Review of egusphere-2022-790

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This manuscript presents a new model for the fracture of sea ice at the intermediate scale, from 100 m to 10 km, using the phase-field method. The manuscript describes the model and then presents some tests where the orientation of the inserted fracture set is studied as a function of the critical failure stress. The authors then discuss the challenges of using this model inside a sea ice DEM and the outlook for ice field campaigns.

The manuscript is well-written, concise, clear, and well-presented. It is a valuable contribution to the field of sea ice modeling, especially to the current effort of high-resolution sea ice DEMs. However, I have some comments: I think there is some missing key literature related to sea ice modeling, especially to non-DEM sea ice models and fractures, the relationship between the orientation and the critical stress is a bit unclear, and compressive and shear tests are missing. Finally, I wonder if this manuscript should be better suited for Copernicus' *Geoscientific Model Development (GMD)* journal instead of *The Cryosphere*.

Therefore, I recommend this manuscript for publication with major revisions after my comments have been addressed. Below you will find my general comments, specific comments, and technical corrections. References are listed at the end of this document.

General comments

Research paper or model development paper

I really like this manuscript; it is a good step for the fracture of floes in DEM models. However, I wonder if it would not be better suited for the *Geoscientific Model Development (GMD)* journal instead of *The Cryosphere (TC)*.

The main result is that the orientation of the lines of reduced thickness is an important factor for fracturing the floe and determines the critical stress. This result is not surprising as embedded lines of reduced thickness reduce the ice strength, so the results look more like a proof-of-concept for the phase-field model for floe fracture than results about sea ice physics. Alternatively, some simulations could be added to describe more the physics of such a model and the behavior of the modeled ice floe and strengthen the manuscript, see my specific comments below.

Specific comments

The notation $\mathbf{u}$- displacement or velocity?

There is a confusing notation that needs to be addressed. The authors use the notation $\mathbf{u}$ on L66 for the displacement vector. Then, they define $\mathbf{u}$ as the velocity vector on L140.

Per convention and common use, $\mathbf{u}$ is better suited for velocity. I suggest using something like δx for the displacement field and keeping $\mathbf{u}$ for the velocity field. This way, any confusion with the sea ice VP models, where the strain-rate $\dot{\epsilon} = \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i}\right)$ with $\mathbf{u}$ the velocity, would be avoided.

Only tension tests

This manuscript only shows tensile tests, although observations of sea ice show more compressive or shear deformations. Is there a reason for this choice?

I would like to see how the model behaves with shear and compressive tests, with one example of each. It would strengthen the manuscript to have more examples of how sea ice behaves. I would guess these are forcing situations that are very likely to happen in the ICEx 2018 datasets.

Missing literature

I think this manuscript is missing some key literature about sea ice models and observations.

- **Page 1, ca. L20::** I think the author should mention the Elastic Anisotropic Plastic model at this point, which takes into account anisotropy in the ice.
- **Page 2, L38 to L40**: There are many studies studying the self-similarity of sea ice in observations and models. I think those should be cited here. See, for example, Hutter et al. (2019), Bouchat et al. (2022), Rampal (2019)
- **Page 10 and introduction**: The literature linking fracture angles of sea ice to stress in other types of models is missing (e.g., Hibler & Schulson (2000), Dansereau et al. (2019), Plante and Tremblay (2021), Ringeisen et al. (2021), Wilchinsky et al. (2011))

relationship between critical stress and orientation of thickness lines

Page 10, L210 to 220:

The correlation between α and *critical force* appears inexistent to me, maybe due to the choice of figure. If the correlation is weak, a correlation coefficient and significance number should be given.

To improve the figure, you could use two panels, one for *critical force* and α and one for *average thickness* and α.

The orientation of fractures in sea ice is being investigated in many sea ice models with different physics. It is usually done at larger scales than the ones presented here, but I think it is nevertheless important to mention them. Sea ice rheological models like the VP or the brittle models (MEB/BBM) set a preferred angle in their physics. I would like to know if this model sets preferred angles (Dansereau et al. (2019), Plante and Tremblay (2021), Ringeisen et al. (2021))).

It would be interesting to see the critical stress dependence with the orientation of a single all-through line of the same reduced thickness, a bit like the study done in Fig. 5., but when the goal is to find the lowest bound of critical stress instead of the highest.

Numerical cost - advantages compared to other models

I could imagine doing similar tests with a VP model. However, it would take an enormous amount of computer time because the numerical convergence of the solver is very slow, especially at a 5m resolution. The cost is discussed on page 12, but this model seems much more efficient than the VP, with which I cannot fathom doing 1000s of simulations.

I would be interested to know how fast the model presented here can predict a fracture, e.g., how much time it takes per processor per 1000 random samples.

Technical corrections

- **Page 1, L10-12:** I find the sentence unclear
- **Page 3, L58 to L63**: This paragraph is unnecessary. The titles of the subsections are sufficient, and these section introductions are unnecessary.
- **Page 3, L70**: The name of the : operator should be given for clarity.
- **Page 6, L146 to L150**: I think this paragraph is unnecessary (same as above)
- **Page 7, L175:** is it the ice *floe* domain?
- **Page 7, L180**: So the resolution of the experiment is $dx = 5\,\mathrm{m}$. Can you say the number for completeness?
- **Page 11, L232 to L235**: I think this paragraph is unnecessary (same as above)

Bibliographie

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