Ice Forces on Jack-up Legs due to Ice Crushing

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To study ice forces on jack-up legs, a series of model tests were conducted to compare ice forces on two cylindrical indenters of the same diameter, one of which has gear teeth on both sides scaled from a prototype jack-up leg, while the other has no gear teeth. Results of the model tests indicate that, because the geometrical dimensions of the gear teeth are very small in comparison to the diameter of the jack-up indenter, crushing ice forces on the jack-up indenter vary slightly when the angle between the ice-moving direction and the gear teeth direction changes, and that the gear teeth do not increase the magnitude of crushing ice force significantly. Based on the model test results and subsequent analysis, a method for calculating crushing ice force on jack-up legs is proposed, and the application of the spectral model for continuous crushing ice forces on cylindrical legs to jack-up legs in the Bohai Sea is discussed.

INTRODUCTION

A jack-up structure is one of the most popular options for offshore platforms in marine engineering. In recent years, there has been a growing need to deploy jack-up structures in cold regions. Unfortunately, up until now, we have had little knowledge about the magnitude of the ice force that jack-up structures must sustain in ice-infested waters, which is attributed to the lack of knowledge about ice forces on cylindrical legs with gear teeth on both sides. According to decades of research on ice actions, ice forces acting on structures depend mostly on structure shapes at ice level, because different structure shapes result in significantly different failure modes of the ice sheet, resulting in different magnitudes of ice force (Sanderson, 1988; Bjerkås, 2004).

The most commonly used offshore platforms in ice-infested subarctic shallow waters have cylindrical legs or conical structures at water level. Research of ice forces on cylindrical legs and conical structures has been done for nearly a century, and much literature can be found on the Internet. Crushing of the ice sheet on a cylindrical leg (Fig. 1) leads to the largest ice force and may result in dynamics problems in some conditions (Sodhi, 1988; Sodhi and Haehnel, 2003; Engelbrektson, 1989, 1997; Yue et al., 2001, 2002; Yue and Li, 2003). Compared with cylindrical legs, conical structures (see Fig. 2) can reduce ice forces to a great extent, because bending failure of an ice sheet results in much lower force on a structure in comparison to that for crushing failure of ice (Yue, Ou, et al., 2006; Yue et al., 2007; Xu et al., 2010).

A jack-up structure is a type of drilling platform that is usually deployed in relatively shallow waters. The legs of jack-up platforms consist of a cylindrical leg and gear teeth on both sides, which are used to lift the deck of the platform. Figure 3 shows a 3D configuration of a jack-up leg, and it is obvious that when the ice sheet acts on jack-up legs, the failure mode of the ice sheet can be more complicated than that for single crushing or bending.

So far, the research on ice forces on jack-up legs is quite limited, and there is no applicable approach to determine ice forces on jack-up legs. Undoubtedly, a field test would be the most effective method for this study, but also very difficult and costly. Therefore, a series of model tests were conducted in the laboratory of Dalian University of Technology to compare ice forces on cylindrical legs and jack-up legs.

MODEL TEST SYSTEM

The model test system is located in the laboratory at Dalian University of Technology, and it is designed for simulating ice actions on fixed offshore structures, including static ice forces and dynamic ice-structure interactions. Figure 4 is a sketch of the side view of the test system, and Table 1 describes in detail different parts denoted by numbers in the sketch.

Fig. 1 Snapshot of an ice sheet crushing on a cylindrical leg
Fig. 2 Snapshot of an ice sheet acting on a conical structure