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Numerical Calculation Analysis of Lift and Bow Thruster Design of Class LCAC Hovercraft

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Abstract

Class LCAC Hovercraft is a hovercraft that can support military operations in transport and distribution of logistics and other combat equipment. Indonesia only has a hovercraft, which is used to transport personnel only. This study aimed to analyze the lift style and design of the bow thruster to obtain the great style and the right blade design in detail. Therefore, the characteristics corresponding to numerical calculation of 200.56 m^3/s Air Volume Elevator Volume, 4905.5 N/m^2Total fan pressure, 1000 mm Outside diameter, 700 mm Input Diameter, 15 Blades, 322 mm Impeller Leaf Width, 0.776 Efficiency could be obtained.

Keywords - *Hovercraft, Lift, Bow Thruster, LCAC*

I. INTRODUCTION

The development of maritime science and technology, particularly the interests of logistic shifts, tends to lead to more effective and more flexible and high mobility leading equipment (L.Trillo, 1971). Hovercraft can provide more significant benefits and efficiencies and move in all-terrain because the friction is smaller than the ground and ship vehicles, so this vehicle is also safe to cross mine-planted beach without activating the mine (Saad, 2017).

This paper has any literature to support the research about it, for example, a paper with the title Dynamic Stability of Hovercraft in Heave (Poland, 1970). Development of a Hovercraft Prototype (Okafor, 2013). Dynamic Mathematical Modeling and Simulation Study of Small Scale Autonomous Hovercraft (M. Z. A. Rashid, 2012). RC Hovercraft: An I-Bylogical Enzyme (I-BE) Biosensor Carrier (Rinta Kridalukmana, 2017). To Study and Fabrication of Air Cushion Vehicle (Tiwari, 2015). Type of Ship Trim Analysis on Fuel Consumption with a Certain Load and Draft (I Nengah Putra, 2017). Air Assisted Directional Control of a Hovercraft (RAJMANOVAH, 2014). Design & Air Flow Simulation of Small Scale Working Model Of Hovercraft (A. V. Kale, 2017). A Study On Construction and Working Principle of a Hovercraft (V Abhiram, 2014). Comparative Analysis Result of Towing Tank and Numerical Calculations With

Harvard Guldammer Method (I Nengah Putra A. D., 2017). Development of an Integrated Air Cushioned Vehicle (Hovercraft) (S.V. Uma Maheswara Rao, 2014). Diagnosis of Fault Modes Masked by Control Loops with an Application to Autonomous Hovercraft Systems (Christopher Sconyers, 2013). Hovercraft Control With Dynamic Parameters Identification (David Cabecinhas, 2017). Analysis of The Propulsion System Toward The Speed Reduction of Vessels Type PC-43 (Arica Dwi Susanto, 2017). Designing Hovercraft Controlled using Android (Pankaj Singh, 2016). Development of a working Hovercraft model (S H Mohamed Noor, 2015). Study of Water Jet Propulsion System Design For Fast Patrol Boat (FPB-60) (Prihanto, 2018). Development of a hovercraft prototype with an aluminum hull base (A. K. Amiruddin, 2011). (William B. Dunbar, 2003). Stokes Equation in a Toy CD Hovercraft (Izarra, 2011).

The development of hovercraft, especially the mastery of hovercraft technology, is one of the alternative options of the Indonesian Navy to develop defense and security forces. In designing a hovercraft up to its manufacture, we have to pay attention to the weight factor of the vehicle, and it requires proper planning, which concerns the structure of construction to provide the body shape of the hovercraft. The authors analyzed the lifting blower and bow thruster on LCAC type hovercraft in detail with the calculation of lifting style and design of the bow thruster so that the style and design of the right blade in detail can be obtained. Thus, the demands of technical capabilities and hovercraft operations capability of LCAC class can be fulfilled.

This paper is organized as follows—section 2 reviews the basic ship theory. Section 3 gives the result, and 4 discussions of research; finally, section 5 presents the conclusion of this paper.

II. RESEARCH METHODOLOGY

A. The Definition of Hovercraft

Hovercraft is a type of fast amphibious ship with trapped air in which the whole body position (hull) of this type of vehicle does not touch the ground surface (soil, water) and moves with the impulse of the fan (Thrust Fan) (Yahya, 1987). The hull force itself comes from the pressurized air just below the hovercraft hull (Plenum Chamber), in which there is no construction other than compressed air inside this plenum chamber. The amphibian capability of this hovercraft is the main difference from a boat, motorboat, ship, or hydrofoil, although all of them have the same speed at high speed. In its development, hovercraft has a name or other designations: Air Cushion Vehicle (ACV), Capture Air Bubble (CAB), and Ground Effect Machine (GEM). However, hovercraft is the most common name used to date (Roshan R. Shrirao, 2016).

B. Definition of Lifter and Bow Thruster

Lifter or lift is the primary system in hovercraft operations that uses high-pressure air supply, the outside air compressor, which is then pressed into a plenum chamber surrounded by a skirt (hovercraft component

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serves as a protective air) (Key, 1987). From this process, therefore, the air supply forms the "air cushion." This air cushion is called a static air cushion. The process is that air is continuously supplied so that the air pressure presenting in the plenum space becomes higher and increases than that outside. Thus, the air comes out through the gap under the skirt by itself, which then gives rise to lift in hovercraft. So, hovercraft lifted and hovered by itself from the surface of the water or the ground, but not flying like a plane.

Whereas, the Bow Thruster is a system used to provide a favorable setting for ship bow movement caused by cross-wind or ocean stream. The effectiveness of Bow-thruster can be determined from the thrust force generated by electric or hydraulic motors in KW or HP.

Based on the propulsion, there are 3 types of Bow Thruster (L.Trillo, 1971):

1. Hydraulic Bow Thruster
2. Electric Bow Thruster
3. Diesel-powered Bow Thruster

C. Principle of the Lift System

As we know, hovercraft is a ship that operates with the whole hull lifted by force generated by the pressurized air located in the Plenum Chamber region (Perozzo, 1995).

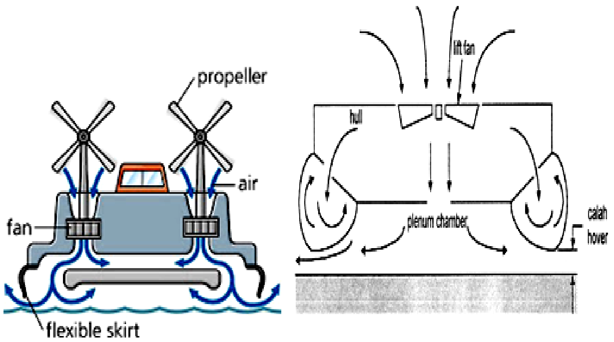

Fig. 1, The principle of lift style on hovercraft

The lift/air pressure in the Plenum Chamber can be adjusted according to the airflow exhaled by the lifter fan (Lift fan). Although when air is blown down the hull of the hovercraft, there is already airflow out through the hover gap. However, since the fan lift blows air with a much larger flow, the air pressure that occurs in the Plenum Chamber is getting bigger and bigger. This pressure gets more significant and more vital to be pushed out through the bottom of the hovercraft so that the hover gap formed is also getting more significant. This increase in pressure continues until the height of the planned hover gap is reached. Whereas the process of lift (lift process) from hovercraft itself can be divided into two stages, namely stage inflating skirt (hovering) and flying stage (Perozzo, 1995).

D. Hovering Stage

This stage is the process of inflating skirts from the process of an empty skirt (off hover) until it reaches a full-fledged position (full hover) (Perozzo, 1995).

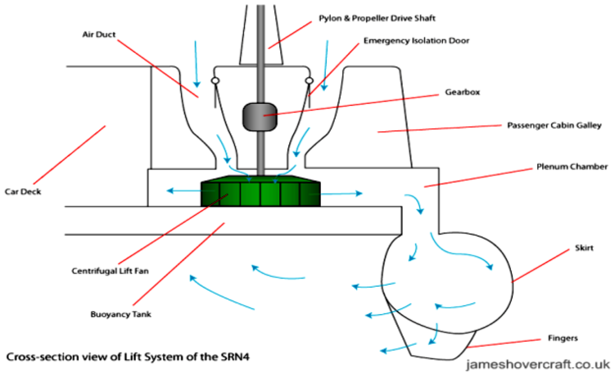

Fig. 2, Lift System Diagram

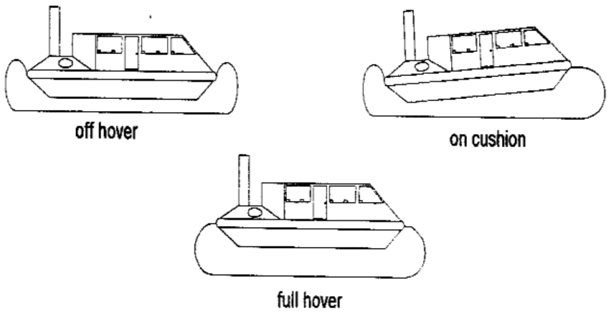

Fig. 3, Hovering phase of hovercraft

The planning of the hovering stage is determined by the air pressure in the skirt used. The ratio of air pressure in the skirt and air pressure in the Plenum Chamber is about 1.2, which further determines the required fan power according to the equation:

$$P_H = P_{Skirt} \text{ X } Q_{Skirt} \quad (1)$$

E. Flying Stage

The flying stage is the process in which the hovercraft is lifted entirely above the runway surface after the skirt is in full hover position (Perozzo, 1995).

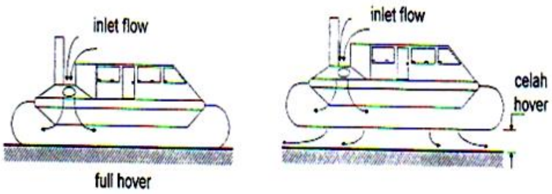

Fig. 4, Flying Stage of hovercraft

To perform the stage of hovering or inflating skirts from the vacant position of the skirt (off hover) until it reaches the full hover position and the flying stage or process in which the hovercraft is lifted entirely above the runway surface after the skirt is in the hover position, there are some very related points to the design of the flying stage of hovercraft as follows: (Rajamani, 2015)

a) Lift Length Parameter

Lift Parameters are the circumference of the area under the hovercraft that is formed and limited by the skirt tangent line with the runway when the hovercraft is in full hover condition. The value of the lift parameter is the circumference of the hovercraft body reduced by a certain percentage as a conversion factor because, in general, the lower part of the hovercraft body has a specific slope shape.

$$P_L = k.P_H \quad (2)$$

b) Hover Gap Area (A_{HG})

Hover Gap Area or wide hover gap is the vertical area, which is formed when the hovercraft is lifted (flying). Thus, the width of this area is the multiplication of lift parameters with a hover slit. By estimating the hover gap, the width of the hover gap can be calculated by the following equations:

$$A_{HG} = P_L \text{ X } G_H \quad (3)$$

c) Cushion Pressure (P_C)

Cushion Pressure or hover pressure is the total weight of the hovercraft (at full load) that works on the field under the hovercraft body. Same with the lift parameter, the width of this press field is the area of the ship after it is converted. So, the hover pressure working under the ship's body is:

$$P_C = W_T / A_{PC} \quad (4)$$

d) Escaping Air Velocity (V_E)

Escaping Air Velocity is the air velocity that comes out of the hover gap when the hovercraft body is lifted up. Furthermore, the value obtained from the table should be converted in practical conditions in the field which must have a temperature difference, so the value which can be taken is 60% of the value obtained from the table, as follows: (Perozzo, 1995)

Table 1, Relation of hover pressure and air velocity, measured under air conditions with a temperature of 70°F

Hover Pressure (psi)	Air Velocity (fps)
0.050	78
0.075	96
0.100	111
0.125	123
0.150	135
0.175	146
0.200	156

Then we get the actual airspeed figure of:

$$V_{EA} = 60\% \text{ X } V_{ET} \quad (5)$$

e) Airlift debit (Q_L)

Airlift debit is the volume of air that passes through the hover gap per unit of time so that the air debit can be calculated as follows:

$$Q_L = V_{EA} \text{ X} G_H \quad (6)$$

f) Theoretical & Actual Power for Hovercraft Lifts (P_T)

The power required to lift the hovercraft is the result of the hover pressure with the air debit working under the hovercraft, so it will be obtained as follows:

$$P_T = P_C \text{ X } Q_L \quad (7)$$

F. Fan Working Principle

The fan is one type of fluid engine that serves to move the fluid (air) with a specific direction and speed per the characteristics of the rotor (impeller) fan used (A.Anandhakumar, 2015).

The air capacity that the fan can move is determined mainly by the size of the fan, the speed of rotation, and the channeling system used in conjunction with the fan itself. According to the direction of the resulting airflow, the fan can be divided into two types: centrifugal fan and axial fan. Based on its impeller leaves, centrifugal fans are divided into 6 categories: AF (airfoil), BC (backward-curved), BI (backward-inclined), RT (radial-tip), forward-curved FC, and RB (radial blade) (Liang Yun, 2000).

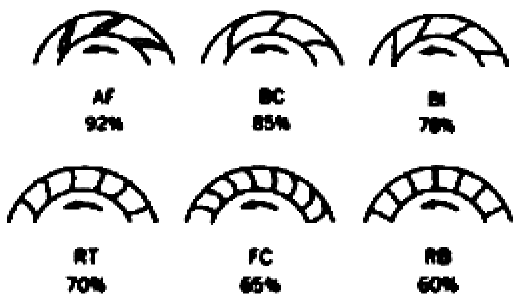

Fig. 5 Efficiency of impeller leaves

G. Centrifugal Fan

It is called a centrifugal fan because it generates air from the input area (inlet) to the outlet region in the radial direction due to the impeller rotation (Perozzo, 1995).

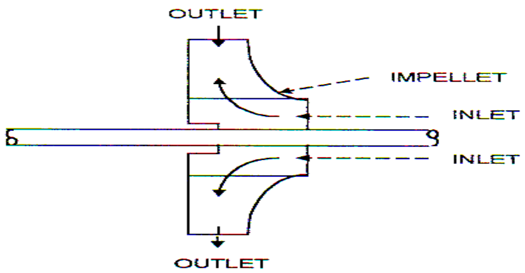

Fig. 6, the airflow of the centrifugal fan

Furthermore, the air is radially thrown out the impeller with high speed and pressure and then enters the fan casing in the form of a spiral. The spiral shape of the fan casing acts as an aerial drive towards the exit portion of the fan, and from this spiral shape, then the centrifugal fan casing is also called the scroll or volute. In experimental conditions, the centrifugal fan is a blower that can operate with an air pressure ratio of 1000 mm W.G by the double inner (L.Allison, 1990).

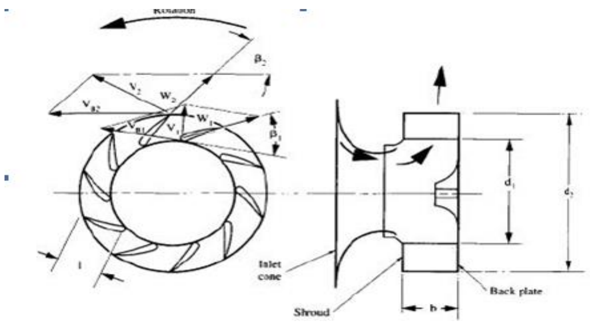

Fig. 7, Schematic centrifugal fan Impeller

According to the air pressure that can be produced, the centrifugal fan can be divided into 3 main groups, namely: (Raj, 2017)

1. Low-pressure fan up to 0.981 kPa
2. Medium pressure fan from 0.981 to 2.943 kPa
3. High-pressure fan from 2.943 to 11.772 kPa

H. Method of Research

In planning the system of lifter and bow thruster, it is not apart from the calculation of empty weight and weight of charge placed on hovercraft that designed later. In its principle, the system of lifter and bow thruster counteract the force caused by the weight of the construction, which is nothing but the weight of the design of the hovercraft itself.

Therefore, in planning a hovercraft, we must consider several main factors, including the primary size, machine requirements, and geometric shapes. Thus, the right selection and calculation must be made so that the requirement of lift and thrust power demanded in the planning will be guaranteed.

III. RESULTS AND DISCUSSION

A. Power Requirement Calculation

The power for the engine lift is the amount of power required to lift the overall hovercraft as high as the height of the skirt from the bottom surface. Thus, in order to have the profile, the layout of lift system type and pressure distribution at various positions are displayed as follows: (Liang Yun, 2000)

Table 3, Fan Selection

No	Fan Selection	Calculation Results
1	Impeller Diameter	1.025 ≈ 1 m
2	Input Area Impeller Diameter	0.7 m
3	Leaf Impeller Width	0.322 m

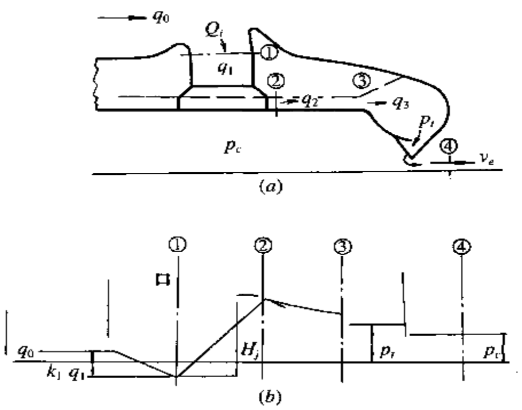

Fig. 8, Layout of lift system type and pressure distribution at various positions

IV. DISCUSSION

Drawing design planning for lifter and bow thruster system begins with partial or part-by-piece depiction and forwarded to assembling and laying on the space designed in this LCAC class hovercraft model. Based on the results of the numerical calculation, we obtain the dimensions used in this planning:

A. Impeller

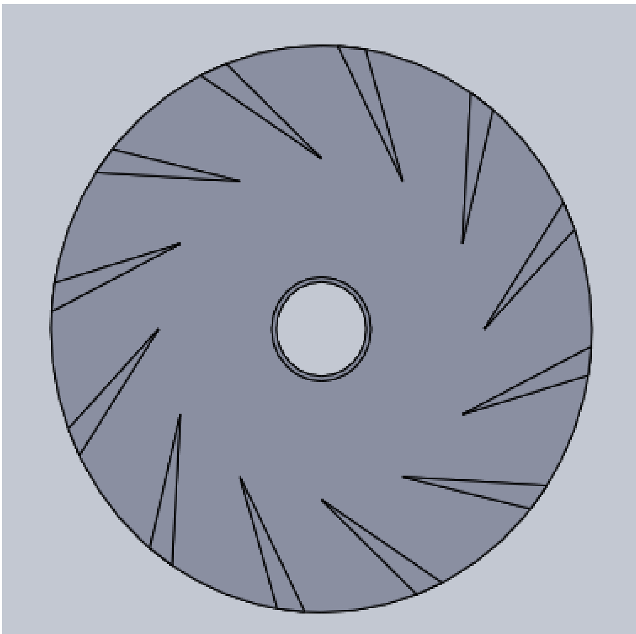

Fig. 9, Impeller and its blades (front view)

Table 2, Power Requirement Calculation

No	Power Requirement Calculation	Calculation results
1	Lift Parameter Calculation	50.22 M
2	Hover Gap Area (A_{HG}) Calculation	0.637 M^2
3	Cushion Pressure (P_C) Calculation	3703.48 Pa ≈ 35 bar ≈ 34.8 atm
4	Determination of Lift Air Volume (Q)	200.56 m^3/s
5	Determination of Impeller Fan Diameter (D_2)	1.03 ≈ 1 m
6	Determination of Impeller Disc Width (F)	0.81 m
7	Determination of Air Fan Volume Coefficient (Q')	3
8	Determination of Total Fan Pressure Coefficient (H')	0.61
9	Determination of Total Fan Pressure (H)	4905.5 N/m^2

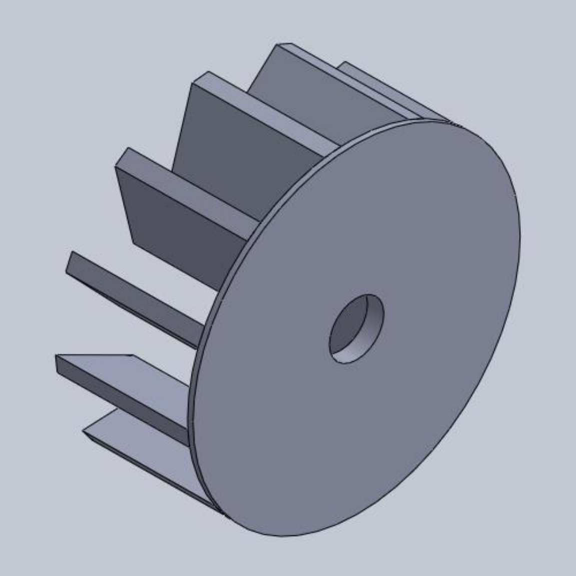

Fig. 10, Impeller and its blades (isometric view)

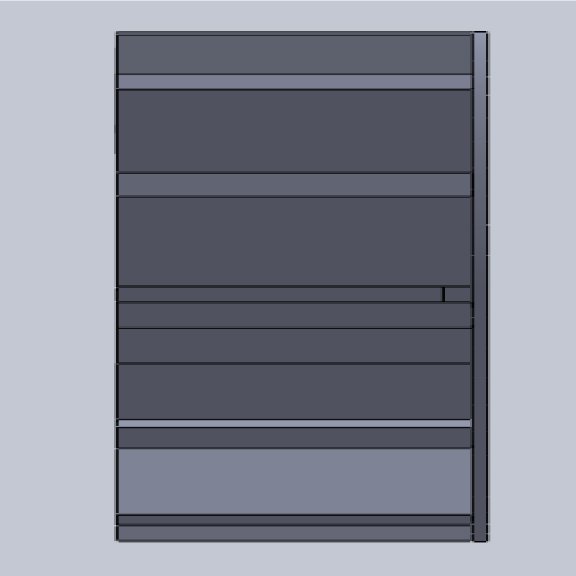

Fig. 11, Impeller and its blades (side view)

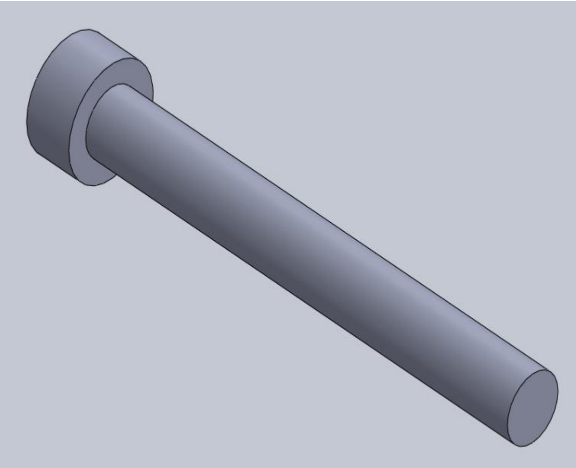

Fig. 12, Shaft and head (side view)

B. Assembly

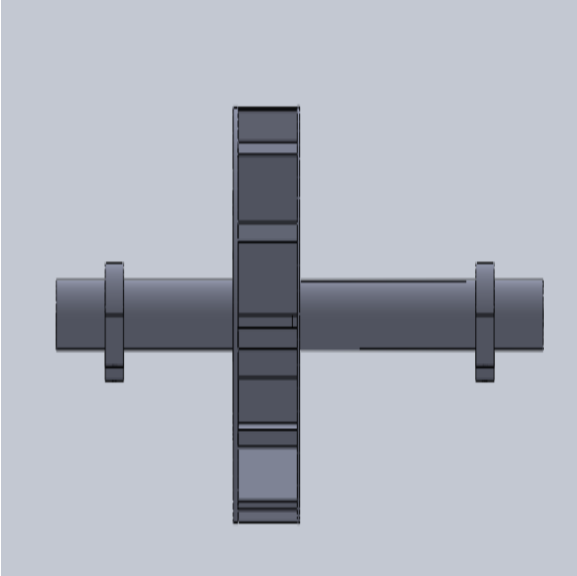

Fig. 13, Axle, Impeller, and head cushion assembly (side view)

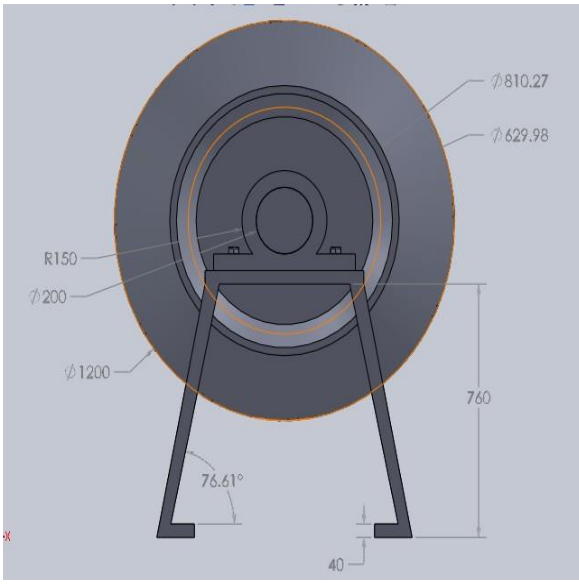

Fig. 14, Shaft, Impeller and Cushion Assembly (front view)

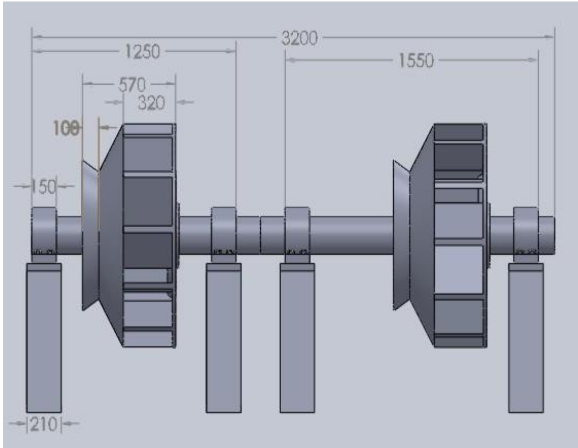

Fig. 15, Shaft, Impeller, and Cushion Assembly (front view)

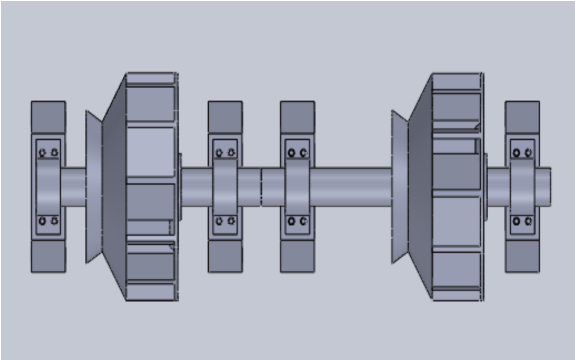

Fig. 16, lift and thruster impeller assembly on the stand (top view)

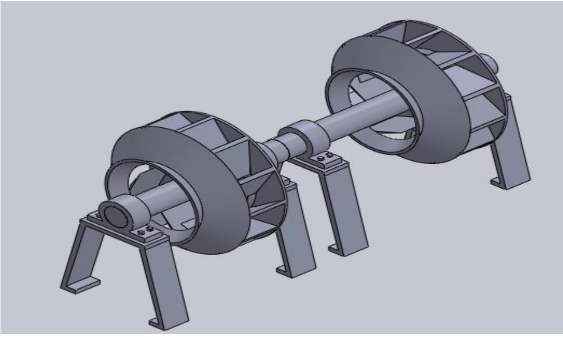

Fig. 17, lift and thruster impeller assembly on the stand (isometric view)

C. Application of the Model

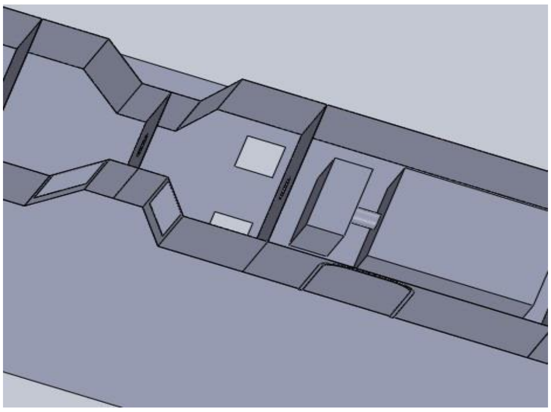

Fig. 18, Placement of machine, gearbox, and ducting lift (top view)

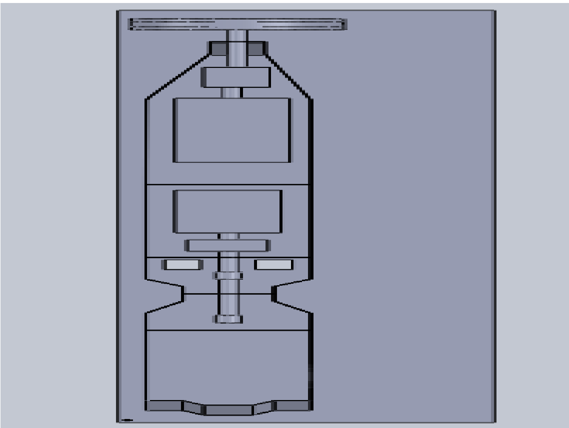

Fig. 19, Axle, Impeller, and machine assembly on the model (top view)

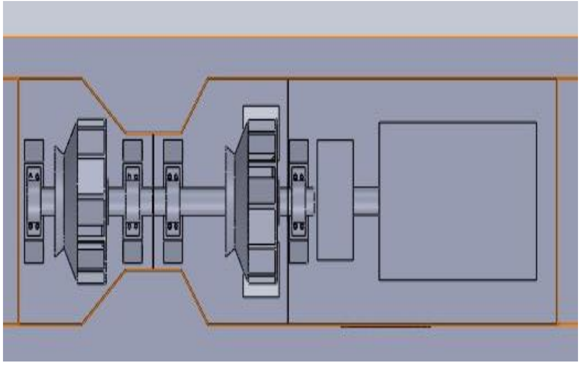

Fig. 20, Placement of machine, gearbox, impeller for lift, impeller for thrust, and holder (top view)

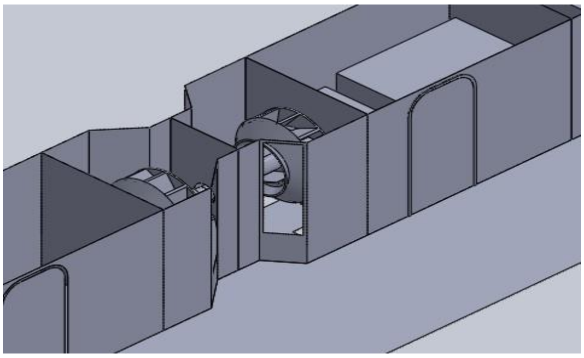

Fig. 21, Placement of machine, gearbox, impeller for lift, impeller for thrust, and stand (isometric view)

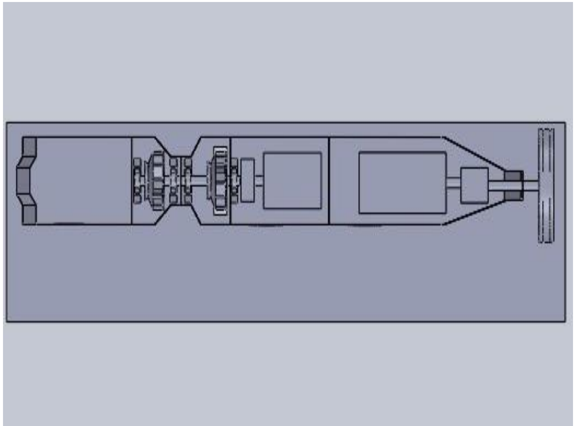

Fig. 22, Placement of machine, gearbox, impeller for lift, impeller for thrust, and holder (top view)

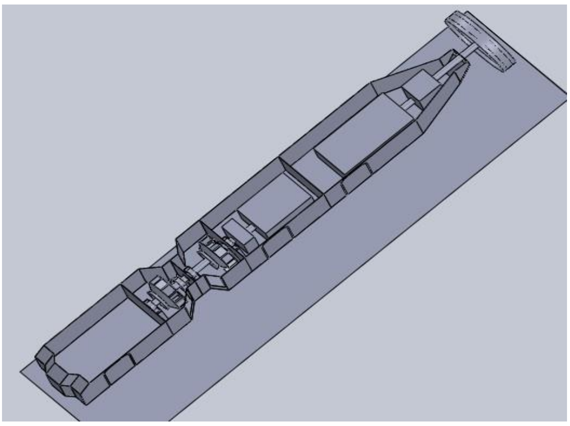

Fig. 23, Placement of machine, gearbox, impeller for lift, impeller for thrust, and holder (isometric view)

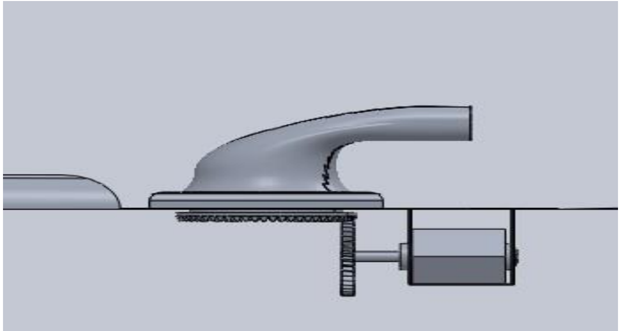

Fig. 24, The mechanism of the bow thruster drive with an electric motor (front view)

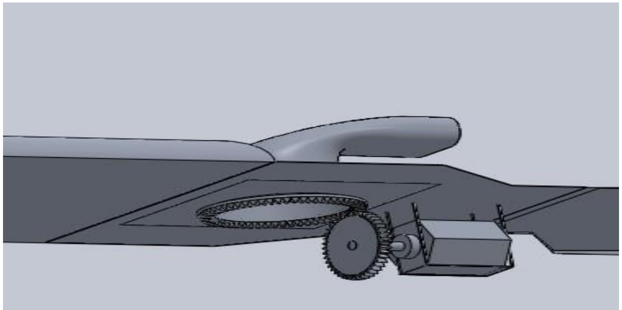

Fig. 25, The mechanism of the bow thruster drive with an electric motor (isometric view)

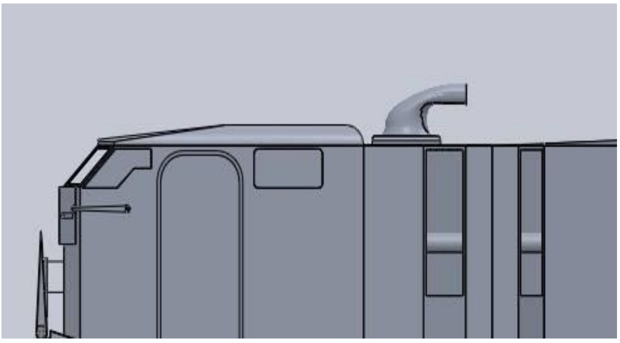

Fig. 26, Bow Thruster on the model (side view)

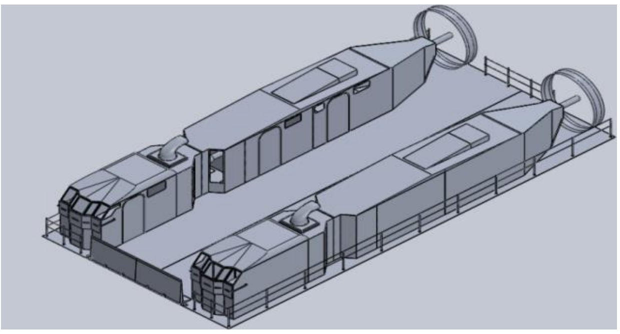

Fig. 27, Lifter and bow Thruster system on closed model

V. CONCLUSION

Using the results of the analysis and calculation of the lift style and the design of the bow thruster, we obtained the great style and the right blade design in detail. Thus, the researchers obtained the characteristics according to the numerical calculation results: 200.56 m^3/s Lift Air Volume, 4905.5 N/m^2Total fan pressure, 1000 mm Outside diameter, 700 mm Input Diameter, 15 Blades, 322 mm Width of Leaves Impeller, and 0.776 Efficiency.

ACKNOWLEDGEMENTS

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REFERENCES

[1] A. K. Amiruddin, S. M. (2011). "*development of a hovercraft prototype with an aluminium hull base*". International Journal of the Physical Sciences , 6, 4185-4194.

[2] A. V. Kale, A. J. (2017). "*Design & Air Flow Simulation of Small Scale Working Model Of Hovercraft*". IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , 23-28.

[3] A.Anandhakumar, S. S. (2015). "*Design and Fabrication of Hovercraft".* International Journal of Innovative Research in Science Engineering and Technology , 4 (6), 597-601.

[4] Adumene, N. S. (2015). "*Predictive Analysis of Bare-Hull Resistance of a 25,000 Dwt Tanker Vessel".* International Journal of Engineering and Technology , 194-198.

[5] Amin, J. K. (2014). "*Performance of VLCC Ship with Podded Propulsion System and Rudder*". International Society of Ocean, Mechanical and Aerospace Scientists and Engineers , 1-7.

[6] Andersen, J. P. (1994). "*Hydrodynamic of Ship Propeller".* Cambridge: Elsevier.

[7] Anthony F. Molland, S. R. (2011). "*Ship Resistance and Propulsion".* United Stated of America: Practical Estimation of Ship Propulsive Power.

[8] Arica Dwi Susanto, A. O. (2017). "*Analysis of The Propulsion System Toward The Speed Reduction of Vessels Type PC-43*". International Journal of Engineering Research and Application , 7 (4), 08-15.

[9] Atreyapurapu.et.al, K. (2014). "*Simulation of a Free Surface Flow over a Container Vessel Using CFD*". International Journal of Engineering Trends and Technology , 334-339.

[10] Bartee, D. L. (1975). "*Design of Propulsion Systems for Hidh-Speed Craft*". The Society of Naval Architects and Marine Engineers , 1-17.

[11] Bertram, H. S. (1998). "*Ship Design for Efficiency and Economy*". Great Britain: Butterworth-Heinemann.

[12] Bertram, V. (2000). "*Practical Ship Hydrodynamic*". Inggris: Great Britain.

[13] Charchalis, A. (2013). "*Designing Constraints in Evaluation of Ship Propulsion Power".* Journal of KONES Powertrain and transport , 1-6.

[14] Christopher Sconyers, Y.-K. L. (2013). "*Diagnosis of Fault Modes Masked by Control Loops with an Application to Autonomous Hovercraft Systems".* International Journal of Prognostics and Health Management , 1-15.

[15] Chun.et.al., H. H. (2013). "*Experimental investigation on stern-boat deployment system and operability for Korean coast guard ship*". International Journal Naval Architecture Ocean Engineering , 488-503.

[16] D'arcalengelo, A. M. (1969). "*Ship Design and Contruction*". Michigan: Professor of Naval Architecture and Marine Engineering University of Machigan.

[17] David Cabecinhas, P. B. (2017). "*Hovercraft Control With Dynamic Parameters Identification*". IEEE TRANSACTIONS ON CONTROL SYSTEMS TECHNOLOGY , 1-12.

[18] Degiuli.et.al., N. (2017). *"Increase of Ship Fuel Consumption Due to the Added Resistance in Waves*". Journal of Sustainable Development of Energy, Water and Environment Systems , 1-14.

[19] Gerr, D. (2001). Propeller Handbook. (J. E. Oppenheim, Penyunt.) United Stated: International Marine.

[20] Guldhammer, H. E. (1974). Ship Resistance. Copenhagen: Akademisk Forlag.

[21] Harrington, R. L. (1992). Marine Engineering (Revised, Subsequent ed.). (Revised, Penyunt.) Jersey City, United States: The Society of Naval Architects and Marine Engineers .

[22] Harvald, S. A. (1992). "*Resistance and Propulsion of Ships*". New York: John Wiley and Sons.

[23] Herdzik, J. (2013). "*Problems of propulsion systems and main engines choice for offshore support vessels*". Scientific Journals Zeszyty Naukowe , 2 (1733-8670), 45-50.

[24] I Nengah Putra, A. D. (2017). "*Comparative Analysis Result of Towing Tank and Numerical Calculations With Harvard Guldammer Method".* International Journal of Applied Engineering Research , 12 (21), 10637-10645.

[25] I Nengah Putra, A. D. (2017). "*Type of Ship Trim Analysis on Fuel Consumption with a Certain Load and Draft*". International Journal of Applied Engineering Research , 12 (21), 10756-10780.

[26] Izarra, C. d. (2011). Stokes Equation in a Toy CD Hovercraft. European Journal of Physics , 89-99.

[27] Key, R. L. (1987). "*Hovercraft Skirt Design and Manufacture*". Journal of Engineering Manufacture , 209-219.

[28] Kleppesto, K. (2015). "*Empirical Prediction of Resistance of Fishing Vessels".* NTNU Trondheim Norwegion University of Science And Technology , 1-87.

[29] Kowalski, A. (2013). "*Cost optimization of marine fuels consumption as important factor of control ship's sulfur and nitrogen oxides emissions*". Scientific Journals , 94-99.

[30] Kuiper, G. (1992). "*The Wageningen Propeller Series*". Netherland: MARIN.

[31] L.Allison, J. (1990). "*Air Cushion Vehicle and Survace Effect Ships for Great Lakes and Great River Transportation*". Marine Technology , 27, 1-8.

[32] L.Trillo, R. (1971). Marine Hovercraft Technology. London: Leonardo Hill.

[33] Lewis, E. V. (1988). "*Principles of Naval Architecture Second Revision*". New Jersey: The Society of Naval Architecs and Marine Engineers.

[34] Liang Yun, A. B. (2000). "*Theory and design of air cushion craft".* New York: Wiley.

[35] M. Z. A. Rashid, M. S. (2012). "*Dynamic Mathematical Modeling and Simulation Study of Small Scale Autonomous Hovercraft*". International Journal of Advanced Science and Technology , 46, 95-114.

[36] Okafor, B. (2013). *"Development of a Hovercraft Prototype*". International Journal of Engineering and Technology , 3, 276-281.

[37] Pankaj Singh, A. B. (2016). "*Designing Hovercraft Controlled using Android*". International Journal of Engineering Trends and Technology (IJETT) , 37-42.

[38] Perozzo, J. (1995). "*Hovercraft as a Hobby*". Auburn: Twin peaks Enterprise.

[39] Poland, H. J. (1970). "*Dynamic Stability of Hovercraft in Heave*". Journal of Applied Mechanics , 37 (4), 895-900.

[40] Premchand, P. K. (2015). "*Numerical Investigation of the Influence of Water Depth on Ship Resistance".* International Journal of Computer Applications , 1-8.

[41] Prihanto, A. D. (2018). "*Study of Water Jet Propulsion System Design For Fast Patrol Boat (FPB-60)".* International Journal of Academic and Applied Research (IJAAR) , 2 (7), 1-7.

[42] Raj, A. A. (2017). "*Design of An Unmanned Hovercraft*". International Journal of Computer Engineering in Research Trends , 4 (5), 190-194.

[43] Rajamani, V. K. (2015). "*Design and Analysis of Winged Hovercraft*". Journal of Applied Mechanical Engineering , 4 (5), 1-8.

[44] RAJMANOVAH, B. S. (2014). *"AIR ASSISTED DIRECTIONAL CONTROL OF A HOVERCRAFT*". International Journal of Mechanical And Production Engineering , 2 (9), 88-91.

[45] Rinta Kridalukmana, B. C. (2017). "*RC Hovercraft: An I-Bylogical Enzyme (I-BE) Biosensor Carrier*". International Journal of Electrical and Computer Engineering (IJECE) , 7, 2003-2007.

[46] Roshan R. Shrirao, S. P. (2016). "*Design & Fabrication of ACV*". International Journal of Emerging Trends in Science and Technology , 3 (5), 3995-4015.

[47] S H Mohamed Noor, K. S. (2015). "*Development of a working Hovercraft model*". IOP Publishing , 1-9.

[48] S.V. Uma Maheswara Rao, V. S. (2014). "*Development of a Integrated Air Cushioned Vehicle (Hovercraft)".* International Journal of Modern Engineering Research (IJMER) , 4 (5), 21-28.

[49] Saad, K. A. (2017). "*The Development of Hovercraft Design with a Horizontal Propulsion System*". Engineering Applications for New Materials and Technologies , 91-103.

[50] Samson, D. I. (2015). "*Effect of Fluid Density On Ship Hull Resistance and Powering*". International Journal of Engineering Research and General Science , 615-630.

[51] Samuel, M. I. (2015). "*An Inventigation Into The Resistance Components of Converting a Traditional Monohull Fishing Vessel Into Catamaran Form*". International Journal of Technology , 1-10.

[52] Sladky, J. (1976). *"Marine Propulsion*". New York: The Winter Annual Meeting of The American Society of Marine Engineers.

[53] Susanto.et.al., A. D. (2017). "*Analysis of The Propulsion System Towards The Speed Reduction of Vessels Type PC-43*". International Journal of Engineering Research and Application , 8-15.

[54] Tabaczek, J. K. (2014). "*Coefficients of Propeller-hull Interaction in Propulsion System of Inland Waterway Vessels with Stern Tunnels".* International Journal on Marine Navigation and Safety of Sea Transportation , 1-8.

[55] Tiwari, A. (2015). "*TO STUDY AND FABRICATION OF AIR CUSHION VEHICLE*". INTERNATIONAL JOURNAL of RESEARCH–GRANTHAALAYAH , 3, 70-84.

[56] Tupper, E. (1975). Introduction to Naval Architecture. Inggris: Great Britain.

[57] Tupper, K. R. (2001). "*Basic Ship Theory*". Inggris: Great Britain.

[58] V Abhiram, N. S. (2014). "*A STUDY ON CONSTRUCTION AND WORKING PRINCIPLE OF A HOVERCRAFT*". International Journal of Mechanical Engineering and Robotics Research , 3, 308-313.

[59] Watson, D. G. (1998). "*Practical Ship Design*". Netherlands: Elsevier Science Ltd.

[60] William B. Dunbar, R. O. (2003). "*Nonlinear and Cooperative Control of Multiple Hovercraft With Input Constraints*" . European Control Conference (ECC) (hal. 1917-1922). Cambridge: IEEE Xplore digital library.

[61] WPA Van Lamerren, T. L. (1984). "*Resistance Propulsion and Steering of Ship*". Holland: Harleem Holland.

[62] Yahya, S. M. (1987). "*Turbines Compressors and Fans*". New Delhi: Tata McGraw-Hill.

[63] Zelazny, K. (2014). "*A method of Calculation of Ship Resistance on Calm Water Useful at Preliminary Stages of Ship Design*". Scientific Journal Maritime University of Szuczecin , 125-130.

[64] Żelazny, K. (2015). "*An Approximate Method For Calculation of Mean Statistical Value of Ship Service Speed On a Given Shipping Line, Useful In Preliminary Design Stage*". Polish Maritime Research , 28-35.