A New Method for the Analysis of Ice Intermittent Crushing Induced Lock-in Vibration

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ABSTRACT

The paper presents a simple method for the analysis of ice intermittent crushing induced lock-in vibration of offshore structures. The method is based on a new explanation of the ice-structure interaction process observed from full scale measurements. The main characteristic of the description is that the ice failure is a ductile damage – collapse process and that the ice only breaks at the collapse stage with a specific break length. A relationship between the ice break length and magnitude of the structure vibration is derived from the new failure process illustration. The method can be used for fatigue damage and magnitude analysis for lock in vibration of offshore structures in ice.

KEY WORDS: Ice induced vibration; Lock-in vibration; Intermittent crushing; ductile damage – collapse failure process.

INTRODUCTION

Intermittent ice crushing induced lock-in vibration of cylindrical offshore structure, also referred to as steady state vibration or self excited vibration, has been recognized as a serious load condition for offshore structure in ice covered sea. It has been found that the vibration might occur on a range of different structure types in different areas. Peyton (1966) and Blenkarn (1970) independently observed such vibrations on the jackets of oil platforms in Cook Inlet. Engelbrektson (1983), Määttänen (1977,1978,1988) Yue et al. (2001) reported the same type of vibration for jacket platforms in Bohai Bay. Even caisson structures, such as the Molikpaq platform, exhibited the same vibration during a test case event that occurred on May 12, 1986. (Jefferies, 1988, Gagnon, 2012). Many efforts have aimed to develop a methodology to analyze such vibration. Matlock (1969), Sodhi (1998) presented a method based on the assumption that the vibration was caused by forced vibrations. Määttänen (1978, 1988), Yue et al. (2009) considered the vibration as a kind of nonlinear vibration induced by the negative damping effect during the ice failure transitioning from ductile to a brittle crushing mode. However, as of yet a well accepted solution is not available to engineers. One reason is that the ice failure process has not been clearly illustrated.

To study offshore structure vibration induced by ice action, several full scale measurements have been accomplished during the past decades. The measurements on the offshore oil platforms in Bohai Bay and at a lighthouse in the Baltic Sea were two of the successful projects among those works. Many intermittent ice crushing failure induced lock-in vibration events have been observed in those measurements. Both the ice load and structure vibration data have been recorded together with videos of the ice structure interaction. This paper presents a new method for lock in vibration analysis based on the analysis of the ice failure process observed in the field and ice load and structure response data. The analysis shows that the ice failure process is an ice ductile damage - collapse process. The ice load increases during the damage process and decreases in the collapse process. The loading and unloading process of the ice load is locked in with the structure’s vibration phase change. During each vibration process, the ice has a specific break length. The magnitude of the vibration can be evaluated by using the ice break length.

FULL SCALE MEASUREMENT OF THE ICE LOAD AND STRUCTURE VIBRATION

Measurement of the ice action on the offshore structures in Bohai Bay was part of a long term sea ice management program. The measurements has been conducted on several oil platforms and mono leg mooring piles for about 15 years. In the measurements from 2000 to 2004, two rows of load panels were installed on legs of the structures. Each load panel was designed with 62 cm height and 27 cm width. Together with the load data, structure responses have also been measured by the accelerometers and stored by a data acquisition system. The ice failure process against the structure was observed by video cameras as well as through in-situ observations. The structures and measurements system are shown in Figs 1-2.

Similar to the measurements in Bohai Bay, the Norstromsgrund lighthouse in the Baltic Sea has also been instrumented with ice load panels, accelerometers and video cameras to measure the ice action against the structure. The lighthouse has total height of 42.3m and diameter of about 7.52m at the water line which is larger than the structures in Bohai bay. Nine sets of load panels, each with an area of 1.2 m width and 1.6m height, cover about 162 degrees of the waterline structure surface. The load panels used on the lighthouse are much larger than those used in Bohai Bay. Hence it measured the ice force...