THE EFFECT OF TIDES AND VESSEL PARAMETERS OF FISHING BOAT GENERATED WAVES

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DEDICATION

Specially dedicated to my mother (*Ibu Wuryati),* my father *(Bapak Soenanto),* my wife *(Choiriyah),* and my children *(Aisyah, Adam, Aysara, Ahsan)*

Al-Fatihah

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ABSTRACT

Ship generated waves (SGW) can cause bank erosion as well as disturbance to moored boats especially in the river at estuary due to the restricted area, very high boat traffic and shallow water. In this river, the dominant environmental effect is tidal, but unfortunately in-depth investigation of this effect has not been conducted before. Tidal effect may present the critical issues that are closely related to the different water depth, as well as current speed and direction of tide flow due to the boats movement at flooding and ebbing condition of the river. The aim of this research was to determine characteristic of SGW in the river that have tidal condition, also to obtain allowable speed of fishing boat while sailing in the river. Results of a full-scale field experimental work during rising and ebbing tides in the Mersing river are presented. The displacement hull fishing boat has dimension 14.05 × 4.35 × 1 m (length × breadth × draft) and the planing hull fishing boat has dimension 6.5 × 1.46 × 0.8 m (length × breadth × draft) and both were run at 6, 9 and 12 knots. Wave heights and wave spectral energy from SGW of the two fishing boats were analysed and the energy obtained are compared to one of the accepted river criteria known as Brisbane River Criteria. The effect of assessing the SGW beside the boats at different distances from the sailing line (SL) was also studied using Computational Fluid Dynamic (CFD) simulations. The results show that higher energy was created at the shallowest water depth (h=3.6 m). As SGW is propagated from 5 m to 13 m off SL with 12 knots, the wave energy density was reduced by 1687.6 kg/s2 (38 %) for the displacement hull fishing boat and 29.75 kg/s2 (83 %) for the planing hull fishing boat. During the field experiment, it was found that the SGW has the highest energy when the boat and tide condition are in opposite directions. The findings also indicate that in order to minimize river bank damage, the displacement hull fishing boat should not exceed a limiting speed of 4.8 knots during the flooding, slack and ebbing conditions. However, for planing hull fishing boat, the allowable speed is less than 9 knots. The findings can be useful for the fishing boats operators and local authorities to regulate fishing boat traffic in rivers.

ABSTRAK

Gelombang yang dijana oleh bot (SGW) boleh menyebabkan hakisan tebing dan juga menyebabkan gangguan kepada bot-bot lain yang ditambat terutama pada sungai yang terletak dekat dengan muara kerana di kawasan ini memiliki kawasan terhad, trafik bot yang sangat tinggi dan air cetek. Di sungai ini, kesan alam sekitar yang dominan iaitu pasang surut, akan tetapi tiada penyelidikan mendalam dilakukan sebelum ini. Kesan pasang surut boleh mengemukakan isu - isu kritikal yang berkait rapat dengan kedalaman air yang berlainan, serta kelajuan dan arah arus pasang surut berkaitan dengan pergerakan bot semasa air pasang dan surut pada sungai ini. Tujuan penyelidikan ini adalah untuk menentukan ciri - ciri pada gelombang yang dijana oleh bot nelayan di sungai yang mempunyai air pasang dan surut, juga untuk mendapatkan kelajuan bot nelayan yang dibenarkan semasa berlayar di sungai. Hasil kerja ujikaji berskala sebenar semasa air pasang dan surut di sungai Mersing dibentangkan. Badan bot nelayan jenis displacement dengan saiz 14.05 × 4.35 × 1 m (panjang × lebar × draf) dan badan bot nelayan jenis planing dengan saiz 6.5 × 1.46 × 0.8 m (panjang × lebar × draf), keduanya berlayar pada kelajuan 6, 9 dan 12 batu nautika sejam. Tinggi gelombang dan spektrum tenaga gelombang dari SGW untuk kedua-dua bot nelayan dianalisis dan tenaga yang terhasil dibandingkan dengan Kriteria Sungai Brisbane. Kesan SGW pada tepi bot berdasarkan jarak daripada garis layaran (SL) juga dikaji dengan menggunakan simulasi Pengkomputeran Dinamik Bendalir (CFD). Hasil ujikaji menunjukkan bahawa tenaga daripada SGW yang lebih tinggi dicipta pada kedalaman air yang tercetek (h=3.6 m). Ketika gelombang bergerak dari 5 m hingga 13 m daripada SL dengan kelajuan bot 12 batu nautika sejam, ketumpatan tenaga gelombang berkurang sebanyak 1687.6 kg/s2 (38 %) untuk badan bot nelayan besar jenis displacement dan 29.75 kg/s2 (83 %) untuk badan bot nelayan jenis planing. Semasa ujikaji lapangan, didapati SGW mempunyai tenaga yang lebih tinggi apabila keadaan bot dan arus bergerak pada arah yang berlawanan. Penemuan juga menunjukkan bahawa untuk memastikan kerosakan tebing sungai yang minimum, badan bot nelayan jenis displacement tidak boleh melebihi kelajuan 4.8 batu nautika sejam semasa keadaan air pasang, tenang dan surut. Manakala, bagi badan bot nelayan jenis planing, maksimum kelajuannya adalah 9 batu nautika sejam. Penemuan ini juga berguna bagi nelayan dan pihak penguatkuasa tempatan untuk mengawal trafik bot nelayan di sungai.

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LIST OF ABBREVIATIONS

ADI	-	Alternating Direction Implicit
AWAC	-	Acoustic Wave and Current Profiler
CFD	-	Computational Fluid Dynamic
CL	-	Center Line
DAQ	-	Data Acquisition
DFT	-	Discrete Fourier Transform
DMA	-	Danish Maritime Authority
DTMB	-	David Taylor Model Basin
FFT	-	Fast Fourier Transform
FSI	-	Flat Side Inner
FSO	-	Flat Side Outer
HALSS	-	Heavy Air Lift Support Siho
HSC	-	High Speed Cruise
IIHR	-	Iowa Institute of Hydraulic Research
LKIM	-	Lembaga Kemajuan Ikan Malaysia
M/V	-	Motor Vessel
NE	-	North East
SE	-	South East
SEAFDEC	-	Southeast Asian Fisheries Development Centre
SGW	-	Ship Generated Waves
TFR	-	Time Frequency Representation
UTM	-	Universiti Teknologi Malaysia
WSF	-	Washington State Ferries

LIST OF SYMBOLS

B	-	Breadth of ship
c	-	Velocity of ship (Havelock calculation only)
D	-	Depth of ship
E_d	-	Energy Density
E_p	-	Potential Energy
E_k	-	Kinetic energy
E_{max}	-	Energy of maximum wave
E_{total}	-	Energy of entire wave train
F	-	Frequency
F_{nd}	-	Depth Froude Number
F_{nl}	-	Length Froude Number
g	-	Gravity coefficient
h	-	Water depth
H_{max}	-	Maximum wave height
L_{oa}	-	Length overall
L_{pp}	-	Length of Perpendicular
L_{wl}	-	Length of water line
m	-	Mass
N	-	Number of data
R	-	Coefficient determination
T	-	Draft
T_{max}	-	Period of maximum wave
T_{ww}	-	Wave mean period
V_s	-	Service speed
V_c	-	Current speed
V_R	-	Relative speed
α	-	Angle between divergent wave line and sailing line
v	-	Vessel speed
ρ	-	Fluid density
ζ	-	Wave amplitude

λ	-	Wave length
ω	-	Period

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CHAPTER 1

INTRODUCTION

1.1 Introduction

In recent decades, researches on Ship Generated Waves (SGW) have focused on the study of wake wash. It has become one of the important design criteria in addition to the particular dimensions of speed, dead weight capacity, number of passenger and manoeuvrability of the ship. Naval architects and shipbuilders also consider that the wake wash is an important issue especially to make environmental-friendly design.

Macfarlane (2012) reported that SGW or wake wash is influential for the user of the waterways and the surrounding environment due to the following:

i. Cause shoreline or bank erosion;
ii. Make nuisance to moored vessels;
iii. Damage jetties and other marine structures;
iv. Endanger people working or enjoying activities in small craft or close to the shore;
v. Destroy fragile water plants and disturb the silt;
vi. Damage the ecology of intertidal and shallow sub-tidal habitat.

Soomere et al. (2011) also described that SGW would contribute to damage in wide archipelago area, narrow straits and inland waterway. Parnell et al. (2015) reported that SGW had an effect on shallow water lagoons. Didenkulova and Rodin (2013) reported that high amplitude water waves in Tallinn Bay, Baltic Sea induced by the regular passing of high speed vessels could cause intense beach erosion and disturb marine habitats in coastal zones. Moreover, Kandasamy *et al.* (2011b) revealed that the wake of high speed passenger ferries caused beach erosion and damage to the habitat in Rich Passage between Seattle and Bremerton.

Recently, research activities were also focused on the phenomenon in rivers. The study of ship-generated waves in this area is important because of its shallow and very narrow water. The characteristic of river leads to consideration of restricted area. Stumbo *et al.* (2000) found that the energy of ship's wake wash in shallow water is higher than deep water. Therefore, the river can acquire higher energy from ship waves than open sea, which later makes it more vulnerable to erosion than coastal area.

Some countries have already had detailed discussion about this issue. In Australia, many rivers have been explored regarding this phenomenon. Bradbury (2005b) revealed that the management in Gordon River tried to monitor wave wake from cruise vessel which had maximum wave height criterion. Macfarlane and Cox (2004) also studied the phenomenon in Brisbane River and eventually proposed some vessel operating criteria based on known erosion indicators such as wave energy and period from simple vessel. They also gave recommendation to regulatory authorities about the means to control boats in traffic and its associated environmental impact. Watterson *et al.* (2012) assessed that vessel wake resulting from towing activities in Tweed River had potential to cause and increase the bank erosion. They concluded that this wave has become the dominant erosion mechanism.

In Europe, a study of SGW in river area has been done by Göransson *et al.* (2014). This research investigated the SGW in the Gota Alv River from the cargo or commercial ships that have low speed condition. They found that the generated waves triggered sediment transport and erosion along the river bed and banks.

The ship waves in the USA rivers have also been observed in Severn River. Tan (2012) made updated equation model of predicting boat-generated wave heights given a set of basic vessel parameters, i.e. vessel lengths, speed and the distance of sailing line from the shore.

In Malaysia, several experiments and simulations have been performed to understand the SGW. The field measurements in Kemaman River and Kilim River Geoforest have been conducted by some researchers. Ahmad *et al.* (2011) explained that wave energy was produced by boat generating wave in Kemaman River and described that riverbank erosion occurred when the boats navigate the estuary. Moreover, Diyana (2017) described the effect of boat speed, the number of passengers and boat trim on SGW. Diyana also investigated the speed limit for tourist boats when passing through restricted areas.

Gourlay (2011) explained that the boat generated waves are the major contributing factor for shoreline erosion. However, the erosion in the river banks have been largely caused by SGW especially at narrows area. Tan (2012) also described that wave of passing vessel could create damages to shoreline and disturb aquatic habitat. Tan also explained that SGW need to be considered by the Navy during clandestine infiltration operation. For that purpose, the boat should be small with low wake wash, thus the wave can disappear before shoreline and minimize water noise and movement on the river.

The other recent research on SGW in the river are provided by Yaakob *et al*. (2015), Mao *et al.* (2016), Thuy *et al.* (2017) and Saha *et al.* (2017). Yaakob *et al.* (2015) studied tourism boat at Kilim River using field experiment and CFD simulation. Yaakob investigated the draft effect in the boat that simulates the number of passengers. Mao observed SGW with field experiment in Xin Xiagang River (a part of Yangtse River in China). Mao *et al.* (2016) developed the numerical model for SGW based on depth averaged Non-Linear Shallow Water (NLSW) equations. Thuy *et al.* (2017) have investigated the effects of river vegetation and timber piling on the attenuation of SGW that cause erosion at river bank. A numerical model was generated based on two dimensional Boussinesq-type equations to predict the ship wave prorogation through river vegetation and timber piling.

Saha *et al.* (2017) carried out a case study of SGW in Buriganga River, Bangladesh using CFD simulation to get the maximum wave height and made the comparison of water based on Kriebel *et al.* (2003). The speed limitation was also proposed to obtain the acceptable wave energy of SGW.

One source of SGW in river is fishing boats. If the river area is close to sea, this area usually has high traffic. When fishing boat passes the river, the boat wake wash can cause disturbance on moored boats and loading-unloading activities. In the actual problem, when any boat passes on the river, the wave will propagate to moored boats and eventually cause motion. As a result, this may cause the moored boats to collide or rub against each other.

Different size and type of boats have been found to produce different effects on the wake wash characteristics. The comparison of several SGW researches are summarized in Table 1.1. The table shows the research based on year, type of ship, research/activity method, Froude Number as well as location of research. Therefore, this table provides the information of previous studies of SGW, and will be discussed in the next section.

1.2 SGW of Fishing Boats

Most studies of SGW were carried out on fast ferry, high speed craft (as of patrol boat), as well as cargo ship. As shown in Table 1.1, Stumbo (2000), Belibassakis (2003), Osborne *et al.* (2007), Velegrakis *et al.* (2007), Dam *et al.* (2008), Soomere *et al.* (2009), Soomere *et al.* (2011), Tan (2012), Kandasamy *et al.* (2011a), Didenkulova and Rodin (2013), Kimura *et al.* (2014), Parnell *et al.* (2015) and Thuy *et al.* (2017) conducted their respective studies with fast ferry (high speed ship). Ghani and Rahim (2008) did the research on a patrol boat, while Göransson *et al.* (2013) used cargo ship in their study.

In terms of hull type, researchers investigated the catamaran as well as monohull. Whittaker *et al.* (2000a), Osborne *et al.* (2007), Kandasamy *et al.* (2011a), Macfarlane (2012) used catamaran hull for the study. Yaakob *et al.* (2012) investigated the configuration of asymmetric catamaran hull form. Table 1.1 shows that most researchers conducted experiment using monohull. Regarding the Depth Froude

Number (F_{nd}), most researchers applied subcritical, critical and supercritical speed regimes.

There are not many studies on SGW for fishing boats in river area, as observed in Table 1.1. However, the investigation of fishing boats SGW is needed because the wave instigates erosion easier in the river than in sea shore area, as the river is narrower with restricted area characteristics. Most SGW studies in river areas showed that SGW increase erosion potential in rivers (Bradbury (2005a); Dam *et al.* (2008); Ahmad *et al.* (2011); Macfarlane (2012); Goranson *et al.* (2014); Thuy *et al.* (2017)).

In Southeast Asia, many fishing boats are operated in the sea. Based on data from Southeast Asian Fisheries Development Centre (SEAFDEC, 2012), the number of fishing boats is divided into two length categories: less than 24 meters and 24 meters and over. Table 1.2 shows the number of fishing boats in ASEAN (Association of Southeast Asia Nations) countries. The table revealed that the majority of fishing boats have length less than 24 meters. The top five countries in terms of number of fishing boats is Indonesia, Philippines, Vietnam, Malaysia and Thailand. In particular, Indonesia and Philippines have more than 400,000 boats each, due to their nature of archipelago islands.

Most of the fishing boats park in the river nearby estuarine without proper boat parking area, which makes the river very restricted. Meanwhile, unsafe traditional berths are common. This is the general condition of fishing boat area. Figure 1.1 shows an example of the crowded situation in rivers. The impact of SGW in the river can result in clashing among boats as well as vibration on traditional berth. In terms of erosion, many banks in the river do not have bank protection such as concrete slab, therefore they eventually erode when hit by SGW.

Table 1.1 Comparison of research work in ship generated wave studies

No	Author (year)	Type of ship	Method	Research Location	Depth water condition
1	Macfarlane,Renilson (1999).	Catamaran	Exp. (Model scale, wave probe); F_{nd} = NA	Australia Maritime College	Deep water
2	Whittaker *et al*. (2000a).	Catamaran, monohull fast ferries	Exp. (field exp, wave buoy & model scale); F_{nd}= 0.8 – 1.1	Loch Ryan, Belfast Lough	Shallow water
3	Stumbo (2000).	Fast ferries (catamaran)	Exp. (field exp, wave buoy); F_{nd} = 0.7 – 1.2	Rich Passage, Puget Sound	Shallow and deep water
4	Fox Associates (2002).	MV Condor Express (ferry)	Exp. (field exp, wave buoy); F_{nd} = NA (V_s=39 kn)	Rich Passage, Puget Sound	Deep water
5	Belibassakis (2003).	Fast ferry (small ferry 38 m)	CFD ;F_{nd}=0.5 – 1.25	No info	Deep water
6	Macfarlane and Cox (2004).	Patrol boat	Exp. (field exp); F_{nd} = NA (V_s= 5 - 27 kn)	Nossa & Brisbane River, AUS	Deep water
7	Bradbury (2005b).	Recreational cruise	Exp. (field exp); F_{nd} = 0.5 (V_s= 5 - 6 kn)	Gordon River, AUS	NA
8	Osborne *et al*. (2007).	High speed ferry (catamaran)	Exp. (field exp, wave gauge); F_{nd} = 0.91 (V_s= 10 - 45 kn)	Rich Passage, Puget Sound	Deep water
9	Velegrakis *et al*. (2007).	Conventional,high speed ferries	Exp. (field exp, video rec.); F_{nd} = NA (V_s= 17 & 26.5 kn)	Cape Lena Beach, Mytilene	Deep water
10	Kumar *et al.* (2007).	Ferry	CFD (Shipflow); F_{nd} = 0.5-2.6 (V_s= 5 - 30 kn)	San Francisco Bay, USA	Shallow and deep water
11	Ghani *et al.* (2008).	Harbour patrol boat (monohull)	Exp. (Model scale, wave probe); F_{nd} = 0.6-1.4	UTM laboratory	Shallow and deep water
12	Dam *et al.* (2008).	Water buses	Exp. (field exp., wave gauge); F_{nd} = 0.45-0.95	Shingashi River, Tokyo, Japan	Shallow water
13	Soomere *et al.* (2011).	Fast ferry (high speed craft)	Exp. (field exp, echosounder); F_{nd} = NA (V_s= 30-35 kn)	Tallinn Bay, Baltic Sea	Shallow water
14	Ahmad *et al.* (2011).	Fishing boat	Exp. (field exp, wave gauge); F_{nd} = NA (V_s= 6 - 16 kn)	Kemaman River, Malaysia	NA
15	Kandasamy *et al*. (2011a).	HSC ferry (catamaran)	CFD; F_{nd} = NA (V_s= 17 & 26.5 kn)	Rich Passage, Seattle to Bremerton	Deep water
16	Yaakob *et al.* (2012).	Asym. catamaran, leisure boat	Exp. (Model scale), CFD *;* F_{nd} = 0.1-0.3	UTM laboratory	Deep water
17	Macfarlane (2012).	Monohull, catamaran	Exp. (Model scale); F_{nd} = 0.2-2.2	Australia Maritime College	Shallow and deep water
18	Tan (2012).	Unified Cruiser (monohull)	Exp. (field exp., video recording) and Wave gauge	Severn River, Annapolis, USA	Shallow water
19	Marrone *et al.* (2012).	Alliance Vessel – Exp., CFD	Exp. (model scale) and CFD;	Italian Ship Model Basin, Rome	Deep water
20	Didenkulova, Rodin (2013).	High Speed Ferries (monohull)	Exp. (field exp., video recording)	Tallin Bay, Baltic Sea	Shallow and deep water
21	Göransson *et al*. (2013).	Cargo ship (monohull)	Exp. (field exp., video recording)	Gota Alv River, Sweden	Shallow water
22	Gomit *et al.* (2014).	Exp. in deep water (monohull)	Exp. (model scale) and CFD	Universite de Poitiers, France	Deep water
23	Kimura *et al.* (2014).	Sakujima Ferry (monohull)	Exp. (Model scale) by wave gauge	Kagoshima Bay, Japan	Deep water
24	Caplier *et al.* (2015).	monohull	Exp. (model scale) and CFD	University of Poitiers, France	Shallow and deep water
25	Yaakob *et al.* (2015)	CFD for wigley hull (monohull)	CFD	UTM laboratory	Deep water
26	Benassai *et al.* (2015).	HSC (monohull, catamarans)	Exp. (field exp., wave gauge); F_{nd}= NA (Vs= 20 - 30 kn)	Gulf of Naples, Italy	Deep water
27	Noblesse *et al.* (2016)	Monohull, catamaran	CFD; F_{nd}= 0.58, 0.68, 0.86, 1.58 (monohull),); F_{nd}= 1, 2.5	Shanghai Jiao Tong Univ., China	NA
28	Mao *et al.* (2016)	Monohull	Exp. (field exp., wave gauge) and CFD; F_{nd} = 0.52-1.15	Yangtze River, China	Shallow water
29	Saha *et al.* (2017)	Waterbuses (catamaran)	CFD and theoretical*;* F_{nd} = 0.6 – 1.07	Buriganga River, Bangladesh	Shallow water
30	Thuy *et al.* (2017)	High-speed ship (monohull)	Exp. (field exp., video rec);F_{nd}= 0.45 – 2.67	Kinh Sang River, Vietnam	Shallow water

Table 1.2 The number of fishing boats in Southeast Asia (SEAFDEC, 2012)

No	Country	Number of Fishing Boat		
		Less than 24 meters	24 meters and over	Total
1	Brunei Darussalam	2,476	4	2,480
2	Cambodia	7,034	0	7,034
3	Indonesia	569,105	1,722	570,827
4	Laos	1,615	0	1,615
5	Malaysia	49,673	83	49,756
6	Myanmar	27,000	1,357	28,357
7	Philippines	472,804	594	473,398
8	Thailand	33,050	865	33,915
9	Vietnam	127,700	300	128,000

(a)

(b)

(c)

Figure 1.1 Fishing boats in the river, (a) Malaysian river (Joysan, 2013), (b) Indonesian river (Adi, 2017), (c) Vietnamese river (Lopez, 2015)

1.3 Wave energy of SGW

There are several known methods to measure the total wave energy of SGW in field measurement. In the field study at Kemaman River estuary, the energy generated by boat at mangrove area was observed and calculated by Ahmad *et al.* (2011) using the formula that correlates the energy of maximum wave. In this experiment, the researchers showed the calculation of energy of maximum wave (E_{max}) and energy of entire wave train (E_{total}). The energy of maximum wave was obtained by using peak period at maximum wave height. The formula is valid only at Kemaman River for water depth of 0.1 meter to 1.8 meter and the boat speed is around 5 – 30 knots for fishing boat and passenger boat. The method to measure maximum wave energy has also been used by Stumbo *et al.* (2000), Macfarlane and Cox (2004).

Another method to indicate the energy uses wave spectral analysis that can represent the total wave energy, not only the energy of maximum wave height. It is useful to estimate and filter the wave component. In field measurement of SGW, this method is developed by Osborne (2007), Velegrakis *et al.* (2007), Gourlay (2011) and Benassai *et al.* (2015). Velegrakis *et al.* (2007) also applied this technique to get the significant frequency / period of the wave. Gourlay (2011) showed that this method gives a direct energy measure based on the integrated wave elevation time trace. Benassai *et al.* (2015) described new spectral energy analysis to filter the wind sea wave component from SGW of High Speed Craft (HSC). Benassai *et al.* (2015) proposed this technique to give more reliable operational strategies and mitigative measures of SGW. Besides that, the study shows a new spectral analysis procedure that allows the filtering of the wind sea component.Therefore, the SGW component can be evaluated separately and both the height and energy density of SGW can be estimated.

1.4 Factors affecting SGW

Many factors contribute to the SGW/wake wash pattern which is very complex. Macfarlane and Renilson (1999) described the factors as environmental factors, vessel parameters, and other factors.

Referring to Table 1.1, all researchers considered the effect of the speed of the vessel. In an experiment, Stumbo *et al.* (1999) observed the SGW with speed and draft (vessel parameter). Whittaker *et al.* (2000) considered speed and water depth. Stumbo *et al.* (2000) added the factors of speed, trim, Depth Froude Number (F_{nd}) and Length

Froude Number (F_{nl}) parameters to consider. Macfarlane and Cox (2004) used variation of speed for demonstrating the wave height. Kumar *et al.* (2007) made the comparison between speed, water depth, and length F_n. Dam *et al.* (2008) investigated river current velocity, although it was not based on actual current velocity. Ahmad *et al.* (2011) observed the SGW at river with different speeds, water depths and tide conditions, but the information on the hull used was not provided. Moreover, they did not adequately discuss the SGW during ebbing, slack and flooding on the tide condition.

Goransson *et al.* (2014) investigated the SGW on Gota Alv River, Sweden by using several cargo ships with speed between 5 and 10 knots. They also considered water depth and river speed as the environmental factors. On the other hand, Bennasai *et al.* (2015) observed the SGW of HSC at coastal environment. Bennasai ran field experiment by using pressure sensor wave instrument to measure wave height. This experiment had several factors to consider, e.g. speed and hullform (monohull and catamaran), but it lacks detailed information about the tidal condition or change in water depth.

Mao *et al.* (2016) conducted the field measurement and numerical study for SGW of ship at Xicheng canal, China. Speed of ship was considered as a factor in the experiment, thus it had several F_{nd}. The measurement used two types of ship based on tonnage with different speeds. Meanwhile, Thuy *et al*. (2017) also investigated SGW of HSC at Ca Mau River, Vietnam. In this field experiment, the speed was the only factor considered for SGW. Lastly, Saha *et al.* (2017) observed the SGW of waterbuses at Buriganga River, Bangladesh. In this research, Saha considered factors of speed and water depth using monohull in the simulation and theoretical study.

In terms of vessel parameters, the speed and hullform types were considered. Based on Table 1.1, all researchers only use one speed per ship or boat in field measurement. However, the wave height due to different speeds is important to understand. Therefore, the present study investigates several speeds for the boat with two different hullforms, so that the wave height with different speeds can be identified.

Tidal condition is an environmental factor which may affect SGW especially at the estuary area. Tidal rise and fall lead to different water depth and current velocity. The river can be considered a restricted area due to limited width and also heavy boat traffic, therefore the tidal will be significant factor affecting the wake wash of boat.

1.5 Problem Statement

Many researches on SGW have focused on HSC, e.g. ferries, patrol boat and cargo ship. Only two studies (Ahmad, 2011) and (Diyana, 2017) investigated the SGW with fishing boat, although the number of this boat is abundant, especially in ASEAN countries. Most of the boats are navigated in the river at estuary area during loading and unloading activity, parking, and sailing in/out, therefore the traffic is very high in this area, and will be very restricted. In estuary, the dominant environmental effect is tidal, but unfortunately in-depth investigation of this effect has not been conducted before. Tidal effect may present the critical issues that are closely related to the different water depth, as well as current speed and direction of tide flow due to the boats movement at flooding and ebbing condition of the river. As the width of the river is restricted, the energy of SGW beside the boat must also be known in order to get the safe distance between fishing boats and other boats. In addition, the speed of boats along river area are mainly based on the experience of fisherman, thus there is no standard of allowable speed during the navigation in the river. Therefore, it is important to indicate the allowable speed along the river. The tide effect can also affect the allowable speed of the boats, thus study of this effect is important especially at estuary area. If a boat sails in such river with relatively high speed, the SGW may cause serious destruction to the river banks and collision between the moored boats..

1.6 Research Questions

i. Does depth fluctuation of water due to tides have significant effect on the SGW?

ii. How does the SGW's energy beside the boat effect other boats?

iii. What is the effect of flooding and ebbing on the fishing boat movement against wave height and energy of SGW?

iv. What is the effect of tide on the allowable speed of displacement and planing fishing boat in the river?

1.7 Objective

v. To determine the effect of water depth due to tidal rise and fall on SGW of displacement and planing hull fishing boat.

vi. To assess the SGW at different width from sailing line.

vii. To investigate the effect of tidal condition on ship wakes.

viii. To obtain allowable speed of fishing boat while sailing in the river.

1.8 Research Scope

ix. The data of water depth and current speed are taken from actual condition measured from fishing boat's sensor.

x. The study uses field measurements and numerical study as CFD (Computational Fluid Dynamic) by using ANSYS CFX.

xi. The methods to measure and characterize boat wake wash using visual observation with digital video are modified from other researchers.

xii. The analysis uses spectral energy on field measurement.

xiii. The reflection phenomena in the field experiment is not considered. The experiment The data of water depth and current speed are taken from actual condition measured from fishing boat's sensor.

xiv. The field experiment uses both displacement and planing fishing boats (commonly used by onshore fisherman). The experiment run at

Mersing River was considered restricted area due to limited width and heavy boat traffic, therefore the tidal will be significant factor affecting the wake wash of boat.

1.9 Significance of the Research

Ship Generated Waves (SGW) of fishing boat in the river is important because the river is a restricted area. The study determines the spectral energy analysis of the SGW. Besides that, the effect of environmental factors such as tidal effect and vessel parameters in speed and hull type are described in accordance with SGW. This research is among the first to investigate tidal effect of such phenomenon in the river particularly at estuary area in Malaysia, which is important for regulating the river traffic especially in crowded areas. The allowable speed is also provided for Mersing River considering the energy impact of the SGW on the bank.

1.10 Organization of the Thesis

The thesis is organized in five chapters. First chapter presents an overview of the current study and provides the objective, scope and the significance of the study.

Chapter two describes the detailed review of the previous researches related to the current work. The chapter elaborates the wave pattern of SGW as per Depth Froude Number, the factors influencing in SGW, the present methods to investigate SGW, the criteria rules of SGW and the theoretical approach as well as statistical analysis of time histories of irregular waves, wave energy and spectrum.

Chapter three presents the flowchart of research methodology that shows the sequence of phases to obtain the objective of the research. The method to obtain wave height for field measurement is explained in this chapter. The description of research area is also presented. This chapter discusses how the field measurement works from the set up to the imaging process to get the wave height Chapter three presents the flowchart of research methodology that shows the sequence of phases to obtain the objective of the research. The method to obtain wave height for field measurement is explained in this chapter. The description of research area is also presented. This chapter discusses how the field measurement works from the set up to the imaging process to get the wave height to how to derive the wave spectral energy. The method to get SGW by CFD simulation is also elaborated including the simulation set up, meshing process, as well as determining the case study with certain parametric study as speed.

Chapter four shows the result of field measurement activity of displacement and planing fishing boat. The result presents the wave height characteristic obtained from image processing. Therefore, this chapter describes the wave height for displacement and displacement fishing boat. This chapter also discusses the wave spectra density for various scenario on displacement and planing fishing boat. The CFD result is also presented in this chapter. After that, the discussion the extent of results from field measurement experiment and CFD simulation will be provided. The explanation of results is divided into four parts with respect to each objective.

Finally, chapter five describe the conclusion of the research. In addition, the recommendation for the future research is presented.

1.11 Summary

This chapter shows that SGW at river is very important to study, as waves have the potential to destroy the riverside in the long term. The effect is more prominent in estuary, which is a restricted area, creating additional exposure leading to greater impact. The tidal effect is studied in this reseach by using field experiment and CFD simulation. This effect can be influenced by different water depth, width of river and effect of the tidal. The factors that influence the wave pattern and methods to determine the SGW impact are elaborated further in the next chapter.

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