Experimental Investigation on Characteristics of Flow Field in ‘Suck-up-based’ and ‘Coandă-Effect-based’ nodule pick-up devices

Jingchao Hu, Guocheng Zhao, Longfei Xiao, Mingyue Liu
State Key Laboratory of Ocean Engineering, Shanghai Jiao Tong University.
Collaborative Innovation Center for Advanced Ship and Deep-Sea Exploration.
Shanghai, China

ABSTRACT

Being one of the most challenging technologies in deep sea mining system, nodules collecting process near seabed is paid great attention because it will directly influence the collecting efficiency and seafloor disturbance. Two models of nodule pick-up devices, namely suck-up-based model and Coandă-effect-based model are investigated with focus on the nodules collecting flow field with and without the sphere. The flow field information near the nodule pick-up device is measured by using particle image velocimetry (PIV) system. Velocity vectors, streamlines, and velocity distributions are measured and analyzed to investigate the similarities and differences in collecting flow fields between the two different nodule pick-up devices. The results show that: for suck-up-based model, flow velocity increases exponentially with the distance to the bottom $h$ in vertical direction in a certain area; for Coandă-effect-based model, three regions can be divided to describe the changes of velocity along the horizontal direction according to the average value and amplitude of variation. For both models, the velocity value near the bottom is relatively small and this will be beneficial in minimizing the sediment disruptions. This study is expected to be useful for further understanding the mechanism of nodules collecting based on ‘suck-up’ and ‘Coandă-effect’ and provide references for the assessment of the impact on the seafloor environment and optimal design of nodule pick-up devices.

KEY WORDS: Particle image velocimetry; Deep-sea mining; Nodule pick-up device; Flow velocity distribution.

INTRODUCTION

With the continuous development of human society, consumption of earth’s mineral resources is bound to increase. As the basis of industrial development, mineral resources have been gradually exhausted, which drives people to look to the vast and deep ocean. The ocean covers more than 70% of the earth's surface area and contains countless precious resources. Among them, polymetallic nodules, cobalt-rich crusts and polymetallic sulfides have huge reserves. Those mineral resources are widely distributed in areas such as the abyssal plain with a depth of 3,000 m to 5,000 m (Chung, 1994). If they can be rationally exploited and utilized, the shortage of terrestrial mineral resources will be alleviated to a great extent.

In 1982, the United Nations convention established the International Seabed Authority (ISA) to organize and control activities and resources in seabed areas on behalf of mankind. The first batch of mining licenses is expected to be issued in 2021. According to results of exploration, in the sea floor southeast of Hawaii (the eastern Pacific c-c zones), there are a large number of manganese nodules distributions. The nickel and manganese content reached 390 million tons and 8.6 billion tons, respectively, compared with the earth's manganese content of only 630 million tons. Many countries and companies around the world have placed the impetus on developing the deep-sea mining technologies for commercial exploitation of manganese nodules.

The deep-sea mining system is mainly composed of three parts: sub-system of seabed gathering, relay transportation system and surface mother ship support system (Handschuh et al., 2001). Among them, the sub-system of seabed nodule gathering, which carries out the task of lifting manganese nodules from seabed, is in direct contact with the operating surface, so it has the most important position in the system (Chung, 1996). As a result, the nodule pick-up technology is considered as a big challenge to the deep-sea mining system. A reasonable design of nodule pick-up device can achieve a high collecting efficiency and collecting rate as well as small disturbance to the marine environment. Three kinds of nodules pick-up methods have been adopted in sea trials before, namely mechanical method, hydraulic method and hybrid method. Japan developed single ship rope mining method in 1972, then double ships with continuous rope mining method. France’s underwater shuttle vehicle mining method appeared in 1979. Later, OMCO developed mechanical mining method and water jet mining method was also proposed by Germany and India. As a powerful improvement on the first two mining method, hydraulic mining method avoids direct contact between components of the mining equipment and the seabed surface, thus greatly reducing the disturbance of mining operations to the seabed.