Global Performance and Tendon Tension Analysis of Tension Leg Platform: Quasi-Dynamic Approach Vs Fully Coupled Approach

Binbin Li¹, Wei Huang¹, Sime Malenica², Guillaume De-Hauteclocque³ and Xiaoobo Chen¹

¹ Deepwater Technology Research Centre (DTRC), Bureau Veritas Marine & Offshore, Singapore
² Research Department, Bureau Veritas Marine and Offshore Division, Neuilly-sur-Seine, France

ABSTRACT

The good motion performance of Tension-leg platform (TLP) does credit to its tendons made of steel tube. The tendon system reliability is crucial for the safety of TLP platform, and the dynamic tension, as one of key issues, should be addressed carefully in design stage. The tendon tension is determined by redundant hull buoyancy, vertical motion at tendon top point on the hull, the set-down effect due to horizontal excursion etc. Moreover, the contributions of hull mean offset, wave frequency (WF) motion, nonlinear low frequency (LF) skew drift motion as well as high frequency (HF) springing effect need to be taken into account in the global performance analysis. The existing fully coupled approach models the tendon as discrete elements and solved by FEM, inertial and drag forces as well as interaction between hull and tendon system are able to be considered. However, on one hand, the computation consumes plenty of resource and time; on the other hand, inertial and drag effects of tendon may not be dominant factors. Therefore, the fully coupled approach is not the ideal solution, at least, in sea-state screening design phase when tremendous 3-hour time-domain simulations are required. Motivated by mentioned reasons, a quasi-dynamic method was initiated by Bureau. Recent results such as extreme tendon tension is obtained and compared to fully coupled results from third party software ORCAFLEX, and the discrepancy is limited within 5%. The tendon characteristics like relation of set-down and TLP offset, relation of horizontal restoring force and offset are pre-described by utilizing analytical method. The WF, LF and HF dynamic motions are assumed to be decoupled since their representative frequencies are far enough from each other. LF motions of horizontal 3-DOF i.e. surge, sway and yaw are solved through motion equation in time domain. 6-DOF WF motions and 3-DOF HF motions in vertical plane are re-constructed by using transfer function obtained from frequency domain. The tendon tension is post-processed based on the total tendon length taking into account vertical motion of tendon top point, set-down height and offset, at each time step. This paper represents and describes the methodology of this approach, assumptions, key steps, and discussions as well as conclusions are drew and conducted.

KEY WORDS: Tension leg platform; tendon; set-down effect; hydrodynamics; Springing

INTRODUCTION

Tension-leg platform has been chosen as one of most popular deepwater solutions since the first prototype was unveiled in early 1980s. Similar with other types of moored floating structure e.g. Spar and Semi-submersible, the horizontal motions like surge are large amplitude and slow-varying. On the contrary, the natural periods of vertical motions (heave, roll and pitch) are short and within 2–5 seconds in typical (Li et al, 2011). The reason is the tendon system made of steel tubes provides tremendous tension and stiffness in vertical plane due to the redundant buoyancy of hull. Thanks to unique design, linear wave frequency motions in vertical plane are minimized because the wave energy is limited to approach to those low periods in most occasions. Nevertheless, the nonlinear high frequency wave force could excite short periodical vibration (springing) which affects tendon global strength and fatigue life. From global motion performance point of view, TLP is mainly subjected to low frequency response in horizontal modes (surge, sway and yaw), wave frequency response related to wave energy region for all six modes, and the high frequency response for vertical modes only. All three categories of dynamic responses have distinct frequency bands, as shown in Fig. 1.

Fig. 1 TLP response spectra (green: wave spectrum; black: WF response; blue: LF response; red: HF response)