LIFETIME PERFORMANCE MONITORING OF SYNTHETIC FIBER MOORING ROPES USING POLYMERIC OPTICAL FIBERS

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INTRODUCTION

The use of synthetic fiber mooring rope (SFMR) on offshore drilling and production platforms in ultra deepwater is an important technological advancement. SFMR makes possible significant weight savings, lower cost, and reduced interference with adjacent property development via deployment in the taut-leg configuration. The initial use of SFMR was in Brazil, and polyester mooring ropes are now planned for deployment in the Gulf of Mexico (GOM). Kerr-McGee will soon be the first oil services company to use polyester mooring ropes for station keeping on a production platform (Red Hawk, located in 5300 feet of water) in the GOM. Whitehill Manufacturing Corporation, a partner in this NGOTP project, is the supplier of the polyester mooring rope. Numerous discoveries have been made in even deeper water and many more synthetic fiber mooring rope installations are expected for both drilling and production.

Environmental conditions associated with hurricanes and loop current are more severe in the GOM than elsewhere in the world, and the Minerals Management Service is requiring complicated inspection procedures to insure their reliability. These inspection procedures involve inserting short test sections in the upper portion of the mooring rope, with periodic retrievals of the test sections for ultimate strength testing. The removal procedure is expensive and introduces undesirable operational risks, including damage to the rope. Furthermore, claims that terminations of the short test sections yield the weakest links in the rope assembly have technically justifications.

The ultimate strain of polyester rope is 3 to 8 percent, including kinematic effects due to the twisted and braided architecture of the rope and stretch in response to loads. Test data indicates that the strain in the rope at failure is essentially independent of load path or history. Measurement of the accumulated strain in the rope should thus provide a reliable benchmark with which to establish criteria for rope re-certification or retirement. Prospects for future safe deployment of deepwater mooring ropes will be significantly improved if a reliable, cost-effective method can be realized for monitoring the performance of the rope during a long service lifetime.

The aim of this project is to develop and commercialize a performance monitoring method and system. The method originated at Oak Ridge National Laboratory, and its path to commercialization is being supported by the project partners. The method provides a direct in situ measurement of the characteristically large axial strains in mooring ropes. The method employs the use of high-strain plastic optical fibers and the optical time-domain reflectometry (OTDR) technique. The optical fiber strain sensor is embedded within the mooring rope, and the measured strain has close to a one-to-one correspondence with the axial strain in the rope. Furthermore, it is anticipated that the method will provide detection of local damage in the rope and will thus address a major concern associated with synthetic fiber mooring ropes.

DISCUSSION OF CURRENT ACTIVITIES

A plastic optical fiber with the desired opto-mechanical properties has been selected and extensively tested for strain fidelity. Several plastic optical fibers were studied, including those made from high optical-grade polymethyl methacrylate and perfluorocarbon polymers. A perfluorocarbon fiber was found to have the lowest attenuation (best transmission) for the OTDR wavelength. It is expected that the strain in ropes with lengths of about 1000 meters can be measured with a single length of perfluorocarbon fiber, although longer lengths might soon be achievable with on-going advancements in fiber formulation and manufacturing.

Results of load cycling tests on a small rope element with an embedded plastic optical fiber strain sensor is presented in Fig. 1. Constant load was applied on each of the five cycles; the maximum strain was approximately three percent rain in the first cycle but reduced to approximately 1.8 percent in subsequent cycles due to termination seating and relaxation of the polyester. Good correlation was observed between the applied strain and the strain measured using the plastic optical fiber and OTDR technique. The plastic optical fiber did not take a permanent set or brake during cyclic loading.

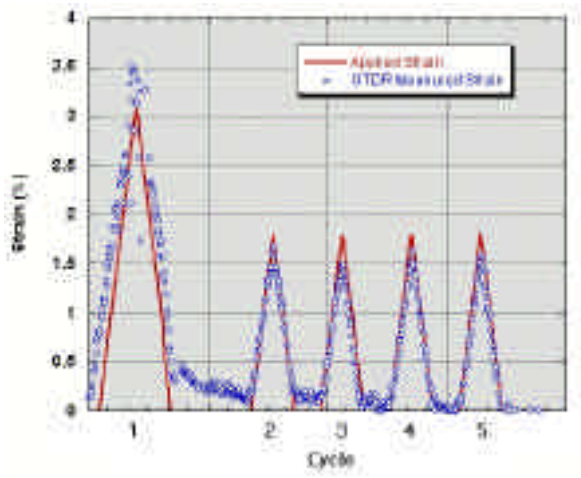

Fig. 1. Correlation between applied and measured strain in braided-strand rope (from Ref. 2).

A method for inserting reflective interfaces in the fibers has also been demonstrated. These interfaces are the means by which gauge lengths of less than 1 meter to 10's of meters will be created at arbitrarily selected positions along the fiber.

Although plastic optical fibers have large strain capability, they are susceptible to local bending and environmental degradation. To compensate for this susceptibility, a method for encapsulating the fiber within a subrope within the mooring rope was demonstrated, and methods for obtaining fiber ingress/egress from the mooring rope have been evaluated. The method for protecting the fiber is being refined into a practical system, including integration of protective shielding during the manufacturing of the optical fiber. Resolution of these issues is critical for deployment of a practical method offshore.

Research activities in the final project year will be focused on conducting tests on larger and longer ropes that are representative of the mooring ropes proposed for offshore service and on refining the technique and instrumentation for practical deployment of the technique offshore.

REFERENCES

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