

## **Comparison of Results of Impact Tests on Laboratory and Natural Freshwater Ice with Hydrodynamic Model Predictions**

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### **ABSTRACT**

An extensive series of drop impact tests were carried out by the Arctic and Antarctic Research Institute (AARI) on natural ice in the late 1960s and by the National Research Council of Canada (NRC) on laboratory ice in the late 1980s. Spherical impactors of radii 286 mm and 100 mm and masses ranging from 33 kg to 300 kg were used. Impact velocities ranged from 0.6 to 5.6 m/s. Measurements of accelerations of the impactor allowed ice resistance and penetration to be determined. The data from both test locations were analysed using the Kheisin and Kurdyumov "hydrodynamic model" of impact of a rigid body on ice. The "ice impact crushing strength", analysed by applying the "hydrodynamic model" to all the data, showed consistency and similar trends. Impact strength decreased with increasing velocity and increasing ice temperature. A velocity dependent "ice impact crushing strength" is suggested as a modification to the "hydrodynamic model".

**KEYWORDS** Ice impact, ice strength, field and laboratory tests.

### **1. INTRODUCTION**

The impact of ships with floating ice is a controlling factor in Arctic navigation. To understand the local loads generated on ship hull structures by these ice impacts, various means have been used. One approach has been to measure the response of ship hull structures and infer the nature of the impact loads. This approach has the advantage of representing actual impacts. The disadvantage is that the ice conditions corresponding to the impact are not well described. Another approach has been to carry out tests under controlled field or laboratory conditions to obtain a material property, an "impact strength" of the ice, and incorporate this strength property into a theory to predict ice impact pressures on ship hulls.

The first comprehensive experimental study of the impact of a rigid spherical body against ice was conducted by the Laboratory of Ship Performance in Ice at the Arctic and Antarctic Research Institute over the period 1967-1969 (Likhomanov and Kheisin, 1971). The primary measurements were acceleration of the body and the depth of penetration into the ice. Based on these tests, the "hydrodynamic model" of impact on ice was developed. More recently Timco and Frederking (1990, 1993) carried out an ice impact test series with a spherical impactor in which both acceleration and local pressure were measured, so it was possible to investigate the spatial and temporal distributions of local pressure during impact. Although the original study was done some time ago, recent events suggest that a re-examination of it, and other impact data, was in order for the following reasons. Firstly, it was of interest to compare the results of the early study with data obtained in a test program carried out at the National Research Council in 1989 and 1991. Secondly, the problem of evaluation of ice impact loads on ship structures has attracted special attention recently. This interest is related to development of harmonised International Polar Shipping Rules and unification of Classification Society requirements to ship structures design. Because the hydrodynamic model is used for prediction of ice loads on ship hulls, verification of this model by both AARI and NRC data would be very helpful. Finally, modern computers and software packages provide an opportunity to carry out a thorough processing of the experimental data that was not possible in the 1960s. This paper will compare the results of the two test series and use them to verify the hydrodynamic model.

### **2. REVIEW OF HYDRODYNAMIC MODEL**

The basic assumption of the hydrodynamic model is that during impact of a rigid body with ice a thin layer of crushed ice develops between the indenting body and the undamaged ice. The crushed ice layer behaviour is similar to the flow of a thin

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