Dynamics of FPSO with Polyester Mooring Lines

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ABSTRACT

The stiffness model of highly extensible polyester mooring lines is studied as part of dynamic analysis of a floating production, storage and offloading unit (FPSO). In more detail, coupled dynamics of FPSO and deepwater mooring system with taut polyester mooring lines is observed. Calculations are done in time domain utilizing nonlinear finite element method (FEM). Newly derived additional stiffness matrices are used to approximate the influence of elongation of mooring line to its geometric stiffness. Presented case study is based on example from the literature with available experimental results.

KEY WORDS: mooring; FPSO; polyester rope; large elongation value; dynamic response.

INTRODUCTION

Polyester mooring lines are commonly used at deep-water locations for a FPSO. Recommended way to describe dynamics of FPSO is to set a coupled model that also contains dynamics of mooring system. Breaking point of a polyester rope can be found at 15% elongation. Such high elongation has great influence on mooring system response. Therefore, high elongation of polyester lines should be included in the coupled model to achieve better prediction of FPSO dynamics.

ISSC 2006 Technical Committee 1.2. reports of three papers which deals with coupled dynamics of moored vessel. Tahar & Kim (2003) developed a computer program for hull/mooring/riser coupled dynamic analysis of a tanker based turret - moored FPSO. Garret (2005) performed a fully coupled global analysis of floating production system, including the vessel, the mooring and riser system. Kim et al. (2005) solved simultaneously the vessel and mooring line dynamics. The vessel global motions and mooring tension were tested at the wave basin of Offshore Technology Research Center (OTRC, Texas, USA) for the non-parallel wind-wave-current 100-year hurricane condition in the Gulf of Mexico. Stiffness nonlinearity of polyester mooring cables was studied by Fernandes et al. (1999). They examined acceptance tests performed with actual full scale cables. As a result they suggested a formula for specific modulus of polyester ropes in terms of dynamic analysis. Tahar & Kim (2008) studied coupled dynamic analysis of floating structures with polyester mooring lines. Their mathematical model allowed relatively large elongation of polyester rope and nonlinear stress-strain relationship. The mooring line dynamics was based on elastic rod theory. Numerical calculations are done utilizing nonlinear FEM.

An improved stiffness model for polyester mooring lines is proposed by Ćatipović (2011). High elongation of a polyester rope is considered during derivation of mooring line restoring forces. Nonlinear tension-elongation relation of the polyester rope is a part of the improved model. Development of the model is done within the coupled dynamic analysis of a moored vessel. For numerical calculations a nonlinear FEM is used. Additional stiffness matrices are derived which approximate the influence of elongation of mooring line to its geometric stiffness. Special effort is invested to achieve symmetrical forms of the nonlinear FEM. These symmetrical forms enable easier numerical implementation utilizing classical FEM codes. The advantage of the improved model is presented in Appendix A, where comparison between the improved model and current equivalent model is done.

In this paper the improved model is used to evaluate dynamics of FPSO with polyester mooring lines with linearized axial stiffness. Obtained numerical results are compared with results presented by Kim at al. (2005) and with experimental results from OTRC wave basin. This study will provide new validation where stability of numerical calculation as well as results are tested, since the improved model is more complex due to additional stiffness matrices.

MATHEMATICAL MODEL

Dynamics of the Mooring Line

Nordgen (1974) and Garrett (1982) presented elastic rod theory which is starting point of the mathematical model. Dynamic response of the mooring line is defined in terms of a centreline position with following assumptions:
- movements are three-dimensional so large displacements are considered