Bending stiffness of submarine cables.

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The development of HV large section three core power cable, to connect wind farms to the shore, is a great challenge because such cables are very large. The installation necessitates a precise knowledge of the mechanical parameters such as the bending stiffness, in order to use appropriate equipment and procedures. For such reasons a specific test equipment has been developed, in order to provide accurate measurement of the flexural characteristics of the cables.

The apparatus is an innovative implementation of the three points bending method, where the cables are bent in the horizontal plane (Figure 1). The cable is supported by specifically designed rollers, in order to minimize the friction and allow large deflection and precise measurement on a broad spectrum of deformations. This innovative solution allows also studying cables subjected to creep, where self-deformation affects the measures.

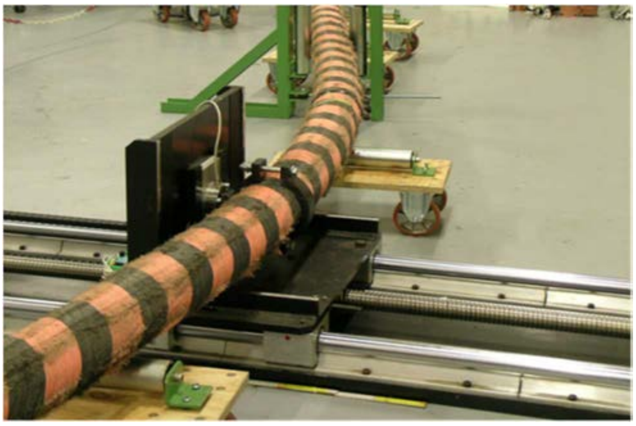

Fig.1 Bending of cable sample

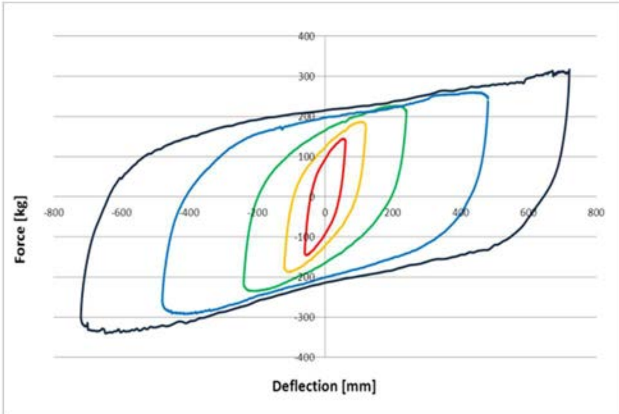

Fig.2 Typical pattern of bending cycles

At the extremities, the sample is resting on two special rolling supports: the deformation is easily modeled as a beam and the Bending Stiffness (BS) can be computed once the applied force and deflections are measured.

Moving speed can range from 0.01 mm/sec to 1000 mm/sec with maximum deflection of 1 m at the center, to span a wide range of frequency and bending radii. The apparatus is very stiff, with compliance measured in 8 mm every 250 kg of load and a friction coefficient of less than 1%.

The testing apparatus described in Figure1 can be adapted to any cable diameter and expected BS value: the $BS=1/(48\ d)\ PL^3$ formula precisely fit the experiment, due the minimization of friction and assembling uncertainties.

To characterize a cable, a series of measures is performed at constant speed, with varying maximum deflection (Figure 2), or at constant maximum deflection, with varying maximum speed. Each measure comprises a number complete bending cycles, because repetition is fundamental to pre-conditioning the sample and to verify repeatability of the measure.

Various types of cables have been tested: single core and three core, with different types of armoring or without armoring. The experimental results show that bending stiffness depends on many factors such as bending amplitude, speed of the deflection (that is cycle frequency), ambient temperature and preconditioning of the sample. Influence of the length of the sample has been solved and an algorithm is provided, in order to cut the sample at a correct length to obtain trustable results.

More information on the mechanical performance can be derived from the typical bending pattern reported in Figure 2: maximum deflecting force to bend the cable, hysteretic friction to prevent the onset of vortex shedding or force recovery after long term deflection.

Results also show that the bending stiffness of cables decreases greatly when the bending radius becomes small, as a consequence of the high plasticity of the cable at large deformation. Moreover, the BS increases slowly when deformation speed is increased in bending cycles.

Cable construction has a significant influence on BS, especially on polymeric materials and friction between adjacent layers and the simple correlation to the cable diameter is not sufficient to predict the BS value.