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Review of Hydrodynamic Challenges in TLP Design

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ABSTRACT

From the early developments of tension leg platform (TLP) a number of hydrodynamic challenges have emerged. Considerable research and engineering effort has been spent, but there is still considerable scope for further work in this research area. This paper outlines the various hydrodynamic effects that must be accounted for in TLP design and how they practically relate to the safety and operation of TLPs. A list of suggested priorities for further hydrodynamic research is given.

INTRODUCTION

The underlying idea leading to the concept of a tension leg platform (TLP) is more than 100 years old, but it was picked up by the oil industry some 20 years ago. In the early '70s two large-scale prototype platforms, the Triton and the DOT TLP (McDonald, 1974; Anon 1975), were placed in areas where sea conditions would simulate full-scale behaviour. At present the Hutton (installed 1984), Jolliet (installed 1990) and the Snorre (installed 1992) TLPs have been successfully deployed. Currently the Heidrun TLP, the largest TLP so far and the first floating platform ever to be built in concrete, and the Auger steel platform are under construction.

Since the early '70s, extensive analytical work, model testing and large-scale testing have been undertaken by several oil and engineering companies. Research institutions and academia have also been involved in resolving the many technical challenges associated with TLPs.

The main attractions of a production TLP are the very low vertical motion, which permits inexpensive sea bottom equipment, and deck-mounted riser motion compensators, which cannot be installed on a semisubmersible alternative for all-weather operation. A TLP offers most of the attractions of a bottom-fixed platform without the high increase in cost with water depth associated with any bottom-fixed alternative. The attractive properties of TLPs for deep-water oil and gas production are, at least to some extent, counteracted by a number of technical issues in the mechanical, structural, installational and operational areas. This review paper, which is written as a contribution to the work of the ISOPE Offshore Technology Committee, will only discuss the hydrodynamic aspects of the practical design of TLPs.

Initially, only the positive features of the TLP were apparent to the designers, and from a motion response point of view the main arguments in favour of the new concept were as follows:

- Horizontal motion response is comparable to that of semisubmersible platforms.
- Due to the taut vertical mooring, heave, roll and pitch response would be insignificant.

There were some notable exceptions. For instance, the TLP concept drew some criticism on account of alleged parametric resonances of the Mathieu type (Rainey, 1977). These parametric resonances could be amplified by the time-varying restoring due to horizontal excursions which would lead to setdown. Although theoretically valid, this phenomenon quickly turned out to be of little practical interest. One reason for this is that they depend on regular forcing, which the waves are not.

Compared to a catenary floating platform, the attraction of a TLP was that there were *no* aggravating resonances. The TLP surge, sway and yaw resonance frequencies would be far below, and heave, roll and pitch resonance frequencies above, the wave frequency range. The ability of the TLP to push the resonances either below or above the frequency range of direct wave energy is still a very attractive feature. However, since the early '70s the understanding of wave loading nonlinearities has progressed considerably through extensive research efforts as well as the many model tests executed during platform design. In some cases research activities have been initiated as a result of unexpected model test results.

Today it is appreciated that both low- and high-frequency responses will occur due to *nonlinear* additions in the wave loading spectrum. And even though the relative magnitude of this resonant excitation is small, compared to first-order wave frequency excitation, the corresponding damping levels are also small, leading to considerable dynamic amplification. For practical TLP design, high- and low-frequency resonant responses are both significant and must therefore be taken into account.

This paper gives a brief overview of the main hydrodynamical problem areas. Wind will also be included, since it adds to the slowly varying wave drift force to give significant horizontal offsets.

TLP HYDRODYNAMICS

The overview of TLP hydrodynamics will be separated into the three frequency regimes of interest:

- Wave frequency range — 1st order motion response due to direct action of waves on the TLP.
- Low frequency range — surge, sway, yaw resonant response — due to slowly varying wave drift and wind gust dynamics.
- High frequency range — heave, roll, pitch resonant response — due to higher order wave effects.

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