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Non-universal aperture-length scaling of opening mode fractures

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Opening-mode fractures, such as joints, veins and dykes, typically exhibit a power-law aperture-length scaling with a power-law exponent of about 0.5. The fracture aperture is hence proportional to the square root of fracture length, a relation which is in fact predicted by linear elastic fracture mechanics (LEFM) for an isolated Mode I fracture subjected to remote tension. The existence of such a ‘universal scaling law’ is however a highly debated topic. High quality outcrop data illustrate that fracture aperture-length scaling may be ‘non-universal’ and indicate that below a certain length-scale scaling is super-linear (power-law exponent > 1). We use a numerical model comprised of a square lattice of breakable elastic beams to investigate the aperture-length scaling that emerges in thin plates subjected to remote tension. Strength heterogeneity is introduced in the regular lattice by randomly assigning beam strengths from a Weibull probability distribution. The model fracture system evolution is characterised by two stages which are separated by the strain at which peak-stress occurs. During the pre-peak stress stage fracture aperture-length scaling is universal with a power-law exponent of about 0.5 as expected from LEFM. Shortly after the material has attained its maximum load bearing capacity, aperture-length scaling becomes non-universal, so that the average aperture-length relation plotted on a log-log graph exhibits a distinct kink. Fractures with a length less than this critical length scale exhibit super-linear aperture-length scaling, whereas fractures with a greater length exhibit sub-linear scaling. The models illustrate that the emergence of non-universal aperture-length scaling is a result of fracture clustering, which occurs after peak-stress in the form of a localised fracture zone. Given that fracture clustering is a common phenomenon in natural fracture systems, we argue that a universal scaling law may be the exception rather than the rule.