ABSTRACT

The forebody of the Research Vessel Polarstern was instrumented to measure normal and tangential ice forces on two 1-m² areas, one mid-bow and the other on the shoulder of the hull. Simultaneous time series records of the normal and tangential ice forces on both areas were used to examine the nature of ice friction on the hull. The friction coefficient varied inversely with the magnitude of the normal force and depended on whether the normal force was increasing or decreasing. The data allowed the more detailed examination of the apparent relation between normal and transvers forces. Friction coefficients averaged 0.5 for normal forces less than 100 kN, but deceased to values in the range 0.05 to 0.15 for normal forces greater than 500 kN.

KEY WORDS: Local ice forces; friction; normal and tangential forces.

INTRODUCTION

Friction is an important factor that influences the performance of ships transiting through ice-covered waters. It enters into certain calculation equations for ice resistance (Keinonen et al, 1996, Lubbad and Loset, 2011, Su et al. 2010). Most testing done to determine the friction of ice on various materials has been done in laboratories. Temperature, speed, wetness, roughness have all been identified as affecting friction. One out of a range of parameters is varied systematically over a range of values, while all the others are kept constant. The result is a value of friction coefficient as a function of a particular set of parameters. Many studies have been aimed at determining friction for direct application, e.g. Calabrese et al (1980), Tatinclaux et al (1986). Understanding friction between ice and various materials has been an area of fundamental investigation, e.g. Barnes et al (1971), Makkonen and Tikannuki (2014). Recently laboratory tests have investigated ice friction processes under crushing conditions (Gagnon, 2016). Actual measurements of ice friction directly on the hull of a ship operating in ice have been much more limited.

A measuring system on the R.V. Polarstern allowed direct measurements of ice-hull friction under actual conditions in the field. The system was developed by the Hamburgische Schiffbau Versuchsanstalt (HSVA) and the results reported by Hoffmann (1985). An inquiry to HSVA about availability of digital data revealed that none are any longer available, however one hard copy record about 15-minutes-long was located and made available. This time series record of normal and tangential forces will form the basis of the analysis of friction and local ice forces from direct measurement on a ship while in ice.

DESCRIPTION OF MEASURING SYSTEM AND DATA

The R.V. Polarstern is an icebreaking research vessel that came into service in 1983. Its primary mission is resupply of the German Antarctic Research Station but it is also a platform for research in Polar Regions. The ship is 118 m in length, 17,300 tonnes displacement and 14 MW power. It was built to Germanische Lloyd ice class ARC3, and the ship is capable of breaking 1.5 m ice at a speed of 5 knots. In May of 1984 the ship conducted icebreaking trials off the coast of Labrador. The trial period extended for 16 days, from May 17 through to June 1, during which various performance measurements were made. As part of these trials, the ship was instrumented to measure performance in ice and response of the ship to ice loading. Of particular note were two local ice force measurements panels installed in the forebody of the ship (Hoffmann, 1985). They were capable of measuring both normal force and tangential forces in the horizontal and vertical directions, so they generated data for evaluation of friction, as well as local ice impact forces.

The general location and arrangement of the panels is illustrated in Fig. 1. The panels were 1.4 m long by 0.8 m high and 8 m apart along the starboard side of the ship. The panels were coated with INERTA 160, but it was reported the conditions at time of application in dock were not optimal. The rear panel was at the shoulder and the front panel was mid-way along the bow. Each panel had a normal load capacity of 4 MN and a load capacity of 1 MN in each orthogonal direction (horizontal and vertical). The system logged data at a frequency of 50 Hz. More details on the system can be found in Hoffmann (1985).