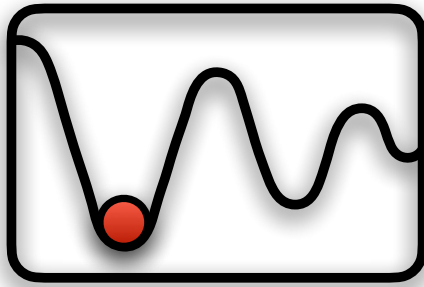


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## Book of Abstracts



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# Extending the Griffith energy criterion on fracture propagation to include thermal effects

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Fracture is an issue that has been faced for as long as there have been man-made structures. Numerous studies have been dedicated to analyzing fracture and crack propagation, with significant contributions from various researchers.

The pioneer in this field was Griffith, who, in 1921, laid the foundation for the present theory of fracture, [1]. However, since Griffith's initial work, several authors have made modifications to his approach to incorporate additional phenomena, such as plasticity, viscoplasticity, viscoelasticity, and the cohesive forces that prevent fracture opening, [2, 3].

Despite these advancements, a comprehensive model that considers the thermal effects on fracture propagation has yet to be developed.

In this work, we present a fully analytical description of how thermal fluctuation influence fracture propagation. Specifically, are able to include temperature effects in small scales systems, with applications both in biophysics and nanotechnology [4].

Therefore, we develop a discrete model consisting of a series of units to investigate the propagation of fracture. This process is described as the gradual rupture of individual units and is analyzed based on the Griffith energy criterion. In line with the Griffith approach, we focus on the propagation of an existing flaw within the system. This flaw propagates when the energy available for crack growth surpasses the material's resistance.

Our model provides a reliable approximation of a thin film delaminating from a rigid substrate. Although the model is initially developed in discrete form, mainly for studying the temperature effects through statistical mechanics, we also perform the continuum limit in order to represent the coupled thermo-mechanical behavior of the system in a clear and transparent way. In particular, this approach allows us to explain the effect of thermal fluctuations as a phase transition characterized by a critical temperature, here obtained in closed form. We eventually obtain that, for supercritical temperatures, the system is fully debonded even without mechanical actions because of the thermal fluctuations.

- [1] Griffith, A. A.: *The phenomena of rupture and flow in solids*. Philosophical Transactions of the Royal Society of London, 221, 163–198 (1921)
- [2] Barenblatt, G. I.: The mathematical theory of equilibrium cracks in brittle fracture. *Advances in applied mechanics*, 7, 55–129 (1960)
- [3] Dugdale, D. S.: Yielding of steel sheets containing slits. *Journal of the Mechanics and Physics of Solids*, 8, 100–104 (1960)
- [4] Kang, K. and Cai, W.: Size and temperature effects on the fracture mechanisms of silicon nanowires: Molecular dynamics simulations. *International Journal of Plasticity*, 26, 1387–1401 (2010)