Fatigue Analysis of Copper Conductor for Offshore Wind Turbines by Experimental and FE Methods

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Abstract

The objective of this work was to investigate the fatigue performance of a 95 mm² copper conductor by experimental test and finite element analysis.

Objectives

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Methods

A. Experimental Method

The specimens used in this work were taken from a 95 mm² copper conductor (ETP copper), designated by the UNS C11000 series. The definition of ETP copper is related to copper alloy purity of at least 99.95% and characterized by a very high electrical conductivity and ductility. The conductor cross section consisted of 19 wires, each with a diameter of 2.5 mm. A centre wire is followed by six and twelve helically wound wires in two layers (see Fig. 1). The specimens were cut, straightened and terminated at the ends using tubular aluminium tubes filled by standard high strength glue (see Fig. 2). Due to the opposite lay angles of the helical layers, the surface irregularities were found to be periodic with a wavelength of approximation 20 mm with a mean thickness reduction amplitude of 0.44 mm with a coefficient of variation (COV) of 0.063, illustrated in Fig. 3. The fatigue specimens were tested in constant amplitude axial tension corresponding to nominal stress ranges (Δσ) of 130, 160, 190 and 220 MPa. The nominal stress range is based on a constant area of 5 mm². The loading test frequency, f, was 2 Hz harmonic loading (sinusoidal) with R-ratio, R = 0.1. The cyclic axial load was applied using a standard fatigue testing machine. The specimens were clamped in both ends. see Fig. 4.

B. FE Method

A finite element model was made in order to investigate the effects from measured thickness irregularities and material plasticity with respect to the expected stress range at the material surface. This was performed by applying a 100 mm long elasto-plastic beam model, using the measured strain-stress curve, a kinematic hardening model and element eccentricities according to the average measured thickness irregularity (see Fig. 5). The computer code Uflex3d was applied, using 48 integration points in the cross-section.

Results

Fatigue testing of single wire specimens taken from a 95 mm² copper conductor has been carried out. This has been combined with systematic measurements of observed surface irregularities resulting from the manufacturing process and FE analysis to predict their effect on the surface stresses. The results indicates that the differences seen in fatigue performance between layers can be explained by inherent variations in surface irregularities. However, more data are needed in order to conclude on this, both with respect to the copper conductor investigated here and other conductor geometries.

Conclusions

Fatigue testing of single wire specimens taken from a 95 mm² copper conductor has been carried out. This has been combined with systematic measurements of observed surface irregularities resulting from the manufacturing process and FE analysis to predict their effect on the surface stresses. The results indicates that the differences seen in fatigue performance between layers can be explained by inherent variations in surface irregularities. However, more data are needed in order to conclude on this, both with respect to the copper conductor investigated here and other conductor geometries.

References

8. UFL3D Version 1.0.1 (User Manual)

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