Application of Thrusts to Elastic Joints on Long Vertical Pipe in 3-D Nonlinear Motions
-- Part II: Numerical Examples by MSE and FEM Results

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ABSTRACT

In applying external forces or thrust vectors to the elastic joints along a vertical deep-ocean pipe, the joints are modeled in Part I of this paper (Chung and Cheng, 1997) by finite elements (FEM) as well as mass-spring elements (MSE). The MSE can provide greater accuracy for a pipe with a joint and for the application of thrust vector to that joint. The MSE is simpler and more precise than the FEM in modeling the accuracy of the elastic joint, and the accuracy of prediction depends on the configuration and size and mass of the joints. The responses predicted by the FEM for the present examples of joints on an 18,000-ft-long pipe are generally close to the MSE predictions. When the mass and mass moment of inertia of the joints made with nonrigid transverse (x) stiffness are accounted for, however, there are noticeable differences between the MSE and the FEM in the predicted pipe responses and eigenvalues. The differences are pronounced in dynamic biaxial bending (y) and torsional (θ_z) responses, even though both models predict nearly identical static responses. The effects of the thrust vector on pipe responses are more obvious in dynamic than static responses. The thrust activation increases the torsional amplitudes, θ_z, though very small, and can change the bending (x) response periods. The thrust vectors reduce the amplitudes of the axial stress and combined axial and bending stresses. The advantages of the MSE, such as the accuracy of the response predictions, over FEM can be more pronounced for complex pipe systems with larger size and mass of joints.

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Unit conversion: 1 m = 3.182 ft.
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INTRODUCTION

Recently, new researchers in developing deep-ocean mining pipe systems tend to prefer a self-propelled, seafloor miner (or collector) to operate at 4,000-6,000-m depth, that is similar to those of Chung and Chung et al. (1980-1997). Further research on such a self-propelled miner will likely lead to change in the pipe-to-miner connecting systems similar to that of Chung, Whitney and Loden (1980).

For such mining systems (Chung and Tsurusaki, 1994), it is desirable for the designers and operators to explore ways to reduce or control the lateral deflection of a vertical pipe and reduce its axial motion and stress, while keeping to a minimum any interruption to vertical slurry transport or lift (or hoist) flows. Changes in or control of the axial or bending resonance frequencies of the deep-ocean mining pipe are often desired in design and at-sea operations. One of the methods is to change the fundamental axial frequency and deflection of a pipe. Dynamic axial stress of a very long vertical pipe is one of the primary concerns for designers and operators, as was first pointed out by Chung and Whitney (1981). Concepts of installing elastic joints on a marine riser (Caldwell et al., 1976, Orloff et al., 1976, Cheng, and Chung, 1995) were previously tested for the purpose of reducing the bending stress. An articulated marine production system was first developed for petroleum production in California’s Santa Barbara Channel in the ’70s and the ’80s for water depth, an order of magnitude smaller than the present example. For their riser configuration and water depth, the axial stress was not a crucial design parameter. The paper did not present substantiating technical data, and it can only be used as qualitative information.

Hydrodynamic damping greatly influences pipe's deflection and lateral as well as torsional vibration amplitudes. The question on the actual hydrodynamic damping values may remain unanswered and may have to be addressed by the control system design for at-sea operations (Chung, Whitney and Loden, 1980).

In a entire pipe system including the pipe-to-miner link, a pin joins a horizontal or inclined pipe to a long near-vertical lift pipe system and connects to a self-propelling seafloor miner (Fig. 1). It allows greater freedom for the miner to maneuver under the least influence of the pipe motion. Such an articulated pipe system was studied in the late ’70s by an international consortium in the U.S. and considered feasible in practice. This concept can apply to both manganese nodule production from 4,000-6,000-m deep seafloor and cobalt-rich manganese crust production from a 800-2,500-m depth.