230 AF

Technical Report CEAC-TR-98-0103

COMPOSITE PRODUCTION RISER DYNAMICS AND ITS EFFECTS ON TENSIONERS, STRESS JOINTS, AND SIZE OF DEEPWATER TENSION LEG PLATFORMS

by

M. Karayaka and S. Wu, Aker Engineering
S. S. Wang and X. Lu, CEAC, University of Houston
P. Ganguly, B.P. Exploration

February 1998

COMPOSITES ENGINEERING AND APPLICATIONS CENTER
FOR PETROLEUM EXPLORATION AND PRODUCTION

UNIVERSITY OF HOUSTON
HOUSTON, TX 77204-0900

2807

OTC 8666

Composite Production Riser Dynamics and Its Effects on Tensioners, Stress Joints, and Size of Deep Water Tension Leg Platforms

Metin Karayaka, Shukai Wu, Aker Engineering Inc., Su-Su Wang, Xiaohua Lu, Composites Engineering and Applications Center, University of Houston, Partha Ganguly, B.P. Exploration Inc.

ABSTRACT

Composite production riser (CPR) joints are being seriously considered in the development of deep water tension leg platforms (TLPs), because of their inherent light weight, superior fatigue and corrosion resistance, and outstanding specific strength and stiffness properties. Current efforts on the development of CPR joints have been mainly focused on low-cost manufacturing and failure strength evaluation of CPR tube body and CPR joint connection. The important issue of system dynamics of TLPs containing multiple CPR strings, has not been addressed.

In this paper, system analysis of a TLP containing 16 CPR strings and 12 tendons subjected to Gulf of Mexico environment loading have been conducted. The riser system is configured for 3,000 ft water depth with CPR joints, standard steel riser joints, splash zone joints, stress joint, and top tensioners. The study embraces several disciplines, including naval architecture, riser dynamics analysis, and composite failure mechanics to develop an iterative algorithm for evaluation of the top tension and stress joint requirement. Specifically, optimum top tension requirements have been determined based on riser dynamics and the failure envelope of the CPR joints. For comparison, the optimum top tension requirements are further used to size the TLPs with all-steel riser and with CPR. For the 3,000 ft water depth case study, reduction in riser weight is magnified by 3.31 times in the TLP size. It is demonstrated that the weight reduction in the riser string is nonlinearly related to the tensioner requirement and TLP size.

INTRODUCTION

Composite materials offer many advantages for deep water applications because of their excellent corrosion and fatigue performance, high strength-to-weight ratio, and design flexibility. As the offshore industry moves aggressively to pursue deeper water developments, composite materials are finding a wide range of new applications for both topside and subsea structures. While most of the current applications are secondary structures in the top side facilities, several major U.S. and international initiatives are underway to develop primary load-bearing system components [1-6]

In deep water exploration and production, significant advantages may be realized when composite materials and structures are incorporated in the offshore system design strategy during conceptual and pre-engineering stages. For a TLP, the effective use of light weight composites may result in a significant cost savings and, perhaps, also enabling benefits. Synergistic reductions in the deck loads, hull, tendon mooring system, and platform size account for the reduced topside facilities weight [2].

This study couples fundamental failure mechanics of composites, dynamic analysis of the composite riser strings, and naval architecture to size the TLP structure. It is demonstrated that an integrated interdisciplinary effort is required to overcome technological barriers in the utilization of composite materials in the offshore industry and effective TLP design.

COMPOSITE PRODUCTION RISER JOINTS

CPR joints are currently being developed in a major project jointly supported by the industry and DoC NIST/ATP. The tube body of the CPR joint is a hybrid material system design in which the axial load is carried by helical carbon-fiber plies and hoop pressure is carried by both carbon and glass fibers wound close to the hoop direction. The detailed laminate structure of the CPR tube body is schematically illustrated in **Fig. 1** [4]. The design is mainly based on load-bearing fiber strength and leakage, caused by through-the-thickness matrix cracking, prevention by liners. Some of the initial design parameters of CPR joint are summarized in References 4 and 5. Metal inserts are placed at each end of the CPR joint to facilitate CPR joint connection. The metal fitting inserts are joined to the CPR tube body through a trap-lock metal-to-composite interface (MCI) developed by Lincoln Composites [4].

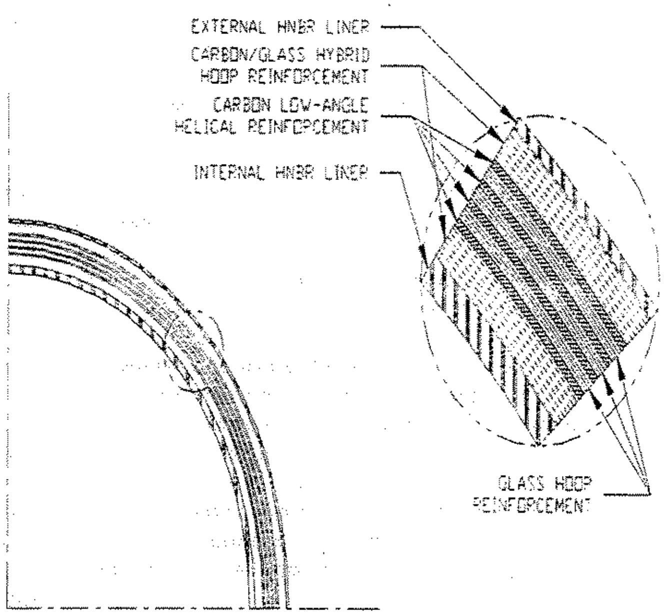

Figure 1: Laminate structure of the NIST Composite production riser joint [4].

RISER SYSTEM CONFIGURATION AND DYNAMIC ANALYSIS

A commercially available three-dimensional frequency domain analysis program, FREECOM 3D, is utilized to analyze the dynamic response of the riser system. Riser configuration for 3,000 ft water depth is presented in **Fig. 2.** A stress joint is placed at the seabed to accommodate high bending. To further protect the CPR joints from the bending load, a transition joint and a steel riser joint is placed after the stress joint. The CPR joints are placed in the middle of the riser string where the dynamic load is predominantly in the axial direction. The riser section in the splash zone is also susceptible to bending stress due to surface events. The CPR section is terminated at 272 ft below the water level.

The same configuration is further used to compare the top-tension requirements of an all-steel riser string with that of configuration with CPR joints. The all-steel riser configuration has the same components, except that the CPR joints are replaced with standard steel riser joints.

The riser joints are modeled with 2-node tube elements with 6 degrees of freedom per node. It is important to note that the anisotropic nature of the CPR joints can not be included in the riser analysis software because of its current formulation. The CPR joints assumed to have uniform geometry and material properties, such as unit weight, outer diameter, equivalent EA, etc. All degrees of freedoms are constrained at the bottom of the riser string. Tensioner loads are applied at the top by spring elements. The surface tree is modeled with a mass element at the end of the riser string.

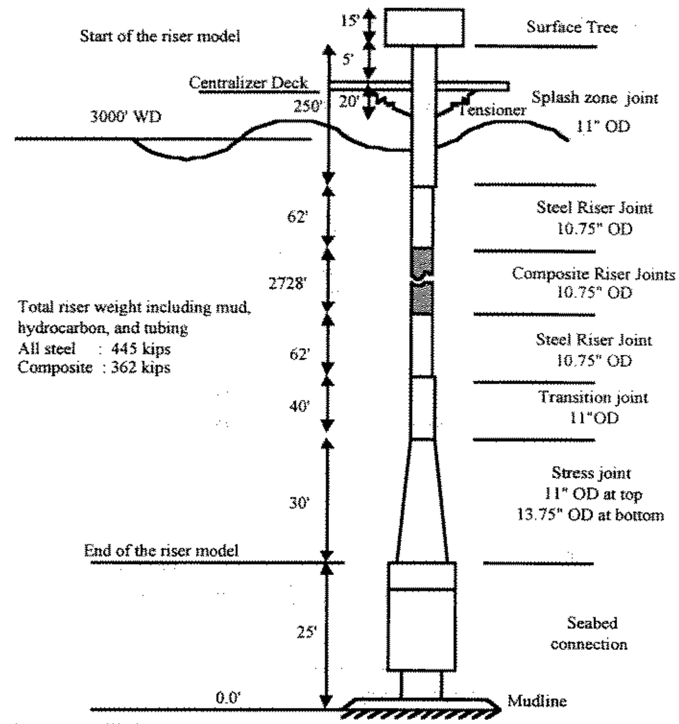

Figure 2: TLP riser configuration for 3,000 ft water depth

ENVIRONMENTAL AND OPERATION CONDITIONS

The riser dynamic analysis is performed only for the case of extreme environmental loading. The current profile and wave parameters are summarized in Table 1. These conditions represent 100-year hurricane loading in the Gulf of Mexico.

A total of 16 composite production risers are used in the dynamic analysis of the TLP. Single riser casing configuration with production tubing is used for all production risers. The production tubing is filled with hydrocarbons of 44.89 lb/ft^3 density. The riser annulus is filled with mud with 97.25 lbs/ft^3 density. The riser loads are calculated when the TLP excursion is 10% of the water depth. TLP excursion, current, and wave are aligned in the same direction.

TABLE 1: ENVIRONMENTAL CONDITIONS

Sea Conditions		Current Profile	
		Water depth (ft)	Current speed (knots)
Maximum Height (ft)	72.		
Significant Height (ft)	40	Surface	3.4
Maximum Period (sec)	13.5	109	2.6
Mean Zero-Cross (sec)	11.5	280	0.0
Peak Period (sec)	14.2	3,000	0.0

ALGORITHM FOR TOP-TENSION REQUIREMENT

composite mechanics/design is necessary.

3. Numerous factors need to be considered in determination of the top tensioner requirements of TLP production risers. In addition to the design parameters and failure modes considered in this study, issues such as vortex induced vibration and riser clashing needs to be considered in a wide range of loading scenarios. In this study the dynamic riser analysis is conducted for the case of 100 year hurricane loading.

4. The riser axial strength and the metal-to-composite joint performance remains to be improved. The CPR tube body's axial strength is higher than the MCI strength in the high axial loading cases. However, degradation and damage of the CPR tube body occurs progressively as the individual plies has different strength when loaded in the axial direction. Advanced long-term strength prediction methodologies must be developed to optimize the materials and lay-up sequence in the composite riser tube body.

5. The potential economic and performance advantages of using composite materials for coupled TLP riser tension and construction are significant. The light weight of such tendons made of composite materials may directly translate into more effective reduction in top tension and, therefore, the TLP size or equivalently, into increase in a TLP payload capacity. The higher stiffness of the composite tendons will make natural periods of the TLP motion in the vertical plane much less sensitive to water depth increase.

ACKNOWLEGMENTS

The authors would like to acknowledge help of Him Lo, Shell Deep water Development Inc., on the TLP production riser configuration selection and subsequent modeling during the course of this study. Metin Karayaka thanks to Rick Hill's, Vice President, Aker Engineering, support in resource utilization in this study

REFERENCES

1. Fisher F.J. and Salama, M.M., "Emerging and Potential Composite Applications for Deep Water Offshore Operations", Proceedings of the 2nd International Conference on Composite Materials for Offshore Operations, S.S. Wang, K.H.Lo, and J.G. Williams, Eds., ABS Publishing, New York. 1998

2. Vennett, R.M., Williams, J.G., Lo, K.H., Ganguly, P., "Economic Benefits of Using Composites for Offshore Development and Operations", Proceedings of the 2nd International Conference on Composite Materials for Offshore Operations, S.S. Wang, K.H.Lo, and J.G. Williams, Eds., ABS Publishing, New York. 1998

3. Houghton, C.J., "Composites Use in Platform Topsides: A Recent Case History and Future Prospects", Proceedings of the 2nd International Conference on Composite Materials for Offshore Operations, S.S. Wang, K.H.Lo, and J.G. Williams, Eds., ABS Publishing, New York. 1998

4. Baldwin D.D., N. Newhouse, K.H. Lo, "Composite Production Riser Development", Proceedings of the 2nd International Conference on Composite Materials for Offshore Operations, S.S. Wang, K.H.Lo, and J.G. Williams, Eds., ABS Publishing, New York. 1998

5. Baldwin, D.D., N.L. Newhouse, K.H. Lo, C. Peterman, "Design Verification of a Composite Production Riser, Proceedings of the 1997 Offshore Technology Conference

6. Drey, M.D., Long J. R., Salama, M.M., Wang, S.S., " Composite Production Riser: Manufacturing Development and Qualification Testing", Proceedings of the 1998 Offshore Technology Conference, May 4-8, 1998Houston, TX

7. Wang, S.S., Lu., X., Gong Z.Q., Composite Production Riser Reliability Assessment: The Influence of Probabilistic Fiber Composite Strength, Proceedings of the 1998 Offshore Technology Conference, May 4-8, 1998, Houston, TX

8. API RP 2T (1987). Recommended Practice for Planning, Designing, and Constructing Tension Leg Platforms. 1st Ed., April, 1.

9. Wang, S.S., Srinivasan S., B.W. Cole, "Long-Term Leakage Failure and Life Prediction of Fiber Composite Laminate Tubing Under Combined Internal Pressure and Axial Loading: Theory and Experiments, Proceedings of the 2nd International Conference on Composite Materials for Offshore Operations, S.S. Wang, K.H.Lo, and J.G. Williams, Eds., ABS Publishing, New York. 1998