The Cryosphere Discuss.,
https://doi.org/10.5194/tc-2020-237-AC1, 2020

The Cryosphere
Discussions

Interactive comment on "Elastic-viscoplastic characterization of S2 columnar freshwater ice" *by* Iman E. Gharamti et al.

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Received and published: 30 November 2020

We thank the reviewer for carefully reviewing our work and making constructive comments. We appreciate all the time and efforts he/she put in their thorough review. All the reviewer's comments were considered in the revised manuscript. Detailed answers to each comment are given below.

1. RC1: The authors go further, however, weakening/endangering the manuscript. They analyze their data in terms of a constitutive model that was developed by Schapery (1969, 1997) for uniaxial loading (noted in lines 171-173). But in the experiments at hand, deformation occurred under a multiaxial stress state. Given that the model and the data relate to different states of stress and given that values of the

many (eight) unknown parameters in the model were derived by fitting the data and not from independent measurements, it is difficult to accept the statement (lines 303-305) that the analysis " provides a firm support of the ability of Schapery's constitutive model to describe the time-dependent response of columnar freshwater S2 ice up to crack growth initiation."

Authors: The Schapery model is developed for a uniaxial normal stress state. In our experimental set up (Fig. 1 in the manuscript), the response of the test specimen is dominated by the normal stresses at the direction normal to the X-axis, ahead of the crack. This stress state can be approximated as uniaxial in the same way as in beam bending; the stress is uniaxial tension at the crack tip and then changes linearly. Adamson and Dempsey [1] have successfully used the same type of modelling for a similar setup. In addition, Schapery's model has been verified and validated by LeClair [2]. Other analyses and approaches didn't do as well. For instance, the experimental data by LeClair [2] was modelled by Schapery's model [2] and by a physically-based FE model [3]. While the physical model did a reasonable job of modelling the data, Schapery's straight-forward model did a better job.

The approach we have used – fitting a model with experimental data by using optimization – is common in fracture models with several parameters. Pure experimental methods to determine these parameters have proven extremely difficult and indirect methods, based on parametric fitting, has been developed and used instead [4].

2. RC1: It is even more difficult to accept the claim (lines 242-243) that under the conditions of these experiments "there is no delayed elastic recovery".

Authors: We understand the reviewer's reluctance to accept the lack of delayed elastic recovery. What we measured for freshwater ice has not been reported earlier. However, this surprising response is what we measured in these tests (Figs 7b and 8b in the manuscript). Further studies are needed to confirm the result and to find explanations for the behaviour. It may be important that, compared with earlier work on freshwater

S2 ice, our samples were large and very warm.

3. RC1: The title presents a problem: it is misleading. This is not the kind of experiment that allows a characterization of elastic-viscoelastic deformation of ice. Rather, as already noted, it allows a conclusion to be made on fracture toughness and its insensitivity to pre-strain. The title needs to be changed to reflect that finding.

Authors: We will change the title into “Creep and fracture of warm columnar freshwater ice” and hope that it reflects the content better than the original title.

4. RC1: The other problem is that the manuscript contains a contradiction. The claim that the experiments were performed on ice at -2 C contradicts the temperature profile shown in Fig. 3a. There, where temperature is plotted versus depth (from 0 to 35 cm) in the ice, temperature ranges from -0.3 C near the top to 0 C near the bottom.

Authors: We apologize for the confusion. During the experiments, the ambient temperature in the laboratory was kept at -2 C. The temperature profile within the ice is shown in Fig. 2a in the manuscript. The text is edited to clear up this confusion.

5. RC1: Finally, it would be helpful to know in which journal the repeated reference to Gharamti et al. is “in press”.

Authors: The paper by Gharamti et al. [5] is now published. The cited reference is edited.

References

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3. O’Connor D, West B, Haehnel R, Asenath-Smith E, Cole D. A viscoelastic integral formulation and numerical implementation of an isotropic constitutive model of saline

ice. Cold Regions Science and Technology 2020;171:102983.

4. Elices M, Guinea GV, Gomez J, Planas J. The cohesive zone model: advantages, limitations and challenges. Engineering Fracture Mechanics 2002;69:137–63.

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