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Modelling Heat Buildup in Large Polyester Ropes

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ABSTRACT

The use of synthetic fibre ropes in offshore rig and platform mooring is becoming increasingly likely. A leading candidate fibre is polyester since it has an excellent blend of properties. Like other fibre ropes, polyester ropes have low weight compared to steel and their consequent flat catenary restricts platform offset. Polyester ropes have relatively low modulus, so minimising fatigue loadings produced by first order wave motions. The inherent tension-tension fatigue life of polyester ropes is good. Polyester is also a good choice in terms of cost. The subject of this paper is the possible heat buildup in the large diameter ropes that will be required to compensate for polyester's relatively low inherent strength.

NOMENCLATURE

c : specific heat capacity (J/kg/°C)
E : Young's Modulus (MPa)
k : radial conductivity (W/m/°C)
Q : internally generated rate of heat generation (W/m^3)
q : internally generated rate of heat generation (W/m^3)
R : rope radius (m)
r : radial position within rope cross-section (m)
T : temperature (°C)
T_0 : temperature (°C) of surrounding medium, ambient temperature
t : time (s)
α : thermal diffusivity (k/ρc, m^2/s)
Ψ : hysteresis loss factor
Θ : angular position within rope cross-section
ρ : material density (kg/m^3)
σ_a : stress amplitude in a given cycle (MPa)
σ_m : mean stress in a given cycle (MPa)
τ : cycle time (s)

INTRODUCTION

The properties of polyester, like those of most polymeric materials, are temperature dependent. For the use of polyester in large diameter ropes, the changes in break load and break elongation with temperature are important properties. Fig. 1 depicts the general changes to polyester's load-elongation properties with increasing temperature.

Earlier papers have been presented on theoretical and computational modelling of (1) the quasi-static tension and torque properties of ropes and splices (Leech, Hearle, Overington and Banfield, 1993) and (2) the long-term fatigue performance of these structures (Hearle, Parsey, Overington and Banfield, 1993), including the three important fatigue mechanisms of creep, hysteresis heating and internal abrasion. A paper has also been presented on an extension of the fatigue modelling to include axial compression fatigue (Hearle, Hobbs, Overington and Banfield, 1995). This paper returns to the subject of hysteresis heating.

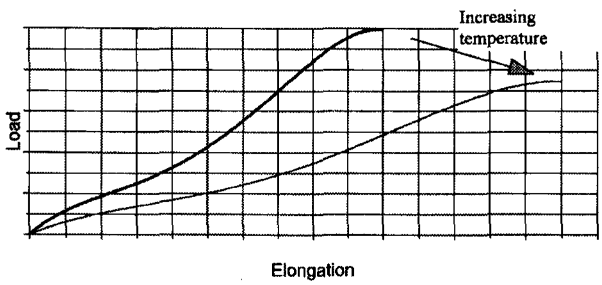

Fig. 1 Change in load-elongation properties of polyester with increasing temperature

As oil production moves to deeper and deeper waters, the low weight and flat catenary of high-performance synthetic fibre ropes offer design advantages when compared to steel moorings for large floating structures. However, with storms of considerable duration being commonplace in the North Sea, it is imperative to ensure that any temperature rise in the rope, due to hysteresis and frictional heating, is kept within acceptable limits.

The computational model described in the earlier papers was used to predict the temperature rise that could be expected in a 250-mm-diameter, 20-MN break load, polyester rope when used in a taut leg mooring system for an oil platform in the North Sea. Using material parameters generally available in the literature, the computational model predicts substantial temperature rises for sustained storm loading over periods of 3 h and beyond. The result of such temperature rises can be divided into three categories.

- Catastrophic failure. Temperatures may reach a level at which rope strengths at the high temperature have fallen to values no greater than the applied load. The rope will then break.
- Moderate effect. If there is a smaller but still substantial temperature rise, the immediate effect on rope strength may not be large enough to cause failure, but the temperature rise may sig-

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