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STABILITY, SEAKEEPING AND SAFETY ASSESSMENT OF SMALL FISHING BOATS OPERATING IN SOUTHERN COAST OF PENINSULAR MALAYSIA

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Abstract: Most fishing boats in Malaysia are built traditionally, usually with no guidance and approval from naval architects. Thus, hydrodynamics performance, viewed in terms of stability and seakeeping as well as safety performance, has become a major concern in traditional fishing boat designs. This study mainly focused on the assessment of hydrodynamics performance and safety of small fishing boats. Two small boats, each from the East and West Coast of Peninsular Malaysia, were selected for measurement of their hulls. Maxsurf Ship Design software was used to assess the seakeeping and stability performance according to the respective requirements or standard criteria. The assessments showed that although both boats fulfill static stability requirements, one of the boats should only be allowed operating in restricted operational area with maximum sea state 2, while the other can be allowed to operate in operational area up to sea state 3. A survey on safety equipment showed that both boats lacked the necessary equipment stipulated by international guidelines for safety of small fishing boats.

Keywords: Seakeeping, stability, safety, fishing boats, Johor, Peninsular Malaysia.

Introduction

Despite the high income from the advance development of technological industries around the world, the fishing industry continues to be one of the main contributors to the economic growth. Department of Fisheries Malaysia reported that the total fish production in 2010 was 1.78 million tones with a total revenue of RM6.66 billion. Apart from providing the nations with varieties of fisheries products (known as Gross Domestic Product), it also plays the role as a source of income and increases the living standard by bringing in foreign exchange, especially to rural communities particularly in East and West Coast of Malaysia.

The Malaysian Department of Fisheries has divided the fishing zone and division of operational vessels into 4 zones based on some criteria and performance of the fishing vessels. The first zone is Zone A, which covers operational areas in less than 5 nautical miles from the shore. This zone is safe and suitable for traditional boats or sampans and small fishing vessels with Gross Tonnage (GRT) between 0 to 19.9 GRT. The second zone is Zone B which covers areas between 5 to 12 nautical miles from the shore. This zone is suitable for medium size fishing vessels with GRT between 20 to 39.9 GRT which usually use drag net for fishing activity. Zone C covers fisheries operation areas from 12 to 30 nautical miles, and finally is Zone C2 which covers more than 30 nautical miles. Trawlers and purse seiners are suitable for both C zones.

According to M. A. Yunus (2007), fishing boats in Malaysia can be classified into 3 categories based on size, which are small boats, medium boats and large boats. The classification of Malaysian Fishing boats is shown in Table 1.

Fishing boats in Malaysia are mostly made of wood and built using traditional methods, which are relatively simple, may possibly be artisanal in design with no body plans or hydrostatic, with no GZ curve of stability, and usually built without any guidance and approval from naval architecture. According to Mohd Zamani & K.Vijaynathan (2000), traditional boat builders are observed to keep templates of their designs, and any special alterations are incorporated based on the rule of thumb and trial and error method in order to overcome an immediate shortcoming of the builders'

Table 1: Typical size and characteristic of Malaysian fishing boats

Type of Boats/ Properties	Small Boats	Medium Boats	Large Boats
Length (m)	5.5-10.0	7.5-15.0	11.0-25.0
Breadth (m)	1.0-2.0	1.8-3.5	2.8-5.0
Depth (m)	0.3-0.9	0.6-1.4	0.5-2.5
Engine	- no engine - outboard engine - inboard engine	- inboard engine	- inboard engine
Horse Power (Hp)	2 – 10 Hp	50 – 200 Hp	100 Hp & above
GRT	< 10	10 - 25	> 25
Fish Hold	- no fish hold - boxes & baskets	- ordinary hold - boxes & baskets	- ordinary hold - insulated hold - Refrigerated hold
Catch Capacity	120 – 200 kg	200 – 2000 kg	1000 kg & above
Number of Fishermen	1 - 5 people	2 - 7 people	5 - 20 people
Type of Boats/ Properties	**Small Boats**	**Medium Boats**	**Large Boats**
Time at Sea	couple of hours - 0.5 day	1/2 – 1.5 days	1 day – 1.5 weeks
Operating Zone (Nautical Miles From Shore)	< 10	< 30	> 30

problem without evaluating its consequences. M. Z. Ahmad (2000) also indicated that most traditional boat builders have no knowledge on the science of designing fishing boats and they are not aware of the importance of design blue prints during construction stage.

Fisheries industry work in a rough environment and dangerous conditions, putting the fleet and crew at risk, thus it is essential for the boat to be safe and seaworthy. According to Míguez González *et al.,* (2012), fishing industry is one of the sectors with more industrial accidents. Thus, the stability and safety of the fishing boats are a major concern in designing the boat (Maimun, Adi & Yaakob, 2006). Besides, boats' performance must be analyzed and assessed so that they meet the requirement of their operational area. Lately, there has been indication that reform is to be introduced to the Malaysian fishing industry due to the need to increase its contribution to the national economy. According to M. Z. Ahmad (2000), one of the factors of productivity is the effectiveness and operation ability of the fishing boats.

In order to increase the effectiveness and productivity of fisheries industry in Malaysia, it is essential for Malaysian fishing boats to meet the standard requirement. This study was conducted with a key question in mind, which is "what is the performance level of traditional fishing boats in Johor coast? Does it meet the standard requirement of stability and safety of small fishing boat appointed by standard regulations?". This study mainly focused on assessment of stability and safety of small fishing boat. This study is significant as the assessment can lead to improvement of small boats and eventually contribute to productivity of fisheries activity in coastal areas.

Safety of Small Fishing Boats

Among the characteristics and issues regarding the safety of small fishing vessels as reported by Royal Institution of Naval Architects (2011) were:

a. Low freeboard, causing easier deck flooding and capsize.
b. Low stability, because many small boats are built with no involvement of naval

architects, and additions or alterations made may compromise the stability of the boats.

c. Small boats have cramped working conditions, in which crews work very close to the machinery and tend to be caught up in winches, ropes etc.
d. Regulatory and financial pressures that lead to single-handed working and small boats working area or sea conditions beyond their capacity, long working hours and fatigue, and poorly maintained vessels.
e. Inadequate inspections and control on small boats.

A survey conducted by Ask (2011) which intended to derive the design of small fishing boats in Malaysia from ethnographic perspectives, suggested that the stabilizing forces needed in high sea states have to be measured against the boat performance. The study also recommended modeling of boat hulls using ship design software applications to determine the hull behavior, as well as calculations of other naval architectural parameters required for the assessments. Stability related accidents have been reported causing more casualties, commonly in vessels less than 24 meters long. It was reported that capsizing due to poor stability contributed up to 42% in maritime accidents of Galician fishing vessels (Míguez González *et al.,* 2012). This is due to the fact that larger vessels i.e. vessels of more than 24 meter in length, present better conditions for operation in adverse weather and have better trained crews who are capable to deal with ship instability.

A review study by Molyneux (2007) addressed the need for calculating the hydrostatic stability of small fishing boats. Webster & Sampson (2006) also highlighted the stability of small fishing vessels, having studied the increase in risk of capsizing in comparison with conventional fishing vessels. The study also recommended assessment of small fishing vessels in a same way as larger vessels for safety purposes. In Malaysia, the small boats are particularly susceptible to the hostile environment. The monsoon weather has been found to significantly affect the operability of Malaysian fishing vessels, as studied by Yaakob & Chau (2007).

Several studies on understanding the seakeeping performance of fishing vessels have also been done by Maimun, Adi &Yaakob (2006), Sayli, Alkan, Nabergoj & Uysal (2007) and Ruiz, Silva & Soares (2009). Loughran, Pillay, Wang, Wall, & Ruxton (2002) who studied fishing vessel safety in United Kingdom, discovered that one of the three major causes leading to fishing vessels accidents is ship movement, while capsizing due to poor stability performance is the main cause of death of fishermen. Due to these facts, small fishing boats performance, mainly in stability, seakeeping and safety aspects, must be taken into consideration in the design of small fishing boats. Two small fishing boats were randomly selected to assess whether both of the boats have adequate stability and safety performance.

Methodology

Measurement of Small Fishing Boats

For the purpose of this study, two small fishing boats of less than 10 Gross Tonnage (GRT) operated using outboard engine in two different coastlines, were selected as a representative boat from each coast. The first boat was from Mersing, representing Johor West coast, and operated in southern region of South China Sea, designated as Boat A, (see Figure 1). Another boat, designated Boat B, was a boat from Pontian, representing Johor East coast and operated in the Straits of Malacca (see Figure 2).

The boats were chosen from two different operating regions for variety purposes as both boats were different in their hull form and design. Note that both boats chosen in this study were not equipped with advance technology or equipment. The principal dimensions of the boats are given in Table 2.

Figure 1: Boat A (Mersing)

Figure 2: Boat B (Pontian)

Table 2: Boat main particulars

	Boat A (Mersing)	Boat B (Pontian)
Length Overall (m)	6.54	5.03
Breadth (m)	1.48	1.32
Depth (m)	0.55	0.30
Speed Range (Knots)	0-12	0-15
Engine Type	Portable Outboard 15 HP 2-stroke	Portable Outboard 15 HP 2-stroke

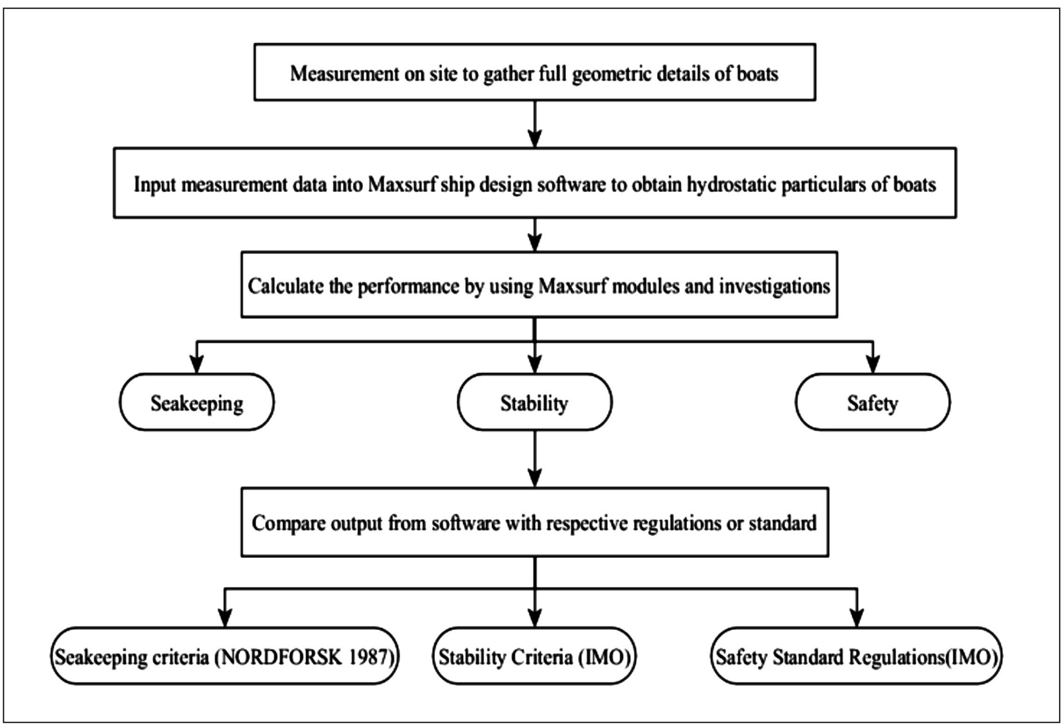

Figure 3: Flowchart of the Assessment

Figure 4: Taking offset data of Boat A (Mersing)

Figure 5: Measurement grid of Boat B (Pontian)

Figure 3 shows the generic steps of the assessment. Both boats were built according to traditional methods and thus had no lines plan. The first stage of this study was to develop the lines plan by physically measuring the boats and modelling the hull form using ship design software. The two boats were brought to a slipway and measurements were carried out manually using nylon strings as grids, as shown in Figure 4 and 5. The offset data obtained from the measurement were used as input into the Maxsurf Ship Design. The Hydromax and Seakeeper modules in Maxsurf ship design software were used to calculate and assess the stability and seakeeping performance, respectively.

The standard criteria used for stability justification was based on the Safety Recommendations for Decked Fishing Vessels of Less than 12 Meters in Length and Undecked Fishing Vessels by IMO (Slf *et al.,* 2007). The criteria recommended by NORDFORSK 1987 by Ormala (1989) were used for the assessment of the seakeeping performance, while the standard criteria for safety assessment were based on IMO standard with adoption of Torremolinos Protocol 1977 (Slf *et al.,* 2007).

Results and Discussion

Once the hull forms of the boats had been modelled using Maxsurf modeler, their hydrodynamic performances in terms of seakeeping, stability and safety could be assessed. The modules used for this purpose were Seakeeper module for seakeeping analysis and Hydromax module for stability analysis. Figure 6 and **7** show the hull forms of the boats, created by using Maxsurf.

Seakeeping Performance Assessments

According to Kiikner (1995), seakeeping assessment generally covers four major categories of seakeeping characteristics, which are habitability, mobility, operability and survivability. Since there are no internationally accepted seakeeping standard criteria for fishing vessels as indicated by Tello, Ribeiro e Silva, & Guedes Soares (2011), the Seakeeper module was used in this study to carry out the seakeeping performance assessment of the boats based on the criteria proposed by NORDFORSK 1987 (Ormala, 1989) for heavy manual work category as, recommended by Odabasi *et al.,* (1991). The parameters are given in Table 3.

The limit values represent the limit of human tolerance towards various kinds of ship motions. Vertical acceleration is the main determinant of comfort and workability on board of fishing vessels. It is therefore necessary to calculate the vertical acceleration at various possible locations where the operator is most likely to work or stay at. For example, the RMS vertical acceleration is related to the motion sickness incidence, MSI signifies the seasickness level tolerable by passengers and crew on board of the vessels during operation in a seaway (McCauley, *et al.,* 1976). In this

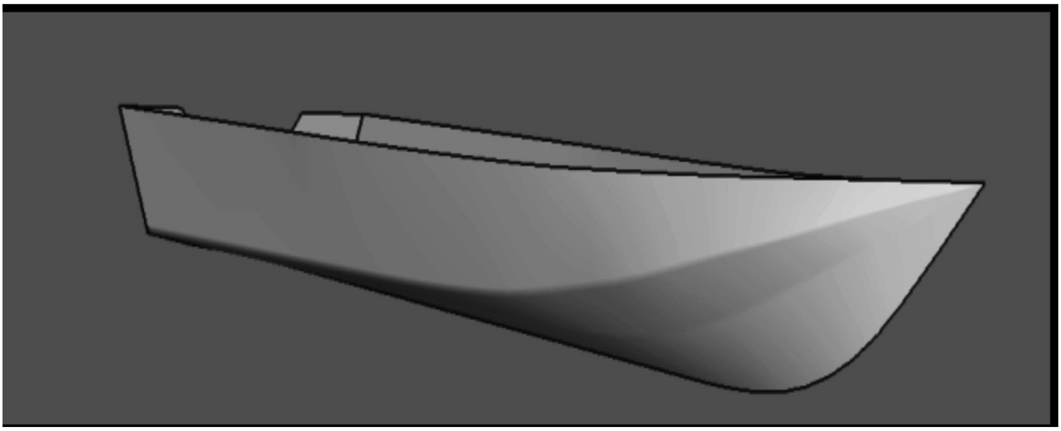

Figure 6: Maxsurf hull form design of Boat A

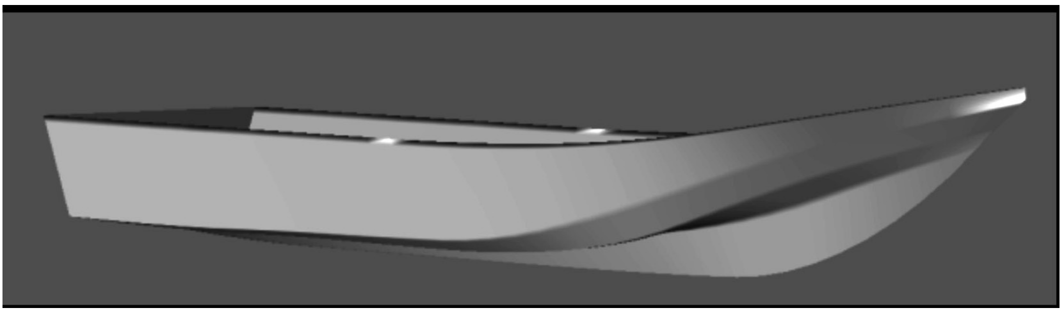

Figure 7: Maxsurf hull form design of Boat B

Table 3: Limiting criteria for accelerations and roll (NORDFORSK 1987)

Parameter	Maximum Value
RMS Vertical Acceleration at FP (g)	0.275
RMS Vertical Acceleration at Bridge (g)	0.150
RMS Lateral Acceleration at Bridge (g)	0.070
RMS Roll Motion (°)	4.0

study, three locations i.e. aft end, bridge and fore end had been chosen for the analysis.

On the other hand, Sariöz & Narli (2005) stated that RMS lateral acceleration due to rolling motion is related to the motion induced interruptions (MII). According to this definition, rolling response indicated by RMS roll motion is closely related to stability during voyage. Working at sea is often limited to a maximum angle of rolling, as excessive rolling could cause the vessel to capsize. According to report by Monk. K (1988), the ability of the crew to perform tasks would be reduced by 50% due to lateral acceleration and 25 to 30% by the RMS roll angle.

It is necessary to assess the seakeeping performance of boats in different sea state condition beforehand. In 1970, the World Meteorological Organization (WMO) established the standard sea state code, as in Table 4. Each code represents a range of wave heights.

Since it is difficult to obtain the actual significant wave height in Mersing and Pontian,

Table 4: WMO Sea State Code

Sea State Code	Significant Wave Height (m)		Description
	Range	Mean	
0	0	0	Calm (glassy)
1	0.0 – 0.1	0.05	Calm (rippled)
2	0.1 – 0.5	0.3	Smooth (wavelets)
3	0.5 – 1.25	0.875	Slight
4	1.25 – 2.5	1.875	Moderate
5	2.5 – 4.0	3.25	Rough
6	4.0 – 6.0	5.0	Very rough
7	6.0 – 9.0	7.5	High
8	9.0 – 14.0	11.5	Very High
9	Over 14.0	Over 14.0	Phenomenal

Table 5: Sea State Conditions (N. Ahmad, 2008)

Sea State Code	Significant wave height (m)	Period (s)	Description
2	0.550	6.5	Smooth
3	0.875	7.5	Slight
4	1.875	8.8	Moderate

the standard sea operational conditions sea state conditions as shown in Table 5 were used.

In seakeeping performance analysis, the sea state is also described by the wave spectrum which represents the spectral wave elevation. It is necessary to choose wave spectrum appropriate to the Southern region of Peninsular Malaysia. Since both fishing boats are frequently operated in coastal waters, the JONSWAP (JOint North Sea WAve Project) spectrum was used in this study. The speeds of the boats were assumed to operate at 9 knot. The seakeeping analysis is usually presented in the form of RAO (Response Amplitude Operator) which describes how the response of the boat varies with frequency. In this study, the RAO graph developed by Seakeeper module was instead summarized into table for ease of comparison with the seakeeping criteria of NORDFORSK 1987.

Table 6 to 8 show the results of seakeeping assessment carried out for Boat A (Mersing). In sea state condition 2 and 3, Boat A passed the limitation for its seakeeping performance. However, Boat A failed to meet certain limiting criteria in sea state condition 4. The high vertical acceleration in this sea state would increase motion sickness incidence (MSI), as well as loss of footing, causing difficulty for operation. In addition, the large roll angle, although still below the limiting value, may adversely affect the stability of the boat. In other words, if Boat A operates in sea state condition 4, it may encounter loss in operability and survivability with risk to capsizing. Therefore, for the interests of comfort, operability and safety, Boat A should only operate in sea states up to sea state condition 3.

Table 9 to 11 show the results of seakeeping assessment carried out for Boat B (Pontian). Unlike Boat A, Boat B only passed the limiting criteria for sea state condition 2, and unfortunately failed to meet certain limiting criteria in sea state condition 3 and 4. Higher

Table 6: Seakeeping parameters of Boat A in Sea State 2

V= 9 knots ; Sea State 2 (JONSWAP: 6.5 s, 0.55 m)			
Parameter	**Seakeeper Value**	**NORDFORSK 1987**	**Status**
RMS Vertical Acceleration at FP (g)	0.173	0.275	Pass
RMS Vertical Acceleration at Bridge (g)	0.099	0.150	Pass
RMS Lateral Acceleration at Bridge (g)	0.017	0.070	Pass
Roll Motion (°)	1.96	4.0	Pass

Table 7: Seakeeping parameters of Boat A in Sea State 3

V= 9 knots ; Sea State 3 (JONSWAP: 7.5 s, 0.875 m)			
Parameter	**Seakeeper Value**	**NORDFORSK 1987**	**Status**
RMS Vertical Acceleration at FP (g)	0.212	0.275	Pass
RMS Vertical Acceleration at Bridge (g)	0.123	0.150	Pass
RMS Lateral Acceleration at Bridge (g)	0.020	0.070	Pass
Roll Motion (°)	2.45	4.0	Pass

Table 8: Seakeeping parameters of Boat A in Sea State 4

V= 9 knots ; Sea State 4 (JONSWAP: 8.8 s, 1.875 m)			
Parameter	**Seakeeper Value**	**NORDFORSK 1987**	**Status**
RMS Vertical Acceleration at FP (g)	0.332	0.275	Fail
RMS Vertical Acceleration at Bridge (g)	0.195	0.150	Fail
RMS Lateral Acceleration at Bridge (g)	0.031	0.070	Pass
Roll Motion (°)	3.94	4.0	Pass

Table 9: Seakeeping parameters of Boat B in Sea State 2

V= 9 knots ; Sea State 2 (JONSWAP: 6.5 s, 0.55 m)			
Parameter	**Seakeeper Value**	**NORDFORSK 1987**	**Status**
RMS Vertical Acceleration at FP (g)	0.239	0.275	Pass
RMS Vertical Acceleration at Bridge (g)	0.131	0.150	Pass
RMS Lateral Acceleration at Bridge (g)	0.020	0.070	Pass
Roll Motion (°)	2.31	4.0	Pass

Root Mean Square (RMS) vertical acceleration at fore end (FP) and bridge compared to the maximum value of NORDFORSK 1987 related to MSI index will make the operability of the boats at that sea state condition inefficient, and may even be posed to risk of instability or accidents. Therefore, Boat B should only be allowed to operate in sea state condition 2, where the wave heights are small with calm (glassy) environmental condition.

Table 10: Seakeeping parameters of Boat B in Sea State 3

V= 9 knots ; Sea State 3 (JONSWAP: 7.5 s, 0.875 m)			
Parameter	**Seakeeper Value**	**NORDFORSK 1987**	**Status**
RMS Vertical Acceleration at FP (g)	0.290	0.275	Fail
RMS Vertical Acceleration at Bridge (g)	0.160	0.150	Fail
RMS Lateral Acceleration at Bridge (g)	0.023	0.070	Pass
Roll Motion (°)	2.84	4.0	Pass

Table 11: Seakeeping parameters of Boat B in Sea State 4

V= 9 knots ; Sea State 4 (JONSWAP: 8.8 s, 1.875 m)			
Parameter	**Seakeeper Value**	**NORDFORSK 1987**	**Status**
RMS Vertical Acceleration at FP (g)	0.452	0.275	Fail
RMS Vertical Acceleration at Bridge (g)	0.253	0.150	Fail
RMS Lateral Acceleration at Bridge (g)	0.036	0.070	Pass
Roll Motion (°)	4.54	4.0	Fail

It is important to assess the seakeeping performance of small fishing boats so that the boats can avoid any accidents as they are only operated in the correct sea state. For small fishing boats to have a good seakeeping performance, it is undesirable to have excessive amplitudes of motion, as it will cause ship onboard tasks become dangerous and reduce crew efficiency, thus hampering the operation of the fishing gear.

Stability Performance Assessment

Usually, building a vessel requires lines plan and calculation of stability and strength before the vessel is built. Traditional small fishing boats are, however, built only based on experience and have no standard design. Thus, their stability is questionable. In this study, the stability performance assessment for the small fishing boats was carried out using stability analysis module, Hydromax, which is capable of obtaining hydrostatic characteristics of the boat from the integration of its hull forms and ability to obtain the stability values resulting from a given loading conditions. The Large Angle Stability Analysis method was used in this assessment, enabling the stability curve or righting lever (GZ) curve for the range of specific angle to be calculated and stability of the vessels evaluated against the IMO stability criteria. Figure 8 shows the GZ curve of statistical stability of vessels. The parameter from this curve is the positive range of righting levers (GZ). GZ maximum values and their corresponding angles, initial metacentric height and other parameters are the IMO stability criteria used to assess the stability, as documented in Annex 29 Chapter 3 - Safety Recommendations for Decked Fishing Vessels of Less than 12 meters in Length and Undecked Fishing Vessels (Slf *et al.,* 2007), as summarized in Table 12.

The required minimum value of GM secures certain stability around the upright position, while the minimum value required for maximum GZ angle prevents the capsizing of the boat when floating on a wave with certain steepness. The specified areas under the GZ curve indicate the amount of energy necessary to heel the ship from the upright position or from an initial heel of 30°. The criteria are required to be checked beforehand against the standard

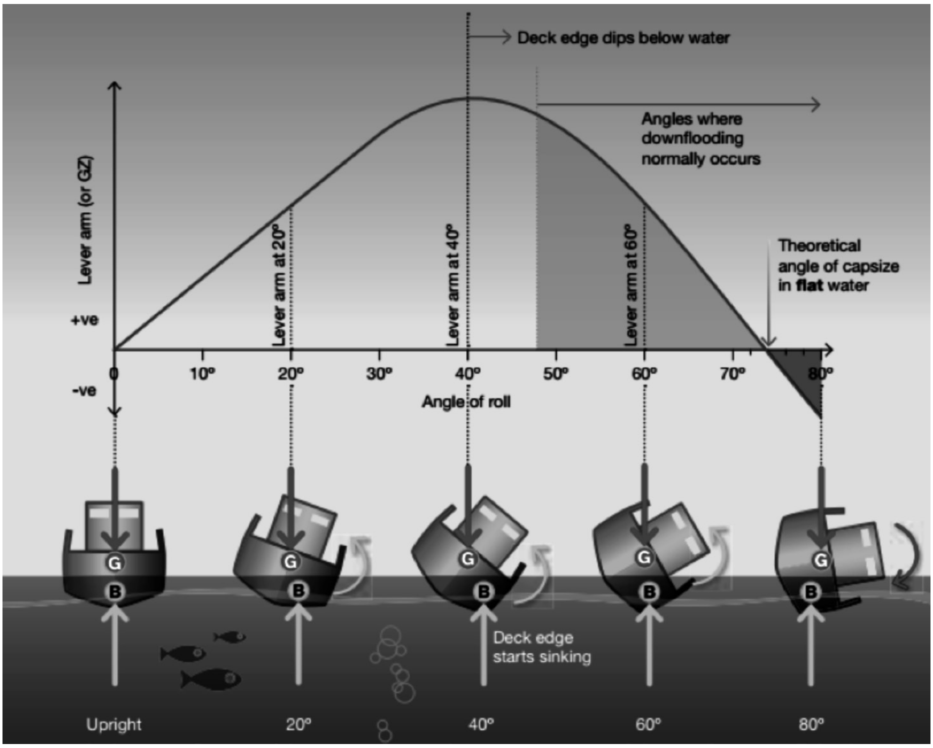

Figure 8: GZ Curve of statistical stability (Maritime New Zealand, 2011)

Table 12: Stability criteria based on GZ curve

Criteria	Limit Value	Units
Area under GZ curve from 0 to 30 degrees	> 0.055	m.rad
Area under GZ curve from 0 to 40 degrees	0.090	m.rad
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad
Maximum GZ at the angle of heel equal to or greater than 30	At least 0.200	m
Angle of maximum GZ	> 30.0	deg
Initial metacentric height, GMt	> 0.350	m

loading conditions which are supposed to be the significant stages of the boat's operation. In this study, three loading conditions were considered in assessing the performance of the boats, as recommended by American Bureau of Shipping (1990) and Gudmundsson (2009) as follows:

1. Departure for fishing grounds with full fuel, ice, fishing gear, etc.
2. Departure from fishing grounds with full catch, 30% stored fuel, etc.
3. Arrival at home port with full catch and 10% stored fuel etc.

Results from Hydromax module were then compared to standard criteria as in Table 12. Table 13 to 15 show the summary of results of stability assessment from GZ curve developed using Hydromax for each loading condition of Boat A (Mersing) in tabulated form. Womack, J., & Johnson (2003) stated that the area under the curve is an indication of the righting forces available to encounter the capsizing forces

Table 13: Stability assessment on departure to the fishing ground (Boat A)

Load Case: Departure for the Fishing Ground				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degrees	0.055	m.rad	0.116	Pass
Area from 0 to 40 degrees	0.090	m.rad	0.194	Pass
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad	0.078	Pass
Maximum GZ at the angle of heel equal to or greater than 30	0.200	M	0.625	Pass
Angle of maximum GZ	30.0	Deg	76.0	Pass
Initial GMt	0.350	M	1.245	Pass

Table 14: Stability assessment on departure from the fishing ground (Boat A)

Load Case: Departure for the Fishing Ground				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degrees	0.055	m.rad	0.129	Pass
Area from 0 to 40 degrees	0.090	m.rad	0.212	Pass
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad	0.083	Pass
Maximum GZ at the angle of heel equal to or greater than 30	0.200	M	0.656	Pass
Angle of maximum GZ	30.0	Deg	80.0	Pass
Initial GMt	0.350	M	1.299	Pass

Table 15: Stability assessment on arrival at home port (Boat A)

Load Case: Arrival at Home Port				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degrees	0.055	m.rad	0.102	Pass
Area from 0 to 40 degrees	0.090	m.rad	0.166	Pass
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad	0.064	Pass
Maximum GZ at the angle of heel equal to or greater than 30	0.200	M	0.523	Pass
Angle of maximum GZ	30.0	Deg	77.0	Pass
Initial GMt	0.350	M	1.102	Pass

acting on the vessel. Meanwhile, Tupper (2013) stated that the larger area under the curve means that larger righting moment is present, enabling the boat to counter larger disturbances or heeling. The assessment shows that Boat A (Mersing) fulfilled all the limiting criteria for each loading condition. Thus, Boat A is stable and safe to operate in all loading conditions.

Table 16 to 18 show the results of stability assessment for each loading condition for Boat B (Pontian). Boat B also fulfilled all the limitation criteria for each loading condition of

Table 16: Stability assessment on departure to the fishing ground (Pontian Boat)

Load Case: Departure for the Fishing Ground				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degrees	0.055	m.rad	0.088	Pass
Area from 0 to 40 degrees	0.090	m.rad	0.140	Pass
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad	0.052	Pass
Maximum GZ at the angle of heel equal to or greater than 30	0.200	m	0.315	Pass
Angle of maximum GZ	30.0	deg	48.0	Pass
Initial GMt	0.350	m	1.128	Pass

Table 17: Stability assessment on departure from the fishing ground (Pontian Boat)

Load Case: Departure from the Fishing Ground				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degrees	0.055	m.rad	0.066	Pass
Area from 0 to 40 degrees	0.090	m.rad	0.100	Pass
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad	0.034	Pass
Maximum GZ at the angle of heel equal to or greater than 30	0.200	m	0.210	Pass
Angle of maximum GZ	30.0	deg	41.0	Pass
Initial GMt	0.350	m	0.891	Pass

Table 18: Stability assessment on arrival at home port (Pontian Boat)

Load Case: Arrival at Home Port				
Criteria	**Limit Value**	**Units**	**Actual**	**Status**
Area from 0 to 30 degrees	0.055	m.rad	0.068	Pass
Area from 0 to 40 degrees	0.090	m.rad	0.103	Pass
Area from 30 to 40 degrees or Angle of Flooding	0.030	m.rad	0.035	Pass
Maximum GZ at the angle of heel equal to or greater than 30	0.200	m	0.214	Pass
Angle of maximum GZ	30.0	deg	41.0	Pass
Initial GMt	0.350	m	0.906	Pass

the boat, albeit with lower parameter values. Thus, Boat B (Pontian) is also stable and safe to operate in all loading conditions. However, the actual area under the curve is smaller, which indicates that the righting moment present is smaller. Boat B (Pontian) thus is only able to withstand smaller disturbance when operating at sea, and capsizing may occur if operating in rough weather and high sea state condition.

Safety Equipment Survey

Poor stability, water trapped on deck, lack of navigation lights, slippery deck were some of

Table 19: Survey on life saving equipment

Life Saving Equipment	IMO/ Torremolinos	Mersing Boat	Status	Pontian Boat	Status
Life jacket	2-3	2	Pass	2	Pass
Life buoys	2	1	Fail	1	Fail
Parachute distress rocket signals	<12	0	Fail	0	Fail
Smoke signals	<2	0	Fail	0	Fail
Survival craft	1	0	Fail	0	Fail
First aid kit	1	0	Fail	1	Pass

Table 20: Survey on navigation and fishing light

Navigation and Fishing Lights	IMO/ Torremolinos	Mersing Boat	Status	Pontian Boat	Status
RED	1	1	Pass	1	Pass
GREEN	1	0	Fail	0	Fail
WHITE	1	0	Fail	0	Fail
RED and GREEN	1	0	Fail	0	Fail

the factors which lead to capsizing, sinking, collision and work accidents while working on board fishing vessels. The safety survey was also carried out to assess the safety equipment of the fishing boats; later the findings were compared to the requirements as recommended by the International Maritime Organization (IMO) safety guidelines as listed in a study by Slf *et al.,* (2007). For Boat B (Pontian), the safety survey was only done for watertight bulkhead aspect since Boat B had not been put into operation at the time of the survey. The survey results on safety equipment and system appliances for Boat A (Mersing) and Boat B (Pontian) are presented in Table 19 until Table 22.

Survey on the life saving equipment is done to know whether enough equipment are available if any accident occurs. All boats should carry life jackets, which should be stored at an accessible place. Life buoys also must be available and stored at the port or starboard side of the boats. Every boat must be equipped with first aid kit with a manual to help dealing with injuries on board. Parachute distress rocket signal and smoke signals can be equipped for calling for help purpose. Table 19 summarizes the survey on life saving equipment on both of the boats. Both boats do not have adequate life saving equipment, which is crucial in emergency situations. If these safety measures are ignored, any nearby passers-by will not be able to lend a hand should any trouble or accident occur while on shore late at night.

Table 20 shows the survey on navigation and fishing light of the boats. According to international rules, fishing boats less than 12 m in length must carry the following lights to prevent collision at night:

1. Sidelight or a combined (RED and GREEN) lantern mounted exactly parallel to the center line of the boat.
2. Combined all-round lantern, lower fishing light and anchor light. WHITE means all around.
3. Upper fishing light showing all around – GREEN means if the boat is trawling, while RED means other fishing methods.
4. Fishing light, WHITE means all around. If the boat uses floating fishing gear extending

Table 21: Fire fighting equipment system of Mersing fishing boat

Fire Fighting Equipment and System	IMO/ Torremolinos	Mersing Boat	Status	Pontian Boat	Status
Water pump, hydrants and hoses	2	0	Fail	0	Fail
Carbon dioxide cylinder system	1	0	Fail	0	Fail
Portable fire extinguishers	1	0	Fail	0	Fail
Breathing apparatus	1	0	Fail	0	Fail

Table 22: Survey on watertight bulkhead

Navigation and Fishing Lights	IMO/ Torremolinos	Mersing Boat	Status	Pontian Boat	Status
Aft peak, fore peak	1	1	Pass	1	Pass
Engine room	1	1	Pass	1	Pass
Fish hold	1	1	Pass	1	Pass

more than 150 m from the boat, this light will be used to indicate the direction of the floating fishing gear so that other boats can avoid the gear.

Fire fighting equipment is also important to be available on board. Table 21 shows the fire fighting equipment system on board the boats. Since both boats are small, thus no such equipment as in standard criteria is available. However, at least one fire extinguisher should be placed in the boats in case of fire.

With inboard engine in both boats, safety against sudden leaks can be improved by having a bulkhead in front of the engine area. In this way, if flooding happens, there would be more time in bailing out the boat. Table 22 shows the survey on watertight bulkhead of the boats, in which both boats pass the standard requirement on the watertight bulkhead.

Based on the survey analysis, both boats fulfill all the requirements for watertight bulkhead but fail to meet certain safety requirements. Thus, it can be summarized that both fishing boats selected in this study do not properly fulfill the safety requirements as recommended by the International Maritime Organization (IMO) or Torremolinos guidelines. Safety is a very important aspect to consider, especially in assessing the performance of small fishing vessels. The small size of vessels makes them vulnerable to adverse sea conditions and may result in capsizing or sinking of the vessels.

Thus, it is important for the boat owners and operators to implement the entire safety requirement as recommended by International Maritime Organization (IMO) Torremolinos guidelines. Boat owners should take seriously the safety measures of the crew and regularly carry out maintenance of boat and safety equipment. In addition, boat crews or operators should make sure they operate in safe operation and the boat is in good condition before sailing to the sea. Boat builders should also be aware and provided with knowledge on safety guideline in designing and construction of boat as recommended by safety authorities. Improvement in this aspect must be done to ensure and provide safe operating condition for fishing activities. Regular safety evaluation on small fishing boats must also be carried out to ensure the boats operate in safe conditions.

Conclusion

The seakeeping, stability and safety performance assessments on two small fishing boats had been performed according to the respective international requirements or standard criteria. The assessments showed that although both boats fulfill static stability requirements, one of the boats should only be allowed operating in restricted operational area with maximum sea state 2 (calm sea), while the other can be allowed to operate in operational area up to sea state 3. It was found that although the boats fulfill the basic stability criteria, they still have serious safety and operability limitations. Besides posing a threat to safety at sea, poor performance of small fishing boats may also affect the operations economics view. It is thus essential for the Malaysian fishing boats to meet the standard requirement, to ensure fishermen's safety and increase the effectiveness and productivity of fishing industry in Malaysia. Nevertheless, it is difficult to establish an absolute view on the performance of small fishing boats in Malaysia, as their design factor and different operating area may produce different results in the assessment. Assessments on small fishing boats are vital to be carried out for the improvement of the boats, which eventually contributes to productivity of fisheries activities, especially in coastal areas.

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