, the slower the boat speed is. The decrease of Sungkur speed is due to the resistance which is caused by the Sungkur fish catcher or the water resistance toward Sungkur fish catcher during operation.

3.1.2. Operation Method. Sungkur Operation uses motor boat (Figure 3). Fishing operation is started by determining the fishing ground. The sea water bottom for fishing ground is required to have 5 meter depth. Sungkur fish catcher is an evolution of push net. The position of the fish catcher is at the side of fisherman and the position of cod end is in front of the back wheel; otherwise, it may be enlaced by the ships' screw. This position also eases the catches lifting since Sungkur is only operated by one or two fishermen only.

Figure 3. Sungkur Boat Operation

The water depth can be reached by Sungkur fish catcher depending on the ropes attached at Sungkur. To arrange the reach of the depth, the rope could be extended or pulled. The depth also affects the boat speed because the deeper the water passed by the fish catcher, the bigger the Sungkur resistance is. The length of operation time is 1 hour/trip; in one day, it is possible to perform 7 operations. During operation, the pitch movement can happen when pushing the fish catcher. To neutralize it, one, two or three ballast tanks should be attached to the back part of the boat with the capacity 75 kg/tank. For boat impetus, the fishermen use these machines: Dongfeng SI 100 A, Diesel Engine, 1 Rating output 12 kw/2200r/min 16,5 Engine, S/2200 RPM 16 HP, Net Weight 155 kg, engine no 122299 dates 1990, Changzhou Diesel Engine Works The Republic of China.

3.2. Characteristics of Sungkur Boat Technic

3.2.1. General Arrangement of Sungkur Fishing Boat. The general arrangement is a technical image which shows general display of the boat room arrangement viewed from upper side and left/right side. The general arrangement of Sungkur boats at Tanah Laut regency consists of machine room, fish catcher room, ballast tank room, and catch room which are located in one deck. General arrangement (Figure 4) is planned for a platform which consists of catching goals and catch storing in one day trip.

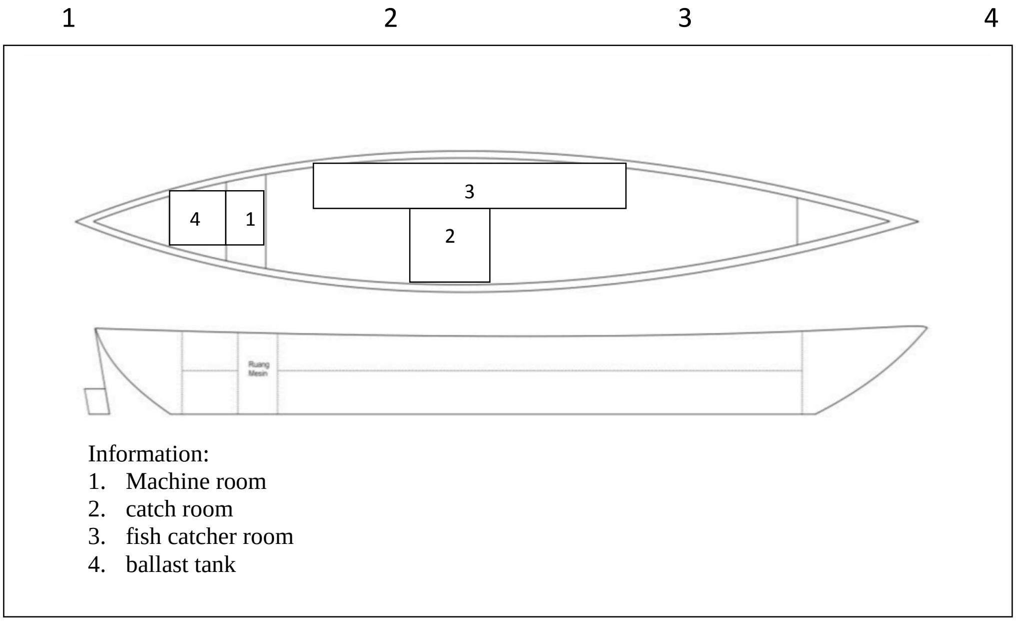

Figure 4. General Arrangement of Sungkur Boat

Machine room is an activator machine along with as propeller which connects it with the propeller at the back. Beside machine room, there is a spare fuel tank to ease the refill. The nature of the boat is still traditional; the machine room is not soundproof yet causing the machine sound roaring. The catch room is in the middle of the boat, which is the biggest part of it. Due to the circumstance, the biggest volume is in midship part. Partition between catch room and machine room is made so that the temperature of machine room does not disturb the temperature at hatch.

The catch room is put at one side of the boat to ease the catching operation. Tank ballast room is room to give pressure to the boat to make it balance and to reduce the movement of boat pitching during the operation.

3.2.2. Lines Plan of Sungkur Boat. Lines plan is an image that displays something in the form of line plan drawn at water lines and ordinates. Lines plan of Sungkur boat is divided into several ordinates stretching out along the boat with 1-meter distance among ordinates. The boat being observed is also divided into the five similar water lines starting from baseline until the highest draft (d) or load water line. The result of boat measurement based on the line plan is put on the offset table (table 2) which is needed for naval architect calculation.

Table 2. Offset of Sungkur Boat Table

Ordinal	½ B	Half Breath Plan				
		WI 1	WI 2	WI 3	WI 4	WI 5
0	0	0	0	0	0	0
1	37	32	28	20	11	3
2	67	60	55	39	24	3
3	75	70	63	48	32	3
4	80	77	68	56	40	3
5	83	78	69	61	45	3
6	81	75	66	55	43	3
7	76	70	62	48	36	3
8	71	65	56	43	29	3
9	62	55	47	36	23	3
10	36	32	26	16	3	0
11	0	0	0	0	0	0

Table 2 depicts the measurement result of Sungkur boat; that is, along the full load line of the boat, an vertical line is made dividing 11 parts into similar shape. The vertical waterline is given number 1-11 starting from after perpendicular (AP) until fore perpendicular (FP). This line is a useful ordinate to make half breadth plan and body plan pictures. Based on the data on the Table offset, a picture of plan line is obtained, manifested in three pictures: profile plan, half breadth plan, and body plan. Profile plan is shown by base line and 5 waterlines. WL 5 shows that the boat is full. Based line is considered as the start of waterline (0.0 wl). Waterline shows the boat position towards water surface when the boat is shrinking.

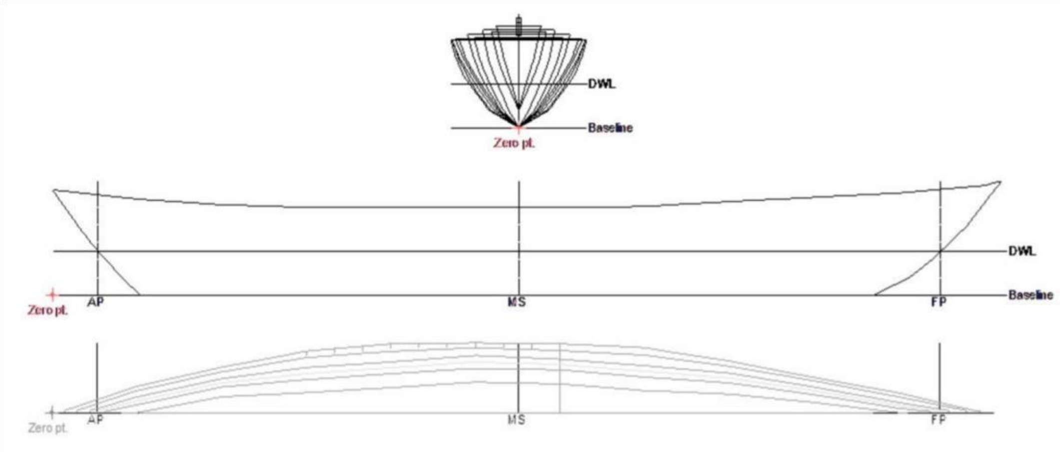

Figure 5. Lines Plan of Sungkur Boat

Half breadth plan is a picture that shows boat waterline viewed from the upper side of each buttock line. Buttock line shows vertical distance between side of the boat and flat surface which is in line with baseline, that is, a line cutting wl and in line with the centerline. Body plan shows the length of front line plan. In this picture, it is shown from the boat body on each ordinate. What is drawn here is half of the whole body. Ordinate 0-5 on the left side is a form from after perpendicular (AP) to midship. Ordinate 5-11 on the right side is a form from midship to fore perpendicular (FP). Based on Figure 5, lines plan of Sungkur boat on the bow and the stern of the boat forms Raked Bow (V). The form of boat is double pointed and the hull is Akatsuki bottom. This is related with the boat work system which focuses on the bow, starting from net placement to catching operation.

3.2.3. Ship Main Size/ The ship main size is the measurement consisting of Length (L), Breadth (B), Depth (D), and Draft (D). the boat characteristics can be viewed from main dimension ration of the boat. The ratio value of main size of each L/B, L/D, and B/D can be viewed at Table 3.

Table 3. Main Dimension Ratio of Sungkur Boat Sample

Boat dimension	Boat 1	Boat 2	Boat 3	Boat 4	Boat 5
L (Length)	10.90	11.20	10,5	12,05	11,55
B (Breadth)	1.68	1.60	1,36	1,85	1,50
D (Depth)	1.00	1.00	0,60	0,75	0,55
d (Draft)	0.70	0.50	0,40	0,50	0,40
Towed/dragged gear					
Ratio L/B (2,86 – 8,30)	6.49	7.00	7,70	6,51	7,70
Ratio L/D (7,20 – 15,12)	10.90	11.20	17,50	16,06	21,00
Ratio B/D (1,25 – 4,41)	1.68	1.60	2,66	2,40	2,72

Based on Table 3, the value obtained for the main dimension of Sungkur boat has mostly fulfilled the standard value determined, but still on the upper threshold limit. The L/B value is relatively closer to the upper threshold then the lower one. It shows that the movement resistance experienced is small, which affects the boat speed. B/D ratio affects the boat stability and impetus. The value relatively tends to the upper threshold even passes it; the stability is good but the propulsive ability could get worse if the resistance of fish catcher used is big. Based on the calculation, L/D ratio has not fulfilled the standard; the longitudinal strength affects the propulsive ability badly. The boat, therefore, experiences difficulty when veering left or right during the catching operation.

3.3. Sungkur *Boat Hydrostatic Parameter*

During a boat expedience test, one of phases to do is calculating hydrostatic parameter. The value of this parameter indicates the boat body statically. The parameter is displayed in table 4.
Displacement value of hydrostatic table range from 0,0999 -5,76 tons. Displacement value of sample boat on each waterline increases, which indicates that there are more stuffing on the boat as well as the draft. The fishermen can estimate the load weight the boat can carry, referring the maximum displacement value, which is 15, 75 tons.

Water plan area value (Aw) is the breadth of flat surface of the boat on certain water line slice. This value shows the breadth of the area on the boat for each waterline. There has been an increase in the value, which shows that the area breadth gets bigger. In other words, the closer the load placement to the deck is, the freer it gets.

Table 4. Hydrostatic Parameter of Sungkur

No	Parameter	Unit	Boat 1			Boat 2		
			WL 1	**WL3**	**WL 5**	**WL 1**	**WL 3**	**WL 5**
1	Ton displacement	ton	0.2751	2.146	5.02	0.0999	0.8648	2.159
2	Water area (Aw)	m^2	4.603	11.724	18.094	2.702	7.664	12.231
3	Midship area (Ao)	m^2	3.858	8.45	11.344	1.952	5.124	7.444
4	Ton Per Centimeter Immersion (TPC)		0.04	0.087	0.116	0.04	0.087	0.116
5	Coefficient block (Cb)		0.281	0.372	0.435	0.249	0.294	0.325
6	Coefficient prismatic (Cp)		0.563	0.593	0.638	0.499	0.511	0.539
7	Coefficient waterplane (Cw)		0.566	0.631	0.705	0.5	0.535	0.574
8	Coefficient midship (Cm)		0.5	0.628	0.681	0.5	0.575	0.603

The midship area value is the breadth of longitudinal section of the slice athwart the boat in the middle. This value shows that the number gets bigger and the midship breadth area gets bigger too following the waterline movement. Placing catch room in the midship, therefore, is correct since it can carry maximum load. Ton per centimeter immersion (TPC) is a value that indicates that the weight needed to change draft is 1 cm. Based on hydrostatic table, the two samples show similar value; changing 1 cm wl needs 0,04 tons load, wl 2 needs 0, 097 tons, and 1l 5 needs 0, 116 tons. The coefficient value of waterplane shows the comparison between breadth value of LWL (length waterline) and BWL (breadth waterline).

The expedience value of the boat can be viewed from its coefficient value of the fineness, which consists of Cb, Cp, Cvp, Cw, Cb and Cm. The boat's coefficient value of fineness is displayed below, in Table 5.

Table 5. Coefficient Value of Sungkur Ship Fineness

Coefficient of fineness	Boat 1	Boat 2	Towed/dragged Gear Standard Value
Coefficient block (Cb)	0,435	0.325	0,40 – 0,60
Coefficient prismatic (Cp)	0.638	0.539	0,51 – 0,62
Coefficient water plan (Cw)	0.705	0.574	0,66 – 0,77

The value usually used in determining the boat overweight is Coefficient block (Cb) value. The closer the number to 1, the weightier the boat gets. Based on the hydrostatic value, cb value which ranges between 0,249 – 0,435 shows that the boat is in fine type category. Coefficient midship shows the diameter breadth of the boat midship area; the bigger the coefficient midship gets, the broader the ship diameter is. The Cm ranges between 0,60 - 0,68 % of the boat diameter breadth athwart the boat.

BM distance (radius metacenter) is metacenter vertical radius and BML is metacenter longitudinal radius. KM distance is a virtual distance from metacenter longitudinal point to the base line and KML is a virtual distance of metacenter longitudinal point. This parameter shows both the position of buoyancy point (B) and metacenter point (M) which affects the boat stability. The closer the distance between K point and B point towards M point, the more negative its influence on the boat stability.

3.4. Sungkur Boat Stability

3.4.1. Sungkur Boat Initial Stability. Stability is the most important thing on the ship, especially fish boat, considering that it has to do fish catching operation in any weather. Stability is the boat ability to return to its original position after heeling which is caused by external force. The analysis on the Sungkur boat static stability is conducted by assuming that Sungkur boat has intact stability and at static condition it does not experience trim; draft difference between bow and stern by then is not significant. Therefore, the static boat stability is tested until vanishing angle. As long as the heeling angle is still below the vanishing angle, the righting arm GZ still has positive value.

Sungkur boat static stability occurs at vertical gravity point (KG) and the boat design draft is calculated based on the position of three points: gravity point (G), buoyancy point (B), and metacenter point (M). All these points are calculated based on baseline point reference K, which then is called KG, KB, and KM. An object floating on the water is balanced when the gravity point (G) and buoyancy point (B) is on the same vertical line. The parameter value of the boats' static stability is shown below on Table 7.

Longitudinal Centre Buoyancy (LCB) is a virtual distance where vertical buoyancy center point exists. Negative CLB point shows that the position of buoyancy point (B) is in behind the midship, heading to the stern. The LCB point which decreases along with the increase of boat draft shows that the boat buoyancy longitudinally moves to the stern. This is due to the position of machine room and ballast which is in the stern.

KB value increases in each WL, with the biggest point 0, 44 for Sungkur boat 2; it shows that when the boat increases its load, the distance between buoyancy point above base line will increase. The distance gets even less until maximum draft. BM, a vertical metacenter radius, is positive. It shows that the buoyancy point is below metacenter point (M), stable equilibrium boat. The positive value shows that when the boat heels because of the wave or load distribution, the boat can quickly return to its original position.

Table 6. Parameter Value of Sungkur Boat Static Stability

No	Parameter	Unit	Boat 1			Boat 2		
			WL1	WL3	WL5	WL1	WL3	WL5
1	Longitudinal Centre Buoyancy (LCB)	m	-0.075	-0.046	-0.024	-0.198	-0.185	-0.189
2	KB distance (m)	m	0.067	0.197	0.322	0.093	0.269	0.44
3	BM distance (m)	m	0.122	0.23	0.251	0.301	0.335	0.309
4	KM distance (m)	m	0.189	0.428	0.574	0.395	0.604	0.748
5	BML distance (m)	m	81.259	27.249	17.794	65.723	22.11	14.209
6	KML distance (m)	m	81.326	27.446	18.116	65.817	22.379	14.648

When KM value is low, the boat heel slowly, not stiffly. The advantage of KM low value is that the tension is small. Crew will feel comfortable. The KML distance shows its longitudinal position from the midship. KM distance shows the distance from metacentre point towards K point vertically. BML distance shows the longitudinal position of BM from the midship.

3.4.2. Righting Arm of Sungkur Boat. The analysis on the sample boat static stability shows the higher value of the ship based on IMO. It means the sample boat used by the fishermen has good stability and high buoyancy. It can therefore support the operation well. GZ value and area value below curve GZ will change when load distribution change. Maximum GZ value is when the load is 0, 605 on boat 1 and 0, 675 on boat 2. The stability of sample boat displayed above shows that Righting arm GZ has bigger value compared to minimum value determined by IMO so it has good stability in the operation. To obtain good stability, the breadth of curve area GZ should be 30^0, not less than 0.005 m-rad; the breadth of the curve area should be 40^0, not less than 0.090 m-rad, and the breadth of the curve area should be 30^0 to 40^0, not less than 0.030 m-rad. In addition, the boat should not have heeling angle for upholder arm GX_{max} less than 25^0; the value of upholder arm GX_{max} should not be less than 0.2 m, and the metacenter height should not be less than 0.15 m.

Table 7. Comparison of Breadth under Righting Arm Curve GZ at Sungkur Boat in IMO Standard

Indicator	IMO Standard (Minimum Value)	Breadth under curve GZ	
		Boat 1	Boat 2
Area 0 - 30	0.050 m-rad	0.101 m-rad (+)	0.0791 m-rad (+)
Area 0 - 40	0.090 m-rad	0.1742 m-rad (+)	0.143 m-rad (+)
Area 30 - 40	0.030 m-rad	0.0732 m-rad (+)	0.064 m-rad (+)
Max GZ at 30 or greater	0.2 m	0.605 (+)	0.675 (+)
Angle of maximum GZ	25 deg	79.1°	83.6°
Initial GMt	0.15 m	0.744 m	0.566 m

3.4.3 Righting Arm Curve GZ of Sungkur Boat. Stability of two Sungkur boat samples was analyzed by calculating the upholder arm value (GZ) formed at curve GZ (figure 5). Those curves show that the upholder arm GZ resulted by sample boat is positive, which means the boat can return to its original position after heeling.

The curve shows the value of righting arm GZ on several heeling angles (0^0-90^0). The calculation of Sungkur righting arm GZ using GZ program was conducted when the boat during dead water. The value of righting arm GZ has a standard issued by International Maritime Organization (IMO).

Based on the curve at figure 6, it is known that GZ value of Sungkur boat tends to increase at angle of heel (0^0-60^0) with maximum performance, that is, 0.675 for boat 1 at heeling angle 80^0 and 0.605 for boat 2 at heeling angle 70^0. The boat have positive value, which means that the boats are capable to return back to its original position after heeling.

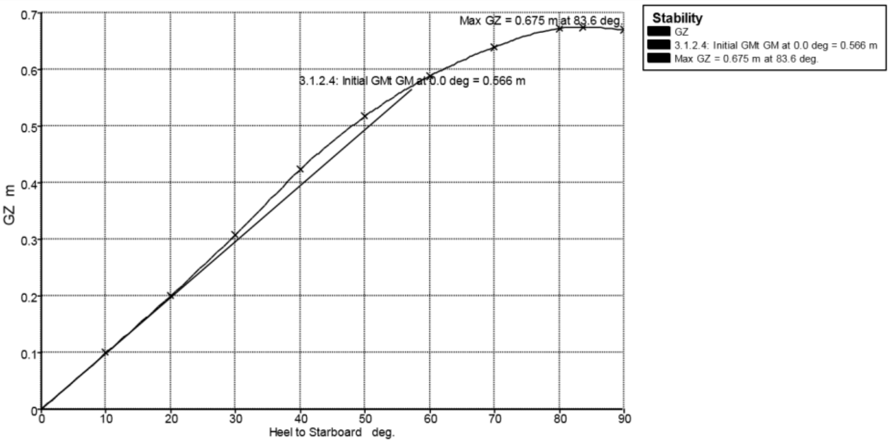

Figure 6. Righting Arm Curve GZ

Figure 6 shows a condition when the heeling point is 0^0 and the boat is in upright position because the righting arm GZ = 0 m. When the heeling point is 80^0, the returning arm GZ returns to upright position 0,6 m. Judging from the crossing points, the stability curve with heeling angle occurs at big angle. It shows that when the boat is heeling 80%, the boat will not turn upside down and can return to its original position because the upholder arm has not reached zero value.

3.5. Discussion

3.5.1. Technical Problem of Sungkur Boat. The value of boats' main dimension is a simple and easy approach to determine the ship's size. Main dimension ration of the boats is a parameter which very much influences the Sea Worthiness. There are several problems at Sungkur boat viewed from the boat dimension ratio: (a) L/B relative value which is closer to upper limit than the bottom one; (b) L/D ratio has not yet fulfilled the standard; the longitudinal strength is poor because the boat is not resistant to the turning movement either left or right during the catching operation; (c) movement resistance experienced is small, which positively influences the boat speed; (d) the Sungkur boats' propulsive ability is hardly good because the fish catcher resistance is big; and (e) the shape of Sungkur boat is in fine type; it can heel on the wave.

L/B value of Sungkur boat is relatively closer to the upper limit than the bottom limit. The resistance value of fish catcher which is big very much affects the catching efficiency. Therefore, it is suggested not to exceed the impetus of the boat because it forces the machine to work harder; it requires more power from the boat to give balancing impetus during operation. According to [2], the bigger the value of L/B, the smaller the resistance is. According to [22] the L / B ratio has a great influence on hull resistance and maneuverability.

Longitudinal strength of Sungkur boats is bad, affecting the heeling period. Therefore, redesigning is necessary by adding breadth. To determine the most optimal boat size, [16] state that the broader the boat is, the broader the heeling period is. The shape of Sungkur boat is in fine type. [24] say that the boat which is in fine type shape is vulnerable to heeling which reduces the comfort on the boat. [4] Argued that the slender body of the boat and quick heeling period are the weakness of the boat which can be overcome if the boat manufacture follows the manufacturing procedure of modern boat. Changes in the boat's breadth and depth can give the boat better technical parameter on the same length.

Based on Lines Plan of Sungkur boat, the bow and stern of the boat form Raked Bow (V) which causes the boat to move forward pushing the Sungkur fish catcher. It is supported by [12] who says that

V bottom enables the boat in certain speed to cleave the water mass with small resistance. It is related to the boat work system focusing on the bow part, starting from placing the net until catching process. According to [20], the general requirement should be owned by the fish boat, such as: the bottom part of the boat is in V (V bottom) shape to enable the boat to move faster.

Sungkur boat which is double pointed with hull is akatsuki bottom. According to [25], hull boat happens because the boat is manufactured traditionally or manufactured in the dry-dock and relies on the boat maker's habit. The decision to produce hull form of a boat is not based on technical consideration or operation expedience.

Based on the General Arrangement, Sungkur boat has very efficient space. [21] Argued that in determining general arrangement of a boat, we rely on several things: length value, which is closely related to the placement of machine room and fish catcher; breadth value, which is closely related to the catch placement, depth value, which is closely related to the luggage placement and stability.

During the operation of fish catching, pitch happened a lot. However, it was solved by occupying stern of the boat by putting away ballast tank; it yet increases the boat resistance. This condition has to be considered before manufacturing a boat. Boat making starts from design. In the design, the boat maker should consider the design requirement which is also called as technical data. Technical data needed consists of five main components: boat type and kind, load, speed, route, sailors, and water limit [23]

3.5.2. *Hydrostatic Parameter*. Beside main dimension, fish also has hydrostatic parameter. Hydrostatic parameter shows the initial boat condition. [5] Explains several important hydrostatic parameters are: displacement, water line area, position per centimeter immersion (TPC) and coefficient of fineness (Cb, Cw, Cp, Cvp and Co). The boat displacement value gets bigger following the draft so that the fishermen can estimate that maximum displacement is 15,78 tons. Based on the coefficient of fineness values, Sungkur boat has fulfilled connection among the coefficients as it is stated by [3] that coefficient represents the body of the boat called block coefficient (Cb), prismatic coefficient (Cp), and midship coefficient (Cm). The connection among the coefficients is Cb = Cp x Cm, and the size of the fishing boats follows the following order: Cb < Cp < Cm.

Cp value works not only as coefficient of fineness and works to ensure the boat stability; it is also useful to determine the smallest value of the boat side endurance [30]. Cb value of Sungkur boat is low; it means the diameter of the boat both on the bow or stern is slender. [13] also say that the bigger Cb value is, the closer the diameter length across the bow and stern to the one across the midship. According to [29] when the coefficient of fineness of a boat is determined, the boat resistance value depends on several things: (1) weight distribution along the boat, indicated by CLB value, (2) water area shape, especially in the bow (shape of crossing cut and stern type). [29] also suggest that one of ways to reduce the total resistance of the boat is by shifting LBC direction to the bow.

3.5.3. Static Stability of Sungkur Boat. According [5], fish boat stability is the ability of the boat to return to its original position after getting external influence. The external influence can come from the wind or wave. Fish catcher in the water can also increase the boat inclination and reduce the boat ability to return to its original position and reduce the righting moment of the boat. The boat originally has its own ability to return to transverse stability, static stability or longitudinal stability, which is based on the rule that fish boat should have initial stability not less than 0.6 meters.

Equilibrium terminology on stability matters needs to be understood. There are three kinds of equilibriums: stable equilibrium, unstable equilibrium and neutral equilibrium [26][6][8][4]. Stable equilibrium is a condition where boat can return to its original position (initial stability/equilibrium) after a force on the boat causes heeling. Unstable equilibrium is a condition in which the boat heels because of the working force on the boat which makes it cannot return to its original position, and keep heeling to one side. Neutral equilibrium is a condition in which the boat heels due to the working force on the boat and it stays permanently.

[26] Elaborates more about it; he says that maximum condition can result from the positive righting arm GZ which can return the ship into its original position. Pitch movement on Sungkur boat usually

happens when Sungkur was operated by pushing. [14] Stated that on beam seas, pitch movement can always be seen on several types of wave, usually very small, so is yaw movement.

When a stabile boat gets external force and causes the boat to heel, the buoyancy center will shift to the lowest position. When the boat heels even more, the righting arm and the distance between weight force and buoyancy force will decrease until it reaches zero points or even negative. In that condition, sea water will enter the ship through the opening on the ship [8]. Maximum stability is maximum GZ value the boat can reach on certain angle and condition while stability estimation is the biggest heel angle of the boat without negative GZ [27].

4. Conclusions

Sungkur boat design is suitable to operate fish catcher by towing or dragging. However, there are several problems: movement resistance tends to be high and the longitudinal strength is not very good to make a turning either left or right. The general arrangement of Sungkur boat consists of machine room, catch room, fish catcher room on the side of the boat to ease the catching operation, ballast tank room to give pressure to the boat to balance it and reduce pitching movement during operation.

Lines plan of the boat consist of Body plan: Akatsuki, half breadth plan : Double pointed and profile plan : bow and stern forming Raked Bow (V) which is very good and suitable to cleave water, and suitable for a boat of which the work focuses on the bow, starting from net placement and catching process.

The boat's coefficient of fineness is Cb, which is in fine type shape, causing the boat to heel easily when there is external force and reducing the comfort on the boat. Displacement on each waterline experiences an increase and stuffing along with the waterline. The biggest load value is located at midship. Ton per centimeter immersion used to change wl 1 for 1cm needs 0.04 tons load.

The boat stability overall is in good condition with relatively high buoyancy capacity. The angle of maximum GZ is positive and the boat can return back to its original position even after getting external force.

Sungkur boat perfection is necessary especially in terms of load balance and boat resistance during fish catching operation by redesigning to ensure the safety and security of Crew on the boat. Therefore, a further research on the boat's resistance and dynamic stability is needed, either during heading to the fishing ground, fish catching operation, or when returning back to the fishing base.

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