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# Quantifying the Residual Creep Life of Polyester Mooring Ropes

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**This paper assesses the ARELIS (Assured Residual Life Span) method for estimating residual creep life of polyester rope used in deepwater mooring lines. A statistical model has been developed to quantify the uncertainties in the method, such as the scatter in creep rupture test data and load sharing between sub-ropes. This model can be used to determine the required test load, duration and number of ARELIS tests, in order to guarantee a minimum creep life for a mooring line at its service load. Creep rupture tests have been performed to provide input for the statistical model.**

## INTRODUCTION

Polyester fiber ropes are increasingly being used as components of mooring lines for offshore structures in deep water. The use of such ropes in long-term mooring systems has raised the question of whether creep rupture should be considered a possible failure mechanism (Lo, Xü and Skogsberg, 1999). The theoretical creep life of polyester fiber mooring ropes operating at or below their design load is millions of years. However, exposure to extreme storm loading or damage to the rope could reduce this life to a much lower figure. To give confidence that the creep life of polyester moorings has not been compromised, Bosman (2001) has proposed a method of testing to assure that the residual rope life is adequate. This method avoids the major problem with creep testing, namely the length of time that creep tests take, and is described below.

Polyester mooring lines can be constructed with removable insert sections fitted in series with the mooring line. After being in service for a length of time, some of the insert sections can be removed and taken ashore for investigation. In a rope construction consisting of parallel sub-ropes, different sub-ropes from the insert can be tested in different ways, including breaking load tests, internal examination and ARELIS (Assured Residual Life Span) testing. The aim of the latter tests is to demonstrate that the mooring lines have sufficient residual creep life remaining.

This paper assesses the ARELIS method and attempts to quantify the effects of uncertainties in creep data and load sharing between rope components. A statistical model is presented which shows how uncertainties in input parameters can affect the duration and number of ARELIS tests needed to guarantee a minimum creep life at a specified confidence level. Results from creep rupture tests on yarn samples and on sub-rope strands are given.

Also discussed is an alternative method of creep damage acceleration using increased temperature rather than increased load.

## THE ARELIS METHOD

The ARELIS method has been developed by Bosman (2001), and is based on work by Coleman (1956) and Zhurkov (1965). Bosman presents the following equation expressing the notional creep damage to the polyester material in terms of loading time and a given tensile load:

$$D = \frac{t}{\tau_0} * \frac{1}{10^{[100*(1-\sigma)]/B}} \tag{1}$$

where $D$ = amount of damage accumulated in time $t$; $t$ = loading time (s); $B$ = creep rupture constant (as percentage of breaking load/decade); $\sigma$ = normalised tension (=load/breaking load); and $\tau_0$ = time to break at $\sigma = 1$ (s).

If it is assumed that the failure load is characterised by a value of $\tau_0 = 1$, which seems reasonable from results presented by Mandell (1987), then failure occurs when $D = 1$ and the time to failure for $\sigma < 1$ will be:

$$t = 10^{[100*(1-\sigma)]/B} \tag{2}$$

If the load is expressed as a percentage of the breaking load:

$$t = 10^{(100-\%\mathrm{BL})/B} \tag{3}$$

which can be written as:

$$\log t = (100 - \%\mathrm{BL}) * \frac{1}{B} \tag{4}$$

or, alternatively:

$$\log t = a + b(\%\mathrm{BL}) \tag{5}$$

where $a$ and $b$ are constants.

Thus the assumption is that the logarithm of the creep life is linearly proportional to the applied load. The slope of the line can be determined from creep rupture test data; to obtain results within a reasonable time, these tests are performed at a high load. It is then assumed that the slope determined at high loads is applicable at the service load level.

ARELIS tests are creep tests performed on sub-ropes taken from a section of the mooring line. A sample is tested at a specified load (which is higher than the mean service load) for a specified time. If the sample does not break, a minimum residual life at the service load is implied. The ARELIS tests can be performed at a load closer to the service load than the creep rupture tests, since the samples do not need to be broken. The difference between the service and the ARELIS test loads needs to be large enough to achieve the required acceleration in creep, but not too great since more uncertainty may then be introduced.

The ARELIS tests aim to demonstrate that the residual life of the mooring line at its design service load is more than some

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