On the Numerical Simulation of Particle Flows within a Deep-Sea Mining Application

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ABSTRACT

Urbanization, energy transition, transportation and digitalisation are just some examples leading to an increased demand in valuable raw materials like copper, cobalt, rare earth and trace metals. For example, emerging technologies with a high growth potential relying on copper are power grid expansion, electrical engines, wind turbines and solid-state batteries [1]. In these branches the demand of copper is expected to more than double until 2035.

In the deep-sea with depths of around 1000-4000 m, major deposits of rare mineral in the form of massive sulphides are found locally limited primarily to tectonic zones and fault lines. The Deep Sea Sampling research project aims for a vertical, minimal invasive pilot mining test of massive sulphide ores. Due to the given deep-sea boundary conditions experimental verification and validation of the mining device and subcomponents under realistic conditions remains hardly possible. This gives rise to the usage of numerical methods to test and validate components of the mining device or even to come up with a model digital twin of the entire setup to assure the functionality during the costly and complex pilot mining test in deep-sea conditions.

Within this contribution the particle-laden flow from the milling region to the separation containment is considered. The multiphase flow is predicted via a Volume of Fluid (VOF) approach together with the Euler-Lagrange strategy to couple both phases by making use of commercial software packages (Siemens Star-CCM+, Ansys Fluent). Basing on the Stokes number and the feed volume fraction one- or two-way coupling between the fluid field and the particle field is considered.

For the prediction of the particle intake from the milling slot into the mining device and the estimation of the separation behaviour inside the separation unit the forces acting on the individual particles are of vital importance. Here, in particular the drag force plays an important role whereas the drag depends on the shape of the particles. This poses a challenge for the desired investigations since real particle probes from the deep-sea with characteristic shapes are not available. Instead, particles from model materials resulting from reference milling tests are considered here. The drag coefficients are estimated from the relation of Haider and Levenspiel [2] as a function of the sphericity. The sphericity range of the model particles is estimated prior to the simulations. The prescribed approach is benchmarked against experimental investigations conducted on a test rig designed to mimic the particle transport within the real system. Basing on this, numerical results on the intake behaviour of the multiphase flow into the mining device, inside the separation containment and the resulting separation efficiency which will be presented. An intermediate conclusion on the simulation strategy and the preliminary design of the mining device will be given.

REFERENCES

[1] F. Marscheider-Weidemann et al., *Raw materials for emerging technologies 2021 – A commissioned study*, DERA Rohstoffinformationen 50, Berlin, 2021.

[2] A. Haider and O. Levenspiel, “Drag Coefficient and Terminal Velocity of Spherical and Nonspherical Particles”, *Powder Technology*, Vol. 58, pp. 63-70, (1989).