Emergence of self-affine surfaces under adhesive three-body wear conditions

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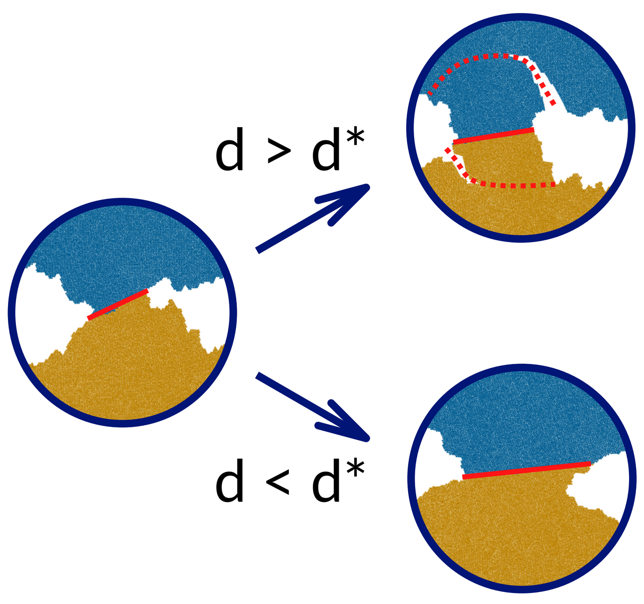
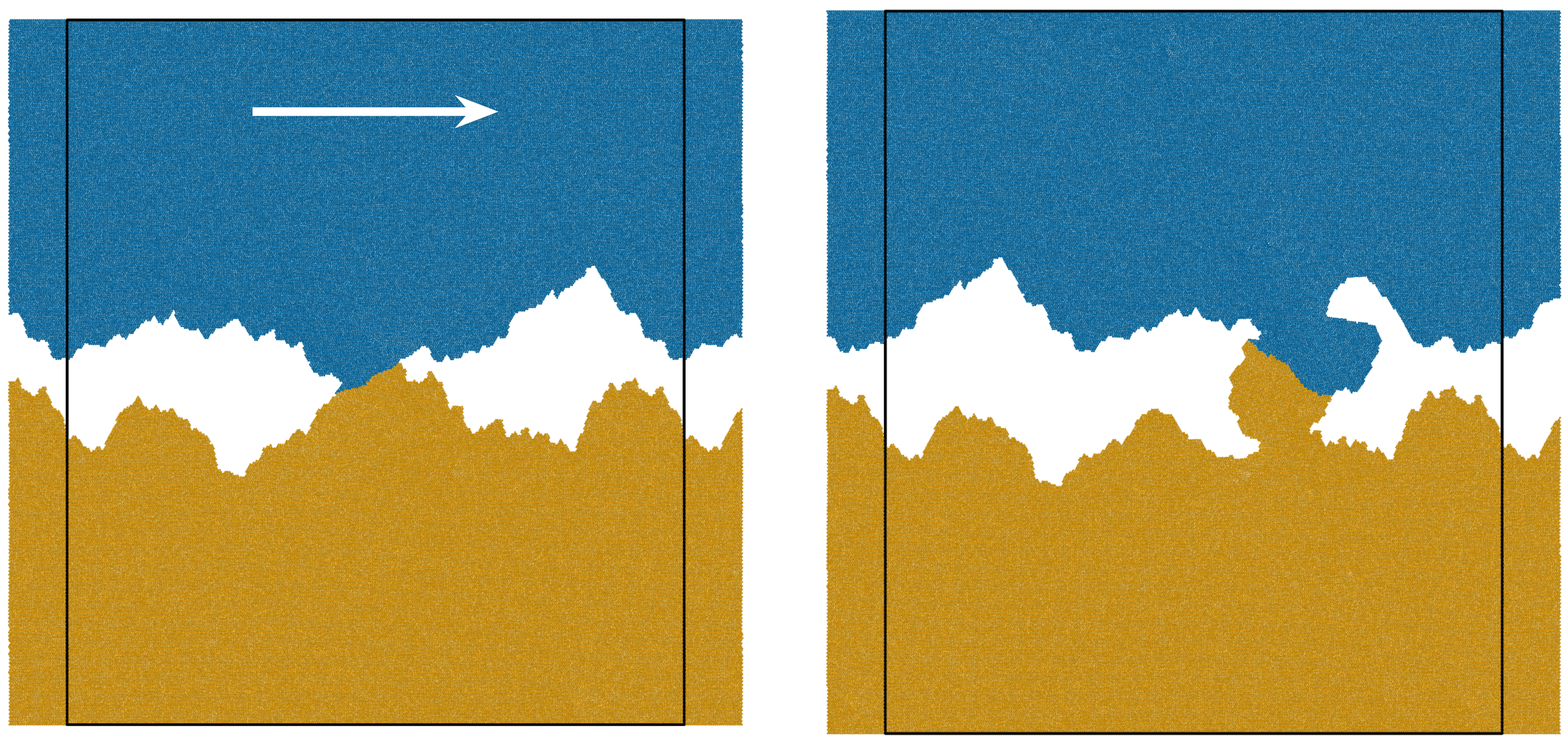
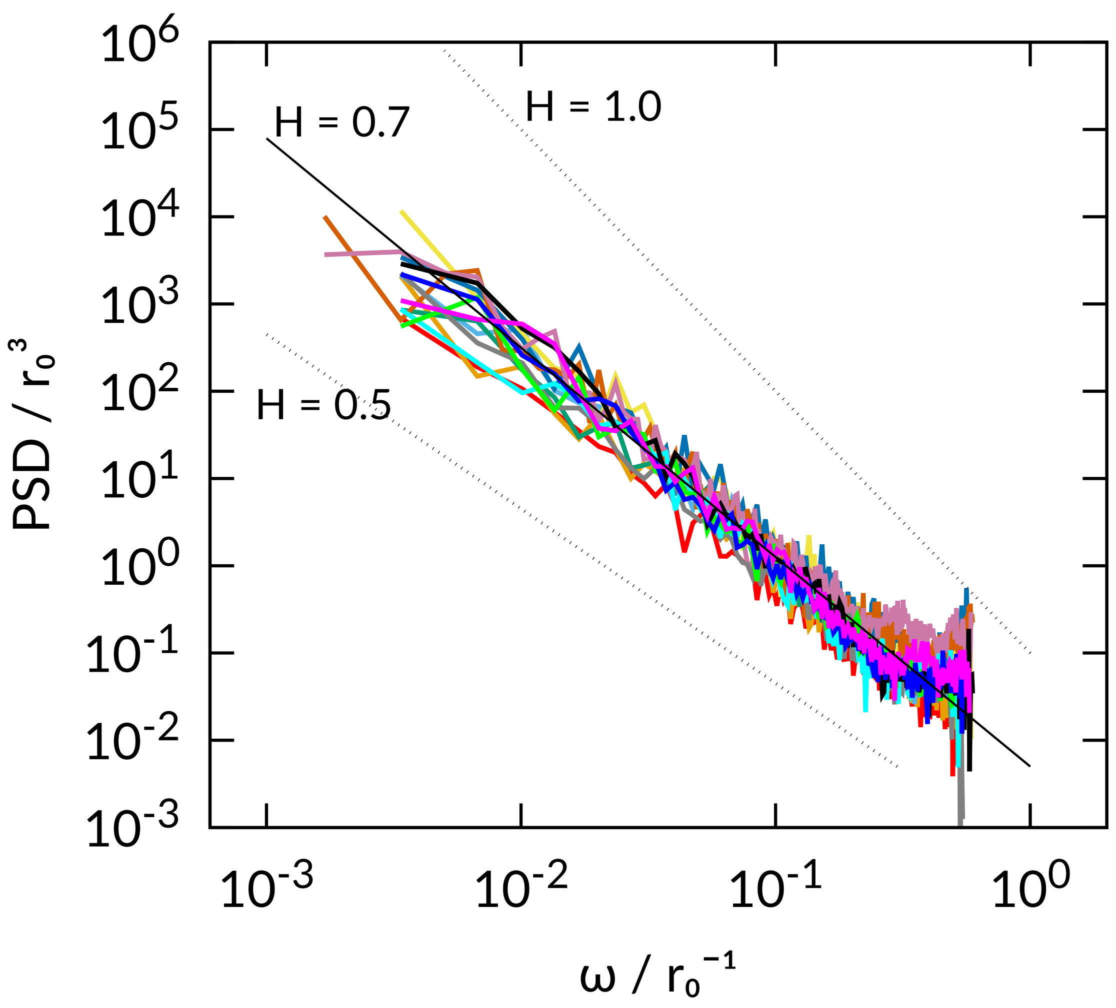
Onset of wear: debris formation



Inspired by the recent finding of a critical length scale d^* that governs the ductile-to-brittle transition in adhesive wear [1], we performed **long-timescale 2D atomistic simulations of rough, sliding surfaces**. The aforementioned critical length scale separates two distinct mechanisms upon asperity collision: ductile smoothing if the junction size d is smaller than d^*, brittle fracture and debris formation if larger. Our simulations are run in the latter condition, such that a debris particle is always formed, and rolls between the surfaces, wearing them off and progressively growing in size.

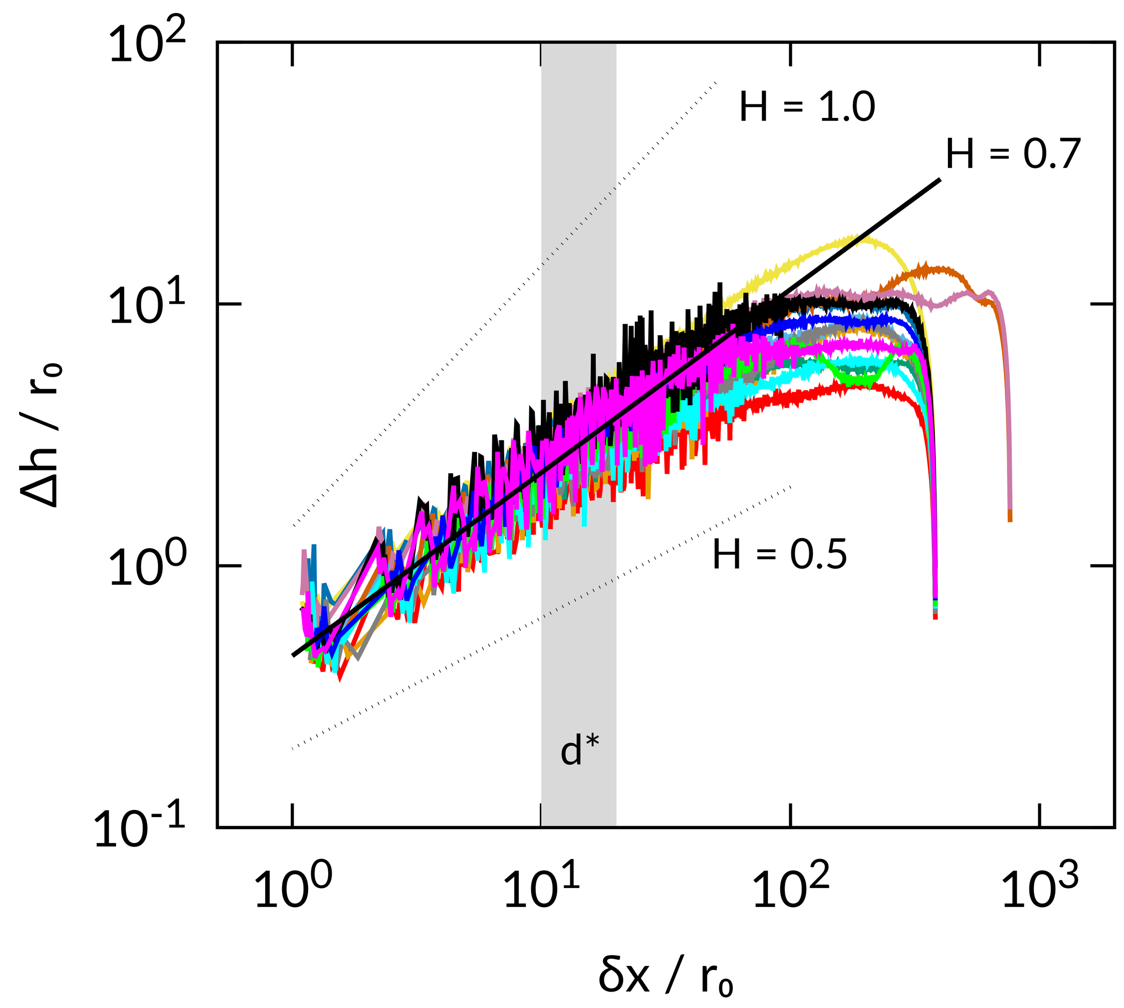


Self-affinity of run-in surfaces

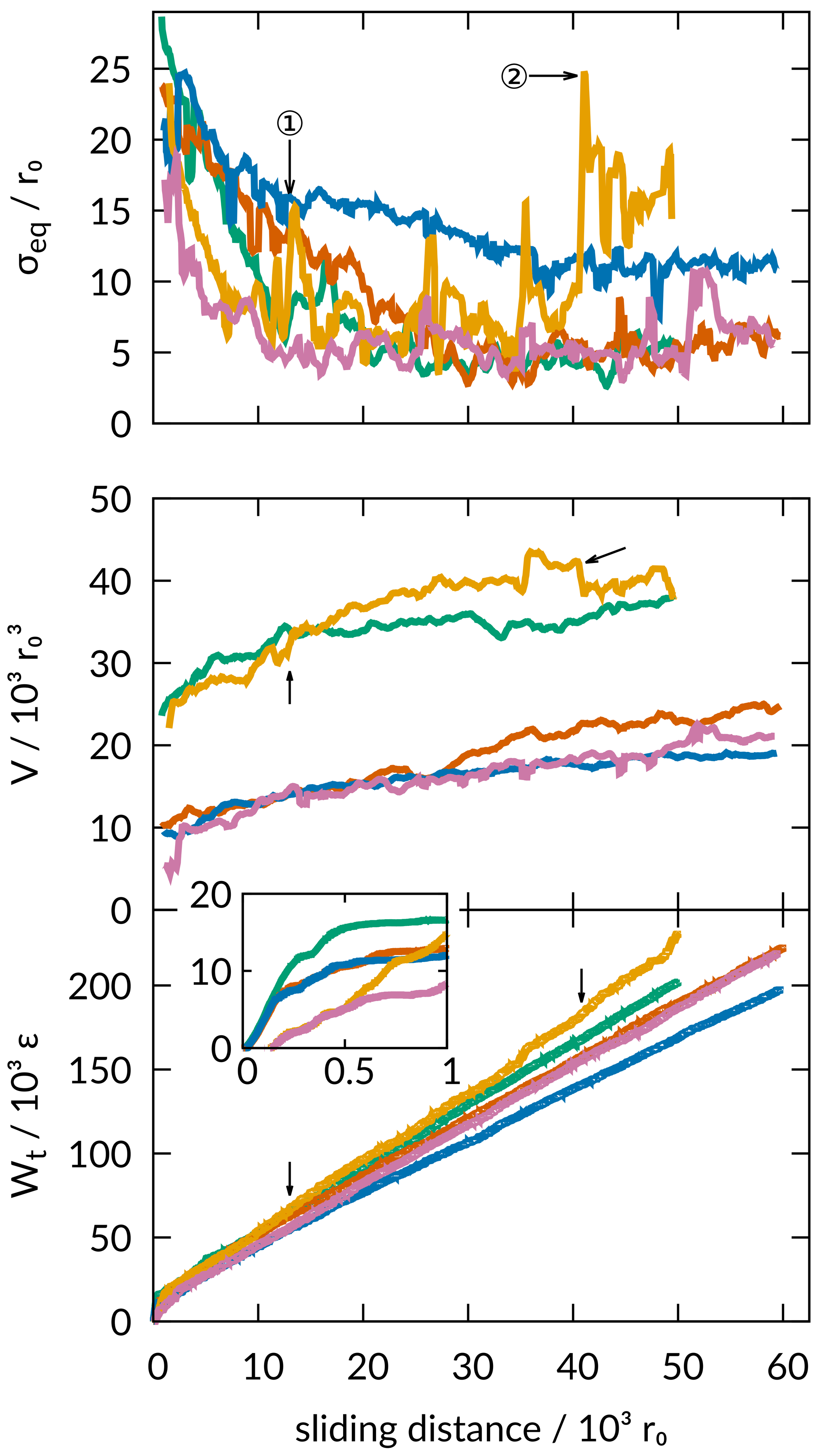


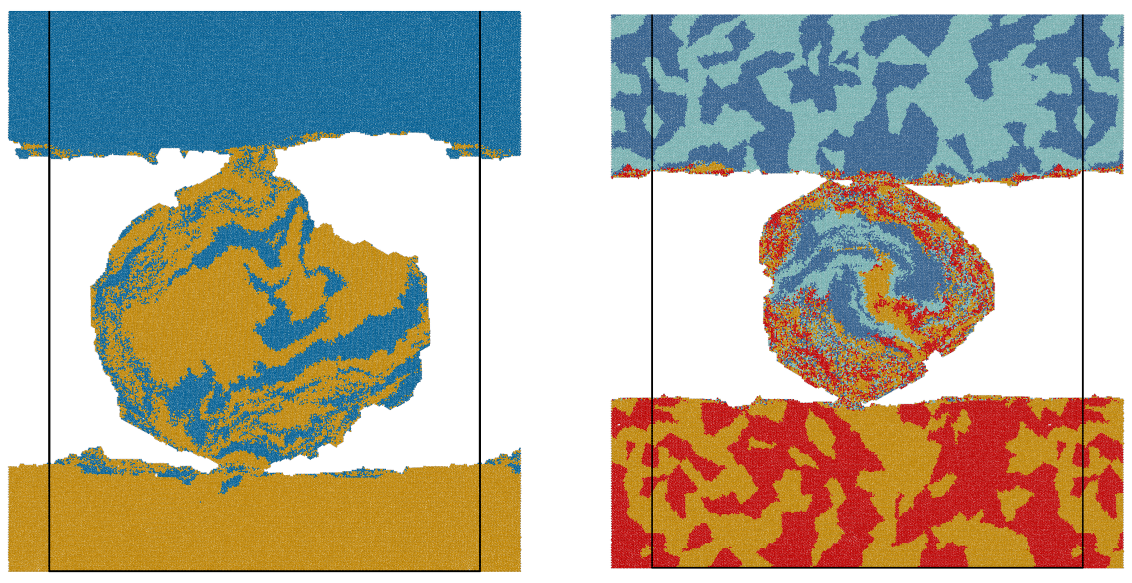
Surface analysis was performed whenever the surfaces, after a running-in period, reached a steady-state for the roughness σ_{eq}. Different intial surface conditions always lead to self-affine morphologies with the same Hurst exponent.

Self-affinity is confirmed by analysis of both the power spectral density (PSD), as well as the structure function $\Delta h(\delta x)$. No scale transition connected to the critical length scale d^* is evident from Δh.



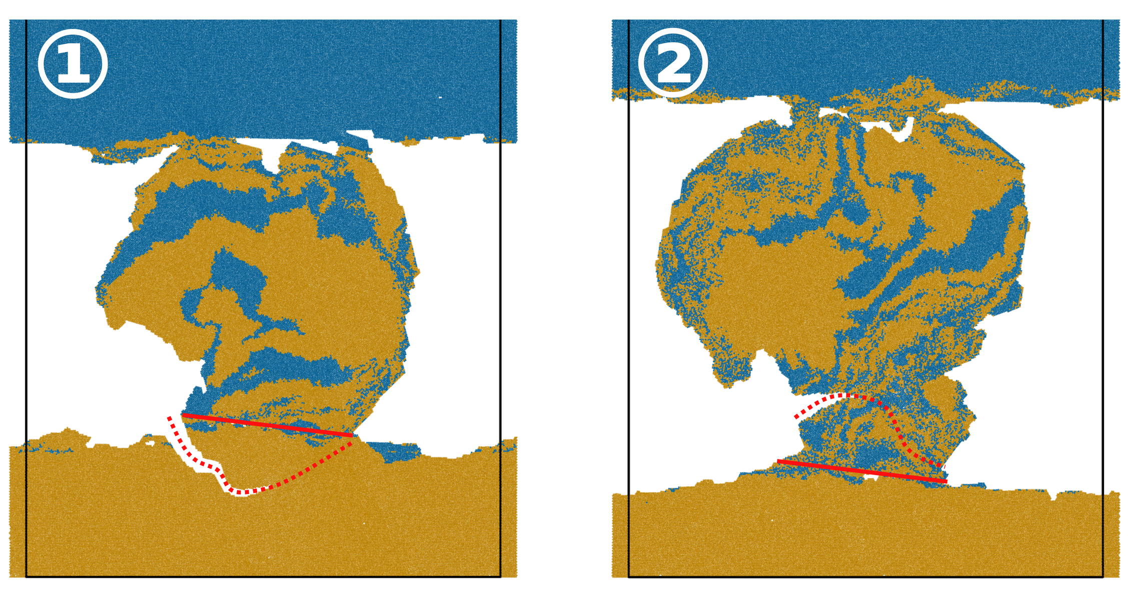
From running-in to steady state





Initially, the particle creation requires work proportional to the particle size (see inset, cf. Ref. [2]). The final shape of the debris particle is generally rough but convex and close to circular, leading to a smooth evolution of surface properties and low frictional force.

Significant deviations from that shape, i.e., concavity, may lead to abrupt changes in the surface roughness (arrows and figures below). This is reflected in the tangential work.



Conclusions

- The **self-affine morphology of worn surfaces** has been successfully reproduced numerically. It is independent of the initial conditions.
- The surfaces roughness is characterized by a **Hurst exponent H = 0.6–0.8, consistent with experimental data.**
- **Wear rate and tangential work decrease** significantly after running-in, indicating a lubricating effect of the third body.

  This reflects the wear regime established in the three-body configuration, which is consistent, e.g., with observational predictions for natural faults [3].
- **Direct proportionality between wear volume and tangential work is lost** after running in, in contrast to the initial stages (cf. Ref. [2]).

References

[1] Aghababaei, Warner, Molinari, Nat. Commun. **7**, 11816 (2016)

[2] Aghababaei, Warner, Molinari, PNAS **114**, 7935 (2017)

[3] Brodsky, Gilchrist, Sagy, Collettini, Earth Planet. Sci. Lett. **302**, 185 (2011)

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