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Where curling collides with rock physics: Characterising the damage evolution of curling stones

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Summary

Only rocks from Ailsa Craig (Scotland) and Trefor (Wales) are used to produce curling stones for international competition. During a game, curling stones collide into and displace each other, inevitably causing damage to their striking bands. Here we interpret the cause and consequence of curling stone impacts from an experimental geoscience perspective, by combining (1) a characterisation of damage in curling stones (building on the modern mineralogical and textural baseline of Leung *et al.* 2019), (2) *in-situ* 4D synchrotron microtomography of loading and subsequent failure in pristine curling stone samples, and (3) on-ice experiments to determine the key mechanical parameters of curling stone impacts. Ultimately, we aim to better understand how repeated impacts affect the mechanical state of granitoids.

Methods

Macro and microfractures have been analysed *via* photogrammetry (macrofracture morphology), optical and scanning (backscattered) electron microscopy (morphology and distribution of macro and microfractures with respect to microtexture), and x-ray microtomography (3D characterisation of pristine samples), with data processed by digital image analysis. *In-situ* 4D synchrotron microtomography of pristine curling stone samples was performed under unconfined uniaxial compression in the x-ray transparent triaxial deformation rig *Stór Mjölnir* (Fusseis & Butler 2019). On-ice experiments consisted of a delivered stone striking a stationary stone, with varying devices to determine mechanical parameters of curling stone impacts: a high-speed camera to document the collision, duration, and associated elastic strain; pressure-sensitive film to document the contact area; and accelerometers to record the acceleration profile and impact duration.

Results

Out of four curling stone varieties (from Ailsa Craig and Trefor), we observe the striking bands of three varieties to show macroscopic curved fractures. The morphology of curved fractures is distinctive and apparently does not vary significantly between individual stones and between curling stone varieties. However, the degree of curved-fracture development differs between aged striking bands of different curling stone types: Blue Trefor (macroscopic fractures not observed), Red Trefor (weakly incipient), Ailsa Craig Common Green (incipient to juvenile), and Ailsa Craig Blue Hone (juvenile to mature). Unfortunately, it is not possible to determine the degree of usage (age) of the selected samples and thus it is not possible to normalize these apparent differences in damage. The curved fractures are arc-like with horizontal rollover at the margins. Microscale damage is strongly localised to the centre of the striking band, with virtually no damage inward from the damage zone. Similarly, preliminary observations from 4D microtomographic reconstructions suggest that damage is strongly localised, with most fractures forming immediately at the onset of failure. Contact areas of curling stone collisions recorded by pressure-sensitive film (Fujifilm Prescale, Super High Pressure) range between 25±5 mm^2 (minor contact) to 190±10 mm^2 (impact with an initial velocity of 3.0±.1 ms^{-1}), with film saturation suggesting stresses in excess of 130 MPa. The contact area of the high-velocity impact consists of a rounded rectangle with dimensions ~1 × 2 cm, which is similar in size and scale to the curved macrofractures.

Conclusions

Curling stone impacts are not point impacts; the margins of contact areas resemble curved fractures, suggesting that imprinting of colliding stones controls the morphology of curved fractures. Preliminary data indicates that within the contact area, impact forces locally exceed the yield stress of the rocks, thus enabling comparison with our 4D microtomography experiments. Given that the striking band limits the lifetime of curling stones, understanding the damage evolution of curling stones can contribute valuable information to the maintenance of curling stones. Moreover, the rock physics of curling stone impacts is linked to dynamic spalling, cumulative damage (applicable to tunnelling, freeze-thaw, and thermal damage), and more broadly to rock failure, as these processes are ultimately related to the initiation and propagation of fractures.

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References

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