International Journal of Offshore and Polar Engineering (ISSN 1053-5381)

Vol. 25, No. 3, September 2015, pp. 205–211; http://dx.doi.org/10.17736/ijope.2015.rf60

http://www.isope.org/publications/publications.htm

Comparison and Cause Analysis of Ice-Induced Structural Vibrations on Different Ice-Breaking Cones

Ning Xu
National Marine Environmental Monitoring Center, SOA
Dalian, Liaoning, China

Qianjin Yue and Dayong Zhang
School of Ocean Science and Technology, Dalian University of Technology
Panjin, Liaoning, China

Yan Qu
DMAR Engineering, Inc
Houston, Texas, USA

Shuai Yuan, Xueqin Liu and Weibin Chen
National Marine Environmental Monitoring Center
Dalian, Liaoning, China

Ice-induced structural vibration mainly depends on the two coefficients of dynamic ice force: amplitude and period. According to the field measurement results obtained on two jacket structures installed with composite upward and downward ice-breaking cones in the Bohai Sea, the ice-induced structural vibrations vary with the ice acting position on the cone because cone shape (upward cone or downward cone and width) is one of the dominant influencing factors of the ice force period and sea ice breaking length. With the increase in the cone diameter, the ice failure mode on the upward cone was transformed from the wedge failure mode (with the long sea ice breaking length) into the plate failure mode (with the short sea ice breaking length). The plate failure mode was observed on the downward cone. When the small cone was selected, the significant difference in the dynamic ice force period was observed between upward and downward cones. When the wide cone was selected, the difference was not significant.

INTRODUCTION

When ice sheets pass through a fixed offshore structure, continuous ice failure produces dynamic ice loads, which lead to the structural vibration called ice-induced vibration. Since ice-induced vibrations were observed on oil platforms in Alaska's Cook Inlet (Peyton, 1968; Blenkarn, 1970), Bothnian Bay Lighthouse in the north of Europe (Engelbrektson, 1977), and other offshore structures in marine ice areas, ice-induced vibrations of offshore structures have been extensively studied. At present, serious ice-induced vibrations are also observed on the oil platforms in Liaodong Bay of the Bohai Sea. When ice loads act on vertical structures, ice loads mainly lead to crushing ice failure, which can produce the largest horizontal ice load compared to other ice failure modes. Yue and Bi (2000) installed measurement systems on vertical offshore structures in the Bohai Sea and observed the most serious ice-induced steady vibrations under a certain ice velocity. The accidents of pipeline rupture and loosening flange occurred on offshore platforms because of ice-induced structural vibrations. It is necessary to obtain a proper way to eliminate or reduce ice-induced vibrations.

Received July 18, 2014; updated and further revised manuscript received by the editors March 23, 2015. The original version (prior to the final updated and revised manuscript) was presented at the Twenty-fourth International Ocean and Polar Engineering Conference (ISOPE-2014), Busan, Korea, June 15–20, 2014.
KEY WORDS: Ice-induced vibration, ice force period, sea ice breaking length, sea ice bending failure mode.

Installing ice-breaking cones at the waterline of offshore structures is one of the solutions to reduce ice-induced vibration. In fact, the original purpose of installing ice-breaking cones on vertical structures was to reduce extreme ice force. The reduction effect on ice force is based on the principle that the ice–cone interaction can convert the sea ice crushing failure mode into the bending failure mode. The principle has been verified by theoretical analysis and experimental tests (Wessels and Kato, 1988; Izumiyama et al., 1991). Therefore, various ice-resistant prototype structures were developed with ice-breaking cones or inclined shape at waterline (Määttänen, 1996; Brown, 1997).

Since the first ice-breaking cone was installed on the JZ20-2MS platform in the Bohai Sea in 1992, more cones have been installed on several ice-resistant offshore structures in the same sea area. According to the monitoring results on conical platforms (Yue and Bi, 2000), the dominant ice failure mode during the ice–cone interaction was the bending failure mode, in which sea ice failure occurred at the intersection of upward/downward cones. Ice force was reduced and ice-induced steady vibrations were even avoided on vertical structures. However, full-scale measurements indicated that the ice bending failure also generated dynamic forces during the ice–cone interaction, which also led to significant vibrations on offshore platforms.

Previous studies indicated that the width, inclination angle, geometrical size, surface friction coefficient, and other parameters of cones significantly affected ice forces applied on conical offshore structures as well as the vibration reduction effect. In the application of ice-breaking cones, the selection of upward, downward, or composite upward/downward cones was mainly determined by