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FULL-SCALE EXPERIMENTS ON A COANDĂ-EFFECT-BASED POLYMETALLIC-NODULE COLLECTOR

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Polymetallic nodules are potato-sized rock accretions that form on vast areas of the abyssal plains of the global ocean. These nodules are rich in commercially precious metals, such as nickel, cobalt and copper, making them a target for potential future deep-sea exploitation. Generally, polymetallic nodules are partially buried in the seabed sediment, which is predominantly composed of clay. Among the existing mechanisms for mining polymetallic nodules (mechanical, hydraulic and hybrid), hydraulic collecting is deemed the most suitable technology in deep sea mining. This is primarily because hydraulic collecting hardly involves interaction with the seabed during the collection process (Agarwal et al., 2012); the collector generates a pressure gradient to harvest the nodules, thus substantially reducing the associated disturbance to the seabed.

The main aim of this study is to develop a hydraulic collector head with an optimal pick-up efficiency while preserving a minimal environmental disturbance. To this end, an insightful understanding of the underlying physical processes of the hydraulic collection mechanism is required. Our philosophy is to minimize the water flow during the collection process for two particular reasons. Firstly, flow rate is directly connected with the power needed for the water pumps and the corresponding costs are correlated. Secondly, water flow near the seabed induces a sediment plume and the extent of which must be reduced as much as possible to minimize the resulting environmental impact.

We present an effective design of a hydraulic collector head, which principally depends on the Coandă effect in picking-up nodules. Coandă effect can be defined as the propensity of a jet flow to adhere to a neighboring surface even if the surface curves. According to Yue et al. (2021), Coandă-effect-based collection is the most promising technique in respect of the pick-up efficiency and seabed disturbance. We tested our design in a series of novel full-scale experiments, which yielded deep insights into the collection efficiency of the collector under different operational conditions and verified its functionality and effectiveness. The latter means, in the field of deep sea mining, high pick-up efficiency and minimum disturbance to the seabed. Figure 1 shows a real view of the tested collector and the sand bed into which the tested nodules were partially buried. During the experiments, local measurements of flow rate, flow pressure, flow velocity and particle concentration were obtained. These measurements were utilized to analyze and investigate the effect of the jet velocity, collector's forward velocity, bottom clearance and bed type on the pick-up efficiency of the collector.

The experimental observations suggest that our collector barely disturbs the seabed sediment. It is also found that a higher jet velocity leads to a higher pick-up efficiency. Two forward velocities were tested and the higher forward velocity led to a lower pick-up efficiency. The results indicate that the available time for the nodules to respond to the pressure gradient under the collector is of great relevance; if the available time is not sufficient, the nodules will not be collected, irrespective of the pressure gradient magnitude. The clearance under the rear cowl of the collection duct is found to play a crucial role in the collection process; a smaller clearance results in a higher pick-up efficiency reaching 100% in a laboratory environment. Besides the useful insights obtained within this study, which pave the way for a more advanced design in the future, our experimental results are critical to examine the validity and reliability of numerical tools utilized for designing such collectors.

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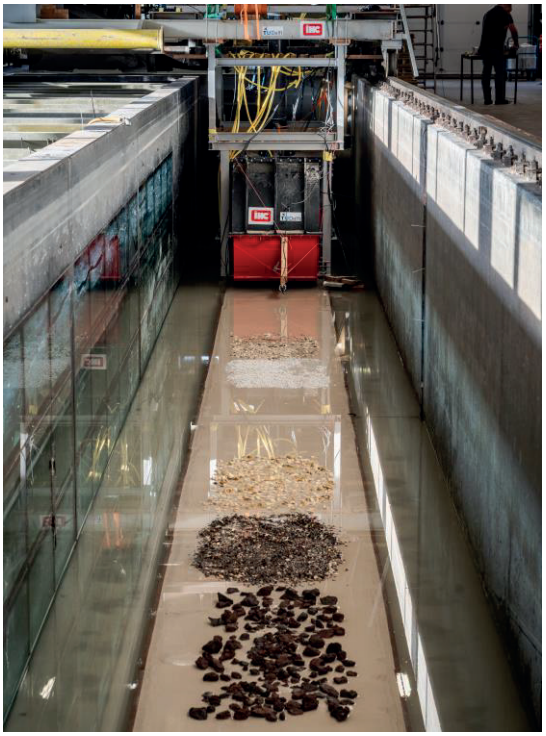

Figure 1. Front view of the hydraulic collector and the sand bed into which the nodules were partially buried

Key words: deep sea mining, polymetallic nodules, nodule pick-up device, hydraulic collector, Coandă effect

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