

A Note on Design and Operation of Waterjet Nodule Lifter of Manganese Nodule Collector

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ABSTRACT

An experimental study on the hydraulic performance of a hybrid pickup device for manganese nodules was conducted in a 2D flume. Based on a series of experiments, the pickup efficiency of the hydraulic lifter has been analyzed, and an operational condition assuring high pickup efficiency has been identified. Fluctuating bottom pressures due to waterjet were measured with varying conditions, and the characteristics of bottom pressure distribution were studied in correlation with the pickup efficiency. The experiment's results provide some guidelines for design and optimal operational condition of the hydraulic lifter of a hybrid pickup device.

INTRODUCTION

The effective collection of manganese nodules out of a sediment surface layer of the deep seafloor is one of the first investigations for an economic and environmentally less disturbing mining operation. A hybrid nodule pickup device has been designed from the concept that direct mechanical disturbance of a deep-seabed environment should be avoided and seafloor sediment be as undisturbed as possible (Oebius, 1993; Amann, 1995; Min et al., 1997). Hong et al. (1997) conducted kinematic analyses of a pickup device motion for the purpose of motion control system design. Hong et al. (1999) carried out a series of experimental studies on the hydraulic performance of the hybrid nodule pickup device. This consists of a hydraulic lifter and a mechanical conveyor. The hydraulic lifter is composed of a pair of waterjet streams and baffle plates. The nodules and sediment fines lifted by waterjets move through the baffle plates to the mechanical conveyor, which transports only the nodules inside the collector by a rotating fin-scraper. The mechanism of the hydraulic lifter is complicated and requires some power, while the principle of the mechanical conveyor is simple and consumes less power. Hence, understanding of the hydraulic lifting mechanism will improve the efficiency of the hybrid pickup device in energy consumption and nodule collection rate.

Fig. 1 shows the experimental setup prepared in a 2D flume. Two kinds of experiments were conducted (Hong et al., 1999): nodule lifting test and bottom pressure measurement. The sediment effects on a nodule lifting were not included in the experiments. A nondimensional parameter, *flowrate ratio*, is correlated with nodule lifting efficiency and optimal operational condition. The experiment's results provided some practical guidelines for the enhancement of design parameters.

NONDIMENSIONAL PARAMETERS OF WATERJET NODULE LIFTING EFFICIENCY

Dimensional analysis of the nodule lifting process illustrated in Fig. 2 provides the following relationship between the vertical lifting height of nodules and 4 nondimensional parameters:

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$$\frac{y_m}{D_m} = F\left(\frac{\rho_m}{\rho_f}, \frac{v_f}{\sqrt{gD_m}}, \frac{\rho_f v_f D_m}{\mu_f}, \frac{D_m}{v_f} \frac{dv_f}{dy}\right) \quad (1)$$

where y_m = vertical lifting height; D_m = a characteristic length of nodules; ρ_m and ρ_f = average mass density of nodule and water, respectively; g = gravitational acceleration; v_f = water velocity; and μ_f = the dynamic viscosity of water.

Under the assumption that the width of the pickup device and the geometry of the hydraulic lifter are predetermined, and the bottom surface is rigid, the nondimensional parameters involved with nodule pickup efficiency can be derived as follows:

$$\eta_p = \frac{\dot{m}}{m_g U_a} = F\left(\frac{\rho_m}{\rho_f}, \frac{U_a L_m}{v_f}, \frac{U_a}{\sqrt{g L_m}}, \frac{D_m}{L_m}, \frac{V_{jet}}{U_a}, \frac{h}{L_m}, \frac{D_{nozzle}}{L_m}\right) \quad (2)$$

where $L_m = \sqrt{m_g/\rho_m}$ = a characteristic length describing nodule abundance; m_g = mass of nodules per unit length in the forward direction distributed across the pickup width; V_{jet} and U_a = waterjet velocity and forward speed, respectively; v_f = kinematic viscosity of water; h = vertical gap between waterjet nozzles and bottom surface; and \dot{m} = nodule pickup rate.

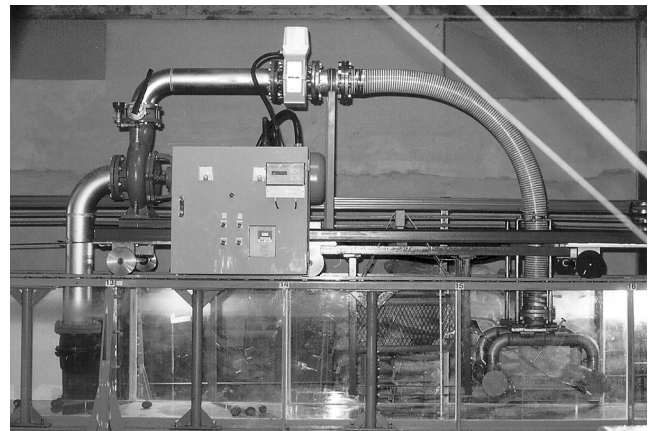


Fig. 1 Experiment setup of hydraulic nodule lifter model