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Stability Analysis for Buoyancy UTeM's Amphibious Hybrid Vehicle (AHV)

MUHAMMAD ZAHIR HASSAN[1,a], SYAHIBUDIL IKHWAN ABDUL KUDUS[1,b], MOHD SHAZNI HALID[1,c], MUHAMMAD ZAIDAN ABDUL MANAF[1,d]
[1]Center of Advanced Research and Energy (CARE), Faculty of Mechanical Engineering, Universiti Teknikal Malaysia Melaka.
[a]zahir@utem.edu.my, [b]syahibudil@utem.edu.my, [c]b040910206@student.utem.edu.my, [d]muhammadzaidan@utem.edu.my

ABSTRACT

The buoyancy of the amphibious hybrid vehicle is depending on the parameter of the bottom hull body to keep it afloat every time. Based on the Archimedes principle, the weight of the object float is equal to the volume of water displace. When stimulates on the water surface, there will always resistant that affect the stability of the vehicle. Besides, the stability level of the AHV is very important to ensure the vehicle is on the stable condition and has the ability to face the rollover and pitch effect. Therefore, bottom hull body parameter of the vehicle is not just make it floating, but plays the important role to keep it in the stable state during face the rolling and pitching effect.

Keywords: *Buoyancy, stability, roll, pitch on water.*

1. INTRODUCTION

Based on the Archimedes principle, the weight of the object float was equal to the volume of the water displace [1]. Because of that, the buoyancy force was produce refer to the volume parameter of the amphibious vehicle. However, the water density that involved in the situation also gives the big impact. When the density of water involve is high, the buoyancy force acted also high due to directly proportional relationship between them. Therefore, there are differences of buoyancy force that refer to the fresh and sea water. Besides, the stability of the vehicle was depending on the gravity and meta center in the vehicle [2]. The effect of the roll from rear view and pitch, side view need to be taken seriously to increase the stable ability of the vehicle and avoid the vehicle from capsizing.

2. ANALYSIS METHODS

In this paper research, there are three sections of analysis which are buoyancy force, roll effect and pitch effect of the whole vehicle body. These kinds of elements are significant to identify the level of buoyancy and stability of the amphibious vehicle on the water surface.

2.1 Buoyancy Force.

To determine the buoyancy force acted on the vehicle, the maximum mass of it was considered. It is because refer to the Archimedes principle, the buoyancy force is also equal the weight force whenever it is in equilibrium state on the water. The equation (1) shows the equation of buoyancy force and the equation (2) shows the weight force in the equilibrium state. While in the equation (3), it shows the relationship between (1) and (2) to determine the ideal parameter of body hull for the vehicle with maximum mass 400kg.

$$F_b = \rho_w g V \quad (1)$$

$$F_b = m_o g \quad (2)$$

$$\rho_w V g = m_o g \quad (3)$$

Where;

F_b = buoyancy force
ρ_w = water density
g = gravity
m_o = mass of vehicle/object
V = volume body hull submerged

With considering the maximum mass of vehicle, the volume of hull body can be determined when the vehicle it in equilibrium state on the water.

2.2 Roll.

The roll effect should be determined and investigate, to ensure the vehicle was in stable condition without rolling to the right or left side. This roll condition was affected by the position of gravity and meta centre of the vehicle. The gravity of body was fixed by weight considerations test which is 665 millimeters from ground of tire. The Fig. 1 shows the sketch view of the rolling effect for the vehicle in the water.

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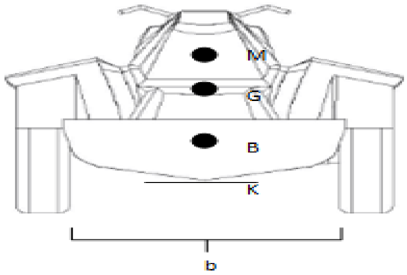

Figure 1: Rear view of AHV.

The symbol K shows the ground level of vehicle in the water, B the buoyant centre, G the gravity centre and M the meta centre. The equation (4), (5) and (6) below shows the formula to determine the distance between buoyant and meta centre and its description that influence the stability respectively [3].

$$d(BM) = \frac{I_y}{V} = \frac{b^3 h}{12V} \quad (4)$$

- Stable if, $d(BM) - d(BG) > 0$ (5)
- Unstable if, $d(BM) - d(BG) < 0$ (6)

Where;
b = width
h = length of the vehicle (out of paper)
d(BM)= position of M refer to B centre.
d(BG) = position of G refer to B centre.

For the roll effect, the width of the vehicle is measured from the left to the right body side, while the length is measured from the rear to the front body side.

2.3 Pitch.

In the pitch effect of the vehicle, the calculation is similar with the roll which is referring to the equation (4). However, the parameter of the equation was bit different in width and length value of the vehicle. The Figure 2 below shows the sketch side view of the pitching effect for the vehicle on the water surface.

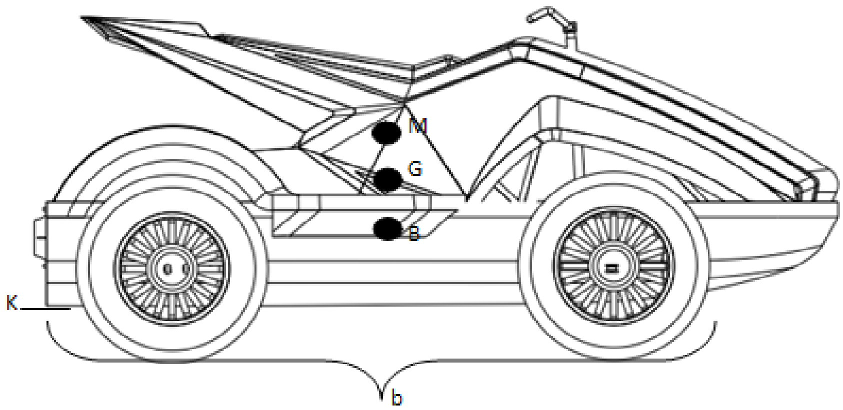

Figure 2: Side view of AHV

For the value of b, the width is measured from the rear to the front side of the vehicle while value of h, the length is measured from the left to the right side of vehicle which is out of paper.

3. RESULTS

3.1 Buoyancy Force.

Refer to the equation (3) with maximum mass of vehicle 400kg, the value of body hull submerged that have been produce is $0.4m^3$. Therefore, the volume of the hull body should be $0.4m^3$ or more. If the value is less, the probability for the vehicle to achieve the equilibrium state on the water is low. Table 1 below shows the parameter of the body hull with different concept that capable to float on the fresh water.

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Table 1: Value of surface area refers to the depth length

Conc.	Depth, L (m)	Area surface, A (m^2)	Length (m) ✕ Width (m)
1	0.45	0.89	2 ✕ 0.45
2	0.30	1.33	2 ✕ 0.67
3	0.20	2.00	2 ✕ 1.00

Figure 3 shows the graph differences results of forces between buoyancy and weight of the body. The buoyancy force that has been produce was referring to the fresh water and concept 3 of vehicle parameter that extends its depth from 0.20 meter to 0.25 meter for precaution steps. While in Figure 4, it shows the vehicle was been driving on the sea water surface. Therefore, the vehicle was capable to float on the water surface for every time.

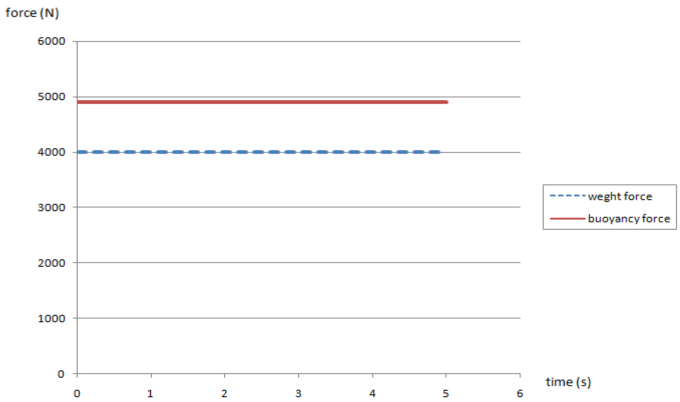

Figure 3: Graph between weight and buoyancy force that acted by the vehicle.

Figure 4: Driving test on water surface.

3.2 Roll Effect.

In the roll effect analysis, the position of BM was decided either the vehicle is in stable state or not. If the value of BM is bigger than BG, the vehicle has higher ability to keep stable but when the BM is less than BG, the vehicle will be capsized [3]. The value of BG was fixed after weight consideration test which is 0.46 meter from bottom surface. Table 2 below shows the comparison results between BM and BG for the roll effect.

Table 2: Results value for roll effect on water

Value		Description
BM	BG	Stable and no rollover happen.
0.72	0.46	

Figure 5 below shows the vehicle that encounter the rolling effect on the water surface by facing the sea wave. The vehicle still stable on the sea water after past the roll resistance and capable to face significant large resistance.

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Figure 5: Roll test on the water surface.

3.3 Pitch Effect.

While in the pitch analysis, the identifying steps is similar with the roll effect but different in length and width value. The facing resistance was coming on from the front to the rear side or otherwise. Table 3 shows the comparison value results between BM and BG for the pitch effect.

Table 3: Results value for pitch effect on water

Value		Description
BM	BG	Stable and no over pitching happen.
2.00	0.46	

Based on the data results, the both of roll and pitch effect have the higher BM than BG. Therefore the ability for the vehicle to be stabilized is high. Figure 6 below shows the vehicle that encounters the pith effect by the sea water and still stables without any problem after pass it.

Figure 6: Pitch test on the water surface.

4. RESULTS ANALYSIS.

4.1 Parameter Optimum.

Refer to the equation (3), the weight force that produce by the body is equal to the buoyancy force acted. Thus, the parameter of volume plays the important role to satisfy the buoyancy force acted to the body. At the same time, the volume parameter of the vehicle is influence by the depth, length and width of the body hull. The equation (6) below shows the equation of hull body volume, V_w that had been manipulated to generate three concept of hull body designs [4].

$$V_w = A_w L \tag{6}$$

Where;

A_w = Area of hull body vehicle

L = Depth of body vehicle

The volume of the hull body has been determined first which is 0.4m^3. Despite on that, the three concept of hull body design is developing to choose which one is the ideal concept with higher stability. The concept was shown as in the Table 1. The Figure 7 and Figure 8 below shows the sketch of the body hull and real body hull that have been fabricated respectively which is refer to the concept 3 as the ideal and optimum parameter.

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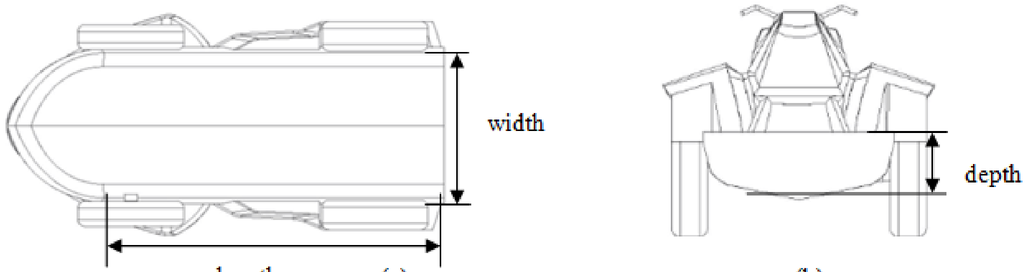

Figure 7: Design of hull body; (a) Bottom view, (b) Rear view

(a) (b)

Figure 8: Hull body concept 3 design; (a) bottom view, (b) side view

4.2 Roll Analysis.

Refer to the Table 1, the all three concept had been analyzed to identify the ability of vehicle to remain stable on the water after facing some roll resistance. This is important to choose which one of the concepts has higher capability to remain stable with avoiding roll and pitch effect. Table 4 below shows the data results of BM for the all three concept which refer to the equation (4).

Table 4: Results of BM value due to difference paramater of hull body for roll

Concept	lenght,h (m) X width,b (m)	BM (m)
1	2 X 0.45	0.04
2	2 X 0.67	0.13
3	2 X 1.00	0.72

While in the Figure 9, it shows the pie chart of percentage which one of those three concepts have higher ability and probability to remains stable for the rolling effect condition. It shows the concept 3 has the higher ability to stabilize to face the roll resistance on the water with percentage of 81%.

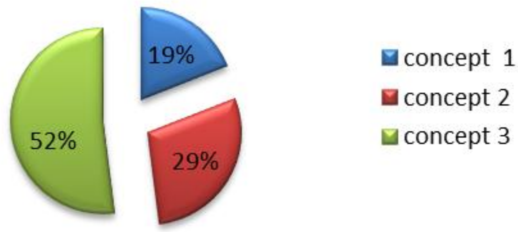

Figure 9: Pie chart of probabilty percentage for roll effect.

4.2 Pitch Analysis.

For the pitch analysis, the Table 1 and equation (4) also be the reference to identify the ability of the vehicle to be stabilized after face the pitch effect on the water surface. The Table 5 below shows the data results of BM value for the pitch effect of the vehicle.

Jadual 5.2: Results of BM value due to difference paramater of hull body for pitch

Concept	Width,b (m) X Length,h (m)	BM (m)
1	2 X 0.45	0.75
2	2 X 0.67	1.12
3	2 X 1.00	2.00

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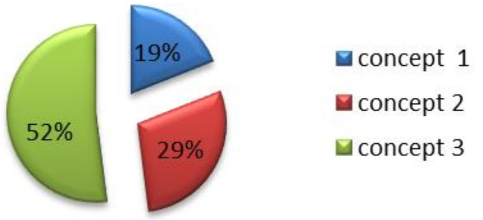

Figure 10: Pie chart of probabilty percentage for pitch effect.

Fig. 10 shows the pie chart of percentage which the concepts that has high capability to stabilized in pitch effect. Due to both roll and pitch effect results, it states that the concept 3 has the higher probability to keep stabilized either face the roll or the pitch effect. While in the Fig. 11 below, it shows the driving test of the amphibious vehicle that faces the roll and pitch resistance on the water surface.

Figure 11: The vehicle was test with the roll and pitch effect on sea water surface.

CONCLUSIONS

In this analyse, it is proven that all of the three concepts hull body have the ability to be float with accommodate maximum weight force 400kg. Despite on that, the roll and pitch effect should be tae seriously to make the vehicle remain stable on the water surface and avoid the rollover happen either in the both left-right side and front-rear side. Based on the data analyse also, it prove that the concept 3 of hull body has the higher ability to remain stabilized after facing some resistance. Therefore, the concept 3 has been chosen to fabricated and be develop due to its higher buoyancy and stabilising ability than the others concepts.

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REFERENCES

[1] Yunus A. Cengel and John M. Cimbala. Fluid Mechanics: Fundamental and Application. New York: Mc Graw Hill (2nd Edi.). pp 97-105. (2010).
[2] Kaarstad B., Aadnoy B. S., Theory and Application of Buoyancy in Wells. Model Applied Science. Vol. 5, N0. 3, June 2011, pp. 15-19. (2011).
[3] SIMON FRASER UNIVERSITY, (SFU). Buoyancy and Stability of a Floating Body. ENSC 283. School of Engineering Science Mechatronic System Engineering. SURREY.
[4] Hassan, M.Z., Abdul Manaf, M.Z., Halid, M.S., Alehan, M.N. and Md. Isa, A.S. (2013) UTeM`s Amphibious Hybrid Vehicle: Ride and Handling Analysis, Applied Mechanics and Material (AMM): Trans Tech Pub. (Accepted for Publication)