Developing 11 x 20 Meter Hovercraft for Military Use

Agoes Santoso¹, Muhammad Badrus Zaman¹, Andryan Herjanto¹

¹Department of Marine Engineering, Institut Teknologi Sepuluh Nopember, Surabaya, Indonesia

Abstract. Hovercraft is an advanced marine vehicle that always attractive military gear for supporting all terrain warfare such as fast landing vehicle, beach raid operation, territorial control, etc. Hovercraft capable of amphibious operation to bring troopers and logistics from landing ship to the certain mainland and even reach the city centre. By hovering in the above grounds with low pressure then the hovercraft operation may not activate minefield. Hovercraft also taken into considerations for Indonesian military. A long planning model of 11 x 20 meters class has been developed by applying gas turbine as an alternative main propulsion power for both lifting and thrusting fans. The low of weight/power ratio that offered by gas turbine can improve payload of the hovercraft by 45.85%. This paper also resumes several technical aspects when the hovercraft upgraded to be a fully military use. The results conclude that the additional payload is a significant feature to improve protective hull material, cargo capacity for military gears, weapons system, and logistics. Increasing speed is also possible because of the use of an adjustable blades design in the thruster fans.

Keywords: Hovercraft, Advanced Marine Vehicle, Gas Turbine, Military Vehicle

1. Introduction
Recently there is higher tension in the South China Sea when it involves two big countries China and the USA. Due to the geographical position, the conflict affects many countries such as Indonesia, Malaysia, Taiwan, etc. In this crucial situation, a strong military power is high in demand. Basic philosophy in defence is how to show that the country is not in the weak condition in military assets. This idea can prevent potential disturbances from other countries. Indonesian Ministry of Defence (MoD) do actual acts by considering buying several military weapons includes a naval ship, main battle tank, jet fighter, hovercraft, etc. The capability of the national industry is also taken in building specific war machines such amphibious vehicle [1]. Modern fleets configuration shows hovercraft as a part of landing platform rather than precedent amphibious tank. The existences of hovercraft not only proven by its effective landing operational, but the advanced marine vehicles can be operated at sea, land, beach, mud, stone gravel, and snow so suitable for search and rescue, and disaster relief operation [2].

Hovercraft is an all-terrain vehicle that has many functions and advantages compared with the conventional ships. Hovercraft classified as Air Cushion Vehicles (ACV). This vehicle is suitable when used in Indonesia, due to the geographical conditions which has thousand islands, coastal and very long coastline, moreover many natural disasters happened in Indonesia especially related with sea behaviour. Indonesia military and several civil agencies had already put hovercraft in their research and realized...
them after Aceh’s tsunami disaster. Combined operation was dominated by military ships and hovercraft where blocked coastline by disaster’s ruins can only conquered by using hovercraft [3].

Author and team in the Department of Marine Engineering ITS had involved in several hovercraft development projects in Indonesian MoD, Navy, and Army that the products can be shown in the following figure. It is a big challenge to improve the previous design for specific purpose as military use. Some military objectives will involve in the technical review and further discussed for application.

Figure 1. Examples of Hovercraft Built by National Industry

Well known hovercraft technology and its benefits should reinforce Indonesian military. Modern hovercraft should be occupied and well developed in this archipelago state. Modern means fully involvement of electronic control, automation system, integrated system, and information technology as declared in industrial 4.0 [4]. This paper will discuss about the upgrade capability of 11 x 20 meters class hovercraft that already used by military to be military standard. The meaning of military use is capable of to fulfil military standard for warfare operation even as supporting vehicles. Amphibious landing operation commonly deal with enemy’s gunshot. Therefore, landing craft has been designed with strong enough structure to encounter incoming bullet to protect insider troopers. Hovercraft needs as light structure as possible. Protected materials such as kevlar or bullet-proof carbon can be laminated in the entire aluminium hull. Light weight also means higher speed. It is important performance that may presented by military hovercraft.

This paper will also suggest some improvements that can be an alternative reference for Indonesian military when realize procurement for hovercraft vehicle. Refer to previous work, this paper still recommends occupying gas turbine as prime mover rather than conventional diesel engine [5]. Many types of small size gas turbine have been developed by some makers [6]. As rotating engine with relatively high rpm make gas turbine contribute low vibration level and noise beside of light and compact size. Short-designated endurance of the hovercraft operation should not be a serious constraint for gas turbine fuel consumption. Less maintenance and high durability of gas turbine should also be taken into consideration that may balanced the initial cost of the gas turbine. Finally, this designated military use hovercraft is not only common use by military body but furthermore the vehicle suits well to fulfil any
military requirements standard even for warfare situation. Landing Craft Amphibious Carrier (LCAC) becomes primary reference in developing this military use hovercraft. The involvement of national industry such as shipyard may economize the cost of building the hovercraft. Transfer of technology scheme should be possible to invite any element of national human resources in university, research institutions, and competence shipyard for long term development and its sustainability.

2. Literatures Review

2.1. Hovercraft Technology

Hovercraft works by lifting its body vertically and then thruster system will force the vehicle to move horizontally. Under-body covered by air cushion that produces simultaneously by blowing air to the integrated skirt. Due to the availability of air cushion then hovercraft can be an amphibious vehicle. Hovercraft should be designed with limited lifting pressure. Higher pressure cause depth of hump that deter the vehicle to move forward. In the other hand, lower pressure causes bigger footprint area of the vehicle.

Commonly, the speed of hovercraft designed up to 40 knots based on ground speed calculation. Even the biggest hovercraft can carry 200 tons of payload, but this class of 11 x 20 meters hovercraft is addressed to bring load at about 15 tons. The capacity of cargo determined not only based on the total weight but also considered to the available space and load distribution, as commonly technical constraints for flying vehicles. So far, hovercraft built in Indonesia use diesel engine as prime mover. The smaller available one is powered by otto engine. Otto engine relatively lighter than diesel engine, but diesel engine is the most usage in military crafts. One alternative prime mover is gas turbine. Even known wasteful of fuel, gas turbine offers lowest weight/power ratio and size/power ratio. Gas turbine should be highly considered for bigger size hovercraft when lightest weight become main objective [7].

The are two technical ways to configure hovercraft propulsion system. First, separated power supply for each of lifting power and thrusting power. Second, integrated power supply when the prime mover give power to thruster system and then use its power take-off system (PTO) to supply mechanical power to the lifting system. Both methods can be applied to the single and twin prime mover system.

2.2. Gas Turbine Technology

Gas Turbine is highly supporting the basic requirement of a hovercraft. For small hovercraft can be fit with small technology gas turbine or even micro gas turbine [8]. Big size hovercraft can occupy any determined power of marine gas turbine [9]. Hovercraft capable of fly up to one meter above the water surface and maintain its level in the entire operation time so the vehicle must be designed as light as possible. The effort not only for hovercraft body but also the entire components onboard include the prime movers. Figure 2 shows the comparison of the diesel engine and gas turbine for certain endurance and the relationship to the unit weight for ideal operation.

![Figure 2. Gas Turbine vs Diesel Weight [7]](image-url)
3. Development Model
Figure 3 shows the design of 11 x 20 meters hovercraft. Main hull uses aluminium marine 5086 and aluminium profiles 6061. The hovercraft designed with 2 (two) unit gas turbine that is in each side of the vehicle. Each gas turbine aft-side is coupled to 1 (one) propeller fans to perform thrusting force that overcome hull resistance. The part of PTO shaft in the fore side is coupled with blower fans to perform lifting force via a diverter unit that also can give its part of power for air bow-thruster operation.

![General Arrangement of the Developed 11 x 20 Meters Hovercraft for Indonesian Military](image)

**Figure 3.** General Arrangement of the Developed 11 x 20 Meters Hovercraft for Indonesian Military

Generated technical specification data of the hovercraft can be listed as below.

**Table 1. Technical Specification Data of the existing Hovercraft 11 x 20 Meter**

| Specification                      | Value       |
|-----------------------------------|-------------|
| Length Over All                   | 20 m        |
| Breadth Over All                  | 11 m        |
| Height (on cushion, including mast)| 4.95 m      |
| Skirt height                      | 1.25 m      |
| Ground clearance                  | 0.5 m       |
| Crews                             | 8 Persons   |
| Maximum overall weight            | 48 Tons     |
| Payload                           | 15 Tons     |
| Ground Speed                      | 35 Knots    |
| Power of Gas Turbine (continuous) | 2 x 4000 HP |
3.1. Modelling Lifting Power
Hovering mode is a special performance of hovercraft. Suitable air must be blow on the entire skirt area then step by step will lift-up hovercraft body. After the body lifted-up, certain amount of air still needed to perform air cushion at designed height that called as ground clearance. When the hovercraft already flew at that designed height then thrusting fan can operated to perform horizontal movement at designed speed. Due to pressure the water surface will be pushed and form basin. The ground clearance should be calculated well to overcome this hump height [10].

Theoretically, to determine the power on the lifting system can use following equation [11].

\[ N_{el} = \frac{\mu_j \times Q_i}{(1000 \times \eta_F \times \eta_M)} \]  \hspace{6cm} (1)

Where:
- \( N_{el} \) = Lift system power (kW)
- \( \mu_j \) = Fan overall pressure (N/m²)
- \( Q_i \) = Air in-flow of the fan (m³/s)
- \( \eta_f \) = Fan Efficiency
- \( \eta_M \) = Transmission system efficiency

3.2. Modelling Thrusting Power
Thrust fan or air propeller commonly uses for thrusting force that capable move forward the hovercraft as designed speed [12]. Higher power of prime mover potentially gives higher speed when the fan or air propeller can overtake the thrust in effectively. Therefore, it is important to do engine propeller matching to achieve the best configuration of propeller based on the dedicated rotational speed. Thrust forces produce by the air propeller must be able to overcome the incoming resistance force. The propeller fan can be designed by using 2 blades up to 10 blades. More number of blades can give low noise and higher efficiency at smaller diameter of blades.

The characteristics of air propeller affects by diameter, number of blades, types of blade profile, pitch, activity factors, and lift coefficient [13]. Diameter of air propeller can be calculated by following formula.

\[ D = \sqrt{\left( M_{tip}^2 - M \right) \frac{a^2}{\pi n^2}} \]  \hspace{6cm} (2)

Where:
- \( D \) = Diameter air propeller (m)
- \( M_{tip} \) = Tip match number (0.72)
- \( M \) = Mach number of craft = \( \frac{v}{a} \)
- \( v \) = Service speed (m/s)
- \( n \) = Air propeller rotation speed (tps)
- \( a \) = Speed of sound (330 m/s)

After the diameter of air propeller obtained then the blade chord can be calculated by using this formula.

\[ AF = \frac{10^5}{D^3} \int_{r=0}^{0.5D} cr^3 dr \]  \hspace{6cm} (3)

Where:
- \( AF \) = activity factor of air propeller, for hovercraft value is 100-150

Finally, the duct air propeller can be calculated by adding 10% to 15% from the value of the air propeller. Entry angle can be designed at 50 to 100 refer to the chord line of the aerofoil. And the chord line of the aerofoil is about 0.4 to 0.6 from air propeller diameter [11].
3.3. Modelling Hovercraft Resistance
There are five components of hovercraft total resistance that must be overcome by the engine thrust power for designed speed. But due to major parts of hull fly above sea water surface then hovercraft has less resistance compared with conventional ships.

1. Aerodynamic Profile Drag ($R_a$)
2. Air Cushion Wave Making Drag ($R_W$)
3. Differential Air Momentum Drag ($R_m$)
4. Aerodynamic Momentum Drag ($R_m$)
5. Skirt Drag ($R_{sk}$)

Based on the previous work in modelling of 11 x 20 meters hovercraft then the total resistance and its components can be summarized as Table 2. There is Total Resistance coefficient (1.0 – 1.1) that already taken [5].

| Table 2. Resistance Components of Designed 11 x 20 m Hovercraft [5] |
|---------------------------------------------------------------|
| Air Cushion Wave-making Drag = 11.3 kN                        |
| Aerodynamic Profile Drag = 41.9 kN                           |
| Momentum Drag = 3.7 kN                                       |
| Skirt Drag = 17.5 kN                                         |
| Differential Air Momentum Drag = 28.8 kN                     |
| Total resistance = 103.7 kN                                  |

4. Analysis and Discussion
There are several technical aspects that interesting in the development of military use hovercraft. As stated previously, targeted hovercraft here is lower grade compared with LCAC class that commonly built at about 26.8 m length x 14 m width and capable of bring 75 tonnes payload. Understanding the demand sharply can saving budget not only capital but also operational and maintenance costs [14].

4.1. Dimension
Hovercraft relatively has short endurance, so this vehicle always carried out by landing ship when crossing the ocean. Hovercraft dis-embark from ship via a wide ramp-door that commonly located in the rear part of its carrier ship. Refer to the existing landing ship owned by Indonesian military then the ideal size of the hovercraft is about 11 meters width and 20 meters length. The maximum height of the hovercraft when hovering is about 5 to 6 meters to suit the available docking space inside the carrier ship.

Powering the hovercraft with gas turbine result benefit in optimizing the dimension balancing to other performances such as loads capacity, speed design and stability conditions.

4.2. Hull and Material
This hovercraft planned to be built by using aluminium marine 5083 and aluminium profile 6061 that had been proved as strong material and light with tensile strength up to 260 MPa. However, designing military use hovercraft needs stronger hull. Then laminating internal hull with bullet-proof material can be a solution. There are several protection materials such as Kevlar, carbon steel, bullet resistance panel and glass, armoured of window and door, etc. Well-determining ballistic level can save budget for relatively expensive of those materials.

Hovercraft hull can also be designed based on diamond-cut pattern to minimize infra-red and radar signature. Special paint that has features to eliminate those signatures, can also be used. Specific camouflage pattern of colour is also effective to be adopted. All features above are leads to the stealth model that one of importance specification of military marine vehicles.
4.3. **Speed and Endurance**

By using gas turbine as prime mover, then this 11 x 20 meters class hovercraft can be designed for maximum ground speed of 35 knots. Figure 4 shows the matching result of the engine and propeller that been used in this design [5] based on the previous equations. Gas turbine power data obtained from maker specifications data. Air propeller performance data obtained from the specific air propeller characteristics model as generated by Equations (2) and (3) based on the total resistances of 103.7 KN (as shown in Table. 2) that may been overcome by the thruster system to achieve maximum speed of 35 knots. Air propeller curve shows how much the absorbed power at certain gas turbine revolution (rpm). The air propeller is a fixed type, so the value of absorbed power depends on the gas turbine revolution and calculated empirically.

![Engine Propeller Matching](image)

**Figure 4.** Engine Propeller matching of the Developed 11 x 20 Meters Military Hovercraft [5]

The hovercraft has integrated power total of 2 x 4000 HP produced by where 70% is used for thruster system and the remaining 30% is used for lifting system. Total power of thrusting is about 2800 HP and lifting is about 1200 HP for each side of gas turbine engine. The two gas turbines weight is 2 x 602 kg or 1204 kg. When using diesel engine, the hovercraft needs 2 units engines with weight of 2 x 2533 kg or 5066 kg for thrusting power and 2 x 1508 HP or 3016 kg for lifting power. Saving weight at 6878 kg is a great achievement in a typical hovering vehicle.

4.4. **Manoeuvrability and Terrain**

Length/width ratio of hovercraft is much lower than any typical conventional ships. This feature gives better stability value when fly over sea surface or even in the above solid surface. With this body width, hovercraft can float in the sea surface and safe for certain sea state when the engines shutdown or the skirt severe tore. Manoeuvring military vehicles must fulfil certain level of standards. Hovercraft is a proven design for military use. Sophisticated mode such as auto pilot and flight by wire technology should be adopted for better manoeuvring duties in all terrain conditions.

Hovercraft capable of fly over sea, sand, snow, solid road, macadam road, stoned or gravel, mud, etc. Those all-terrain capabilities must be support by perfect high-end technology. Integrated automation system for main engine, auxiliary engines, and navigations should be provided. Combat management system (CMS) can be adopted depend on the specific warfare strategies.
4.5. **Crews and Automation System**

Minimum Crews number can be calculated based on the mission. But automation system can reduce crew number and improve safety and security manner when the risk of human error can be minimized. This modern era also offers highest level of automation system called as autonomous mode. And it is also possible to be developed in hovercraft vehicles. Due to certain operation still needs human, then the autonomous system may be limited as driver-less system only. All weapons and combatant gears possible to be designed autonomously, also carried cars already available under autonomous system.

4.6. **Reliability and Logistic Support**

Military use also means higher reliability level than common vehicles. Hovercraft as a flying vehicle seems a weak, fragile, and easy targeted object. It is a designer task to give extra protection. Hull already covered as previous explanation. Defence and offence weapons can be upgraded for both Closed-In Weapon System (CIWS) and Remotely Control Weapon System (RCWS) capable. All improvement can be done easily when the payload increased due to the use of gas turbine system.

Wide area of hovercraft main deck can be utilized for land vehicles, logistic and consumables, or even troopers. Hundreds of troopers can be accommodated on the main deck with protected tends semi-permanently.

4.7. **Payload and Weapons System**

Using gas turbine gives weight reduction of about 6878 kg. It is amazing results that can be converted as payload. Previous conventional design by using diesel engine gives payload about 15 tonnes. This gas turbine type can handle 22 tonnes payload. However, loading the main deck must consider deck strength, so the load distribution must be also calculated precisely. Without any alteration to the deck strength, it is prohibited to bring a single unit truck or military tank with weight over 12 tonnes. Improving deck strength is an easy works if in demand.

Weapon system possible can be improved when potential payload still available. Depends on the budget, hovercraft can also be utilized with limited CMS, CIWS, and encounter measure (EMS).

5. **Conclusion**

Using gas turbine as prime mover of this designed 11 x 20 meters hovercraft can improve the payload up to 45.85% or 6878 kg. This results mainly obtained from the weight differences between gas turbines and diesel engines. But in more comprehensive way, it is caused by the reduction of structures and supporting beds. Modular gas turbine units also contribute weight reduction when the installation and auxiliary system can be simplified.

Using gas turbine for this class of hovercraft should also be considered by Indonesian military body when the performances of the vehicles insist to be comparable with the proven type like LCAC Class. Reducing the weight of main components such as prime mover will influences many technical aspects that dedicate to the better performances in the operation. Many technical aspects have been discussed before gets benefits from the extra payloads. Therefore, improving the capabilities of hovercraft 11 x 20 meters class to be a powerful military use vehicle is possible. Extra payload can also be used to improve hovercraft speed rather than used it for bring more loads.

National shipyards are ready to involve in the development of hovercraft whether in term of transfer of technology or direct newbuilding. Finally, Department of Marine Engineering ITS with several experiences [15] in the built of military used hovercraft, confidently ready for accompanying any parties in collaborating national hovercraft projects.

**References**

[1] Santoso A, and Semin 2009 Improving the Warfare Performances of OPV90 to Become Corvette Class, National Conference of Marine Technology (SENTA), 17 December 2009, Surabaya

[2] NY 2005 Japanese Military lands in Aceh for Relief Work, The New York Times, January 28, https://www.nytimes.com/2005/01/28/world/asia/japanese-military-lands-in-aceh-for-relief-work.html
[3] Anonym 2004 Annex C-Case Study: Indian Ocean Tsunami, Aceh Province Indonesia

[4] Santos A, Kusuma IR, and Lin J 2018 The Application of Vessel Integrated Automation Systems to Improve Ship Safety and Security, *Maritime Safety International Conference* (MASTIC), 9-11 July 2018, Denpasar, Bali.

[5] Santoso A, Zaman M.B., Herjanto A, 2019 Design on Hovercraft Using Gas Turbine as Main Engine for Combined Thruster and Lifter System, Int. J. of Marine Engineering Innovation and Research, Vol. 4(1), Sept.2019, pp.01-11.

[6] F. K. Takebe, Y. Daimon and S. Ejima, 1977, An Application of TF25 Gas Turbine Engine to Hovercraft Operation in Japan, ASME, Japan.

[7] Armellini A, Daniotti S, Pinamonti P, and M. Reini, 2018, Evaluation of Gas Turbines as Alternative Energy Production Systems for a Large Cruise Ship to Meet New Maritime Regulations," *Applied Energy 211*, pp. 306-317.

[8] Soares C 2014 Gas Turbines: An Introduction and Applications in Gas Turbines, Waltham, Elsevier, pp.1-40.

[9] Kayadelen HK, and Ust Y, 2013, Marine Gas Turbines, in *7th International Advanced Technologies Symposium*, Istanbul.

[10] Yuliawan HD, and Santoso A, 2009 Designing Separated Thruster and Lifter system for 15 Ton Payload Hovercraft, Undergraduate Thesis, Dept. of Marine Engineering ITS, Surabaya.

[11] Yun L, and Bliault A, 2000 Theory and Design of Air Cushion Craft, London: Arnold, A Member of the Hodder Headline Group.

[12] Durgawale AA, Raut SS, Suryawanshi AL, Patil SP, and Mali VP, Design and Fabrication of Hovercraft, www.ierjournal.org, ISSN: 2395-1621.

[13] Abhiram V, Krishna NS, Raju TMM, and Anjiah M, 2014 A Study on Construction and Working Principle of a Hovercraft," *International Journal of Mechanical Engineering and Robotics Research*, India.

[14] Amyot JR, 1989, Hovercraft Technology, Economics and Applications, *Studies in Mechanical Engineering*.

[15] Nugroho B, Musriyadi TB, and Santoso A, 2006 The Analysis of Thruster and Lifting System at Military Hovercraft by Using Single Engine, Undergraduate Thesis, Dept. of Marine Engineering ITS, Surabaya.