Aerodynamic instability of a cylinder with thin ice accretion

The present work is motivated by a hanger vibration event on the Great Belt East Bridge, involving hanger ice accretion from March 27-31, 2001. The paper outlines a series of icing tests performed on a cylinder at the NRC Altitude Icing Wind Tunnel in March 2009 and the wind tunnel tests thereafter, leading to a description of the mechanism behind the hanger motional instability. Transmission line vibrations due to ice accretion have received considerable interest in recent years [1-5]. Although much work has been done on the wind-induced vibrations of bridge cables e.g. [6-8], little or no research on ice-accreted bridge cables exists. Figure 1 shows a typical section of ice accretion as has been found on a vertical hanger of the Great Belt East Bridge, with a diameter of approximately 115mm. This ice shape is not from the specific aforementioned vibration event, but it illustrates that a fairly uniform ice accretion can be generated on cylindrical cables.

In order to investigate the nature of accretion, a set of wind tunnel tests were performed at varying temperatures and with varying levels of liquid water content. From these experiments, one ice shape similar to that of Figure 1 was selected. This was then used in the generation of a generalized ice profile. The generalized ice profile was selected so as to depict with a fair degree of representation the most commonly observed ice accretion on the Great Belt East Bridge. Subsequently, the generalized ice profile was manufactured by use of rapid prototyping. Next, a series of static wind tunnel tests were undertaken to determine the aerodynamic force coefficients of the rapidly prototyped hanger sectional model. Finally the aerodynamic force coefficients (drag, lift and moment), found from the static wind tunnel tests, were used to determine the potential for aerodynamic instability of the hanger through application of the quasi-steady theory developed by Gjelstrup et al. [9-10]. The application of the theoretical model yield regions of expected aerodynamic instability in which the observed vibrations of the Great Belt East Bridge hangers lie.

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