The Cryosphere Discuss.,
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Interactive comment on "Behavior of Saline Ice under Cyclic Flexural Loading" *by* Andrii Murdza et al.

Anonymous Referee #2

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General Comments: The key contribution of the paper, in addition to provide new experimental data on flexural strength of saline ice under cyclic loading, is discussing fatigue and its apparent non-classical manifestation under the cyclic loading conditions of these experiments. The key finding was that cyclic flexural stressing of a saline ice beam leads to an observed increase of flexural strength. The manuscript merits publication, but more description and explanation of the tests is required first. Specific items are identified here and in the "Line" items following. The authors present a comprehensive literature review of cyclic loading in the context of the breakup of ice sheets under ocean swell. Most of the literature on sea ice has been on weakening under cyclic loading, interpreted in terms of an S-N curve and an endurance limit (cyclic stress limiting value under which failure would not occur). Fully understanding the experiments

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Discussion paper

and analysis in this paper requires familiarity with the authors' previous publications on this strengthening phenomenon in freshwater ice, including several which were just published in 2020. The paper requires a more detailed description and explanation of the tests and results. Ice, being a high temperature material with relatively large grains, I would expect time and strain are critical parameters in characterizing its behaviour. Your loading periods are from 1 to 10 s, certainly providing time for delayed-elastic and plastic strains. A representative plot of force and deflection versus time should be added to show the reader whether time and strain are significant, or can be ignored. Figure 7 shows that for the low salinity ice and Type 1 cycling at 0.35 MPa no strengthening was observed. Provide an additional figure where results show a clear example of significant strengthening for saline ice. From Figure 8 it appears a stress amplitude of 0.7 MPa or higher is required to see a strengthening beyond 0.96 MPa simple flexural strength. This means that for low salinity ice you had to go to Type 2 cycling to get strengthening. The results in Figure 8 are hard to follow, with the results of many different tests jumbled together. Similarly, Figure 9 mixes different tests without saying how many cycles were conducted before loading to failure. Add a table which provides the test results as a function of the cycle type (Type 1 or 2, and the actual program of the Type 2 cycling for that test, number of cycles, frequency, time). This would greatly improve the paper. The purpose of 4-point loading is to create a centre section with a constant bending moment. Did the failures occur at random locations between the two inner loading cylinders? Provide some observations on failure location. More of an aside, the authors may be interested in an observation in the book by D. Masterson published in 2019, "The Story of Offshore Arctic Engineering". It mentions experience in the field of moving a lightly loaded vehicle back and forth on a floating ice road before moving a greater load along it, as a means of improving the load bearing capacity of the ice road. Your work on cyclic flexural loading seems to provide an explanation for this field experience.

Specific Comments: Line 21; suggest adding 'and failure' to the end of the sentence. Line 35; the sentence starting with 'For instance…' is not clear, are you saying that

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the structure is being fatigued, or the ice? Line 70; you mention ‘recovery’, what is being recovered and does that mean increasing or decreasing strength? Line 78; Your experiments were performed on and analysed as beams, change ‘plates’ to beams. Lines 80-90; You mention that ice plates were grown in a circular tank, how deep was the tank? Did you seed the sheet? You mention melt water salinities, were the values given from the tested beams or samples from the whole ice sheet? Density of the ice beams should also be provided, that would help distinguish between brine pockets and air filled voids. Line 121; Make clear the orientation of these blocks in the original sheet, presumably the long dimension was in plane of the plate. Line 132, Figure 5; This figure indicates that deflection at the centre-point of the beam was measured with respect to the outer pair of loading cylinders of the four-point loading apparatus, this introduces an error. You should be measuring the deflection of the beam with respect to the inner pair of loading cylinders. Line 151; ‘softening’, what do you mean? Rewrite sentenced to be clearer. Line 168; were the test beams always in the same orientation as in the original puck? Also for the simple flexural tests, or the final loading to failure after Type 1 or 2 cycling, was the top or bottom surface the one in tension? Line 186; sp. ‘contain’ Line 289; would brine not fill cracks making them difficult, if not impossible, to detect visually; also if I understand the orientation of the thin section, the chance of having a crack in it would be rare. Line 300; could emissions also originate from grain boundary movements? Line 317; ‘water hammer’ is usually associated with pressure waves in a fluid in a closed system, If you are proposing brine movements in pores, some further explanation of the mechanism is needed. Line 331; where is the air and brine distributed, separate pockets or both in the same pocket? Line 347; explain how a brine pocket or channel makes saline ice more susceptible to premature failure. Brine pockets are very rounded, have a much larger radius and lower stress concentration than for a crack. Line 352; this discussion of brine pockets is very subjective, careful thin sectioning could have provided more definitive information on the grain structure. Line 376; the tests were done on beams, don’t refer to them as plates. Line 380; does this conclusion apply to all ice, fresh water and saline? Line 581, Fig. 12; why a negative value of hit rate, start the ordinate at 0.0, also state the units for hit rate on this axis.

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