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The Effects of Vibration Absorbers on the Longitudinal Vibration of a Pipe String in the Deep Sea — Part 2: A Case of Mining Manganese Nodules

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ABSTRACT

In order to reduce the longitudinal vibration of the pipe string for mining manganese nodules in the deep sea, a vibration absorber, composed of a mass, springs and dampers, was attached to two pump modules as well as to the buffer. Then the effect of the absorber on the vibration was analyzed theoretically. The results indicate that the above-mentioned absorber attached only to the buffer could reduce the resonance amplitudes of the buffer and pump modules by almost 50% and the maximum axial stress produced at the top of the pipe string by about 17% in comparison with those pertaining to the buffer with no absorbers. There are the optimum values for the spring constant and mass of the absorber to minimize the axial stress as well as the vibration of the pipe string. Furthermore, the absorber attached to the buffer causes much greater effect on the vibration of the pipe string than that attached to the pump module.

INTRODUCTION

For mining manganese nodules from deep-sea bottoms, a pipe string is needed to connect the mining ship on the sea surface with the miner on the sea floor. Furthermore, in the pump-lift system, the string must be equipped with one or more pump modules for pumping the nodules up to the ship, and with a buffer for regulating the density of nodule-fluid mixture in the pipe string and for stabilizing the mechanical behavior of the string. The pipe string in this system is apt to vibrate longitudinally, laterally and torsionally due to the ship motions. Hence, these vibrations of the string must be analyzed for the design of the above-mentioned mining system.

As mentioned in the previous report (Aso et al., 1991b), the longitudinal vibration is more destructive as far as the strength of the pipe string is concerned, and so it must be controlled as much as possible. Furthermore, it was proved (Aso et al., 1991b) that the vibration absorbers attached to the pump module and buffer were very effective for reducing the longitudinal vibration in the cobalt-crust mining system under 2500-m depth of water.

In this study, first the pump-lift system with the pipe string equipped with two pump modules instead of one pump module in the aforementioned mining system and with a buffer was assumed for mining manganese nodules under 5000-m depth of water, considering the lifting efficiency of the nodules. Next, a vibration absorber, composed of a mass, springs and dampers, was attached to the buffer as well as to the pump modules. Then, the forced longitudinal vibration of the pipe string equipped with those pump modules and buffer was analyzed theoretically by introducing the ship's vertical motion. Finally, the effects of the absorbers on the vibration and the axial stress of the string were studied, and the optimum values for the absorber's elements were determined for minimizing the vibration and axial stress induced in the pipe string.

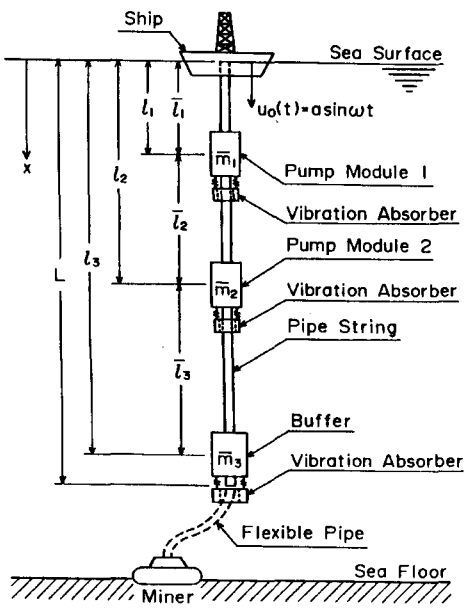

Fig. 1 Analytical model

ANALYSIS

The analytical model of this problems is shown in Fig. 1, in which the vertical pipe string of length, L, equipped with a buffer (mass; $\bar{m}_3$) at its lower end (at $x = l_3$) and two pump modules (mass; $\bar{m}_1$, $\bar{m}_2$) in between (at $x = l_1$, l_2), is suspended from the mining ship on the sea surface and connected to the miner on the sea floor through a flexible pipe. Furthermore, both the pump modules and buffer are equipped with a vibration absorber (Fig. 2). The absorber is composed of a mass ($\bar{m}_4$, $\bar{m}_5$ for pump modules or $\bar{m}_6$ for buffer), springs with the resultant spring constant k_4, k_5 or k_6 (k_4 , k_5 for pump modules or k_6 for buffer) and dampers with the resultant viscous-damping coefficient g_4, g_5 or g_6 (g_4, g_5 for pump modules or g_6 for buffer). Here it is assumed that the top of the pipe string is forced to vibrate vertically in the

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KEY WORDS: Mining manganese nodules, longitudinal vibration, pipe string, buffer, pump modules, vibration control by absorber, amplitude, axial stress, optimum condition of absorber.