Porpoising instability study of the floatplane during take off operation on calm water

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Abstract. Floatplane is a type of airplane that can take-off and land on the surface of the water, for that it is equipped with a float that is installed under the fuselage to serve the buoyancy force. An important phenomenon that often occurs and should be avoided during a take-off operation is porpoising because it causes longitudinal instability of the float which has an impact on passenger safety and comfort. This paper describes the porpoising mechanism and the variables that can influence the occurrence of this phenomenon. The most dominant variables include the location of the longitudinal center of gravity (LCG) and the deadrise angle which are optimized by considering the take-off speed. A numerical arrangement based on computational fluid dynamics (CFD) techniques is proposed to simulate a three-dimensional fluid flow around a free-floating float in calm water. The accuracy of the simulation results shows a good fit compared to the previously published experimental and numerical results.

1. Introduction
A floatplane is a type of seaplane that can take off and land both in water and on runways on land. It can be used for tourist transportation, passenger transportation, and emergencies such as rescue missions and disaster response actions. Therefore, floatplane is often looked at and developed, especially by countries that have a long coastline [1]. However, the floatplane has problems related to safety and passenger comfort, namely porpoising instability when taking off. At the time of takeoff, the floatplane has three conditions, namely displacement condition, plowing condition, and planing condition. The planing condition is a condition in which the entire weight of the floatplane is supported by the hydrodynamic lift from the floating body and generally occurs when traveling at high speed. In the planing condition, if the pitch angle is too high or too low, the plane will experience instability. In such a case it will be possible to cause porpoising and result in accidents if the pitch angle can't be controlled properly [2].

Porpoising is a rhythmic pitching motion of amphibious aircraft, caused by dynamic instability in the force acting on the floater. The sensation of this movement is often equated with swinging. This phenomenon can occur if the plane exceeds a certain pitch angle range and the plane begins to experience a cyclic oscillation of the pitch angle which can increase and end with the plane plunging into the water and possibly turning over. It can also happen if the aircraft's longitudinal stance is too high during takeoff. It could cause the plane to stop and drop its front half into the water. Porpoising can also be caused by placing a transverse step too far forward or behind the center of gravity. Porpoising can be reduced by flattening the end of the forebody by 1.5 times the width. It will result in relatively uniform pressure at the bottom of the hull, where the curved section will exert a variable pressure resulting in a more dynamic response [3].
The porpoising phenomenon that occurs on the floatplane during take-off must be avoided because it can cause problems with the operability of the floatplane. Some of the problems that can be caused by this phenomenon, namely:

1. Porpoising can cause problems in the use of time and length of the course used for taking off. The floatplane must be able to take off in less than 60 seconds, and the maximum length of the course used for take-off is less than 10000 feet or equivalent to 3.048 kilometers for a large floatplane and it would be better if the take-off path length is less than 5000 feet or equivalent to 1,524 kilometers [3].

2. Porpoising can cause accidents during take-off. Take-off occurs at high speed as well as porpoising occurs at high speed. When porpoising occurs the hydrodynamic forces experienced by the float change fast enough so that there will be a large longitudinal moment that occur fast enough. This phenomenon can cause the floatplane to reverse if there is no equilibrium at the moment along the length of the ship and the correct pitch attitude is not corrected [2]. This is very dangerous for the safety of pilots and passengers.

3. Porpoising can cause inconvenience to both the pilot and the passenger. The large amplitude of the pitch and the acceleration value of the large pitch angle will cause the floatplane to swing at high speed. This can cause passengers and pilots to experience the same swing as the response from the floatplane due to hydrodynamic forces [4]. Excessive swinging can cause nausea and vomiting for passengers who are not used to extreme swing conditions.

4. Porpoising can cause defects in the construction of the float hull. The large amplitude of the pitch and the angular acceleration under pitch conditions can cause a large impact load on the hull of the float. This impact load does not only occur once but repeatedly. It can cause damage to the construction of the float hull so that the float must be repaired and the floatplane cannot be operated for a while. It is not desirable by the owner due to the expense of repairs for damaged construction.

From the several problems caused by the porpoising phenomenon. Porpoising is something that must be avoided and is a consideration in designing the float hull. One of the easiest ways to solve the porpoising problem on the floatplane is to adjust the position of the longitudinal center of gravity (LCG) [5], by shifting the main body of the floatplane forward or backward, it will change the LCG position of the float and change the shape of the float hull deadrise. Therefore, this research will focus on determining the optimum location of the LCG and the effect of the deadrise angle on the float to avoid the porpoising that occurs on the floatplane during takeoff operations.

2. Floater model and computational grids
Simulation is carried out by only modeling the float of the floatplane, the main body of the plane is ignored and focuses on the part of the floatplane that is submerged in water. Figure 1 shows the design of the float that will be simulated in this study. The float has a deadrise angle of 20 degrees. The deadrise angle on the float will be varied by 10 degrees and 20 degrees, to determine the effect of the deadrise angle on porpoising. The hull of the floater is divided into two parts, namely afterbody and forebody separated by a transverse step with a forebody length of 5.4 meters. The transverse step has a function to reduce water resistance when the float is in planing conditions. The float used in this study has a transverse step height of 150 mm. The overall length of the float model is 9.6 meters with a width of 1.25 meters and a height of 1.1 meters. The distance between the demi hulls is 3.95 meters, with a displacement of the float of 7,664 tons.

Figure 2 shows the comparison of the body plan between a floater with a deadrise angle of 10 degrees and a floater with a deadrise angle of 20 degrees. It can be seen in the figure that due to the change in the deadrise angle there is a change in the draft of the floater. Whereat the 20-degree deadrise angle, the submerged part of the ship was 0.8 meters, while due to the deadrise angle that changed to 10 degrees, the submerged part of the ship changed to 0.745 meters. There was a drop of 0.055 meters in the submerged part of the float. This occurs because a change in the deadrise angle causes a change in the submerged volume of the float. Due to the need for constant displacement and the increased volume
of floaters that are immersed in water so as to provide the same hydrostatic force, there is an arrangement of the submerged floater so that there is a change in the draft of the floater.

![Floater Body Plan](image1)

(a) Floater Body Plan

![Floater Side View](image2)

(b) Floater Side View

**Figure 1** Linesplan Floater with 20° deadrise angle.

![Figure 2](image3)

(a) 10° deadrise angle  
(b) 20° deadrise angle

**Figure 2** Comparison between a body plan floater with a 10° deadrise angle and a floater with a 20° deadrise angle.

![Figure 3](image4)

**Figure 3** Computational Domain Size used for CFD simulation.
Figure 3 shows the size of the computational domain used in this study. The computational domain is rectangular shaped and represents the simulation as performed on a towing tank. The size of the domain that is on the back of the floater is made to be longer than the other parts in order to see the shape of the water surface on the back of the floater when it is moving. The computational domain is created using a multiple of the length of the object as a basis in order to make it easier to determine the size of the computational domain as a whole.

It can also be seen in the figure that the domain size of the length of the ship and the height of the ship is made quite large, this is intended to provide space for the ship to move in two degrees of freedom, namely, heave motion and pitch motion. In addition, by using the dynamic mesh method, the grid used will experience deformation during the simulation, causing the numerical calculation process to become unstable and potentially error in the middle of the simulation process due to the large deformation of the mesh. So, to avoid this problem, the domain size is enlarged to lengthen the ship and ascend the ship.

Figure 4 shows the mesh of a floater with 5.4 million cells. Since the hydrodynamic force is the main force component that supports the net force that occurs in the float in high-speed operation, getting an accurate picture of the overall fluid flow that occurs is very important. Therefore, the mesh in the float wall area is smoothed which serves to get a more accurate picture of the flow that occurs in the float wall area [6]. In addition, the mesh in the free surface area is also refined to obtain accurate fluid flow on the free surface and to get a better picture of the free surface that occurs on the back of the object. Heave and pitch simulations on the float are performed using the dynamic mesh method during the calculation process.

![Figure 4 Computational Grid.](image)

3. Mathematical model and computing method
The CFD flow solver, uses the incompressible unsteady Reynolds-averaged Navier Stokes equations (RANSE). The solver is based on the finite volume method to build the spatial discretization of the transport equations. The face-based method is generalized three-dimensional unstructured meshes for
which non-overlapping control volumes are bounded by an arbitrary number of constitutive faces. The velocity field is obtained from the momentum conservation equations and the pressure field is extracted from the mass conservation constraint, or continuity equation, transformed into a pressure-equation. In the case of turbulent flows, additional transport equations for modeled variables are solved in a form similar to that of the momentum equations and they can be discretized and solved using the same principles. Incompressible flow phases are modeled through the use of conservation equations for each volume fraction of phase.

The flow solver can deal with multi-phase flows and moving grids. In the multi-phase continuum, considering incompressible flow of viscous fluid, mass, momentum and volume fraction conservation equations can be written as:

\[
\frac{\partial}{\partial t} \int_V \rho dV + \oint_S \rho \left( \bar{U} - \bar{U}_d \right) \cdot \bar{n} dS = 0
\]

(1)

\[
\frac{\partial}{\partial t} \int_V \rho U_i dV + \oint_S \rho U_i \left( \bar{U} - \bar{U}_d \right) \cdot \bar{n} dS = \oint_S \left( \tau_{ij} l_j - p l_i \right) \cdot \bar{n} dS + \int_V \rho g_i dV
\]

(2)

\[
\frac{\partial}{\partial t} \int_V c_i dV + \oint_S c_i \left( \bar{U} - \bar{U}_d \right) \cdot \bar{n} dS = 0
\]

(3)

Where \( V \) is the domain of interest, or control volume, bounded by the closed surface \( S \) with a unit normal vector \( \bar{n} \) directed outward, where \( V \) is the domain of interest, or control volume, bounded by the closed surface \( S \) moving at the velocity \( V_{ect} U_d \) with a unit normal vector \( V_{ect} \bar{n} \) directed outward. \( \bar{U} \) and \( p \) represent, respectively, the velocity and pressure fields. \( \tau_{ij} \) and \( g_i \) are the components of the viscous stress tensor and the gravity vector, whereas \( l_j \) is a vector whose components vanish, except for the component \( j \) which is equal to unity. \( c_i \) is the \( i^{th} \) volume fraction for fluid \( i \) and is used to distinguish the presence \( c_i = 1 \) or the absence \( c_i = 0 \) of fluid \( i \). Since volume fraction between 0 and 1 indicates the presence of a mixture, the value of \( \frac{1}{2} \) is selected as a definition of the interface. The effective flow physical properties (viscosity and density) are obtained from each phase physical properties \( \mu_i \) and \( \rho_i \) with the following constitutive relations:

\[
\rho = \sum_i c_i \rho_i
\]

(4)

\[
\mu = \sum_i c_i \mu_i
\]

(5)

\[
1 = \sum_i c_i
\]

(6)

When the grid is moving, the so-called "space conservation law" must also be satisfied:

\[
\frac{\partial}{\partial t} = \int_V dV - \oint_S \bar{U}_d \cdot \bar{n} dS = 0
\]

(7)

The \( K - \omega \) turbulence model is used in this research to model the turbulence that occurs in this simulation. The \( K - \omega \) model of Wilcox [7] has proven to be superior in numerical stability to the \( K - \varepsilon \) model primarily in the viscous sublayer near the wall. This model does not require explicit wall-damping functions as do the \( K - \varepsilon \) model and other two-equation models due to the large values of \( \omega \) in the wall regions. The numerical wall boundary conditions require the specification of the distance from the wall to the first point off the wall. The two transport model equations for the \( K \) and \( \omega \) scalar turbulence scales are defined below.
\[ \frac{\partial \rho K}{\partial t} + \frac{\partial}{\partial x_j} \left( \rho U_j K - \left( \mu + \sigma^* \mu_t \right) \frac{\partial K}{\partial x_j} \right) = \tau_{ij} S_{ij} - \beta^* \rho \omega K \]  

\[ \frac{\partial \rho \omega}{\partial t} + \frac{\partial}{\partial x_j} \left( \rho U_j \omega - \left( \mu + \sigma \mu_t \right) \frac{\partial \omega}{\partial x_j} \right) = \frac{\omega}{K} \tau_{ij} S_{ij} - \beta \rho \omega^2 \]  

Following Wilcox [8], the model constants are defined as \( \alpha = \frac{5}{9}, \beta = \frac{3}{40}, \beta^* = \frac{9}{100}, \sigma = 0.5, \sigma^* = 0.5. \)

4. Validation of the numerical method

Before performing the numerical simulation of the floater, the hydrodynamic force acting from the numerical simulation must be verified first. Some of the verifications carried out include determining the optimum number of grids that can be used in the simulation. However, due to the limitations of the testing facilities, the validation of the results from the pitch and heave within a certain time will be compared with the experiments conducted by other researchers regarding the porpoising motion on high-speed craft. Validation related to numerical simulations is carried out to obtain simulation results that are close to and following real events and to obtain reliable results.

4.1. Grid Independence Study

Grid independence study is performed to eliminate/reduce the influence of the number of grids/grid size on the computational results. It is always good practice to follow this for every individual geometry, which is tedious. In this study, the parameters used as a reference in carrying out the grid independence study are the values of drag force and lift force that occurs in the floater [9].

Figure 5 shows the relationship between the drag force and the lift force acting as the number of grids increases. As the number of grids increases, the value will be smaller and then the force value will not change significantly. When the force value has not changed significantly, the number of grids in the area will be used as the optimum number of grids to be used in the numerical simulation. It can be seen from the graph that the drag and lift force start not to change after passing through the number of grids of 5 M. Therefore, a grid number of 5.4 M is used in this study.

![Grid Independence Study Graph](image-url)
4.2. Porpoising Motion Validation

Validation related to the porpoising motion was carried out using experimental data conducted by Sajedi and Ghadimi [10]. Sajedi and Ghadimi experimented with the longitudinal stability of high-speed craft, in this case, porpoising motion. The experiments were carried out using two different ship models, namely a ship without a stepped hull and a ship with a stepped hull. In this study, the experimental results from Sajedi and Ghadimi regarding a ship without a stepped hull will be used to validate the numerical simulation of porpoising motion [11].

Table 1 Comparison of the characteristics between the Sajedi and Ghadimi Ship Model and the CFD Ship Model that will be used as a validation tool in this study.

| Parameter | Sajedi and Ghadimi Ship Model | CFD Ship Model | Error |
|-----------|-------------------------------|----------------|-------|
| L (mm)    | 2640                          | 2640           | 0%    |
| LCG (mm)  | 791                           | 791            | 0%    |
| VCG (mm)  | 184.6                         | 184.6          | 0%    |
| LBP (mm)  | 2368.18                       | 2373.35        | 0.22% |
| m (kg)    | 86.024                        | 86.350         | 0.38% |
| V (m³)    | 0.08585                       | 0.08424        | 1.87% |
| \( \tau_s \) (degrees) | 2.34                           | 2.33           | 0.58% |
| B (mm)    | 551.9                         | 551.9          | 0%    |

Table 1 shows the comparison between the experimental ship model and the CFD simulated ship model. It can be seen on the table that the two ship models are almost similar with the largest error in the volume of the ship with a value of 1.87%. However, the overall error of each parameter is below 2%, so that the two models have similarities and tolerable errors.

![Figure 6 Time History Comparison of Heave Motion.](image)

**Figure 6** Time History Comparison of Heave Motion.

Figure 6 shows a comparison of the experimental and numerical simulations related to the motion of the high-speed craft model. It can be seen from the graph that the ship's heave movements are similar up to 1.5 seconds. Then in the next second the period of the heave porpoising movement increased and
preceded the heave movement that occurred in the experiment. This happens because the numerical simulation is starting to become unstable due to the deformation of the grid. This can be corrected by increasing the size of the domain horizontally and vertically so that the deformation experienced by the computational grid can be reduced. However, the heave motion porpoising phenomenon can be fully captured by numerical simulations. Therefore, it can be said that numerical simulations can model the porpoising phenomena that occur on ships working at high speed.

![Figure 7 Time History Comparison of Pitch Motion.](image)

It can also be seen in Figure 7 that up to 1.5 seconds the phenomenon of pitch motion porpoising that occurs on ships has similarities between the experiment and CFD then in the next second the pitch motion in the numerical simulation changes in period. However, the phenomenon of pitch motion porpoising can be fully captured by numerical simulations. It can be concluded that numerical simulations can be used as a tool in modeling the porpoising phenomenon that occurs in ships operating at high speed.

5. Simulation results of porpoising motion

Porpoising motion is a problem most often experienced by ships operating at high speed. Thus, studies related to porpoising motion are important concerning the many losses that can be experienced due to this phenomenon. One of the things that are considered related to the porpoising phenomenon is the history of the movement of objects in a function of time. The movement of objects over time can be observed related to the porpoising phenomenon. When the porpoising phenomenon occurs, you will see oscillations from the heave and pitch on the object [12]. Besides, the characteristics of the heave and pitch amplitude also need to be observed. This research will show the results of the simulation of the heave and pitch movements of the floater over time.

One of the things reviewed is the movement of objects from time to time. The movement of the object in question is heave motion or vertical displacement of the center of gravity. The next object movement to be reviewed is pitch motion, which is the longitudinal angular position of the ship. Figure 8 and Figure 9 shows the comparison between the results of the porpoising motion on a floater with a speed of 15,492 m/s. It can be seen in the graph that there are two variations of the deadrise angle value and two variations of the LCG value, the LCG value is a multiple of the LOA (Length Over All) value.
The variation of the deadrise angle is 10 degrees and 20 degrees. While the LCG vary based on floater’s LOA which is 0.50LOA and 0.55LOA.

![Graph showing heave motion time history of two variations of LCG and two variations of deadrise angles.]

**Figure 8** Comparison of heave motion time history of two variations of LCG and two variations of deadrise angles.

**Figure 8** shows the heave motion of the floater. The graph shows that the largest heave value is generated from the deadrise angle of 20 degrees and LCG 0.55LOA configuration. From the graph it can also be seen that at a small deadrise angle a larger motion heave can be seen in the same LCG configuration. This is because the small deadrise angle will cause an increase in lift force on the object so that it can increase the displacement of the ship's heave motion [13]. The graph shows, that in the first second when the ship starts to get the lift, there is a similarity in the heave elevation up to 1.5 seconds, then the heave elevation of each configuration begins to experience differences.

| Average Heave Porpoising Period (s) | Average Heave Porpoising Amplitude (m) |
|-------------------------------------|---------------------------------------|
| \(\beta=20^\circ, \text{LCG}=0.50\text{LOA}\) | 1.75 | 0.23 |
| \(\beta=20^\circ, \text{LCG}=0.55\text{LOA}\) | 1.97 | 0.32 |
| \(\beta=10^\circ, \text{LCG}=0.50\text{LOA}\) | 1.73 | 0.26 |
| \(\beta=10^\circ, \text{LCG}=0.55\text{LOA}\) | - | - |

It can also be seen that a configuration with an LCG value of 0.50LOA produces the same heave period, which is approximately 1.75 seconds, even though the deadrise angles have different sizes, period data can be seen in **Table 2**. However, the amplitude value of the float movement varies and increases with time. Besides, it can also be seen that in the configuration of the deadrise angle of 10 degrees and the LCG of 0.55LOA, the heave motion at 1.8 seconds underwent a very sharp change. The CG of the object drops rapidly in a very short time and may not be able to correct its position again.
Such conditions cause a large enough impact load in the bow float area and have the potential to damage the structure [14].

Table 2 shows the heave porpoising period and amplitude of the deadrise angle and LCG configurations. As previously explained, the LCG value of 0.50 LOA has almost the same period average, only 0.02 second difference. However, there is an increase in the average amplitude wherein the LCG 0.50 LOA configuration, at the deadrise angle of 20 degrees the average amplitude is 0.23 meters and at the deadrise angle of 10 degrees of 0.26 meters, there is an increase in the average amplitude of 3 centimeters, so it can be concluded that the change in deadrise angle. can increase the heave porpoising amplitude and shifting the LCG closer to the bow of the floater can increase the average period and amplitude of the heave porpoising.

![Comparison of pitch motion time history of two variations of LCG and two variations of deadrise angles.](image)

Figure 9 shows the pitch motion that occurs in the floater. As a result of the location of the LCG, the initial condition of the floater is in a trim condition, where at 0.50LOA LCG, the floater has a stern trim of 1,174 degrees, while in the LCG configuration of 0.55LOA the floater has a bow trim of 0.874 degrees. Therefore, it can be seen on the graph, that at 0 seconds the pitch of the ship has a different value, where the negative value indicates that the floater is experiencing a bow trim. The graph shows that the largest pitch motion is generated by the deadrise angle configuration of 10 degrees and LCG of 0.50LOA which is shown at 3.1 seconds with a value of approximately 18 degrees. It can be seen from the graph the initial seconds to 1.5 seconds, the increase in the pitch angle has almost the same gradient in each configuration, then starts to change in the next second. Besides, it can also be seen that in the deadrise angle configuration of 10 degrees and LCG of 0.55LOA, the pitch of the motion at 1.8 seconds experiences a very drastic change. The float experienced a very extreme change in trim conditions in a very short time, reaching 22 degrees of the bow trim, causing the entire bow of the ship to enter the water. In this condition, the float is no longer possible to return to a stable condition and there is the possibility of an accident. Figure 12 shows the extreme conditions of the ship with the bow of the ship completely submerged in water.
Table 3 Average Pitch Porpoising Period and Amplitude

|        | Average Pitch Porpoising Period (s) | Average Pitch Porpoising Amplitude (deg) |
|--------|-------------------------------------|------------------------------------------|
| β=20º, LCG=0.50LOA                | 1.73                                | 4.68                                     |
| β=20º, LCG=0.55LOA                | 1.95                                | 5.57                                     |
| β=10º, LCG=0.50LOA                | 1.71                                | 5.86                                     |
| β=10º, LCG=0.55LOA                | -                                   | -                                        |

Table 3 shows the pitch porpoising period and amplitude that occurred in the simulation time interval of eight seconds. From the table, it is shown that the 0.50LOA LCG configuration has a porpoising period that is almost similar, with difference of 0.02 seconds, even though the deadrise angle values are different. Besides, it can also be seen that at the same deadrise angle configuration, namely the deadrise angle of 20 degrees, an increase in the amplitude of the porpoising pitch in the LCG configuration is 0.55LOA. This occurs because the center of gravity of the float is closer to the bow, making it easier for the bow to fall. When the bow falls, the bow gets more hydrodynamic force and raises the bow higher. At the same deadrise angle configuration, the shift of LCG to the bow of the floater will increase the period and amplitude of the pitch porpoising, this also occurs in the heave porpoising.

Figure 10 shows the maximum heave and pitch conditions at a 20 degrees deadrise angle configuration with an LCG value of 0.50LOA. In this condition, the pitch is 16.26 degree and the heave elevation is 0.756 meters. It can also be seen that at the maximum heave and pitch conditions the water surface forms a wave with an amplitude of about 0.5 meters around the floater body. It can also be seen that the part of the floater which is immersed in water is very small, if the operating speed is increased, the floater body may come out of the water completely.

Figure 11 shows a series of side view images of the ship's motion cycle from the first second to the fourth second. These images are shown to provide a comprehensive picture of the movement and porpoising motion experienced by the floater. Unstable oscillations around the center of the object's center of gravity can be seen clearly. The floater moves and bends above the water surface. The amplitude of the porpoising pitching movement in the bow of the ship increases over time which can be seen from the 0 seconds to the 1.5 seconds. The floater experiences an extreme pitch angle with a maximum pitch of 16.2 degrees, in that condition the floater will throw its body forward and try to return...
to its position by raising the bow. In this condition, passengers who are not used to extreme conditions will experience nausea and vomiting.

Figure 11 Series of movement showing the motion of the vessel with configuration $\beta=20^\circ$, LCG=0.5LOA at intervals of 0.5 seconds to 4 seconds labeled from (a) to (h).

It can also be seen at the third second, the floater is unable to leave the water due to its high speed. However, the lift generated by the air has not been able to lift the weight of the entire floater so that the floater may hit the water very sharply in the next cycle. This porpoising motion occurs in all deadrise angle and LCG configuration conditions described in the previous section. One in four configurations
underwent extreme movement in a very short period and caused extreme pitch conditions and was unable to regain its position and was likely to result in an accident. It can also be seen that the 1.5 second and the 3.0 second in Figure 12 are the peak of the pitch condition in one cycle, then in the next second the pitch condition decreases then increases again, this is called the heave and pitch rhythmic oscillatory motion of the ship. This condition will continue continuously if the pitch condition is not improved.

**Figure 12** The occurrence of extreme conditions of heave and pitch motion at the deadrise angle configuration $\beta = 10^\circ$ and LCG = 0.50 LOA seen from the side view and perspective view.

**Figure 12** shows the extreme conditions experienced by the floater. The floater experienced a bow trim of 22 degrees, so the floater's bow was completely submerged in the water. It is most likely that in this condition the floater will not be able to return to the displacement position or the planing position because the bow that is immersed in water will tend to be immersed and then the floater will reverse if the high-velocity fluid flows continuously. Therefore, in these conditions the best way to prevent the floater from turning over is to reduce the operating speed when extreme conditions occur. The speed reduction allows the floater to be more stable but also has the possibility that the floater will continue to spin and then reverse completely. It can also be seen that the free surface formed indicates that the water surface is subjected to an impact load from the hull of the floater due to a large change in pitch with a
very fast period. The free surface experiences turbulence and a basin that reaches 1 meter below the water surface, and irregular water splashes occur in all directions.

6. Conclusion
The CFD simulation described in this study is used to study high-speed fluid flow. CFD simulations are able to capture the porpoising phenomenon on ships or floaters from seaplanes operating at high speed. Unsteady flow RANSE and K-ω turbulence models are used for the numerical simulation of high-speed fluid flows. The use of unstructured hexahedral mesh and dynamic mesh is used to model motion that occurs in objects due to fluid flow. In addition, the numerical problem solving has been validated using porpoising motion experiments on high-speed craft. Overall, the dynamic characteristics of the floater porpoising motion have been investigated in detail.

1. By decreasing the deadrise angle value, it can increase the lift force that occurs in the floater, causing the floater to experience an increase in heave motion faster in the same time compared to floaters with high deadrise angles.

2. The high deadrise angle makes it easier for the hull of the floater to break the surface of the water so that the reduction in impact loads that occur at the bottom of the floater's hull can be reduced. Besides, the small deadrise angle can increase the occurrence of accidents on seaplane floaters traveling at high speed due to the inability of the hull to break the surface of the water when the bow of the ship falls to the surface of the water quickly.

3. The position of the LCG that is close to the bow can increase the heave and pitch period that occurs on the ship when experiencing porpoising. It can also increase the heave and pitch amplitude over time if the floater pitch conditions are not immediately corrected.

4. During porpoising motion, pitching oscillations occur due to hydrodynamic forces acting on the object. At high velocities, the center of the hydrodynamic force moves forward from the object's center of gravity, which results in a continuous amplification of the unstable oscillations. Careful control of the trim angle is very important, especially when the floater is in the planning condition. When porpoising begins to occur, it is recommended to reduce the speed so that the floater will go to a displacement condition without further instability.

The author realizes that there are still many shortcomings in this paper. Therefore, the author tries to provide recommendations for the development of research related to floatplane motion behavior in the future. It would be better if the simulation time is longer, this is to provide an overview of changes in floater motion conditions as a whole phenomenon. Besides, it is also necessary to make variations related to the use of the dynamic mesh method used, where different methods can be used such as the overset grid method to provide an overview of the accuracy level of each dynamic mesh method. It is also necessary to simulate a floatplane when taking off in a rough water environment.

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