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SHIP RESISTANCE ANALYSIS WATERJET REMOTELY OPERATED VEHICLE (ROV) USING COMPUTATIONAL FLUID DYNAMICS (CFD) METHOD

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ABSTRACT

The propulsion system is a system that supports the performance of high-speed ships. Waterjet ship propulsion systems have long been known and used as propulsion systems for various types of ships, but their widespread application is still subject to their relatively low propulsive efficiency when compared to ship propulsion systems that use propellers, especially during relatively low ship speeds. The usual problem with ROVs using conventional propellers when inspecting in low water in the river is the blockage of river impurities, such as water hyacinths and underwater roots, on the ROV propellers. But there is a limitation to the problem when this waterjet is installed on the ROV should be used on inspections that do not work on the seabed, and the ROV can only be in a hovering position because the waterjet is susceptible to dirt. The purpose of this study was to analyze the ship's resistance of the waterjet remotely operated vehicle (ROV) propulsion system with the results of simulating the effect of the Waterjet ROV design on the total resistance of the Waterjet ROV increased by 5.69 N using the CFD method and the difference in prisoner comparison using the maxsurf method was 1.75%. The thrust analysis of the ROV model with a waterjet propulsion system has a higher thrust increase of 9.21 N when compared to the ROV model with a conventional propeller propulsion system, with a thrust value of 6.94 N. From the analysis of the fluid velocity contour results of the two best ROV models, namely the Waterjet ROV because the placement of the waterjet position on the outer side of the ROV frame so that the placement of the original Propeller inside the inner frame of the ROV is released as a result it tends not to create more turbulence and friction in the water in the middle of the ROV but the surface of the ROV frame on the outside which is added waterjet propulsion components causes higher hydrodynamic pressure.

Keywords: Resistance, waterJet, propulsion system, thrust

Introduction

A propulsion system is a system that moves a ship forward and backward that has thrust [1]. An engine is a device that has the ability to convert heat energy owned by fuel into motion energy. Based on its function, the engine terminology is used as a source of power or prime power [2]. The propeller is the most common form of ship propulsion used in moving ships.

The propulsion system is a system that supports the performance of high-speed ships [3]. Ship propulsion systems with waterjets have long been known and used as propulsion systems for various types of ships [4]. However, widespread applications still hit their relatively low propulsive efficiency when compared to ship propulsion systems that use propellers, especially during times of relatively low ship speeds [5]. A common problem with ROVs using conventional propellers when inspecting low water in rivers is clogging cables and underwater roots in their propellers [6].

There are various types of ship propulsion systems, for example, waterjets. The manufacture of waterjet propulsion systems began in the seventeenth century, called waterjet, because this system utilizes the thrust of water to drive ships [7]. Harnessing this water boost will have an impact at an increasing rate [8]. Thrust waterjet propulsion systems are used on patrol boats. The patrol boat is one of the Indonesian Navy ships tasked with monitoring Indonesian territorial waters [9]. Thus, a ship with high speed is needed.

ROVs are tethered underwater vehicles, commonly used in the deep-water industry, such as offshore hydrocarbon extraction [10]. These vehicles are connected to surface vessels by buoyant moorings or, often when working in rough conditions or deeper water, load carrier umbilical cables are used in conjunction with a TMS mooring management system [11]. The ROV has evolved from its first introduction in 1953 by Dimitri Rubinoff, to now it has been used in a variety of activities [12]. Underwater intervention, repair, and use in maintenance operations are some of the capabilities of the ROV, which is the result of one of its features, being able to capture underwater images [13].

The purpose of this study was to analyze the effect of installing a WaterJet propulsion system on a Remotely Operated Vehicle (ROV) based on total resistance, thrust, and speed contours. This study used the Computational Fluid Dynamics (CFD) method. This research hypothesis is expected to provide innovations, replacing the waterjet propulsion system on the ROV with a More Responsive Thrust and reducing cable clogging and underwater roots compared to conventional propellers.

Methodology

a. Modeling ROV

The ROV data used is data obtained from Surovotic Indonesia in the field survey process, as shown in Table 1. Surovotic is the only ROV company and community in Indonesia. As seen in Figure 1. This ROV data will be used as a reference for WaterJet ROV modifications. Research into the WaterJet propulsion system on this ROV is needed to validate other research, such as simulation research. In this study, only the main dimensions of the ROV from Surovotic Indonesia were taken, which will be modified with the Waterjet propulsion system.

Table 1. Main Dimensions of ROV Surovotic.

Information	Unit	Dimension
Overall Length	Cm	45,7
Waterline Length (LWL)	Cm	44,32
Breadth ROV (B)	Cm	33,8
Depth ROV (H)	Cm	25,4
Draft ROV (T)	Cm	12,7
Displacement (Δ)	Kg	12
Speed ROV (Vs)	Knot	3

Figure1. Modeling ROV Surovotic Indonesia

b. Modification ROV WaterJet

Model creation and simulation using CAD Inventor, Maxsurf, and Rhinoceros 5.0 applications. and Computational Fluid Dynamics (CFD). WaterJet ROV modeling will be simulated to find the total resistance value, contours, speed, and thrust. In Figure 2 will be shown the model of the modified Waterjet ROV seen above, front and side using the CAD Inventor application

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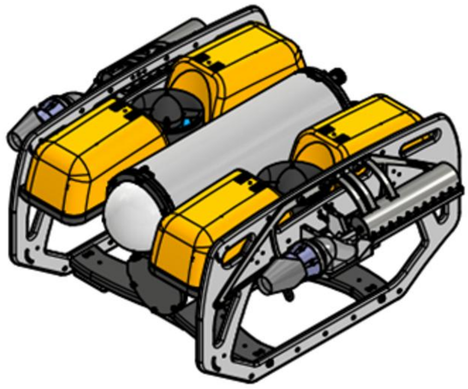

Figure 2. TOP View ROV WaterJet

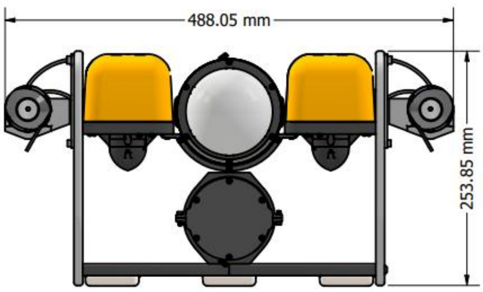

Figure 3. Front View ROV WaterJet

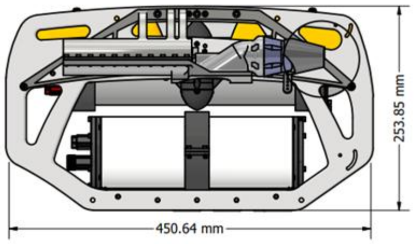

Figure 4. Side View ROV WaterJet

c. *Simulation Method*

The author uses Ansys Fluent Meshing because it provides more detailed meshing controls and is also easy to control. After the model creation process is complete and solid, the next step is to carry out the flow simulation process on the model using CFD simulation with software where anys. The purpose of this simulation is to determine the ship's resistance, flow pattern, speed contours, and thrust on the WaterJet ROV.

a. Geometry

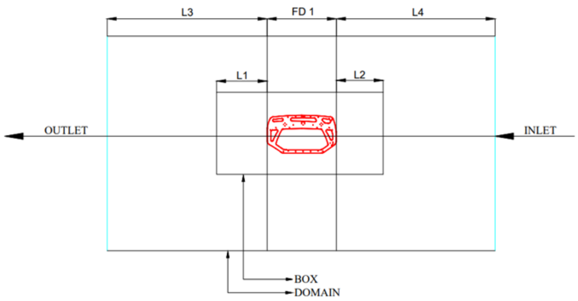

Figure 5. Geometry stage modelling ROV WaterJet speed 3 knots.

For pool dimensions used on ROV with WaterJet Propulsion System can be seen as follows (ITTC, 2011):

L1: length from stern to rear side of box
= 2,5 x ship length
= 2,5 x 45,7
= 114,25 cm = 1142,5 mm

L2: length from bow to front side of box
= 2,5 x ship length
= 2,5 x 45,7
= 1142,5 mm

L3: length from stern to the back side of the domain
= 3 x ship length
= 3 x 45,7
= 137,1 = 1371 mm

L4: Length from bow to front side of domain
= 4 x ship lenth
= 4 x 45,7
= 182,8 cm = 1828 mm

FD1: ROV length from stern to bow
= 1 x ship length
= 1 x 45,7
= 45,7 = 457 mm

b. Meshing

The meshing process is the arrangement of components into small elements to determine the character of a ship shape to be analyzed. At this meshing stage, restrictions such as inlets, outlets, walls, and non-hulls are also added. Inlet is defined as the direction of entry of fluid flow, outlet is defined as the direction in and out of fluid flow, wall is defined as the right and left side pool boundaries, and non-hull is defined as the frame of the ROV Waterjet ship that affects fluid flow.

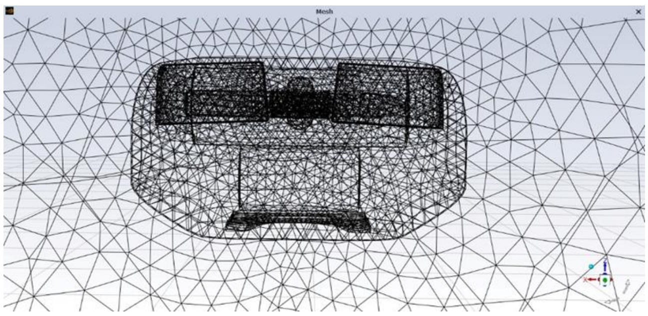

Figure 6. Meshing Stage modeling ROV WaterJet speed 3 knots.

Independent grid test to check the quality of mesh simulation is evaluated by cell slope. Table 2 show the result of the quality of skewness mesh obtained.

Table2. Meshing slope results

Information	Result
Body Sizing	0,1 m
Skewness Quality Sizing	0.55151257 mm
Element	1123912
Meshing type	Hexcore

c. Set Up

The set up process is one of the stages that must be passed in a computational fluid dynamic simulation. Where in the set up process is a setting of parameters that include success in simulation. Here are the set up parameters for the ROV with the waterjet propulsion system with speed 3 knot.

Table 3. Parameters seu up ROV system propulsion waterjet 3 Knot

GPU Type Gravity	none steady Pressure-Based Z = -9,81 m/s^2
Models	
Viscous Multiphase Phase 1 Phase 2	k-epsilon (2 eqn), SST off air Water liquid
Boundary conditions	
Inlet Multiphase	
Bottom level Velocity magnitude	-0.91 1,543 m/s atau 3 knots
Outlet Multiphase	
Bottom level Monitor Initialization Open channel	-0.91 drag force, delta time, iterations per-timestep, flow time hybrid initialization none
Run calculation	
Timescale factor Number of iterations	0,1 1000

Here is a picture of the ROV set-up process with a Waterjet propulsion system with a speed of 3 knots.

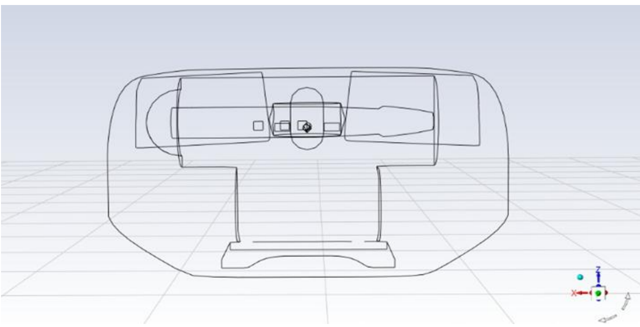

Figure 7. Set up the Stage ROV with a propulsion system waterjet.

d. Result

The solution process is a process after the setup process is complete. The result of the solution process can be seen in Figure 8, which is a graph with the x-axis showing iteration and the y-axis showing drag (n). From the results of the simulation graph shows 1000 iterations as follow

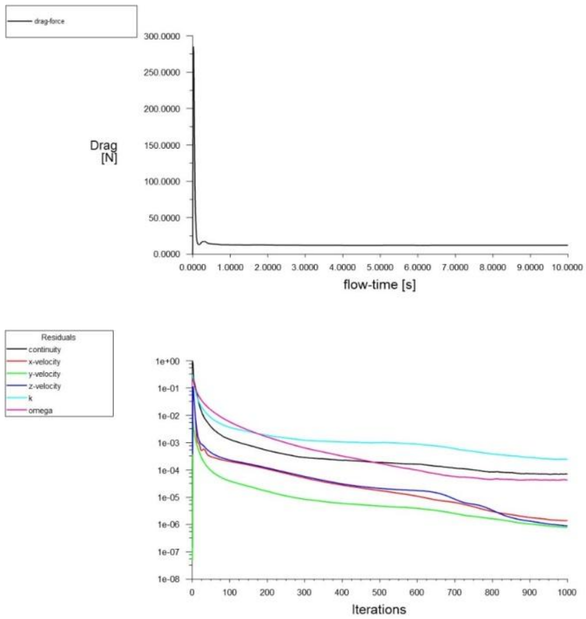

Figure 8. ROV Graphic result with waterjet propulsion system.

Result and Discussion

a. *Simulation Results*

The results of the simulation of the WaterJet ROV model based on the results of analysis using Computational Fluid Dynamic (CFD) software at a speed of 3 knots or 1.543 m/s get a total resistance value of 5.69 N. in this model the flow pattern shows laminar flow because the manual reynold number calculation value shows 7,715 x 10^5. The highest thrust yield with a service speed of 3 knots on the WaterJet ROV model is 9.21 N and the lowest thrust result with a service speed of 3 knots on the Conventional Propeller ROV model is 6.94 N.

Table 4. Simulation result of both ROV models using CFD

Kind	Calculation Result Resistance (N)	Calculation Result Thrust (N)
ROV Propeller Konvensional	4,29 N	6,94 N
ROV Waterjet	5,69 N	9,21 N

b. Flow *Patterns* ROV

The following is the result of the ROV flow pattern representing velocity using streamlined velocity flow in the water phase. In Figure 9 can be seen that the direction of fluid flow can be laminar, and that ROV undergoes laminar flow can be seen by the calculation of the Reynolds number (Rn) below.

For external flows in the ROV frame or hull, the magnitude of the Reynolds number is as follows (USNA, 2002):

- Flow laminar: Rn < 5 x 10^5
- Flow turbulen: Rn > 1 x 10^6
- Transition to laminar to flow turbulen: 5 x 10^5 < Rn < 1 x 10^6

$$Rn = \frac{Lwl \; x \; Vs}{\nu} \quad (1)$$

Where:
LWL = Ship length
Vs = Speed ship (m^2/s)
ν = viscosity kinematik (1,188 x 10^{-6} m^2/s)

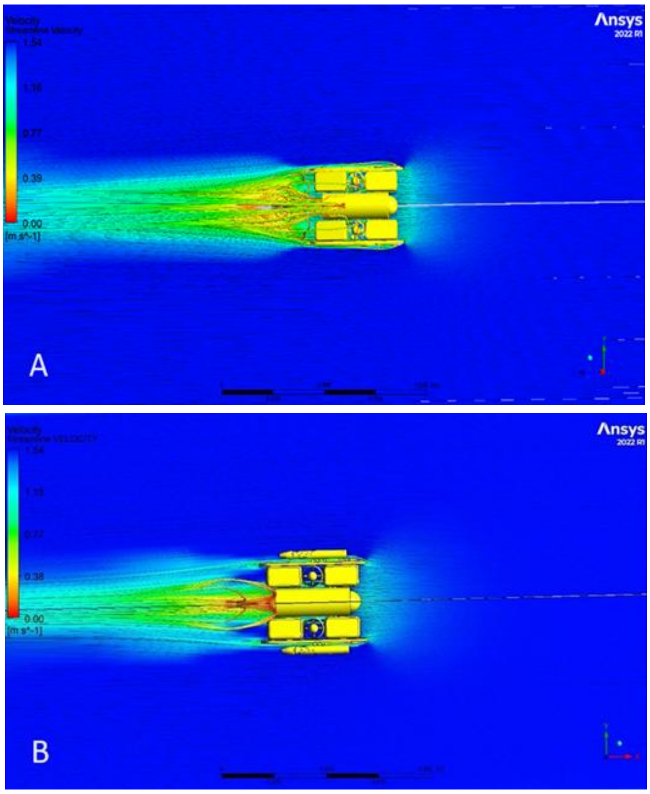

Figure 9. Flow patterns ROV Propeller (A) and Waterjet (B), speed 3 knots.

c. *Speed Contour ROV*

Visualization of the ROV speed of the conventional propeller propulsion system as shown in figure 10 shows the contour of the fluid flow velocity around the ROV at a speed of 1.54 m/s by showing blue and green colors in the outlet area. At the time of inflow, the flow velocity value ranges from 1.16 m/s to 1.54 m/s. It decreases in speed when it hits the ROV frame.

While on the contour of the fluid flow velocity around the ROV in the inlet area by showing green and yellow colors. At the time of inflow, the flow velocity value ranges from 0.77 m/s to 1.15 m/s. It decreases in velocity when it hits the ROV frame. As in Figure 10.

The results of the ROV Water jet analysis of the fluid velocity contour of the two best ROV models, namely the Waterjet ROV, are due to the placement of the waterjet position on the outer side of the ROV part frame. so that the original placement of the propeller inside the inner frame of the ROV is removed. tends not to create more turbulence and friction in the water in the center of the ROV, but the surface of the ROV frame on the outside, to which the waterjet propulsion component is added, causes higher hydrodynamic pressure and greater resistance to fluid flow. The rated speed at the front location of the bow of the ROV Waterjet is 1.15 m/s and 0.77 m/s, while in front of the bow of the ROV Propeller is 1.30 m/s and 1.46 m/s.

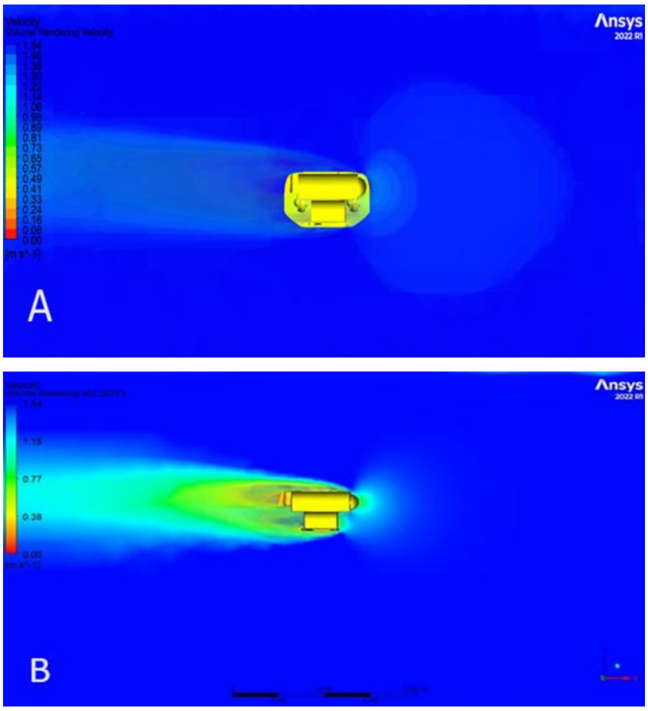

Figure 10. Speed Contour ROV Propeller (A) ROV WaterJet (B) speed 3 knots.

d. Manual Calculation Result

After conducting simulations, there are manual calculations that use algorithms from CFD (Fluent Meshing) to be used as reinforcement of simulation results in determining the total resistance value of the ROV, and there are deep validation results with a maximum error of less than 5% to show the accuracy results. Of course, this manual calculation uses the Harvald method as follows.

- Calculation coefficient of friction (Cf)
  $Cf = \frac{0.075}{(\log Rn-2)^2}$ (2)
- Modeling Ship Correlation Allowance (C_A)
  For the ship with L≤100m, $10^3 C_A$ = 0,4
  So that C_A = 0,4 x 10^{-3} = 0,0004
- Calculation of Viscous Coefficient (C_V)
  $C_V = (1 - k) \times C_F + C_A$ (3)
- Calculation coefficient total resistance (C_T)
  $C_T = C_F + C_A + C_V$ (4)
- West surface area (S)
  S = 1,025 x Lwl (Cb x B + 1,7 x T) (5)
- Calculation resistance total (R_T)

$$R_T = \frac{1}{2}\, \rho\, x\, C_T\, x\, S\, x\, V^2 \quad (6)$$

Where:
ρ = density of seawater (1,025 kg/m3)
C_T = coefficient of total resistance
S = underwater fuselage (m^2)
V = speed flow (m/s)

e. Manual Calculation of Thrust

In manual calculations of thrust using the book of resistance and propulsion of the SV ships. Aa. Harvald 1989 Manual calculations determine the thrust generated by the Waterjet ROV model, including calculations such as advance speed (Va). And the calculation of thrust (T) is as follows:

- Advance Speed Calculation (Va)
  $V_a = V_s \times (1 - w)$ (7)

Where:
V_a = *advance speed*
V_s = Ship Speed m/s
w = Wake fraction = 0.5 x Cb – 0.05

- Thrust (T)
  T = R_T/(1-t) (8)

Where:
T = *Thrust*
R_T = *Resistance*
t = *Thrust deduction factor* (k = 0,7–0,9)
= k x w

Conclusion

The effect of the Waterjet ROV design on the total resistance of the WaterJet ROV increased by 5.69 N, with the previous result of the ROV Propeller model of 4.29 N. The design of the Waterjet ROV on thrust increased by 9.21 N., and the previous result of the ROV Propeller model by 6.94 N; the difference in the thrust ratio of the two models was 32.7%. Therefore, Waterjets produce greater thrust compared to Propellers. In the design of the Waterjet against the contours of the fluid velocity of the two best models, namely the Waterjet, because of the placement of the position of the waterjet on the outer side of the ROV frame. so that the original placement of the propeller inside the inner frame of the ROV is removed. tends not to create more turbulence and friction in the water in the center of the ROV, but the surface of the ROV frame on the outside, to which the waterjet propulsion component is added, causes higher hydrodynamic pressure and greater resistance to fluid flow. The rated speed at the front location of the bow of the ROV Waterjet is 1.15 m/s and 0.77 m/s, while in front of the bow of the ROV Propeller is 1.30 m/s and 1.46 m/s.

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