PAPER • **OPEN ACCESS**

Simulation sediment transport in development location of a diesel power plant using Computational Fluid Dynamic (CFD) methods

To cite this article: E Yohana *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **623** 012006

Simulation sediment transport in development location of a diesel power plant using Computational Fluid Dynamic (CFD) methods

E Yohana[1], T S Utomo[1], V S Sumardi[1], D A Laksono[1*], K Rozi[1], K H Choi[2]

[1] Departemet of Mechanical Engineering, Faculty of Engineering, Universitas Diponegoro, Jl. Prof. Sudharto, SH., Tembalang-Semarang 50275, Central Java, Indonesia
[2] College of Engineering, Pukyong National University, 365 Sinseon-ro, Nam-gu, Busan 608-739, Korea

dimazaji199@gmail.com

Abstract. Research about Sediment Transport is important for the sustainability of coastal buildings. The infrastructure construction of the Halmahera Diesel Power Plant (PLTD) in the coastal area requires water supply as a cooling system. The supply of cooling water can be reduced because of erosion or sedimentation. This study uses CFD modelling of ANSYS FLUENT applications with variations in mass flow rates. The Eulerian-Lagrangian approach is used to predict the rate of erosion and accretion that occur around the place of Halmahera. Methods of Particle Size Distribution (PSD) numerical simulation is uniform. The simulation process results consist of particle mass, erosion, and accretion rate in the seabed. Variations in mass flow rates of 0.05 kg/s, 0.1 kg/s, 0.15 kg/s, 0.2 kg/s, 0.25 kg/s obtained the erosion rate respectively 5.425 x 10^{-7} mm/year, 1.085 x 10^{-6} mm/year, 1.626 x 10^{-6} mm/year, 2.170 x 10^{-6} mm/year, 2.712 x 10^{-6} mm/year. The result of the accretion rate obtained from the variation in mass flow rates is 301.43 mm/year, 602.87 mm/year, 904.30 mm/year, 1205.50 mm/year, 1507.77 mm/year. From this research. The result of simulation to be important to predict the rate of sediment transport for consideration in the development location of construction Halmahera PLTD.

1. Introduction

A natural process that often happens in the coastal area will have resulted in sediment transport. These conditions will result in accretion and erosion. Sedimentation or erosion across the coastline will have impacted the form of coastal buildings (ex: pier, jetty, wave breaker, groin, artificial sea wall, etc.). Halmahera East Ternate island is a specified location for Diesel Power Plant Construction (PLTD). The diesel power plant is usually used for fulfilling the electric in low capacity, new isolated place, village, and industrial needs. The diesel power plant needs a huge water consumption for its cooling system. The lack of water needs for cooling system because of sediment transport, will prevent diesel power plant to work properly [1]. The research uses the data from the temporal change of shoreline that needs expensive cost and longtime research so that simulation needed to be efficient processes [2].

Research about sediment transport conducted by Javaherci and Aliseda (2017) used Discrete Random Walk (DRW) method on simulation to obtain sediment transport rate which marine hydrokinetic turbine effect [3]. The result shows a simulation with stokes number equal to 1 that the particles went through the wake's core were centrifuged out by the particle rotation. The strong sediment suspension localized under vortices that reach the bed [4]. This simulation uses the Discrete Particle Model to develops simulation in inner surf and swash zones. The particles' influence on the fluid phase is higher when the particle size and volume fraction increases [5]. This simulation was conducted with the Discrete Phase Model (DPM) for sedimentation tanks.

Therefore, as a preliminary study, the model sediment transport coastal building location of the diesel power plant will use Ansys fluent software. This modelling aims to determine the rate, direction, amount of sediment transport in the development location construction of Halmahera Diesel Power Plant.

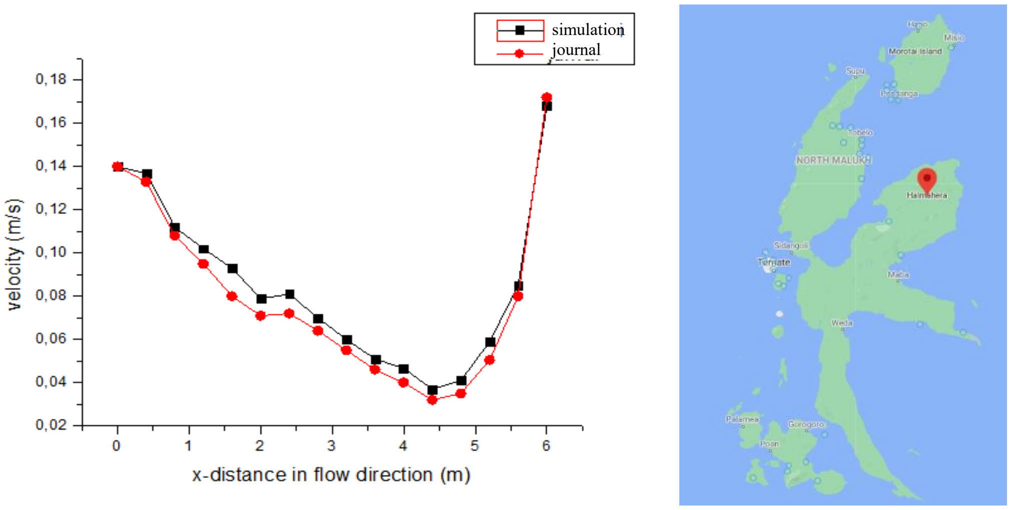
2. Methodology

2.1 Validation

Validation 3D simulation is used to determine the suitable method with real-time conditions. Validation based on Terpagkou and Pantokratoras (2013) analyzed the effect of the secondary phase (solid particle) to the primary phase (fluid) that happens in a sedimentation tank using the lagrangian DPM (Discrete Phase Model) method. The result of the simulation has been compared with the result of the journal validation maximum 14.63% error value [5]. Journal validation is shown in figure 1.

2.2 Modelling area

This erosion and accretion rate modelling area is located in Halmahera, North Maluku, geographically located at coordinates 00º41'46.6 "N - 127º32'57.7" E. Modelling area is shown in figure 1.



(a) (b)

Figure 1. (a) Jurnal validation, (b) modelling area.

2.3 Governing equation

The governing equation used to solve the multiphase flow between solid-liquid is the momentum, continuity and erosion-accretion equation [6]:

Continuity equation:

$$\frac{\partial \rho f}{\partial t} + \vec{V}.\left(\rho_f v_f\right) = 0 \quad (1)$$

Momentum equation:

$$\frac{\partial \rho_f v_f}{\partial t} + \vec{V}\left(\rho_f v_f v_f\right) = -\vec{V} + \vec{V}\,.\left[\mu\left(\vec{V}_{v_f} + \vec{V}_{v_f}^{T}\right)\right] + \rho_{fg} \quad (2)$$

Erosion rate and accretion equation:

$$ER = \sum_{p=1}^{N} \frac{\dot{m}_p C(d_p) f(\alpha) v_p{}^{b(v)}}{A_{face}} \quad (3)$$

$$R_{accretion} = \sum_{p=1}^{N} \frac{\dot{m}_p}{A_{face}} \quad (4)$$

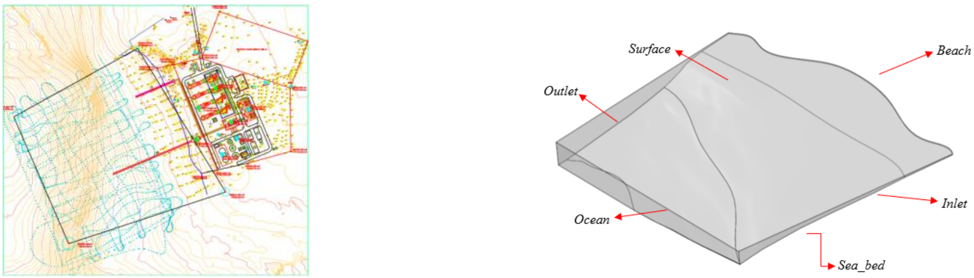
The particle flow rate and velocity are represented by $\dot{m}_p$ and v_p. The term *f (a)*, *b (v)*, and *C*(d_p) respectively shown the function of impact angle, particle relative velocity and particle diameter. A_f represents the shell face area along the wall.

2.4 Model input data and scenario

2.4.1 Bathymetry. The bathymetry map illustrates the depths of the sea and the land boundaries. The depth-sea value that has been modelled is 0-28 meters. The bathymetry map used as a reference is computational domain geometry. The boundary conditions of the computational domain model on bathymetry maps are 267 x 293 meters.

2.4.2 Ocean current. Halmahera's ocean currents are the result of field measurements carried out in November 2017. From the results of measurements for 3 x 24 hours, it was found that the current was dominated by non-tidal currents, where the current direction was dominated towards the north from the south-southeast direction. The current value ranges between 0-0.55 m/s with a maximum amount located at a depth of 2 meters. The current data used in the simulation is north direction current with a maximum current value of 0.4 m/s.

2.4.3 Geometry making. Geometry modelling was made using Solidwork based on the 267 x 293 x 28 meter bathymetry map of Halmahera's waters. Water and sand enter from the inlet at the same speed, while the particle mass flow rate is varied. The regional boundaries (domains) taken from the research of Terpagkou and Pantokratoras [5] can be seen in figure 2 below.



(a) (b)

Figure 2. (a) Modelling bathymetry map, (b) computational domain.

2.4.4 Simulation operation boundary conditions. Boundary conditions used in the erosion and accretion simulation rate refer to the validation of the journal Terpagkou and Pantokratoras (2013). Parameters for simulated boundary conditions can be seen in table 1 [7].

Table 1. Parameters of boundary condition modelling of erosion rate and accretion.

Parameter	Value
Computational Domain	297 x 293 x 8 m
General Setting	a. Pressure-Based b. Steady
Flow Models	a. Turbulent k-epsilon Realizable b. Discrete Phase Model

Parameter	Value
Material	a. Water liquid b. Solid Particle
Boundary Conditions	a. Inlet & Ocean: Velocity Inlet b. Outlet: Outflow c. Surface: Symmetry d. Sea_bed & Pantai: Wall

2.4.5 Defining material. The fluid used is water, while the solid phase uses sand particles by Terpagkou and Pantokratoras (2013) research with properties as shown in table 2.

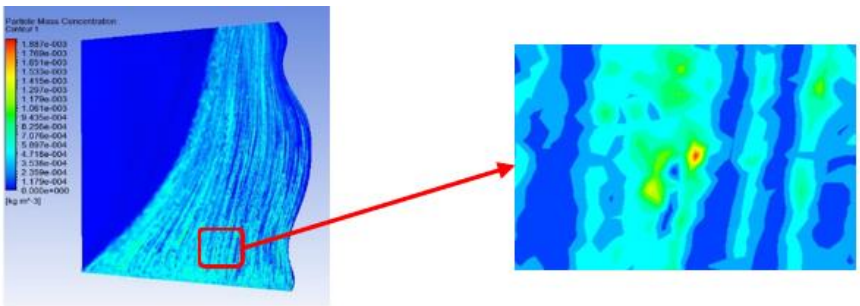
Table 2. Material properties.

Material properties	Value	Unit
Seawater density	1025	kg/m^3
The density of sand particles	2650	kg/m^3
Water viscosity	0.001003	Ns/m^2
Particle diameter	0.05	mm
Velocity	0.4	m/s

3. Result and discussion

3.1 The contour of sediment concentration

In figure 3 shows the particle mass concentration contour explains the pattern of sediment distribution in Halmahera waters, which is dominated towards the north according to the data from the analysis condition of Halmahera waters in 2017. The sediment concentration in the area around the inlet is higher compared to the surrounding area outlet. This is because the particle velocity in the inlet vicinity is slowers than the particle velocity in the outlet as in the study of Yudhatama, et al. (2018) [8].



(a) (b)

Figure 3. (a) Contour of particle mass concentration, (b) enlargement of the highest value of particle mass concentration.

3.2 Erosion and accretion rate contours

Figure 4 and figure 5 indicate the direction of the spread of erosion rate and accretion rate. In this simulation the variation of particle mass flow rate is 0.05 kg/s, 0.1 kg/s, 0.15 kg/s, 0.2 kg/s, and 0.25 kg/s with input speed equal 0.4 m/s. The particle mass flow rate is the number of particles that can be moved in one second. The more particles injected, the higher the concentration of particles in the water flow, making the frequency of particles collide with the seabed wall. The worst erosion and accretion occurred when the particle mass flow rate was the highest value of 0.25 kg/s. The fluent simulation shows the same contour on each particle variable, in the form of erosion and accretion points due to sand particles' collision after crossing the seabed wall.

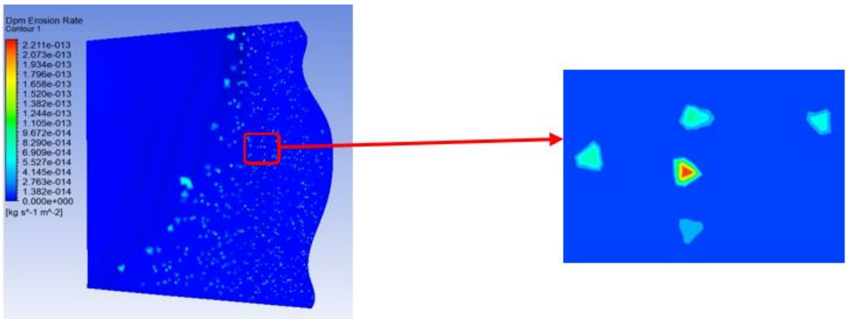


Figure 4. The contour of erosion rate.

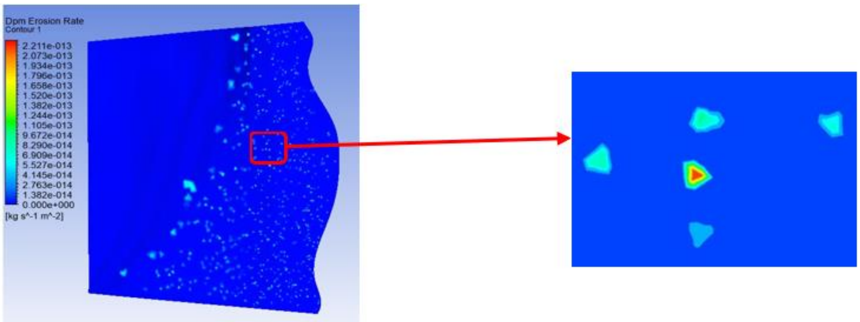


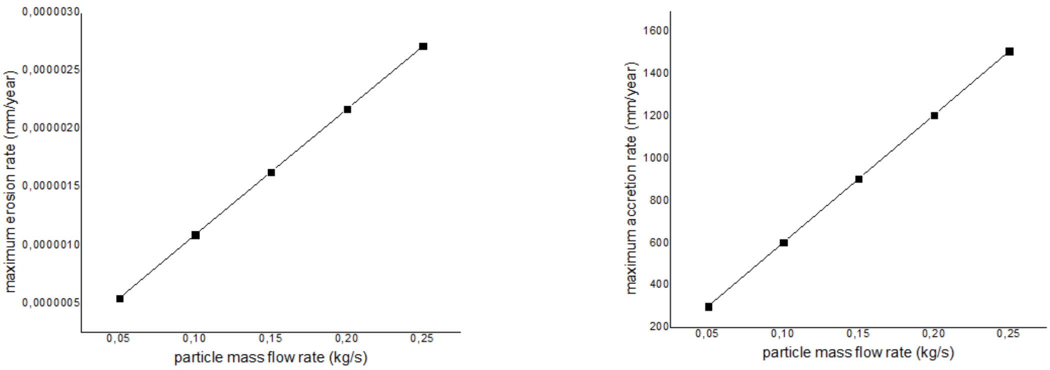
Figure 5. The contour of accretion rate.

3.3 Conversion of erosion and accretion rate units

Based on the simulation results of the rate of erosion and accretion with variations in particle mass flow rates obtained. The unit results of the simulation of the rate of erosion and accretion are kg/m^2.s. This value will be converted into mm/year units to predict the rate of erosion and accretion that occurs around Halmahera waters within one year [9].

$$ER\ /\ R_{accretion}\left(\frac{mm}{tahun}\right) = \frac{ER\left(\frac{kg}{m^2 s}\right)}{\rho\left(\frac{kg}{m^3}\right)}\ x\ 1000\ \left(\frac{mm}{m}\right)\ x\ 3600\left(\frac{s}{hr}\right)\ x\ 24\ \left(\frac{hr}{day}\right)\ x\ 365\left(\frac{day}{year}\right)$$

The results of the conversion of erosion rate units and maximum accretion based on variations in particle mass flow rates can be seen in figure 6.



(a) (b)

Figure 6. (a) The graph of the relationship between particle mass flow rate and erosion rate, (b) the graph of the relationship between the mass flow rate of a particle to the rate of accretion.

Figure 6 illustrates the relationship between the particle mass flow rate with the rate of erosion and accretion is directly proportional. It can be concluded that the higher the particle mass flow rate, the greater the rate of erosion and accretion. Increased particle mass flow affects the rate of erosion and accretion to increase. It can be seen that the rate of erosion and accretion in the graph where the highest particle mass flow rate of 0.25 kg/s results in the highest rate of erosion and accretion.

When the particle mass flow rate is high enough, the particle mass flow rate will approach the fluid's velocity. The worst erosion and accretion occurred when the particle mass flow rate was of the highest value of 0.25 kg/s. A small increase in the particle mass flow rate can result in a considerable increase in the rate of erosion and accretion [10]. The graph in figure 6 has the same graph trend as Kusuma and Utomo (2014) research.

4. Conclusion

The model of sediment distribution pattern in Halmahera waters is predominantly headed north in accordance with the data from the analysis of the condition of Halmahera waters in 2017. The result of this simulation predicts the amount of sediment transport in the location of the construction Halmahera diesel power plant. Sediment concentrations in the area around the inlet are higher than the area around the outlet. With different particle mass flow rates of 0.05 kg/s, 0.1 kg/s, 0.15 kg/s, 0.2 kg/s, 0.25 kg/s obtained an erosion rate of $5.425x10^{-7}$ mm/year, $1.085x10^{-6}$ mm/year, $1.626x10^{-6}$ mm/year, $2.170x10^{-6}$ mm/year, $2.712x10^{-6}$ mm/year. The accretion rate obtained from the particle mass flow rate variation is 301.43 mm/year, 602.87 mm/year, 904.30 mm/year, 1205.50 mm/year, 1507.77 mm/year. By the data, we know that amount of particle mass flow rate is linear to the amount of erosion and accretion rate caused by sediment transport. Predicting the amount of sediment transport in Halmahera can be used to consider the development location of the construction Halmahera Diesel Power Plant to work properly.

Acknowledgment

We are grateful for the financial support from Diponegoro University. The author would like to thank Mrs. Eflita Yohana for his support and encouragement.

References

[1] Susiati H and Mellawati J 2013 *Journal of Nuclear Energy Development* **15** (1) p 56
[2] Latief H 2002 *Oceanography Beach* (Bandung: Bandung Institute of Technology)
[3] Javaherci T and Aliseda A 2017 *Ocean Eng.* **129** pp 529-537
[4] Calantoni J, Puleo J A and Holland K T 2006 *Cont Self Ref* **26** pp 610-621
[5] Tarpagkou R and Pantokratoras A 2013 *Appl. Math. Model* **37** (5) pp 3478–94
[6] Kannojiya V, Darshan M B and Chandra Y P 2018 *Arch. Mech. Eng.* **65** (3) pp 361-78
[7] ANSYS 2017 *ANSYS Fluent Theory Guide* (Pennsylvania: SAS IP Inc.)
[8] Yudhatama I W, Hidayat M I P and Jatimurti W 2018 *J. Eng. ITS* **7** (2) pp B134-139
[9] Mohyaldinn M, Noaman E and Ismail M 2011 *Evaluation of Different Modelling Methods Used for Erosion Prediction* (Malaysia: Universiti Teknologi Petronas Mechanical Engineering Department)
[10] Kusuma H D and Utomo T S 2014 *Jurnal Rotasi* **2** (4) pp 488-95