DRAG REDUCTION OF WING-IN-GROUND CRAFT BY USING MICRO-VORTEX GENERATOR

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DEDICATION

In the name of Allah, the Most Gracious and the Most Merciful. Alhamdulillah, all praises to Allah for His blessing along the journey in this study. Gratitude from His servant in completing this thesis. Special appreciation goes to my love, my soul, my parents;

Said Bin Hosen

Habibah Binti Maryun

Special thanks to my supervisor;

Ir. Ts. Dr. Mohd Rashdan Bin Saad

And to

myself, who has finally succeed to juggle and sacrifice a lot of things in this research

ABSTRACT

Wing-In-Ground (WIG) craft has become one of the latest technologies in the marine vehicle sector. The current design of the hull-fuselage can cause flow separation and increase in drag hence flow control devices can be used to improve flow separation phenomenon on the hull-fuselage of the WIG craft. The objective of this study is to investigate the effect of micro vortex generator (MVG) on the drag performance of WIG craft through wind tunnel experiments. This experimental study has gone through subsonic wind tunnel testing in UPNM. Different configurations on height, angle, and spacing of the flow control device helped in obtaining minimum C_d. The height was setup from 0.5δ to δ based on boundary layer thickness of the model. The angle of the MVG tested such as 10°, 16° and 23° has shown a significant effect on drag reduction. Nevertheless, merging the previous configuration with MVG spacing 4.1δ, 4.8δ and 5.4δ, this flow control device was proven to reduce C_d for up to 25% from the baseline model. This indicates that flow control device is helpful in improving the drag performance of WIG craft.

ABSTRAK

Pesawat Wing-In-Ground (WIG) telah menjadi salah satu teknologi terkini di sektor kenderaan marin. Reka bentuk badan pesawat boleh menyebabkan pemisahan aliran dan peningkatan seretan oleh itu alat kawalan aliran dapat digunakan untuk memperbaiki fenomena pemisahan aliran pada badan kapal kapal WIG. Objektif kajian ini adalah untuk mengkaji pengaruh alat Micro Vortex Generator (MVG) terhadap prestasi seretan kapal WIG melalui eksperimen terowong angin. Kajian secara eksperimen ini telah melalui kajian terowong angin subsonic di UPNM. Konfigurasi yang berbeza pada ketinggian, sudut, dan jarak MVG, ia membantu dalam mendapatkan pekali seretan, C_d yang minimum. Ketinggian MVG adalah dari 0.5δ hingga δ berdasarkan ketebalan lapisan sempadan model. Sudut MVG yang diuji seperti 10°, 16° dan 23° mempunyai kesan ketara ke atas pengurangan seret.Walau bagaimanapun, penggabungan konfigurasi yang lepas dengan jarak MVG yang merupakan 4.1δ, 4.8δ dan 5.4δ, peranti kawalan aliran ini terbukti mengurangkan C_d sehingga 25% daripada model asas. Ini menunjukkan bahawa alat kawalan aliran membantu meningkatkan prestasi seretan kapal WIG.

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APPROVAL

The Examination Committee has met on 16th March 2021 to conduct the final examination of Irahasira Binti Said on her master's degree thesis entitled 'Improving Drag Performance of Wing-In-Ground Craft By Using Micro-Vortex Generator'.

The committee recommends that the student be awarded the Master of Science (Mechanical Engineering).

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APPROVAL

This thesis was submitted to the Senate of Universiti Pertahanan Nasional Malaysia and has been accepted as fulfilment of the requirements for the degree of Master of Science (Mechanical Engineering). The members of the Supervisory Committee were as follows.

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Student's full name	: Irahasira Binti Said
Date of birth	: 5th July 1994
Title	: Drag Reduction of Wing-In-Ground Craft By Using Micro-Vortex Generator
Academic session	: 2021

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged.

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CHAPTER 1

INTRODUCTION

1.1 Background

Aerodynamics is the way air moves around things and parts. It is one of the physics fluid dynamics studies, which analyses fluids' behaviour. The principle of aerodynamics explains how an airplane can fly. Anything that moves through air reacts to aerodynamics even on a craft since air flows around the craft body. The Wing in Ground (WIG) craft has been designed aerodynamically to help this craft airborne above the seawater level. Meanwhile, the hull-fuselage of the WIG craft has been designed based on aerodynamics and hydrodynamic principles. Figure 1.1 shows one of the modern WIG crafts, Airfish 8.

WIG craft is a new technology of marine craft that converges marine and aviation designs. This craft can travel over land, ice, or snow suggesting its amphibious qualities. WIG craft is a high-speed vessel with few features of dynamically supported craft. WIG craft flies above the sea and gives a comfortable flying experience to the passengers as it is away from the wavy seas. This craft has a low propulsive power, wide flight range, high lift to drag ratio, and is able to carry a large load. WIG craft deals with two kinds of fluids namely liquid and air. This craft has the potential to encourage prospects for commercialisation by its ability to carry more passengers or cargo, to be used to attract more tourists as well as for special purposes such as for APMM or armed force missions and operations. In the early stage of top-secret WIG development, Rostislav E. Alexeyev was an engineer from Rusian was the first to conduct research on ground effect (GE) vehicle and had succeeded to build the Ekranoplan. The craft is also well known as the Caspian Sea Monster as it flies over the Caspian Sea which means it can fly over the surface of sea water. Extensive work studies and developments on GE vehicle has been done after the extinction of Ekronoplan at the end of the Cold War.

Figure 1.1: A marine craft using WIG phenomenon [1]

The principal mode of operation is in the zone of aerodynamic influence, which flies through the water or another supporting surface. This type of vehicle is different from any other common airplanes due to its aspect ratio. The principal mode of operation is always brought about on the surface of the water as it is a multi-purpose craft that flies using Ground Effect (GE) above the water. A lifting system that increase the aerodynamics performance by its lift-to-drag (l/d) ratio from an underlying relative in ground distance is known as GE. When there are interference on the flow of the air around moving object within the wingspan, it will triggered GE. The fluid flow of the air around and near to the wing can be altered and cause an increase in the lift as well as the drag of wing with hull-fuselage and a reduction in induced drag of the wing and hull-fuselage. The effectiveness of any lifting body can be explained by the l/d ratio as combination greatest lift and lowest drag.

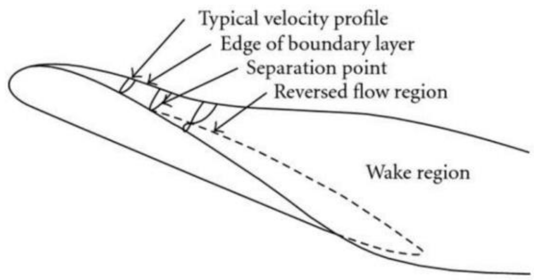

Figure 1.2: Development of flow separation on airfoil body. [2]

The boundary layer is the viscous forces fluid close to the solid surface, which happens to any solid objects that travel through a fluid or vice versa. Figure 1.2 illustrates the flow separation produced when the boundary layer moves away and against an adverse pressure gradient. Eddies, vortices are types of fluid behaviours that are formed when the fluid flow is detached from the surface of the object. Flow separation often degrades craft performance, which absolutely depends on the design aerodynamically on the airfoil profile. Laminar and turbulent are two types of boundary layer that can be determined by the calculation of the Reynolds number of local fluid flow conditions. Expanding the lift or diminishing the drag and division delay classified beneath the common heading of flow control are the methods that have been created to control the boundary layer. WIG craft technology, however, reduces the drag to minimum values by eliminating hydrodynamic drag compared to conventional marine craft that consumes excessive fuel to reach an optimum speed.

1.2 Problem Statement

WIG craft is a unique technology as it can operate close to the water or ground surface besides being the fastest technology among the marine crafts so far. Research and development on WIG craft have been conducted to reduce drag and improvise the fuselage design to achieve drag reduction. The speed and aerodynamic efficiency of the WIG craft can still be improved to obtain higher speed.

To achieve this goal, a more powerful engine needs to be installed which will increase the load of the craft which something that needs to be avoided because it will increase fuel consumption. Another solution is to approach the backward facing step (BFS) of WIG craft. The difference between WIG craft and other crafts lies in its hull-fuselage, where its BFS is purposely designed to be part of its airframe due to its necessity and function. BFS helps to increase the speed where the wetted area at the bottom of the fuselage is reduced, which helps to reduce hydrodynamics drag during take-off.

Although the BFS helps in reducing the force needed, aerodynamic drag is still increased during airborne as its geometry creates a shear layer after the BFS. Most of the previous studies were focusing on the wings of this WIG craft. However, there is no study has yet been done that focuses on the BFS of WIG craft. Therefore, the investigation proposes the use of micro vortex generator (MVG), on WIG craft to delay flow separation after BFS. This research analyses a novel configuration using MVG on the WIG hull-fuselage to obtain a better drag coefficient, C_D.

1.3 Objectives of the study

The objective of this study is to study the effect of the MVG on the drag performance of WIG craft hull-fuselage. This research has gone into deeper objectives such as the following:

i. To investigate the relationship between the height of micro vane and reduction in the drag coefficient.
ii. To study the relationship between the spacing array of micro vane and reduction in the drag coefficient.
iii. To find the relationship between the angle of micro vane and reduction in the drag coefficient.

1.4 Scope of Work and Limitations

The scope of work and limitations of this study are as the following:

i. Subsonic Flow was used in the range 55×10^3 to 331×10^3 Reynold number.
ii. Small size of the 3D model due to the limitation on test section size of the wind tunnel in UPNM.
iii. Computational Aided Design (CAD) drawing using SolidWorks software was used to design the location of flow control on hull-fuselage of WIG craft.
iv. C_D was analysed based on the modifications of flow control configurations on WIG craft.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

There are several designs of WIG craft that have been commercialised such as Airfish 3, Airfish 8, Earkorplane and Hoverwing. Over the past century, the WIG craft came up with the latest technology and improvement in the design itself. This study was focused on drag reduction of the WIG Craft.

2.2 Wing-In-Ground (WIG) Craft: History

The phenomenon of ground effect has been noticed and studied for quite some time. In the earlier stage of research, the aviator noticed lift increased on landing when WIG craft approached the ground. The study on this phenomenon has been taking place since the 1920's. Ground effect has been used on a few models of early aircraft to get an additional lift for increasing their efficiency [3]. Back in World War 2, the ground effect was used by bomber pilots by flying low over the water since the engine had lost its control. They managed to get the desired range resulting in an increased L/D ratio and landed safely. At the initial development of the WIG in the 1960s, few problems were found on water drag due to lack of take-off power. Fin Kaairo and then Alexander Lippisch were the early developers of DSTO-GD-0201 17 in 1963 [4]. Most countries that involve in ground effect research and development of this craft are the USA, USSR, and Japan [3].

More tests and prototypes have been developed by the countries to obtain a satisfying result. USA is the country that succeeded to develop X-112 by Lippisch. From the success of X-112 design and testing, America started to continue their research on large cargo-sized hovercraft, Surface Effect Ships (SES). Soon after developing a high-speed craft that able to be achieved with less risk through SES and lower cost, the decision was made, which was exactly what Stephen Hooker thought. Few testings have been done with poor results obtained from WIG craft due to landing and take-off consideration. Rhein Flugzeugbau GmbH (RFB), a German company, had bought X-112 from Lippisch due to military funding from WIG craft development in the USA. KM or known as "Caspian Sea Monster" is the largest WIG craft ever to be built, which started sea trials in 1966. Numbers of research and studies on WIG craft have been done during this period. Most of the data and findings were successfully gained to look continue this marine craft project [5]. Few experimental crafts were tested following the formation of design rules and proper testing procedures. After a few tests and development were done in the 1920's, the US military started its review in a different perspective, combat vehicle. Even though the US military decided that this technology did not need to be cultivated, the potential capabilities of this technology must be continuously observed. The Soviet military has begun the step by bringing the first WIG craft into operational service in the 1970's [5].

The spark on this technology became bigger as it led to the construction of the assault craft, A.90.150 Orlyonok, and troop transport. Russian Navy has joined the operation in 1979 and lasted more than 10 years until the early 1990s. PARWIG, a craft with very high efficiency, became the object of the study conducted by the Advanced Naval Vehicle Concepts Evaluation team [3]. Back in 1990's, more conferences were held by civilians dealing with fast sea transport, which stressed WIG craft. The conferences included Sydney "Ekranoplans and Very Fast Ships" on 1996 at University of New South Wales, Yokohama "Fast 1993" in 1993 at the Second International Conference on Fast Sea Transportation, London Royal Institution of Naval Architects (RINA) International Conference on WIGs from 4-5 December 1997 as well as on 1995 at Sydney "A Workshop on Twenty-First Century Flying Ships" at the University of New South Wales.