The Microgeometry of Pressure Seals

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Introduction: As an important step towards creating an analytical theory of sealing, we test the following hypothesis:

"The microgeometry of a seal depends on the difference between mechanical sealing pressure S and fluid pressure P."

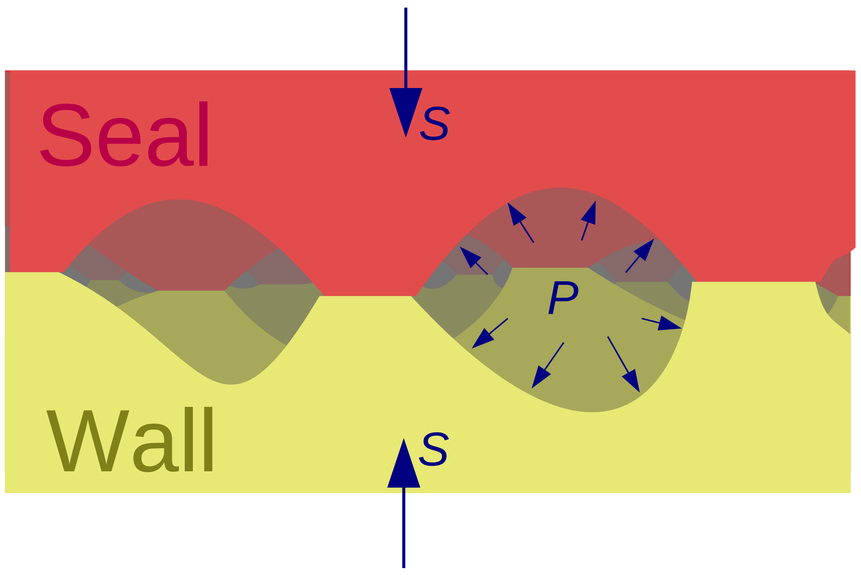

Figure 1. Seals leak because fluids seep through a microscopic network of caverns formed by surface imperfections. The geometry of these caverns affects the fluid flow.

Simulation: To test the above hypothesis, we model a "toy" geometry where a seal with spherical protrusions presses against a smooth wall. There is wild local variation in mechanical pressure at the point of contact, but the pressure becomes uniform at a certain distance away from the surface.

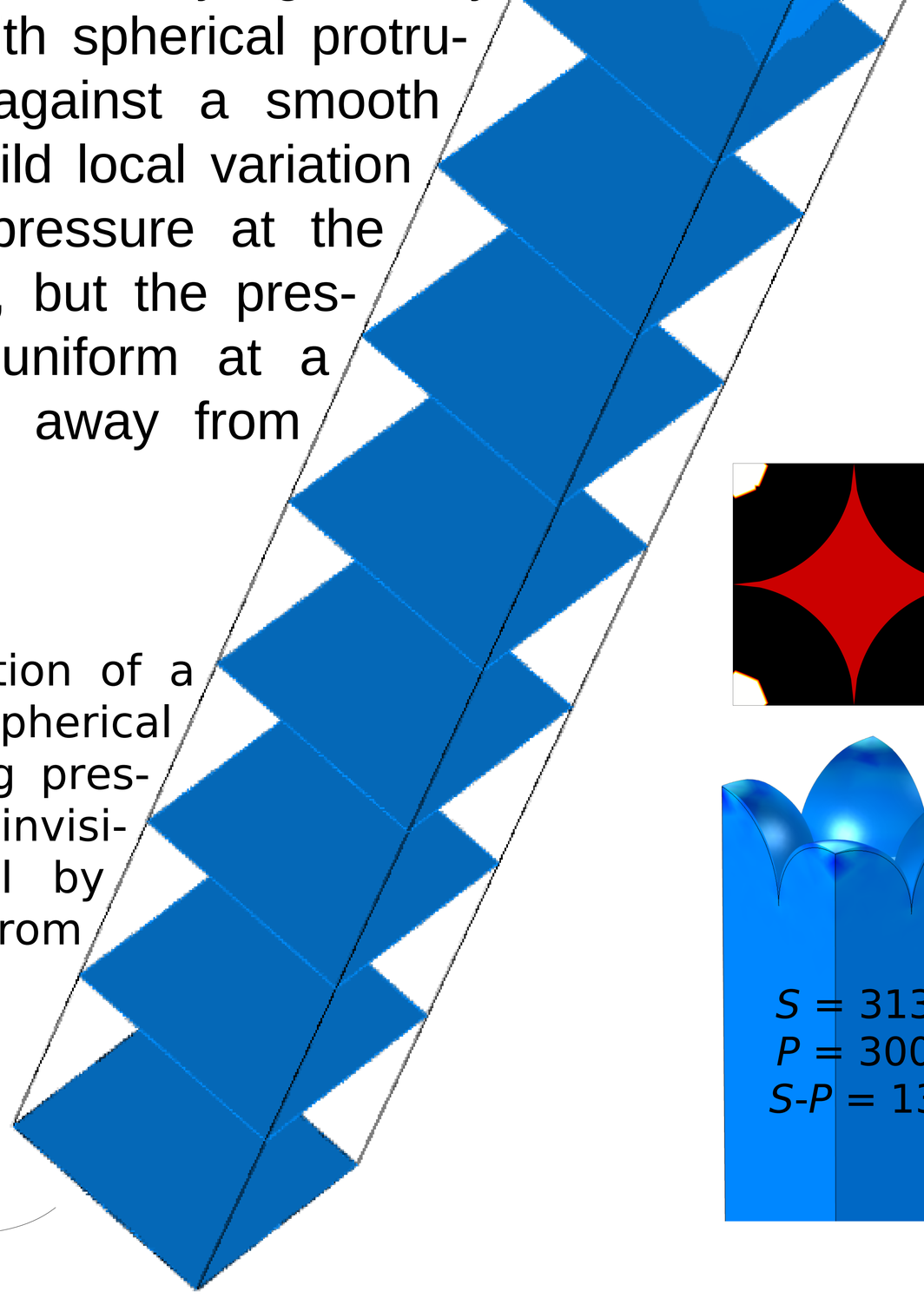

Figure 2. A section of a seal with spherical undulations, being pressed against an (invisible) smooth wall by being pushed from here.

Results: Simulation indicates that the microgeometry varies to a large extent as $S - P$ changes, but is completely impervious to changes in S and P, if $S - P$ remains a constant! The hypothesis thus stands verified.

Conclusion: The microgeometry, and hence performance of a seal is dependent on $S - P$, and not individually on S and P. This significantly simplifies the theory of seal performance.

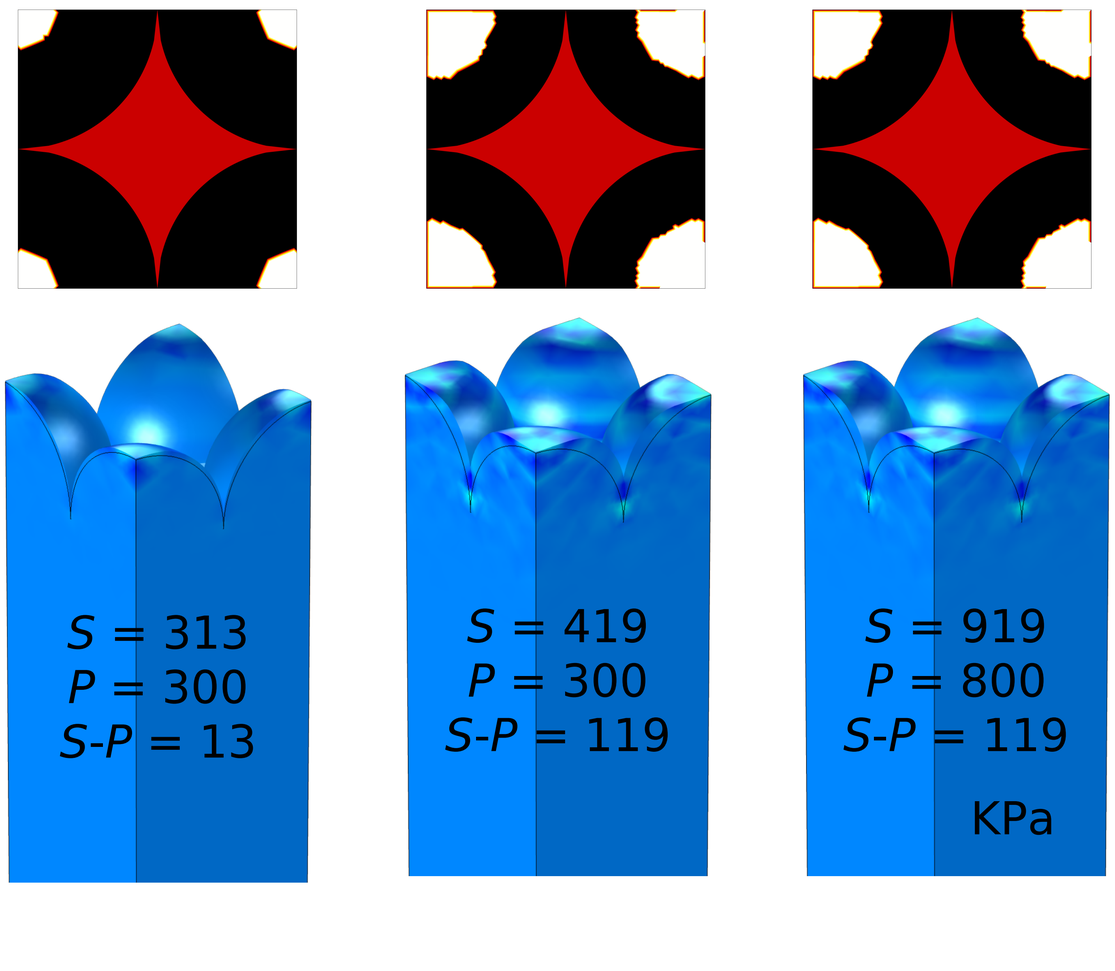

Figure 3. Deformed geometries and region of contact for exemplary values of S and P. Notice that, if $S - P$ does not change, the geometry does not change even if S and P change drastically.