Rapid crack development in glass modelled by phase field damage approach

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This contribution concerns the response of the laminated glass plates to dynamic loading. Laminated glass is a composite layered material composed of several plies of float glass and polymer interlayers. Although glass is almost purely elastic material before the breakage, it suffers from brittle failure and cracks are developing with a very small process zone. Furthermore, the visco-elastic nature of the polymer interlayer also affects the cracks evolution. As a result it is possible to effectively simulate such material before failure but the initialisation and development of cracks still brings many research challenges.

Simulation of the dynamic response of laminated glass loaded by an external impactor or explosive blast brings several phenomena that need to be investigated:

- Fragmentation and numerous branching that occurs in glass layers
- Contact problem characterises the transfer of the impactor's energy to the laminated plate
- Damping and energy dissipation through rate-dependent viscous interlayer

For brittle material, such as the glass, the phase field damage model appears to be a suitable model. At the very least, it is worth examining it and finding out what can be expected from such an approach. The presented phase-field damage model is based on the assumption that the sharp crack, traditionally represented as a singularity, can be mathematically regularised and spread to a finite length. The position of the crack is obtained by energy minimisation. This brings the the main advantage: the variational approach allows for the initialisation and development of cracks without additional ad hoc criteria.

We are therefore trying to test the aforementioned phase-field damage model for prediction and qualitative assessment of suitability for rapid crack propagation under impact or explosive blast, with a specific application to the laminated glass. We especially want to grasp the damage model itself and use our own code, for that reason the problem is simplified by neglecting viscous effects and solving the contact problem in simplified fashion. The situation is further simplified by using a spatially reduced Mindlin plate model, which significantly reduced the computational demand. The proposed model assumes that the cracks initiate on glass surface. This assumption is considered in the spatially reduced model by the damage initialisation driven by the highest tensile stress near glass surface. With this assumption the resulting crack patterns qualitatively correspond with the experimental results.

Considering simplicity and good agreement to experimental observations, the spatially reduced phase-field damage model proves to be applicable to structural elements made of laminated glass.

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References

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