Full Scale Fatigue Test on Dynamic Submarine Power Cable

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ABSTRACT

Global dynamic behavior of cable connecting FPSO and WHP with catenary configuration has been simulated with 4,000 load cases to ensure the design prototype comply with extreme loads. In local analysis, FEM with detailed 3-D model is used to determine endurance strength of conductors and armor wires under varying external loads. 560 bins with above 200 million of tension and bending cycles are created for fatigue life determination. Results reveal that minimum fatigue life occur at the FPSO hang-off, but still preserve service life of 450 years .
Test has been carried out at full-scale cable sample with length of 12m, installed with bend stiffener at rocking end. Cyclic bending is divided into 7 blocks, each with different bending radius but constant tension. Total number of cycles is decreased to 1.5×106 using inverse power laws for test acceleration.
The test demonstrates the integrity of cable throughout service life. Failure modes, mainly fatigue cracks and fretting on individual wire are identified after cable dissection, but none of them cause direct loss of service under electric tests.
This test has also adopts DAS method to monitor the optical fibers during bending behavior under different frequencies, which showed promising prospect in dynamic service.

KEYWORDS

Dynamic submarine cable; Global dynamic analysis; Marine growth; Distributed acoustic sensing; Full-scale fatigue test.

INTRODUCTION

Dynamic submarine cable is a kind of comprehensive cable that transmitting electrical power and communication control signals with changing position and loads state. The main application areas including:
(1) To provide power from shore to offshore oil and gas platforms, where the dynamic cables connects the floating platform to a static cable which is connected to the onshore power grid.
(2) To provide power from a floating oil and gas production platform to subsea installations, and the water depth usually reaches up to 2000km.
(3) To export power from floating marine renewable energy system such as floating wind turbines, wave energy converters or floating nuclear power platform.

Hanging from floating units through the water-column portion, dynamic submarine cables are usually presented with standard configuration, like lazy-wave, which could greatly reduce the environmental loads and fit the long distance offsets of floating unit[1,2]. Dynamic power cables are subjected to fatigue loading from wave, current and movement of the vessel, therefore, cable structure must be electrically and mechanically fit-for-purpose throughout the design life[3,4]. According to standard, to meet 25-years service life, the design process of dynamic cable includes global dynamic analysis, loads of key components extracting, local stress/strain analysis, fatigue life calculation, and cable structure optimizing based above[5,6].

Cross-section design

This field is located offshore in the Madura Strait East Java with a average water depth of 56m. The project envisages development of a wellhead platform, an offshore spread moored converted tanker based Floating, Production, Storage and Offloading (FPSO). The FPSO is located at a distance of 125 m from WHP, and moored by 12 catenary anchor chains in 4 directions. Due to the wind and wave loads, offsets of FPSO are divided into 8 directions, especially the Far and Near directions, which could stretch and slack the cable in the seawater. After comprehensive dynamic simulation of whole system, the cable is designed with four layer of armors with catenary configuration connecting between FPSO and WHP. Total length of cable is determined considering all extreme states, to avoid straightening and touching down the seabed. The sketch of 3-D model of dynamic cable is shown in Fig.1.

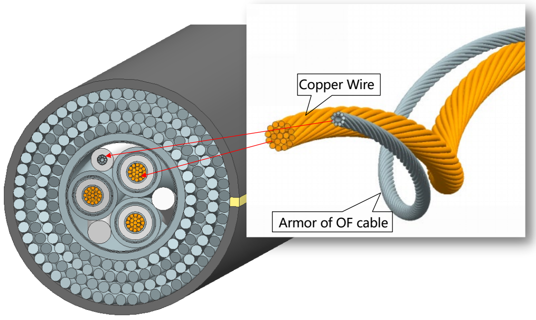

Fig.1: Sketch of dynamic submarine cable

In Fig.1, the strands of copper conductor wires and armor wires of optic fiber cable present double helices structure. That is the strand of copper wires is considered as a single wire wrapping around center core.

To model the cable structure with double helical geometry, it is necessary to use special parametric equations. In which, the centerline of copper conductor or optic fiber cable is considered by using its parametric equations as[7],

$$x_s = r_s\cos(\theta_s), y_s = r_s\sin(\theta_s), z_s = r_s\tan(a_s)\theta_s \quad [1]$$

In which, x_s, y_s, z_s are space coordinates of first helix, r_s is the radius of the single helix, a_s is the single helix lay angle and θ_s is the position of the wire within a strand. The outer double helical wires are wound around the given centerline of single helical wire in Eqn.(1) by using the following parametric equations defined for double