Jurnal
Teknologi

Full Paper

THE HYDRO PLANING SIMULATION OF FLYING BOAT REMOTE CONTROL MODEL

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Article history
Received
24 March 2015
Received in revised form
11 Februari 2016
Accepted
15 May 2016

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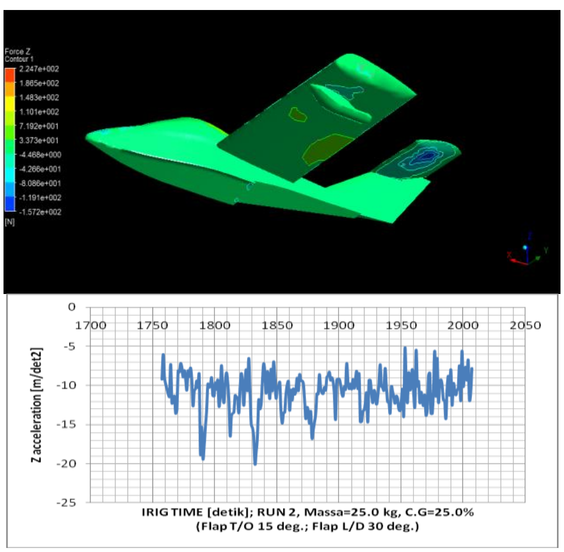
Graphical abstract



Abstract

The measurement of unknown model to get the three dimensions of object configuration is by using the laser camera photo tracking. The three dimensions model became from solid drawing on the CATIA software. The CFX ANSYS computational fluid dynamics software is used on the 3D of Flying Boat remote control model full configuration. The rectangular and dihedral configurations of the model have Z forces value during acceleration on the water surface. The pressure distributions hydro planing have a good result also. The speeds on the simulation model are around (0 - 25) knots and Angle of Attack, a = 0^0. The downwash effect and vortex could be shown in the CFD results. To verify the simulation data analysis is uses the takeoff flight performance testing data during takeoff of Unmanned Aerial Vehicle "Alap alap" with the same Thrust per Weight ratio around 0.4, such as altitude height, airspeed, Z acceleration and pitch angle data. The hump drag of Flying Boat remote control model and the friction during takeoff of Unmanned Aerial Vehicle have been ignored.

Keywords: Laser camera, CATIA, CFX ANSYS, Thrust per Weight ratio, Flying Boat remote control model

1.0 INTRODUCTION

The background of this research was become from the problem of the aerodynamics lift and hydrodynamics resistance with the power on the Wing in Surface Effect craft A2B prototype B type. The power was not enough to counter the weight of craft during takeoff performance phase. The flight performance requirement of Wing in Surface Effect craft Lippisch configuration is not satisfied due to the drag forces in the hull, pontoons, and reverse delta wing. The composite materials adding the total weight of craft. The thrust measurement, weight and balance measurement of the Wing in Surface Effect craft A2C B type with 4300.0 Newton Maximum Takeoff Weight (MTOW) and the 115.0 HP power have been analyzed. After that, the authors found the better ratio of Thrust per Weight is around 0.4. The

step position calculation is recommended by theoretical analysis [8].
The CFX ANSYS as numerical analysis had been done on the full configuration of Flying Boat remote control model, while the hydro planning speed range between 0 to 25 knots. The aerodynamic and hydrodynamic characteristics of the full configuration Flying Boat Remote Control model are fulfill the takeoff procedure on the water surface. The flight test data of Unmanned Aerial Vehicle (UAV) "Alap-alap" is used to verify the Flying Boat simulations.

The aim of this research is to propose the improvement of flight simulation technology by using the flight testing data of other UAV.

In the other research, the authors have been proposed the Adaptive Control simulation verification by using Adaptive Control flight testing data on the UAV "Alap-alap" [9].

1.1 The History of Wing In Surface Effect Craft

The wing In Surface effect is a phenomenon that affects all aircraft in some way, due to vortices of air that become trapped between the wings of an aircraft and the ground (when the aircraft is near to the ground). It is important to note that 'ground' may refer to not only land, but also water, ice, snow and sand. The effects of the wing in ground effect can be beneficial or detrimental to the aircraft. Various craft have been designed specifically to utilize the benefits of this ground effect, and hence are not actually regarded as 'aircraft'.

Although the development of Wing in Surface Effect craft has taken place over many decades, the technology has not progressed to the point where such craft can become a mainstream commercial success, due in part to early design inefficiencies and a lack of government funding for research and development in this area worldwide.

However, it is still widely believed that the potential exists for Wing in Surface Effect craft to have practical applications. The topics or research of Surface Effect craft are founding in Taiwan, South Korea, China, Malaysia and Indonesia.

This paper investigate the characteristics of Wing in Surface Effect craft C type by using Flying Boat remote control model as objective.

2.0 THEORY

There are many different shaped bodies which can produce lift; however the most efficient design so far is the wing. Wings generate lift because the movement of the wing through air results in a higher static pressure on the lower surface than on the upper surface. This difference in pressure results in an upwards force known as lift which allows the aircraft to overcome its weight force acting downwards [12].

The flight performance about the aero and hydrodynamics characteristic of Flying Boat remote control model during hydro planning were analysis by CFX ANSYS on this paper. The aerodynamics and hydrodynamics theoretical prediction of Wing in Surface Effect craft B type has been used on last research. Several data of the aerodynamics model are calculated to known the aerodynamics coefficients versus angle of attack, a by software DATCOM [16]. The towing tank test model is to known the water resistance versus Froude number, F_n of Wing in Surface Effect craft B type [15].

CFX ANSYS solvers are based on the finite volume method. The fluid region is decomposed into a finite set of control volumes. General conservation (transport) equations for mass, momentum, energy, species, etc. are solved on this set of control volumes. Continuous partial differential equations (the governing equations) are digitized into a system of linear algebraic equations that can be solved on a computer.

2.1 Computational Fluid Dynamics

The CFX ANSYS was use on the full configuration of Flying Boat remote control model to know the pressure distribution, meshing, isometric and the air velocity streamline, etc during hydro planning. The hump drag versus speed of high speed craft is used also as the theoretical background. The CFX ANSYS solvers are based on the finite volume method [17]:

- The fluid region is decomposed into a finite set of control volumes
- General conservation (transport) equations (1) for mass, momentum, energy, species, etc. are solved on this set of control volumes:

$$\frac{\partial}{\partial t}\int_V \rho\phi dV + \oint_A \rho\phi V.dA = \oint_A \Gamma\nabla\phi.dA + \int_V S_\phi dV \quad (1)$$

Unsteady + Advection = Diffusion + Generation

- Continuous partial differential equations (the governing equations) are digitized into a system of linear algebraic equations that can be solved on a computer. This formula became from Navier Stoke equations

2.2 NACA 23012 Airfoil

The NACA 23012 airfoil was developed by E. Lasauskas, *et al*. [17], the Reynolds number, Re and amplification ratio was varied to achieve good comparison of calculated and measured drag polar. Figure 1 is the original of NACA 23012 airfoil.

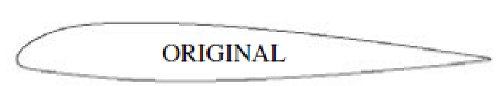


Figure 1 NACA 23012 airfoil[17)]

Figure 2 is the graphic of original, trailing edge short tab and long tab aerodynamics characteristics of NACA 23012 airfoil.

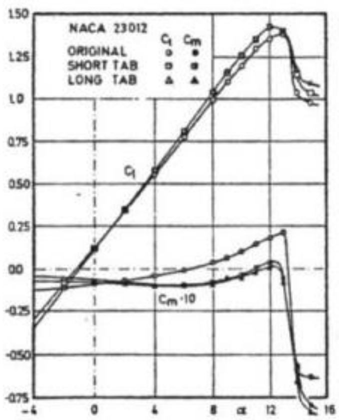


Figure 2 The aerodynamics characteristic of NACA 23012 airfoil (original and modification)[17]

The comparison of calculated and measured data of the original NACA 23012 airfoil and an airfoil with a trailing edge tab (long tab) at Re 2.0 x 10^6 and n = 0.1 full turbulence flow is shown in Figure 3 [17].

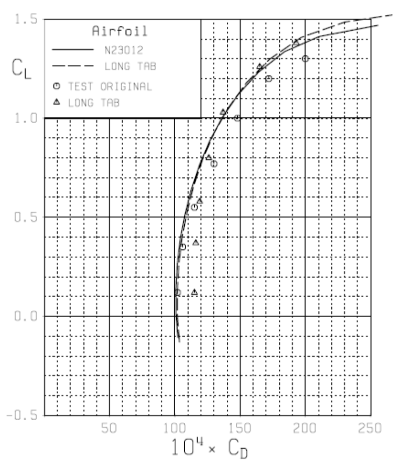


Figure 3 The drag polar of NACA 23012 airfoil[17]

3.0 PAPER REVIEW

As importance part of this research is how to made Flying Boat remote control model by hand with low cost on the limited schedule. This part, step by step there was controlled for the weight and the strength of material structure. After that, the real Remote Control model could airborne smoothly during flight test.

3.1 The Wingtip Vortex

For a lifting wing, the air pressure on the top of the wing is lower than the pressure below the wing. Near the tips of the wing, the air is free to move from the region of high pressure into the region of low pressure. The resulting flow is shown in Figure 4 at the left by the two circular blue lines with the arrowheads showing the flow direction [12].

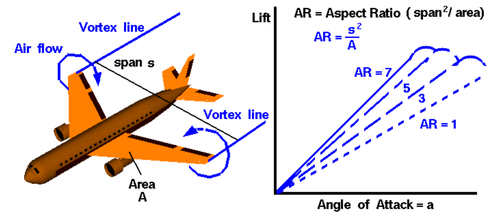


Figure 4 Wingtip vortex theory[12]

As the aircraft moves to the lower left, a pair of counter-rotating vortices is formed at the wingtip. The lines marking the center of the vortices are shown as blue vortex lines leading from the wingtip. If the atmosphere has very high humidity, you can sometimes see the vortex lines on an airliner during landing as long thin "clouds" leaving the wingtip. The wingtip vortices produce a downwash of air behind the wing which is very strong near the wingtip and decreases toward the wing root.

Benson, T. [12] the effective angle of attack of the wing is decreased by the flow induced by the downwash, giving an additional, downstream-facing, component to the aerodynamics force acting over the entire wing. The downstream component of the force is called induced drag because it faces downstream and has been "induced" by the action of the tip vortices. Benson, T. [12] the lift near the wingtip is defined to be perpendicular to the local flow. The local flow is at a lower effective angle of attack than the free stream flow because of the induced flow. Resolving the tip lift back to the free stream reference produces a reduction in the lift coefficient of the entire wing [12].

3.2 Overview of Surface Effect

At the current time Wing in Surface Effect craft is poised between success and failure. Wing in Surface Effect craft is not experiencing the high level of activity of the 1960-80's, but there is still a low level of activity underway worldwide which proceeds with mixed success. Those projects of note are [12]:

- Aquaglide, Russia, by ATTK who recently exhibited their 5-seat craft at ILA 2006, Berlin. Amphibious Type A is shown in Figure 5 [12].

Figure 5 Aqua glide, Russia[12]

- Korean Ocean Research and Development Institute (KORDI) multi-million dollar funded development program to create high speed Wing In Surface Effect craft based transport/logistics sea network in Korea. C type prototype is shown in Figure 6 [12].

Figure 6 C type prototype Korean versions[12)]

The surface effect on the upper of water surface become from the wingtip vortex that vortices are blocked by the ground phenomenon. The method is by using Computational Fluid Dynamics.

3.3 The Flying Boat Remote Control Model C type

The Flying Boat remote control model C type has been developed to verification the adaptive control system during ground effect altitude connecting to the control surfaces deflection.

The analysis is become from the vortex on the wingtip. The T/W ratio around 0.4. The step position calculation of Wing in Surface Effect craft is implemented on the Flying Boat remote control model design.

3.4 The New Methodology as Verification

The power used is on engine of the Flying Boat remote control model is around 5.5 HP with MTOW = 250.0 Newton [9]. The wing airfoil uses NACA 23012, the Horizontal Tail Plane (HTP) is use the NACA 0010 and the Vertical Tail Plane (VTP) is uses NACA 0012 on the root and NACA 0010 on the upper. The new NACA 23012 airfoil develops a reasonably high maximum lift and a low profile drag, which results in an unusually high value of the speed-range index. In addition, the pitching-moment coefficient is very small**.** This aircraft configuration is usefully for Short Takeoff and Landing capability. The results of this research is about the verify data Flying Boat remote control model simulation with the UAV "Alap alap" flight test data during takeoff.

The flight performance verification of Ground Effect craft is based on the flight performance criteria such as the Thrust per Weight (T/W) ratio. The Aspect Ratio, AR_{PUNA} of PUNA "Alap-alap" is around 10.0. The Aspect Ratio, $AR_{FLYING\ BOAT}$ of RC model Flying Boat is around 5.0. The Aspect Ratio, $AR_{LIPPISCH}$ of RC model NA-4 Lippisch configurations is around 3.5.

The fuselage, wing and HTP on Flying Boat remote control model are built by wood. This Flying Boat remote control model is shown in Figure 7.

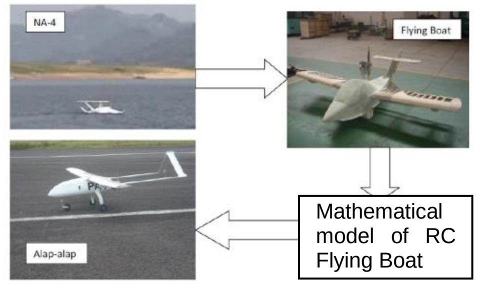


Figure 7 Full configuration of Flying Boat remote control model between NA4 Wing in Surface Effect RC model and Unmanned Aerial Vehicle "Alap alap"

The aerodynamics and hydrodynamics problems on the full configuration model were solved by using Computational Fluid Dynamics.

4.0 THE DATA ANALYSIS

For equilibrium relationships the hydrodynamics data, aerodynamics data, and the equilibrium relations for forces and moments must all be used on the formula.

4.1 The 3 D Drawing Process

The three dimension of HTP and hull of Flying Boat remote control model have been measured by using the laser photo camera and then processed it to the computer. This drawing transferred to CATIA software. The Figure 8 is the photo camera laser tracking process.

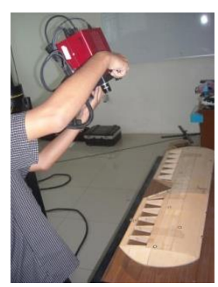


Figure 8 Laser photos tracking on HTP

Figure 9 is photo camera laser tracking on the fuselage (hull).

Figure 9 Laser camera photos tracking on thefuselage

4.2 Data Analysis by Using CFD

The meshing and the lifting forces on the full configuration that calculated by Computational Fluid Dynamics software. This program took so many times for computational from meshing as input data to the results. These CFD results will be combined with the references. The water line is 10 cm.

Figure 10 is the model geometry with a = 0^0 without towing tank.

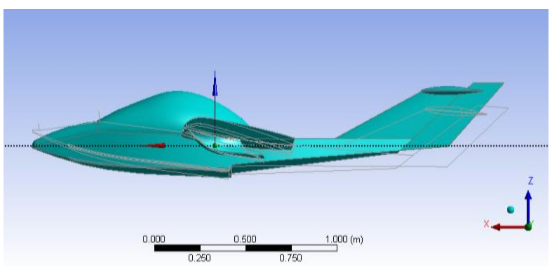


Figure 10 Model geometry with a = 0^0 without towing Tank

The Figure 11 is the geometry of Flying Boat remote control model on the towing tank.

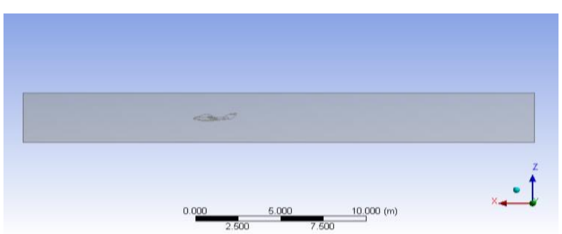


Figure 11 The Flying Boat remote control model half geometry on the towing tank

The Figure 12 is meshing process of the Flying Boat remote control model with a = 0^0. This figure is also presented the ground effect characteristics of RC model Flying Boat.

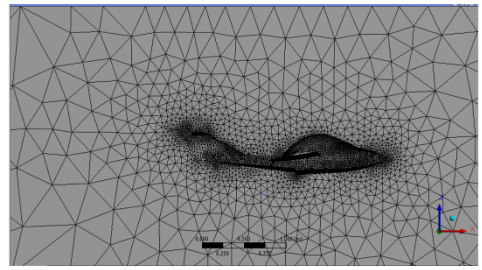


Figure 12 Meshing of the model with a = 0^0

The boundary condition of the remote control model with a = 0^0 is shown in Figure 13.

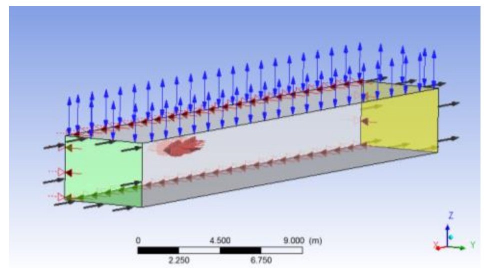


Figure 13 Boundary condition of the remote control model with a = 0^0

Parameters on Figure 14 are:

Inlet	:	speed 25.0 knots
Outlet	:	pressure 0.0 Pa
Wall	:	no slip wall, smooth wall
Symmetry	:	free slip wall
Half geometry	:	half geometry

The result took from ZX plane at Y offset = 0 m with a = 0^0. The pressure distributions are showed in Figure 14. It is show the trend of the curve from the Pressure distribution result. The bottom of leading edge has the maximum pressure.

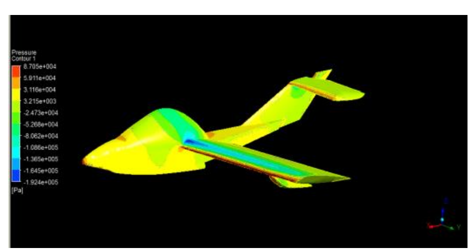


Figure 14 Pressure distribution with a = 0^0

The air velocity streamlines is showed in Figure 16.

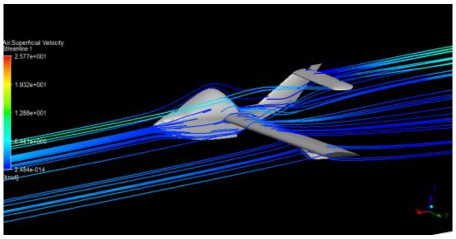


Figure 15 Air velocity streamline with α = 0^0

It is show the trend as result of the curve from the Air Velocity Streamline on the wing and body. The T tail on HTP has downwash effect. The vortex is showned in the wingtip. The force Z lifting surface is showed in Figure 16.

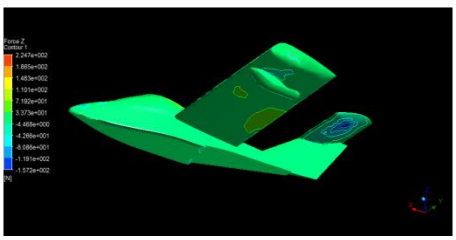


Figure 16 Force Z (lifting) force with α = 0^0

The Thrust (HP) per Weight (kg) ratio was used around 0.4 to build the Flying Boat remote control model. The Z axis, center of gravity, c.g and step position made the angle between $(2 – 10)^0$.

Figure 17 and Figure 18 are the Unmanned Aerial Vehicle of "Alap-Alap" and telemetry system installation near by the runway at Rumpin test areal.

Figure 17 The preparation test of UAV "Alap alap" before flight testing

Figure 18 The telemetry of Unmanned Aerial Vehicle "Alap alap" during flight testing

The Height, h of Unmanned Aerial Vehicle "Alap alap" flight testing data during takeoff at MTOW = 240.0 Newton. There is an stable condition as showed in Figure 19.

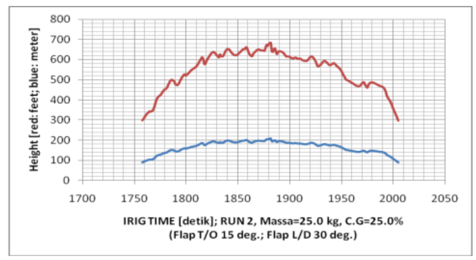


Figure 19 The Height, h of Unmanned Aerial Vehicle "Alap alap" flight testing data during takeoff

The True Airspeed, V and Pitch angle, θ of Unmanned Aerial Vehicle "Alap alap" flight testing data during takeoff at MTOW = 240.0 Newton is stable condition as showed in Figure 20 and Figure 21.

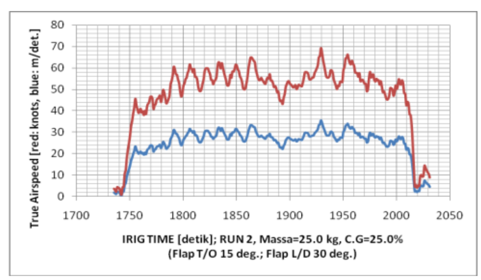


Figure 20 The True Airspeed, V of Unmanned Aerial Vehicle "Alap alap" flight testing data during takeoff)

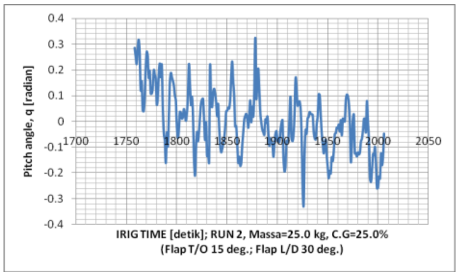


Figure 21 The Pitch angle, θ of Unmanned Aerial Vehicle "Alap alap" flight testing data during takeoff

5.0 CONCLUSIONS

The CFX ANSYS simulation as Computational Fluid Dynamics on the full configuration of Flying Boat remote control model with original NACA 23012 airfoil during hydro planing have carried out some conclusions as follows:

- The aerodynamics characteristic during hydro planing in speed between 0 to 25 knots already calculated by Computational Fluid Dynamics have good results. It is shown by the downwash effect on the T tail of horizontal tail plane.
- The hydrodynamics characteristic on the hull have no porpoising effect in the region speed.
- The Z forces more acting on trailing edge of the main wing. It is mean the Flying Boat remote control model wills liftoff and takeoff in the speed schedule.
- The time histories (t) data for longitudinal mode of Unmanned Aerial Vehicle of "Alap alap" flight test data during takeoff are fulfill the takeoff procedure of RC model Flying Boat. The both models have the same T/W ratio, around 0.4 and without the friction/ hump drag correction.

Acknowledgement

The authors would like to thank Head of Agency for the Assessment and Application of Technology for the support towards conducting the study. The authors also to head and staffs of Transportation System Technology Division (PTSPT), head and staffs of MEPPO Laboratory, Puspiptek, Serpong, head and staffs of Indonesia Hydrodynamic Laboratory, Surabaya. And, special thanks to Dr. Samudro and flight test team from PTIPK, TIRBR, BPPT, Serpong.

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