Creep Properties of Nylon Ropes. Comparisons of Test Results and Computations

EERA DeepWind 2022 - Digital conference

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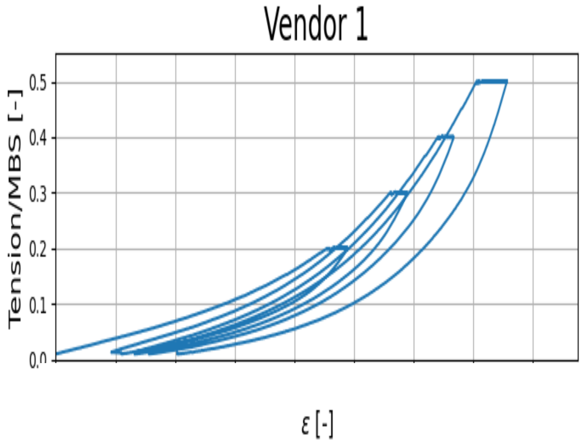
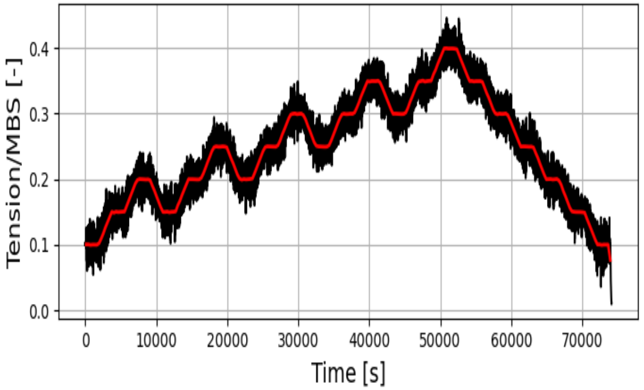
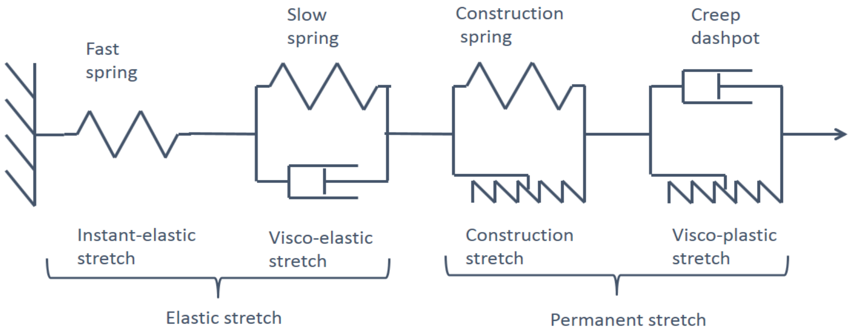




Fibre Rope Mooring (FIRM) project participants:

The Research Council of Norway, aibel, equinor, Dr. Techn. Olav Olsen, Hendrik Veder Group, Kongsberg, Seasystems (A part of Scana), SEMAR, IFE, NGI, NORCE, Royal Lankhorst Euronete, Bridon-Bekaert The Ropes Group, DSR

Modeling of fibre ropes with the SYROPE element



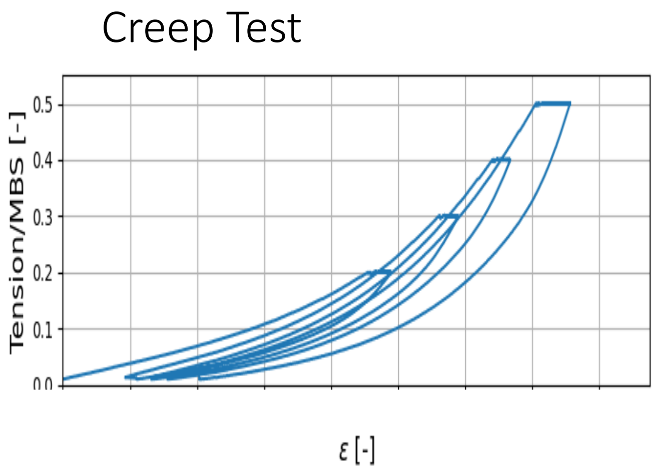
- **Instant-elastic**: Axial stiffness in response to «rapid» changes in tension (wave and surge frequencies, periods 15s and 120s). Axial stiffness modeled as function of mean tension. To a lesser degree function of frequency and amplitude.
- **Visco-elastic**: Viscosity is the result of the diffusion of atoms or molecules inside the material. The material responds to stress with a time-dependent strain rate. For fiber ropes typical time constants of 1 – 30 minutes.
- **Construction**: When the rope is first tensioned, the various yarns and strands compact and realign, and the lay length of the yarns and strands in the laid or braided rope increases. These actions cause the rope length to increase. This process is sometimes called bedding in (Flory et al., 2004)
- **Creep**: Permanent elongation after prolonged application of loads. Continue to undergo a creep flow as a function of time under the influence of the applied load.

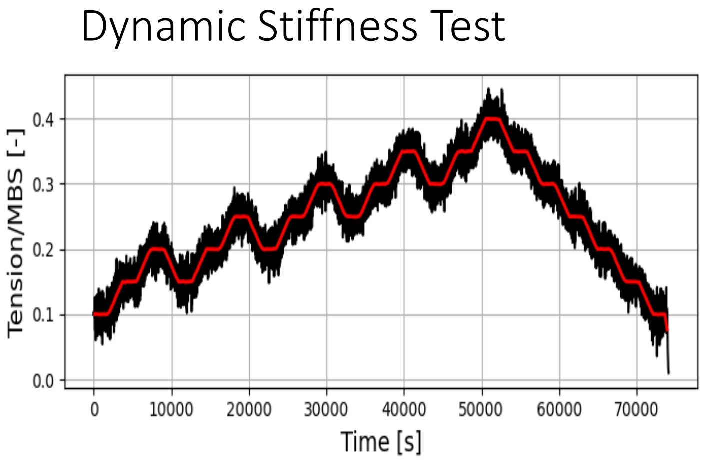
Falkenberg, E., Yang, L. and Åhjem, V. (2018). *The syrope method for stiffness testing of polyester ropes*. Proceedings of the ASME 2018 37th International Conference on Ocean, Offshore and Arctic Engineering, OMAE2018

Nygaard, T.A et al.(2021). *Fibre Rope Mooring for Floating Wind Turbines.* Presentation at the EERA DeepWind 2021 - Digital conference

Testing of nylon ropes in the Fibre Rope Mooring (FIRM) project

DNV GL Technology centre for offshore mooring and lifting, Bergen, Norway





This short presentation will focus on the creep test:

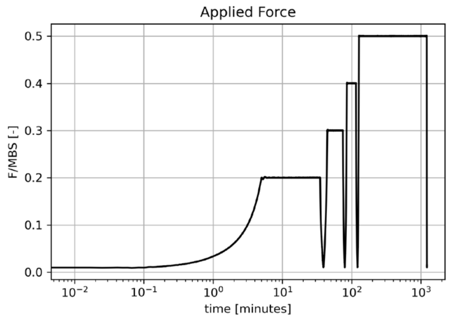
1. Tension the rope to 20 % of MBS and maintain for 30 minutes
2. Reduce to reference load and record the remaining elongation
3. Repeat steps 1 and 2, with tension of 30, 40 and 50 % MBS
4. Increase load to 50 % MBS and hold for 18 hours
5. Record rope elongation

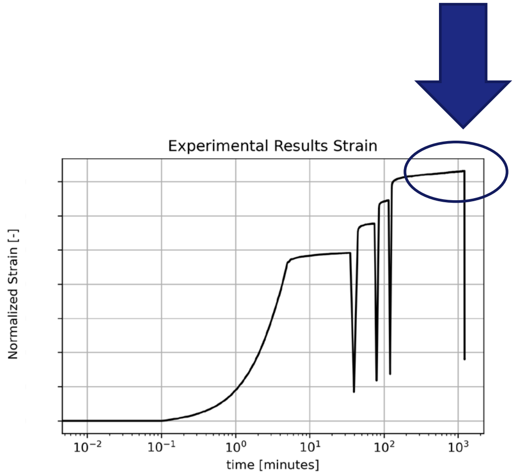
Tests for polyester yarns (Flory et al., 2004) show that for constant tension, strain is proportional to the log of elapsed time. Yarns and complete ropes behave in a similar fashion regarding creep.

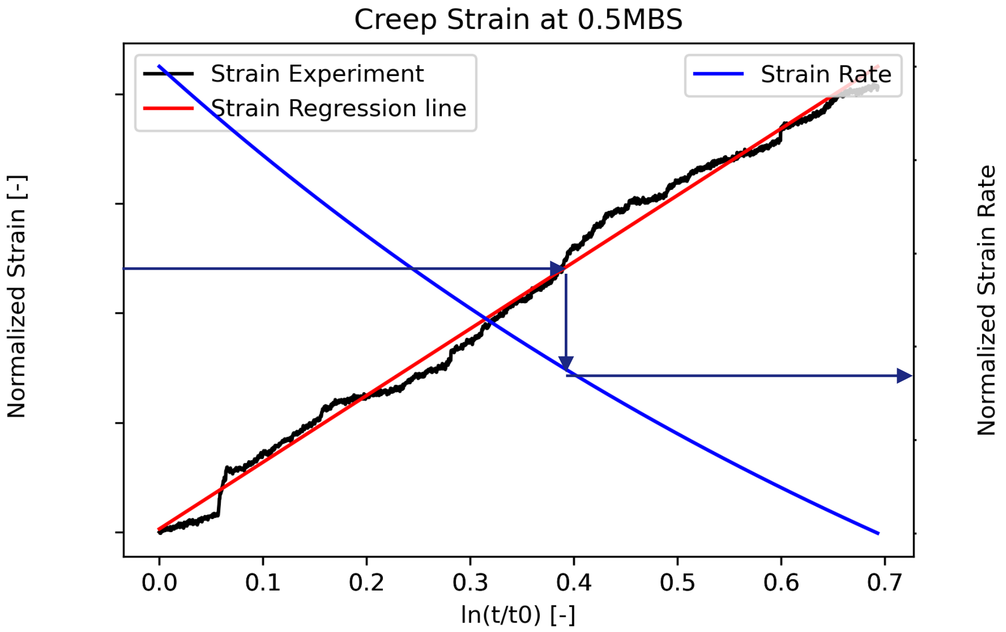
Do nylon ropes behave in the same way ?

Flory, J.F., Banfield, S.P and Petruska, D.J (2004). *Defining, Measuring, and Calculating the Properties of Fiber Rope Deepwater Mooring Lines.* Offshore Technology Conference, Houston, Texas, USA, 3-6 May 2004.

Modeling of mooring line creep in the aero-servo-hydro-elastic simulation tool 3DFloat







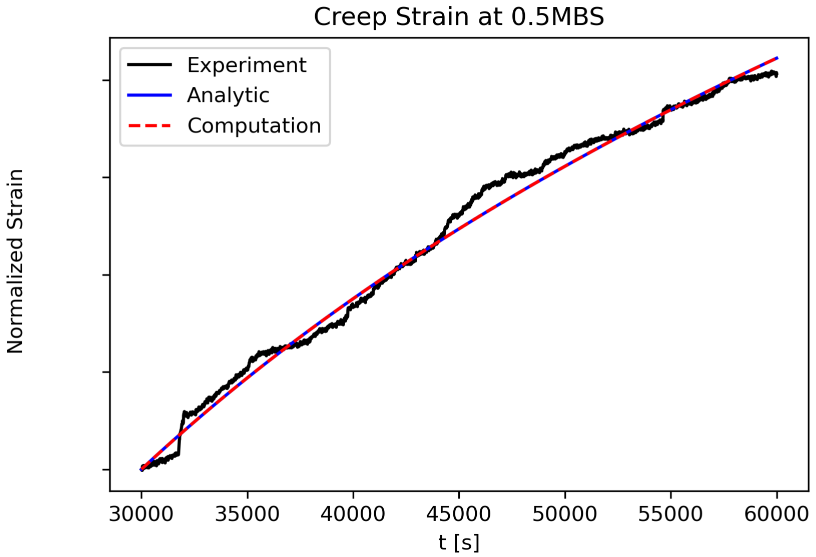
Strain proportional to ln(time) at constant stress seems reasonable for engineering purposes also for the nylon ropes in the test

The implementation in 3DFloat follows the main ideas of (Eiksund, Svanø and Nagel, 1995).

- The creep strain rate is assumed to be function of strain and stress, not time.
- A linear relationship is fitted to strain vs. natural log of time at each stress level. Interpolation between stress levels.
- The strain rate as function of strain is calculated from the regression line.
- At each time step in the simulations, the creep strain rate is obtained from the updated stress and strain.

Eiksund, G., Svanø,G. and Nagel, N.B.(1995): *Creep related subsidence caused by oil and gas extraction.* Proc of the Fifth International Symposium on Land Subsidence, The Hague, 1995

Comparisons and Conclusions



- Integration in time by the fourth-order Runge-Kutta method has been verified for the last part of the creep test, at 0.5MBS. The creep strain can then be used to update the free length of the cable element.
- In the SYROPE element, creep strain can possibly be taken into account by updating the creep dashpot damping coefficient at each time step according to tension and strain rate.

- The test results of three nylon rope samples from three rope suppliers Lankhorst, Bridon and DSR in the project Fibre Rope Mooring (FIRM) showed similar properties.
- The creep under constant tension is modeled well as being proportional to the logarithm of elapsed time.
- The implementation in the aero-servo-hydro-elastic time-domain simulation tool 3DFloat is inspired from creep models in geotechnics, where the creep strain rate is modeled as function of strain and stress.
- The numerical scheme has been verified for constant stress.
- The next step is to determine the coefficients for the rest of the SYROPE element in 3DFloat and compute the complete creep and dynamic stiffness tests.
- Good models for creep may help in the design of fibre rope mooring systems with reduced need for re-tensioning.