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On the Dynamics of Suspended Modules During Deep Water Installation Operations

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ABSTRACT

The paper investigates the problem of installing a subsea module from a single surface vessel in waves. Both lateral and longitudinal excursions of the submerged load are considered, and a variety of numerical examples provided.

Particular emphasis is put on discussing differences arising when the model is extended from in plane, two dimensional motion to include genuine three dimensional motion of the surface vessel and the submerged module.

Features of installation operations related to nonlinear dynamic effects are discussed at some length, and potential pitfalls associated with linearizarion pointed out.

INTRODUCTION

Traditionally, marine operations has to a considerable extent been relying on empirical methods and established procedures. In recent years, however, the industry has been faced with a number of new challenges, among which the most important ones have been a general drive toward deep water and subsea developments. Other aspects that call for more innovative and robust strategies are:

- Increased focuse on areas in cold and/or harsh environemnts
- Increased mobilization time associated with developments far from shore.
- Year round installation and intervention.

High vessel costs and scarcety of adequate vessels may introduce additional challenges both for operators and contractors alike, and makes it highly desireable to identify efficient and robust procedures. One answer to this is to carry out complex numerical simulations well in advance in order to document that the chosen method is safe and otherwise viable under given environmental conditions.

The present paper is highlighting a situation where a sub sea module is installed from a monohull construction vessel, employing a single lifting wire and no guidelines. This is a simple strategy that conceivably might work well as long as the installation tolerance and other requirements are not too tight. The main focus is on the quantification of the lateral excursions of the submerged load, or module. In the numerical examples the dry weight of the module is taken to be approximately 4.7 metric tonnes, and with a volume of 1.17 m^3. Two different water depths (or levels of submergence) are considered; 100.0 m and 1000.0 m. The monohull in question is a construction vessel with diving support and with a displacement of approximately 4,500 tonnes. For the given mass ratio between vessel and load (approximately 1 to 1000) the feed back coupling from the submerged load to the surface vessel is negligible, and has therefore been ignored in the computation of the vessel motions.

2-D SIMULATIONS OF A SUSPENDED MODULE.

One of the more generic situations to be considered is a submerged module suspended from a surface vessel moving in an e.g. combined sway-heave fashion (Fig. 1). Assuming regular waves and predominantly inertia driven forces we may restrict attention to a suspension point following an elliptic orbit. This system was studied in Teigen (1988), and the characteristics of the solution discussed for a system with linear damping.

A further simplification can be achieved by ignoring the damping and allowing a circular motion of the suspension point. Despite the simplification this system is still sufficiently complex to exibit some essential features of the response. Following the notation used in Teigen (1988), in the latter case the resulting equation has the form:

$$(m + m_a)\{l\ddot{\theta} + \omega^2 r \sin(\theta - \omega t)\} + m\zeta g \sin(\theta) = 0 \qquad (1)$$

Here the unknown function θ denotes the angular excursion of the submerged load, l is a measure of module submergence (length of the pendulum), r is the radius of the circular suspension point orbit, and ω the wave period in rad/sec. g denotes the constant of gravity, m and m_a