

Comparison of Standards for Predicting Ice Forces on Arctic Offshore Structures

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ABSTRACT

Ice force predictions using the ISO 19906 Arctic offshore structures standard and three national standards have been compared for structures offshore Sakhalin. A multi-leg structure with leg diameters 18 and 24 m subjected to several design ice conditions, level ice 1.2 m, rafted ice 3.5 m and a first year ridge keel 21 m deep was evaluated. ISO 19906 is the most complete and transparent standard in providing guidance. It incorporates guidance on ice strength from the Russian standard, and ice thickness and geometry effects from the Canadian standard. Further guidance is still needed for multi-leg structures.

KEY WORDS: ice-structure interaction; ice forces, offshore structures; standards.

INTRODUCTION

Late in 2010 an international standard, ISO 19906 Arctic offshore structures (ISO, 2010), was published. It reflects a consensus of the international ice engineering community, and covers a range of topics pertinent to the design of offshore structures in Arctic and cold regions areas (Spring et al, 2011). ISO 19906 comprises a Normative part, which contains the provisions a designer must follow in order to be compliant with the ISO standard. It also contains an Annex A of informative text and commentary to assist the designer in complying with the requirement of the Normative text, e.g. methodologies, equations, descriptions and references. It should be noted that ISO 19906 only covers Arctic and cold region aspects of offshore structure design. It is part of a suite of 13 ISO standards for offshore structures, and other standards in the suite have to be consulted for any structural design application. There are three national standards which were reviewed in preparation of ISO 19906, and provided guidance for Arctic offshore structures; Canada's CAN/CSA S471-04 General requirements, design criteria, the environment, and loads (2008), the United States' API (American Petroleum Institute) RP 2N Recommended Practice for Planning, Designing, and Constructing Structures and Pipelines for Arctic Conditions (1995) and the Russian Federation's SNiP 2.06.04-82* Loads and Effects on Hydrotechnical Structures (from waves, ice and vessels) (1995). It can be taken that best practices from these national codes have been combined in

ISO 19906. A comparison of global ice pressure and force predictions of the standards is of interest. Recently Bekker et al (2010) and Masterson and Tibbo (2011) compared a number of standards for several ice loading scenarios on a vertically-faced "Molikpaq" type structure and a multi-leg structure. In this paper other structures will be compared, and trends in ice forces relation to ice thickness and structure size determined. Because of the broad range of ice properties possible, conditions in the Okhotsk Sea off the northeastern coast of Sakhalin Island have been selected for illustrative purposes. This paper will provide a comparison of the results of ice force prediction equations for single vertically-faced structures and multi-leg structures exposed to level ice and ridges.

ICE LOAD STANDARDS

In one form or another, all of the four standards reviewed consider, the following force limiting mechanisms; limit stress for ice failing against the entire structure width, limit energy where force is limited by the kinetic energy of the impacting ice feature, and limit force where the force is limited by driving force on the ice feature. Limit stress is the mechanism which leads to the highest ice forces, and this mechanism of force determination will be examined for each standard. All the standards have a similar equation that relates the global ice pressure, p_G , to a global ice load, F_G , on a structure

$$F_G = p_G \cdot h \cdot w \quad (1)$$

where h is ice thickness and w is structure width. In some circumstances structure dynamics are a factor in determining ice forces, however here only static ice forces are considered.

While not discussed in this paper, all the standards adopt a version of partial factor design to achieve an overall level of reliability in the design of a structure. For ice forces generally this is achieved with the 10^{-2} annual exceedance condition and a factor of 1.35. Bercha and Gudmestad, 2008 and Moslet et al, 2011, have compared reliability based design approaches in several standards and the reader is referred to them for further discussion of this issue. Use of the global ice forces predicted in this paper should only be done after a careful reading of the individual standard being used, to ensure proper interpretation of guidance and selection of appropriate load (safety) factors. In the