Comparison of Pressure-Area Effects for Various Ice and Steel Indenters

Chris Ulan-Kvitberg, Hyunwook Kim and Claude Daley
Memorial University of Newfoundland
St. John’s, Newfoundland, Canada

ABSTRACT

Ice crushing tests typically use either ice or steel as an indenter. Of interest is a comparative study of the two in order to gain an understanding of the strength characteristics and the relationship to geometry of ice compared to steel. In this experiment, two indenter shapes are used: a cone and a wedge. The impact surface is a flat plate of ice or steel. Tests are performed at an impact speed of 100 mm/s with ice as the indenter and then repeated with steel as the indenter. Force-penetration history and pressure-area curves are determined from the data and the results are compared.

KEY WORDS: Ice indentation; force-time history; pressure-area curve; constrained ice

INTRODUCTION

Physical properties of ice and ice behaviour during ice and steel collisions are of interest to anybody operating ships or offshore structures in an ice-environment. Ice-crushing tests, such as the Hobson’s Choice Ice Island tests described by Meaney et al. (1996), have proven to be a valuable method for understanding ice strengths and the complex pressure effects and crushing patterns that occur during interactions. Small scale laboratory tests can be extrapolated, with careful scaling, to give a sense of full scale interactions in the field. In ice-structure collisions in the environment, complex geometries of both ice and structure mean that neither ice nor steel can be considered the indenter in all cases. Consequently, a comparative analysis of crushing experiments with ice as an indenter and with steel as an indenter is of interest.

In this paper, two different indenter geometries were used: conical and wedge-shaped. Ice was shaped into either a cone or a wedge and then crushed into a flat steel plate at a set speed. The tests were then repeated with conical or wedge shaped steel indenters crushed into a flat plate of ice at the same speed. From the data, force-penetration histories and process pressure-area curves were created and analyzed.

UNIAXIAL CRUSHING TESTS

Test Apparatus

The tests performed were crushing experiments whereby a shaped indenter was driven into a flat surface. Two indenter shapes were chosen: a 22° cone and a 22° wedge. For the ice, artificially produced ice of a high degree of purity with large ice crystals was chosen. This ice contained a high degree of variability in grain orientation; for these tests, grain orientation was not considered and further tests with a set grain orientation may be of interest to determine the influence of orientation on ice loads. The ice was produced in large blocks from which all of the test samples could be drawn. For the ice indenter tests, the ice was first cut and shaped into a 10 cm cylinder and then formed into the desired indenter shape and frozen into a steel ice holder for a period of at least 5 hours. The experimental setup detailing the steel wedge and ice cone indenters are shown below in Fig. 1.

![Steel Wedge and Ice Cone Indenter Setup](image)

Fig. 1 – Steel Wedge and Ice Cone Indenter Setup

Freezing the ice for 5 hours ensured that the ice was secure in the ice holder and not free to shift during loading. A source of error in the experiments lay in the shaping method: the ice cone and wedge could not be guaranteed as being perfectly shaped. Thus, for the initial penetrations, the cross sectional area was estimated rather than being exact which would affect the pressure-area curves. For the steel indenter tests, plates of ice were cut and frozen into a secure steel holder.