Application of New Measurement and Simulation Methods to Marine Icing on Offshore Structures

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ABSTRACT

Offshore structures are subject to ice accretion during Winter conditions when the air temperature falls below about -2°C, and sea spray is generated by wave-structure interaction. Cases have been reported in which an estimated 200 to 500 tonnes of ice have accreted on semi-submersible platforms. However, to date, there have been no instruments to automatically measure the ice accretion rate on platforms, and consequently there are no offshore ice accretion climatologies. In this paper, we describe the design, testing and deployment of a novel offshore ice thickness sensor. We also show how the N_RIGICE icing model can be used, in conjunction with six years of environmental data measured on the Rowan Gorilla rig, to establish a preliminary offshore structure icing climatology. Data from the new icing instrument will be used to test and calibrate the N_RIGICE model, providing "ground truth" for the icing climatology.

KEY WORDS: marine icing, offshore structures, instrumentation, modeling, climatology

1. Introduction

Offshore structures in the marine environment are very likely to be subjected to ice accretion during Winter conditions, when the air temperature drops below about -2°C, and when the wind and waves interacting with the structure are sufficient to generate significant amounts of spray. When this process continues for some time, substantial ice loads can develop. Several cases have been documented where between 200 and 500 tonnes of spray ice have accreted on semi-submersible platforms, causing problems with draft and stability (Minski, 1984; Brown and Roeber, 1985). An additional problem is the higher wave impact forces which arise from the ice-enhanced cross-sectional area of the structural members.

Apart from the few extreme cases referenced above, there is little offshore structure icing data available to designers and regulators. What does exist is sporadic, because no long-term systematic observation programs have been undertaken, and so far rather few platforms have been operating year round in the Canadian offshore.

With a view to remediying this deficiency we have developed a two-pronged approach to the problem. The first has involved the development of a novel marine icing sensor, which is designed to operate automatically onboard a rig, and to provide continuous quantitative ice thickness measurements. The second is the development of a simulated marine icing climatology, using measured environmental data, in combination with a calibrated model of spray ice accretion on offshore structures.

Most marine icing measurements to date have involved manual or photogrammetric estimates of ice thickness. Both techniques require a human observer and have generally been applied only after the icing event is over. Consequently, there has been a long-standing need to develop an instrument to automatically measure in-situ ice loads and thicknesses as an icing event unfolds. Such an instrument operating unattended below deck, could provide the rig operator with real-time data. The long-term measurements from such an instrument, in conjunction with simultaneous environmental measurements, could also be used to test and calibrate existing and new marine icing models.

To the best of our knowledge, there are four models of icing on offshore structures: the Ashcroft Model (Ashcroft, 1985), the Romagnoli Model (Romagnoli, 1988), the ICEMOD Model (Horjen and Vefsnmo, 1986), and the RIGICE Model (Brown and Horjen, 1989). Of these, only the RIGICE model appears to be in the public domain. In the present paper, we will use an improved version of this model, N_RIGICE (Mitten, 1994), to simulate icing on a semi-submersible rig, for the purpose of developing a preliminary offshore structure icing climatology for part of the Scotian shelf.

2. The Marine Icing Sensor

After several unsuccessful attempts to measure the thickness of spongy marine ice accretions by ultrasonic methods, we decided to devise a mechanical instrument. The design of the instrument was constrained by the following criteria:

1. The instrument was to be installed on the jack-up rig, Rowan Gorilla, in the Sable Island region, offshore Nova Scotia.