Deep Water TLPs - Tether System Loading

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ABSTRACT

The paper focuses on the specific challenges of deep water for the design of tension leg platform (TLP) for harsh environment. Whilst the topside and hull are relatively unaffected by the water depth, the mooring system requires a technological step change. In order to develop a design, the system loading has to be determined. In deep water, the non-linear effects of springing and ringing become increasingly important.

This paper addresses the increased fatigue loading of the tethers, due to increased system compliance with water depth. The normal procedure for calculating the fatigue loading has been to consider the high frequency response to be induced by second-order response (springing), while the wave frequency response is calculated above a cut-off threshold. Model test results and full scale measurements show that the high frequency response is not directly proportional to the square of the wave height. A systematic investigation of first and second order responses shows the relative contribution to the high frequency response and its variance with the sea states. The effects will reduce the fatigue loading of the tether system, as compared with the normal calculation procedure.

A significant research effort has been dedicated to prediction of ringing loads. Even so, the tether response estimates have so far been based on model test data. A calculation procedure for ringing loads based on third order wave load theory, is the extended FNV/N (Faltinsen, Newman and Vinje) theory. The third order loads of a cylinder are added with phase shift to the first and second order loads, to give the full TLP column loads. The calculated response have been compared with model test results. The comparison shows that the theoretical estimates are somewhat higher than the model test results.

KEY WORDS: TLP, Tether loads, Springing, Ringing

INTRODUCTION

As the natural periods in heave and pitch for a TLP increases with the water depth, the non-linear effects of springing and ringing become increasingly important for estimation of the tether loads.

Springing, which is associated with steady-state resonance oscillations in the tether system, is observed in low to moderate seastates. The amplitudes are small, but the resonance response causes a high number of stress cycles, giving a significant contribution to the total tether fatigue damage.

For moderate water depths a normal calculation procedure has been to establish Quadratic Standard Deviation Transfer-functions (QSDT’s). The resonance tether tension is then normalised by the square of the significant wave height, $H_s$, assuming it to be caused by second order excitation forces.

The increase in vertical natural periods will enhance the importance of springing response. However, as the natural periods increases, linear forces may also contribute some to the resonance in the tethers. This fact may lead to some confusion if the normal procedure of QSDT’s is used. If the QSDT’s i.e. are established by model test measurements, the total high-frequency tether tension will include responses from both linear and second-order excitation. The objective of the investigation presently carried out, was to quantify the overlap between linear and second order resonance in moderate seastates.

The platform configuration used for the springing investigation was a 3-column steel TLP design for 1300m water depth. The natural periods in heave and pitch are 3.9s and 4.1s respectively.