MEC-E6007

Case Study

Fracture Mechanics of Sea Ice

Sid Oksala 878355

Aalto University

MECHANICAL TESTING
OF MATERIALS

Introduction

The case study I have chosen are mode I fracture experiments with saline ice. The aim of these experiments is to study and explain the fracture processes within ice. Several theories have been used to explain the fracture of ice, but none of them have, to date, been shown to unambiguously work. For instance, the use of linear elastic fracture mechanics (LEFM) has been criticised because ice is rarely linearly elastic and the use of the viscoelastic fictitious crack model (VFCM) has been criticised because it has been shown that ice is not always viscoelastic. Consequently my tests aim to systematically study the processes through a range of parameters in laboratory conditions to establish the fracture properties of ice. My experiments will utilise traditional force and displacement measurements along side digital image correlation (DIC) to study the crack propagation in the specimens. This will allow us to not only establish factors such as the fracture toughness, but also study small scale deformations processes at the grain scale.

Test Description

The tests will use edge cracked rectangular plates with a 2:1 width to length ratio. A range of different sizes will be tested with approximately 2 m by 4 m being the largest. The specimens will be loaded at the crack mouth with a loading device. Crack opening displacements will be measured at 5 locations along with the force caused by the loading device. The specimen will be stamped with a DIC pattern along the expected path of the crack. The experiments will be performed in the Aalto cold room at temperatures ranging from -2.5 °C to -10 °C and at variety of loading rates.

The most time intensive part of the tests will be to prepare the specimen. First we will have to grow the specimen. This will be done in a purpose built tank that allows for the control of the temperature and salinity of the water. Specimens of thickness up to 30 cm will be grown. Once the specimen is grown it will be characterised using salinity, grain size and orientation, density, and temperature. It will then be cut free from the sides of the tank and to the desired dimensions. A notch will be cut into one edge of the specimen. The loading device will be installed into the notch and displacement sensors will be installed at prescribed intervals. The speckle pattern will also be applied. How exactly the speckle pattern will be applied remains to be seen but different methods will be tested, including using titanium oxide and carbon black.

The installed loading device will have a load cell which will allow measurement of the imparted load in newtons. The displacement sensors will work with lasers. With all measurements that are made care must be taken that the devices remain accurate in subzero temperatures. It is also important that the loading device is rigid. Any stored elastic energy in the loading device will significantly affect the results of the experiment.

Compared to the same experiments conducted on real sea ice in the field, these experiments are fairly safe. However, it must still be remembered that they are being conducted in cold conditions and consequently all participants must be dressed appropriately and make sure to avoid getting too cold. Furthermore special care must taken when handling metal objects with bare hands to avoid frostbite. Also, when working in the cold room, either a buddy system should be maintained, or at the very least someone outside the cold room should be made aware that that someone is working there.

Data Processing

Once the tests have been completed the collected data can be processed and analysed. The DIC data will be processed by the VIC-3D software acquired by the school from Correlated Solutions. Commenting on the analysis of these results is challenging at this stage, but among other things, we are hoping to see whether the crack travels through grains or along grain boundaries. The force and displacement measurements require fairly simple processing and can then be compared to results attained by application of LEFM and VFCM to the same case. The results will also be compared to those gained in similar field experiments conducted in Svalbard. This will also help evaluate the accuracy of the experiments. Significant deviations from the results attained during these campaigns likely suggest that the grown ice is not behaving as sea ice or that there are significant differences in, for instance, the way the samples are loaded.

Reflection

For the most part I am fairly confident in conducting these experiments my self. My main concern is in my lack of experience using DIC. However, for this concern this course has been quite helpful. The laboratory experiment we did with Farid using DIC to study the bending failure of a glue laminated timber beam helped me further familiarise myself with the DIC method. However, some help with setting up the DIC system will never the less be undoubtedly needed.