EFFECT OF HULL SEPARATION RATIO AND VARIOUS SHIP DRAFT TO A LOW-SPEED CATAMARAN IN SHALLOW WATER

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ABSTRACT

Putrajaya is Malaysia's federal administrative capital and a well-planned city. With a display of colored boats floating across the lake at Marina Putrajaya, Putrajaya Lake is turned into a beautiful sight for everyone to enjoy it. It has a high potential to be a part of the growth and development of Malaysia's tourism industry. In addition, the Management of Putrajaya Lake plans to cater to recreation, fishing, water sports and water transport. Currently, there are a few catamaran cruise boats that are used for sightseeing propose. Therefore, the number of cruise boats is planned to increase in the future due to accommodating a large number of tourists. The existing design of catamarans shall be improved and fulfill the limitations of Putrajaya Lake especially the low operational speed catamarans and shallow water conditions. However, limited researches has been found for low-speed catamaran studies in shallow water conditions. In order to fulfil the research gap, the current study is focused on studying the effect of hull separation ratio, *H/L* of the catamaran and various ship drafts, *T* on the low-speed catamaran in shallow water and improving the catamaran design with better operational performance in terms of better resistance and lower operating cost. This research aims to provide a more competitive hull separation ratio, *H/L* for catamaran boats to operate in this low-speed condition. Then, a parametric study was conducted to identify the effect of hull separation ratio and different catamaran drafts on the low operational speed in shallow water using Computational Fluid Dynamics (CFD) software, which is Flow3D. Grid independence study and method validation were carried out in methodology. Three types of catamaran drafts were calculated with water depth to ship draft ratio, *h/T* for 2.5, 2.32, and 2.18 to analyse the total coefficient and free surface elevation effect. The objectives of this research were successfully achieved and the collected data is able to contribute to future development either for Putrajaya Lake Management or low-speed operation catamaran. The results showed that the smaller hull separation ratio, *H/L* is more suitable since lower total coefficient of resistance and free surface elevation occurred during the Froude number, $Fr = 0.4$ condition. Also, it recommended to use of a higher water depth to ship draft ratio, *h/T* due to the smaller ship draft, *T* showed smaller total coefficient of resistance and free surface elevation. In conclusion, this research is able to contribute valuable data for Putrajaya Lake management in improving its catamaran design in the future, as public transport operators always face challenges in producing a more environmentally friendly catamaran with commercial speed.

ABSTRAK

Putrajaya merupakan pusat pentadbiran persekutuan Malaysia dan sebuah bandar yang terancang. Dengan paparan bot berwarna terapung melintasi tasik di Marina Putrajaya, Tasik Putrajaya telah bertukar menjadi pemandangan indah untuk dinikmati oleh semua orang. Ia mempunyai potensi yang tinggi untuk memberi sumbangan dalam perkembangan sektor pelancongan di Malaysia. Tambahan pula, Pengurusan Tasik Putrajaya merancang tasik ini dengan aktiviti rekreasi, memancing, sukan air dan aktiviti pengangkutan air. Pada masa kini, pengurusan Tasik Putrajaya mempunyai beberapa katamaran bagi tujuan persiaran. Namun begitu, jumlah katamaran di tasik Putrajaya dijangka bertambah pada masa yang akan datang bagi memenuhi bilangan pelancong yang ramai. Reka bentuk katamaran yang sedia ada hendaklah ditambahbaik bagi memenuhi keadaan khas di Tasik Putrajaya terutamanya kelajuan operasi yang rendah dengan kawasan perairan yang cetek. Walaubagaimanapun, kajian katamaran yang beoperasi dalam keadaan kawasan air cetek masih agak terhad. Bagi memenuhi jurang kajian, penyelidikan ini tertumpu kepada mengutamakan kepada kajian kesan nisbah pemisahan badan katamaran, *H/L* dan pelbagai draf kapal, *T* pada katamaran berkelajuan rendah dalam kawasan air cetek dan untuk menambah baik reka bentuk katamaran supaya ia dapat beroperasi dengan lebih baik dan jimat kos. Penyelidikan ini juga bertujuan untuk menyediakan nisbah pemisahan badan kapal, *H/L* yang lebih kompetitif untuk bot katamaran yang beoperasi dalam kondisi kelajuan rendah. Seterusnya, kajian parametrik dijalankan dengan menggunakan perisian Dinamik Bendalir Berkomputeran, iaitu Flow3D. Semakan grid bebas dan pengesahan kaedah telah dijalankan dalam metodologi. Tiga jenis draf katamaran, *T* dengan nisbah kedalaman air kepada draf kapal, *h/T* iaitu 2.5, 2.32, dan 2.18 dipilih untuk menganalisis jumlah pekali rintangan dan kesan ketinggian permukaan air. Objektif penyelidikan berjaya dicapaikan dan pengumpulan data yang dapat boleh menyumbang kepada pembangunan masa hadapan sama ada bagi pengurusan Tasik Putrajaya atau kajian katamaran berkelajuan rendah. Keputusan kajian menunjukkan bahawa nisbah pemisahan badan kapal yang lebih kecil, *H/L* adalah lebih sesuai memandangkan jumlah pekali rintangan yang lebih kecil dan juga ketinggian permukaan air berlaku semasa nombor Froude, *Fr* di 0.4. Dengan ini, adalah dicadangkan untuk menggunakan nisbah kedalaman air kepada draf kapal, *h/T* yang lebih tinggi kerana draf kapal yang lebih kecil, *T* menunjukkan jumlah pekali rintagan dan ketinggian permukaan air yang lebih rendah. Kesimpulannya, kajian ini mampu menyumbang data yang bernilai kepada pengurusan Tasik Putrajaya dalam menambahbaik reka bentuk katamarannya memandangkan pengusaha pengangkutan sering menghadapi cabaran dalam menghasilkan katamaran yang lebih mesra alam dengan kelajuan komersial.

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Bh/T	Breadth (individual hull) to draft ratio
C_b	Block coefficient
C_f	Frictional resistance coefficient
C_t	Total resistance coefficient of a ship
C_r	Residual Resistance coefficient
	Force
Fr_L	Froude Number $[V(gL)^{-1/2}]$
Fr	Froude Number
g	General a characteristic external field, $9.81 m/s^2$
h	Water depth
h/T	Water depth to ship draft ratio
H/L	Hull separation ratio
IF	Interference factor
KG	Vertical centre of gravity
L	Length of a ship
LCG	Longitudinal of gravity
L_{oa}	Length overall ship
P	Pressure
Re	Reynolds Number
R_w	Resistance due to wave caused by ship
T	Ship draft
S_b	Squat
Δ	Displacement
A_s	Area of midship section
A_w	Area of the canal or river cross-section
C_{fi}	Frictional resistance coefficient of individual hull
$Diff_\varepsilon$	Diffusion of dissipation
$Diff_t$	Diffusion term
ε_T	Rate of turbulent energy dissipation
G_T	Buoyancy production

K	Total number of individual hull
K_T	Turbulent kinetic energy
ρ	Water density
PT	Turbulent kinetic energy
R_{DIF}	Diffusion turbulent
R_{SOR}	Mass source
R_f	Frictional resistance
R_t	Total resistance
S_c	Turbulent Schmidt number
S_i	Wetted surface area of the individual hull
μ	Coefficient of momentum diffusion
U	Ship speed
V_F	Fractional volume open to flow with fluid density
v_s	Ship speed

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CHAPTER 1

INTRODUCTION

1.1 Background

The distance between the hulls of multihull vessel, such as a catamaran, will affects ship resistance significantly. The improvement of wave resistance for a multi-hull vessel was relying on the separation of distance between demi-hull and the operating characteristics. The main reason is because of interaction between the wave systems leaving from the hulls. Despite numbers of research has been made in this related field, but theres is still some ambiguity of data for this resistance of catamaran operated in low speed condition. Calm water resistance of catamarans is in general attributed to two major components namely, viscous resistance and calm water wave resistance. This research will focus study on calm water resistance during operation in shallow water, Putrajaya Lake.

Characteristic of shallow water was from Putrajaya Lake Cruise and this has become one of scope study in this research. Better known as Cruise Tasik Putrajaya or CTP, it was launched on Aug 30, 2003, by the then prime minister Tun Dr Mahathir Mohamad. Putrajaya is a well-planned city and represent federal administrative centre of Malaysia. In process of development of Putrajaya Lake, it will be transformed into a mesmerizing colourful wonder, with a parade of lighted boats floating across the lake at Marina Putrajaya for spectators to feast their eyes on. It could be a good potential to be part of growth and development tourism industry in Malaysia.

In addition, the requirement of this hull resistance analysis has created a new challenge for the naval architecture sector, which has been significant requirement to be considered. The important requirement needed to be considered: operating speed and fuel consumption. All of these contributed a significant impact on ship operational expenses. Also, several published studies together with discuss on ship resistance and it’s characteristics of the catamaran in recent decade, This is especially obvious when one considers how a catamaran's resistance differs significantly from that of traditional monohull ships. Thus, The primary reason is because the existence of incoming divergent waves that involve with the simultaneous wave fields interactions between two demihulls on the catamaran is generally a highly complex phenomenon and superposed non-linearity to induce the total resistance coefficients. (Fitriadhy, Azmi, Mansor, & Aldin, 2017) Same goes to this research, catamaran will be further investigated effect of hull resistance which generated by catamaran with various separation ratio during low-speed operation condition in inland waterways. Therefore, for various resistance experiment setups, employing a towing tank with a model is relatively expensive, time-consuming, and limitation of condition. To obtain more accurate simulation of hull resistances for catamarans in this shallow water field, it is clearly that trustable Computational Fluid Dynamics (CFD) approach has become an optimal strategy. It is obvious that a reliable Computational Fluid Dynamics (CFD) approach has become a necessary aim to gain more accurate predictions of the hull resistances for catamaran with this shallow water condition.

According to the Putrajaya Lake Wetland Management & Operational System (PLWMOS) stated that Putrajaya Lake contains 60% of the lake water flow from the wetland and the remaining 40% is direct discharge from bordering promenade. (Sharip, Zaki, Shapai, Suratman, & Shaaban, 2014) The as stated below:

(a) The 20-meter-wide promenade serves as a buffer along the lake's shorelines;

(b) The total water surface area of the lake is around 400 hectares;

(c) The total amount of water in the entire lake is around 3.5 million cubic metres.;

(d) The water depth varies between 3 and 14 metres;

(e) The lake was designed to serve a variety of purposes, including recreation, fishing, water sports, and water transportation;

(f) The lake and its foreshores also form Putrajaya's most popular resource for informal recreation as a waterfront city.

Since tourism industry in Putrajaya Lake is getting popular, water transport for this area should be well development especially like water taxi which will convenient for tourist. In area nearby Putrajaya lake, there's a lot of interest place such as Alamanda Putrajaya, Putrajaya Water Sports Complex, Millennium Monument, Botanical Garden and etc. (Qureshi & Ho, 2011) Cruise boats in Putrajaya lake provide a chance to become a "trade-mark" of style on its foremost geographic asset. Cruise boat designs might just be romantic, traditional, entertaining, or high-tech, but they must always be attractive and efficient. Cruise boats, in example, may provide a chance to demonstrate cutting-edge maritime technologies relevant to Malaysia and in line with Putrajaya's environmentally themes. Figure 1.1 below showed the current cruise boat tour route, which departs from the cruise boat terminal at the Precinct 5 Aquatic Recreation Centre marina as shown on the map. Duration estimated for this map up to 15 kilometres, resulting in a cruise time of 90 minutes.

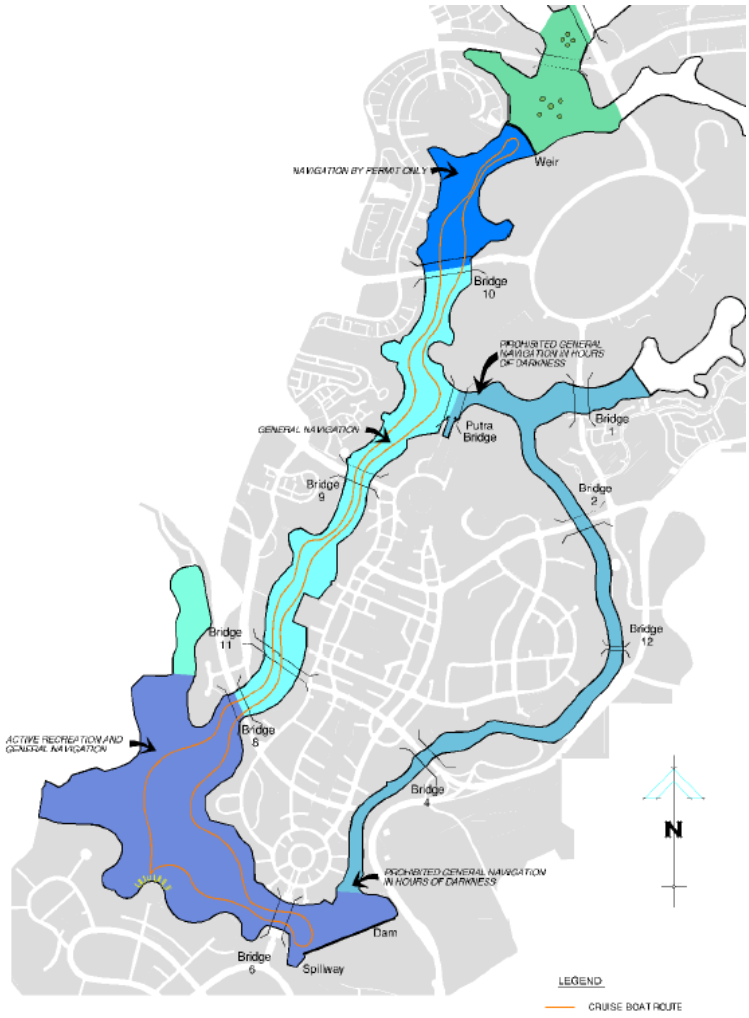

Figure 1.1 Indicative Cruise Boat Tour Routing. (Moser, 2010)

However, no precious studies have been conducted and this is the main purpose for doing this research in Putrajaya Lake. Till now, they are still using the same catamaran design for the existing passenger boat. Throughout this research, design of a catamaran will be improved by hull separation ratio, *H/L* and water depth to ship draft ratio, *h/T* within stated lake's limitation in Putrajaya Lake. In addition, water taxi also known as a tourist boat, is a type of watercraft that is used to offer public or private transportation in large cities. This service can be planned with numerous stops, similar to a bus, or delivered on demand to different places, similar to a taxi.

1.2 Problem Statement

In this research area, greatest level of the lakebed at 17.4m is recommended to give enough navigation clearance across the main lake system currently in place, as well as at vessel quay facilities closer to the lake border. This level is calculated by deducting a 19.8m low water level from a 1.4m vessel draught and a 1.0m clearance between the ship hull and propellers.

From the Lake Navigation Management manual, it contains a complete set of recommendations for the implementation and maintenance of all parts of operations on Putrajaya Lake. Table 1.1 below showed the suggested components of this handbook are taken from the Putrajaya Lake navigation manual, which includes a reference where needed to changed or new instructions to the existing Lake User Guidelines.

Currently, Putrajaya Lake has a variety of boats to fulfill the cruising demands for current market. However, for existing design, catamaran design has been used for the sightseeing tours and takes the passengers pass through along the route. Due to the slow travelling speed, it could expect that viscous component would contribute the larger portion to the total resistance of catamaran. Based on previous study, the viscous component can be influenced by beam separation ratio due to the effect of boundary layer as well as squat effect in this limitation depth in inland waterway. As stated in the Putrajaya Lake Master plan above, maximum operation speed in Putrajaya Lake can up to 15 knots. However, this cruise boat design purposely for all passengers able to enjoy and take in the breath-taking surroundings with more than 20 Putrajaya Landmarks. There will be no rushing, but there will be plenty time to take in the amazing sight, which includes the famous Putra Mosque Seri Wawasan Bridge and the Perdana Putra (Prime Minister's office). Since the length of the route is 15 kilometers, estimated up to 90 minutes cruise time with average speed at 6 knots. Therefore, operation speed in Putrajaya lake maintain 6 knots for all the analysis unless require shorten the cruise duration. Other than operation speed, the water condition will be set at calm water since Putrajaya Lake is inland waterway

Table 1.1 Putrajaya Lake Navigation Manual. (Kasturi, 2001)

Principal Dimension	Description	Remarks
Length overall	Not more than 25m	The Putrajaya Bridge has three additional 25-meter navigable spans.
Ship Draft	Not more than 1.4m	Exclude 1.0m clearance between the bottom boat or its propellers.
Breadth	Not more than 8.0 m	
Maximum operation Speed	Not more than 6 knots	For Cruise boat

As mentioned in earlier, there are no enough of studies have been conducted to study effect of principal dimension of catamaran during operate in shallow water condition such as the Putrajaya Lake. The draft to water depth ratio focus in this research is between 1.5 to 2.5 where the nearest previous study draft to water depth ratio collected from literature is 2.0 to 2.5. (Castiglione, He, Stern, & Bova, 2011) Hence, this research conducted to understand in between interference of between the dimension of catamaran resistance and the effect of shallow water to the performance of the hull. In addition, research of study needed to be carried out for a better design of cruise boat with better sustainability, economy and environmentally as well as fulfilled the requirement of master plan in Putrajaya Lake. (Kasturi, 2001)

1.3 Research Question

In this research, 3 main research questions to be focus as per listed below:

(a) How to evaluate the shallow water effect for resistance of a low-speed catamaran?

(b) How do the dimensions of a catamaran affect the resistance performance of low-speed catamaran which operates in shallow water?

(c) What is the optimum dimension of a low-speed catamaran which operates in shallow water such as in Putrajaya Lake?

1.4 Research Objectives

The Putrajaya Lake will be directly impacted by all planning, approval, and enforcement control over all land development and human activities in this surrounding range. Therefore, the purposes of this research are:

i. To study the relationship of main dimensions and their design parameters to the resistance of a low-speed catamaran in the Putrajaya Lake.

ii. To analyse the interference of shallow water effects to the resistance of a low-speed catamaran when operation in a limited draft.

iii. To propose principal dimensions of a cruise boat on Putrajaya Lake.

1.5 Scope of Studies

The scope of study as shown in below:

i. Due to limitation of Putrajaya Lake, catamaran Delft 372 model will be used in this research.

ii. To simulate the resistance of designed catamaran using Flow3D simulation software.

iii. The limitation of boat's draft in Putrajaya Lake cannot be more than 1.4m.

iv. Hull Separation ratio, *H/L* from 0.16, 0.19, and 0.21 were used to study the effect of hull resistance.

v. 3 Different catamaran's draft, *T* were used from 0.15, 0.17 and 0.19 m.

vi. Water depth to catamaran's draft ratio, *h/T* were 2.18, 2.32, 2.5.

vii. Simulation operation speed from Froude number 0.2 until 0.4.

1.6 Significance of research

This research is focused to investigate the effect of hull separation ratio and various ship drafts on the low-speed catamarans in shallow water. Different water depth to ship draft ratio, *h/T* of catamaran will result impact of squat effect on lake bed due to shallow water operation. As mentioned in the scope, the maximum draught of the ship, *T* is limited to 1.4 meters while the length overall of the ship must not be more than 25 meters. From the previous studies, no research and related studies have been found regarding hull form analysis in Putrajaya Lake, Malaysia. With the limitation of Putrajaya lake, this research will be a significant and valuable finding in future development of Inland Waterway, Malaysia. (Noordin, 2008)

The relationship between the ship principal parameter to the ship resistance can be study and all this result will be valuable date not only for hydrodynamic studies in low-speed operation with shallow water but also good reference for Putrajaya Lake's development in future.

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LIST OF PUBLICATIONS

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