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Marine Current Numerical Simulation
in the Lembeh Strait, North Sulawesi, Indonesia

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Marine Current Numerical Simulation in the Lembeh Strait, North Sulawesi, Indonesia

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Keywords: Numerical simulation, marine current, RANS model, marine current turbines.

Abstract: This paper presents a numerical simulation to describe the velocities of marine current in the Lembeh strait, North Sulawesi, Indonesia. These velocities were used to make the turbine profile in the marine current turbines. The RANS calculations were performed in its modelling. The turbulence model using the 3D mixing-length model for shallow water flows that the vertical velocities are small. It's found the marine current velocities can be used to design of the marine current turbines in the power plant installation. The power density maximum capacity in the small zone of Lembeh strait by the numerical measurement result is 82.11 kW/m^2 which enable to the power plant installation in the future.

1 INTRODUCTION

The study in the Lembeh strait is conducted (Hadi *et al*, 2015) to observe the relationship between morphological and species diversity of sponges in coral reef ecosystem in the Lembeh Strait and to investigate the most influential factor of habitat on the sponge diversity. The study is not investigated a numerical model and its simulation. Also, in study (Dwinovantyo *et al*, 2017) is only to determine sediment concentration from measured acoustic in the Lembeh strait. Atmojo *et al*. (2017) are conducted experiments and numerical simulations in Lembeh strait. The results are showed that in the Lembeh strait enable to applied farming method of some turbines.

The numerical models and its simulations of marine current are used by researchers to find velocity distributions. The validation of a numerical model is studied by (Rompas *et al*, 2017d) for analyzing kinetic energy potential in the Bangka strait, North Sulawesi, Indonesia. Rompas and Manongko (2016) are studied the numerical simulations of marine currents in the Bunaken strait, North Sulawesi, Indonesia. They study are to get simulations of the velocity and kinetic energy distributions. A numerical model is got by (Rompas *et al*, 2017b) who described the velocity distributions of marine current in the Bangka strait by using RANS (Reynolds-Averaged Navier-Stokes) equations. The approach of a numerical model is conducted (Rompas *et al*, 2017a) to study on marine currents in the Bangka strait, North Sulawesi, Indonesia to plan the marine current power plant. The same study is conducted by (Rompas and Manongko, 2018a; Rompas and Manongko, 2018b) in the Manado bay but (Rompas and Manongko, 2018b) presented on the free surface by numerical modelling. Rompas *et al* (2017c) are designed a numerical model for predicting the velocities and kinetic energies by conditions at low and high tide currents with two discharges of 0.1 and 0.3 Sv, respectively. Study on tidal marine currents has conducted by Martinez *et al*. (2018), Badshah *et al*. (2018), Fraser *et al*. (2018), Bishoge *et al*. (2018), Lust *et al*. (2018), Frost *et al*. (2018), and Dai *et al*. (2018) which explains that marine currents can produce electrical energy through the velocity of marine currents that drive tidal turbines. They are used the models of numerical and experimental. Study on modelling and numerical simulations of marine currents by using CFD (Computational Fluid Dynamics) has investigated by Schuchert *et al*. (2018), Vogel *et al*. (2018), Gong *et al*. (2018), Bonar *et al*. (2018), Nuernberg and Tao (2018), Hachmann *et al*. (2018), Brown *et al*. (2017), Lo

Brutto *et al.* (2016), Malki *et al.* (2014), and Turnock *et al.* (2011).

The objective of the study is to get a numerical simulation of marine current in the Lembeh strait, North Sulawesi, Indonesia for the goal making the turbine profile that used in development of marine current power plant in the Lembeh strait in the future.

2 METHOD

The RANS equations that are deformed by the Navier-Stokes equations after turbulent averaged and assumed the pressure in the depth is hydrostatic (Rompas *et al*, 2017c). The numerical model is used the semi-implicit finite difference to solve 3D with the 3D mixing-length model for shallow water flows that the vertical velocities are small.

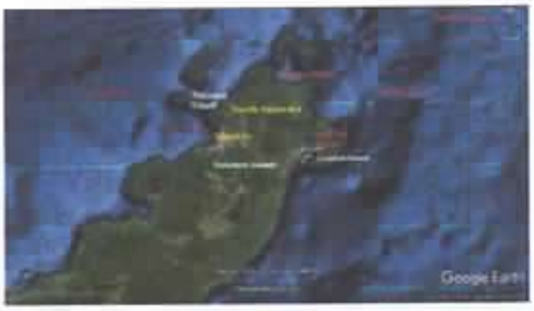

Figure 1: The map of the Lembeh strait

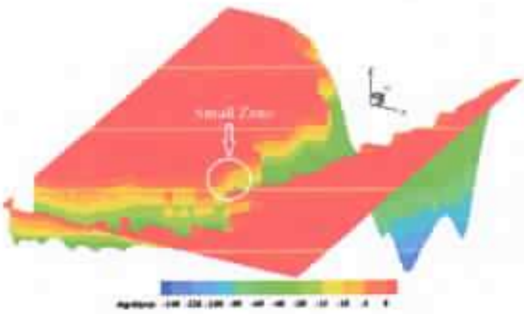

Figure 2: The bathymetry of the Lembeh strait

Figure 1 shows the map of study in the Lembeh strait, Indonesia. The zone of numerical model is located between Lembeh Island and Sulawesi Island on 125°11'15.95"E-125°17'21.98"E and 1°25'47.65"N-1°32'52.29".

Figure 2 shows the bathymetry in the Lembeh strait with the maximum depth of 140 m and at the small zone is average of 15 m depth and width of 550 m.

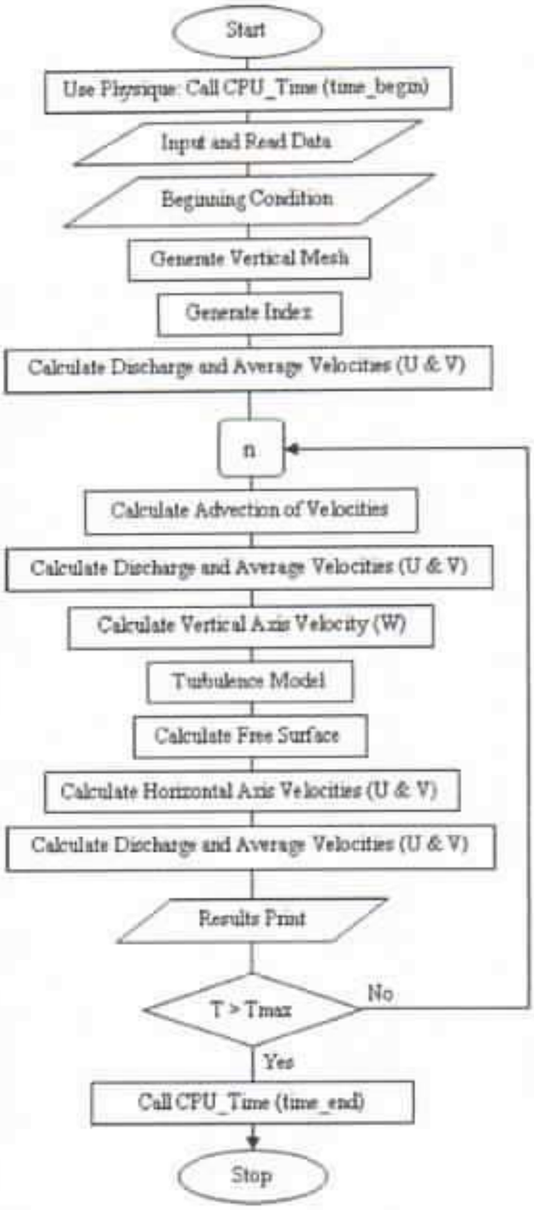

Figure 3: Flowchart of a numerical model

Figure 3 shows steps of a numerical model for the calculation of velocity distributions by using

Fortran 90 application programs. The input and read data is the process to read all data and the calculation of parameters needed for calculation of the velocities in direction axes x, y, and z respectively included maximum time to do iteration that using the all of parameters as explained in Rompas *et al* (2017c). The beginning condition is the all of variable as beginning velocities is zero included calculation to *Tecplot 9* application programs which is an application for simulation. The seawater depths are generated by the vertical mesh using *Argus One* application programs. The layers of vertical axis (depth) are generated by indexing and generating index of boundary layers as denote for deformation of the meshes. The discharge and average velocities are calculated to beginning conditions in calculation the velocities.

The "n" symbol shows the calculation quantity in iteration to do the calculation process until maximum iteration. Determination whether a program can proceed to velocities calculations needed to process of the advection. The using of model turbulence refers to Rompas *et al* (2017a) with 3D mixing-length models. The free surface is calculated by using a linear five-diagonal system to get the seawater surface elevation. In the other hand, the components of velocities (U and V) are calculated by using a linear three-diagonal included for calculating the convective and viscous term, whereas for calculating velocity vertical W used equation in Rompas and Manongko (2018b). Finally, the calculation results as the velocities (U, V, and W) printed to simulations in the *Tecplot 9* application programs. If iteration is not maximum then the process back to "n" to do the process again, and if iteration is maximum then calculation stop.

The velocity distributions are calculated by numerical computational at the conditions of low and high tide currents. The conditions are conducted by Rompas and Manongko (2016), Rompas and Manongko (2018a), and Rompas and Manongko (2018b) in the Manado bay and by Rompas *et al* (2017a), Rompas *et al* (2017b), Rompas *et al* (2017c), and Rompas *et al* (2017d) in the Bangka strait.

Power density of marine current can be calculated by equations (1) and (2) respectively (Rompas *et al*, 2017a).

$$P_d = 0.5 \rho V^3 10^{-3} \qquad (1)$$

where, P_d is power density per cross-sectional area in kW/m^2 and V is the velocity resultant of marine current, $V = \sqrt{\bar{u}^2 + \bar{v}^2 + \bar{w}^2}$, $\bar{u}$, $\bar{v}$, and $\bar{w}$ respectively are scalars (numerical equations), and $\rho = 1024\ kg/m^3$ (at 20 C and salinity of 34).

The results of print which are calculated by numerical then used to process simulation by using *Tecplot 9* application programs. The simulations are resulted 2D-simulated of velocity distributions when low and high tide currents. The results of simulation analyzed by compare to the results of other studies. Then, the results concluded to reveal the conditions of marine current in the Lembeh strait.

3 RESULTS AND DISCUSSION

Figure 4 shows the velocity distributions when low tide currents at discharge of 0.1 Sv (1 Sv = 1000000 m^3/s) (Rompas *et al*, 2017c). The results are showed that velocities in around small zone are different to big zone. That's because flow of marine current is blocked by the small zone. Also, the perpendicular cross-sectional area passed by the current is very small (average of 8250 m^2) compared to the other zone, so that the velocities of current become large. Figure 5 shows the velocity distributions when high tide currents at discharge that same as Figure 4. The higher velocities are showed on the small zone with the perpendicular cross-sectional area is so small.

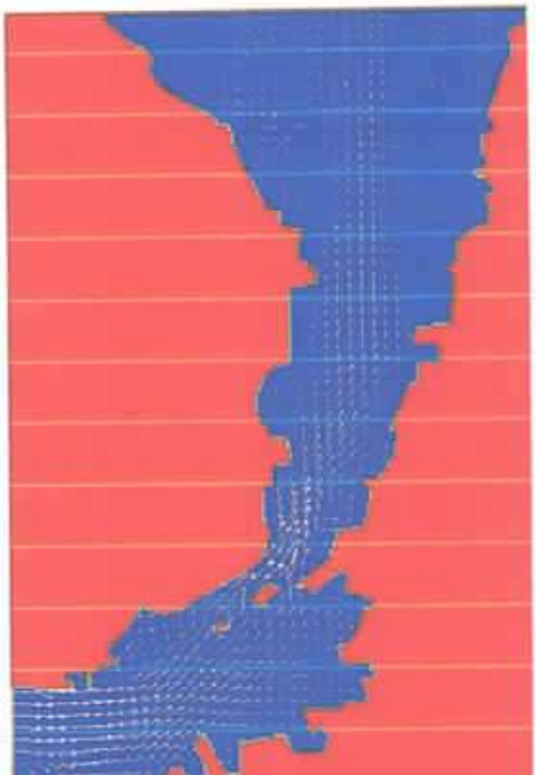

Figure 4: 2D-simulated of velocity distributions when low tide currents

Figure 5: 2D-simulated of velocity distributions when high tide currents

Figure 6 and 7 are show the velocities in around of small zone are varied from 0.00-5.09 m/s (when low tide currents) and when high tide currents of 0.00-4.59 m/s (Figure 8 and Figure 9). Both of when inside and outside the small zone, the velocities are become small and between the small zone become large. The results are greater than Atmojo *et al.* (2017) who study of marine current energy potential in Lembeh strait by using numerical simulations of *software world tide 2009*. Likewise the results from Rompas and Manongko (2016), Rompas *et al.* (2017), and Rompas and Manongko (2018) by using the numerical simulations of *Fortran 90* and *tecplot 9*. The current movement is straight not only before enter the small zone but also after out of the small zone (Figure 7 is enlarged from Figure 6 which is marked with red color rectangle), while in Figure 9 (enlarged from Figure 8 which is marked with red color rectangle), the current moves before enter the small zone with the direction to Northwest and living the small zone to West.

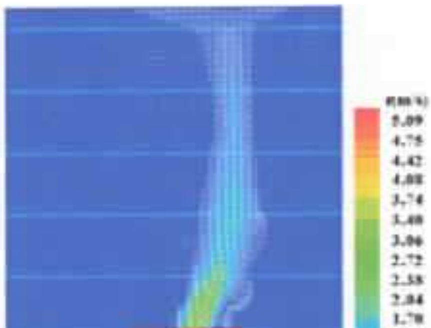

Figure 6: 2D-simulated of velocity value distributions when low tide currents

The average velocity before enter the small zone is 4.00 m/s at the low tide current (Figure 7) and when the high tide current is 4.00 m/s (Figure 9). When the currents living the small zone, the average velocity at low tide currents is 4.50 m/s and when the high tide current of 4.00 m/s.

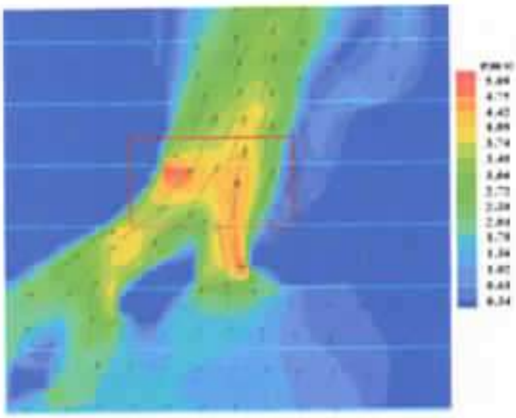

Figure 7: 2D-simulated of velocity distributions when low tide currents in around the maximum velocities

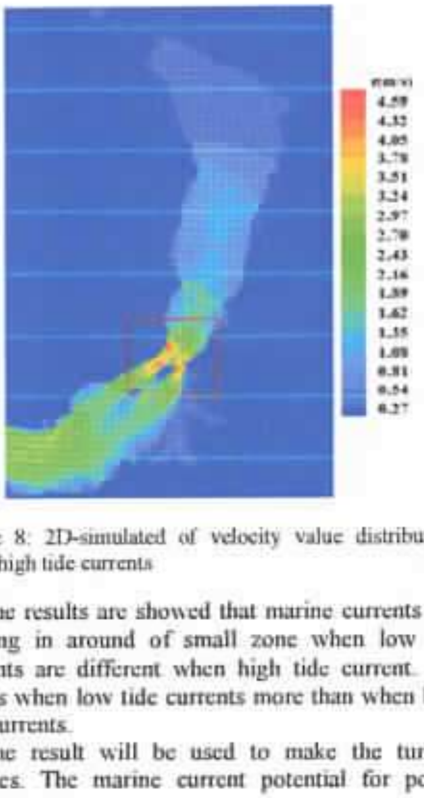

Figure 8: 2D-simulated of velocity value distributions when high tide currents

The results are showed that marine currents that flowing in around of small zone when low tide currents are different when high tide current. The values when low tide currents more than when high tide currents.

The result will be used to make the turbine profiles. The marine current potential for power plant installation is the small zone that the current velocities are biggest (Figures 7 and 9 that showed by the red color rectangle). In this zone, the maximum capacity of power density that installed by farm turbines (Figure 7 shows maximum capacity greater than Figure 9) is 82.11 kW/m^2. The results, if compared by Atmojo *et al.* (2017), Rompas and Manongko (2016), Rompas *et al.* (2017), and Rompas and Manongko (2018) are greater. The results are enabling to develop marine current power plant at the small zone (Figures 7 and 9 in areas the red color rectangle) in the future.

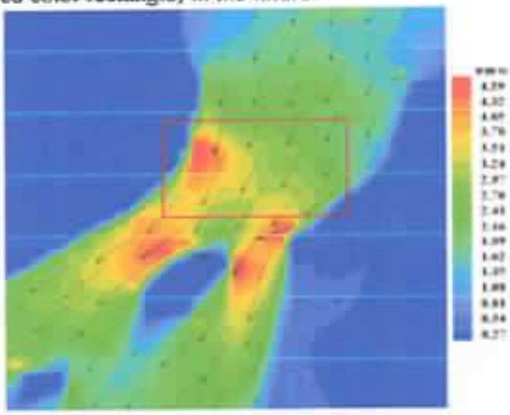

Figure 9: 2D-simulated of velocity distributions when high tide currents in around the maximum velocities

4 CONCLUSIONS

The numerical simulation of marine currents in the Lembeh strait, North Sulawesi, Indonesia was successfully studied. The velocity distributions when low tide currents are different when high tide currents include the values of velocity distributions which the values when low tide currents are bigger than when high tide currents. The values are can be used to design marine current turbines. The capacity of power plant by the numerical measurement is enable to install marine current power plant at the small zone of Lembeh strait, North Sulawesi, Indonesia in the future.

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