Application of self-affine fractal methods for generating fractures with internal aperture heterogeneity and impacts on flow

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Understanding fluid flow through fractured crystalline rocks is important in many areas, including subsurface infrastructure and storage of nuclear waste. Aperture variability exhibits significant control of the flow field through single fracture and fracture networks within sparsely fractured crystalline rock. Inclusion of aperture heterogeneity however is often hampered due to lack adequate numerical representations and field measurements. Self-affine fractal methods, which use two key parameters, the Hurst exponent and scaling parameter, are used to develop a model for aperture generation which accounts for relative anisotropy and correlation between the upper and lower surfaces creating the aperture. Surface scans of a natural rock fracture are used and a methodology for analysing and extracting relevant parameters is developed. Analysis of the natural fracture surfaces displays a range in Hurst exponent and scaling parameters across parameter space, and pairwise combinations following a linear upper bound can be used to generate aperture fields that accurately reproduce measurements. It is shown that correlation between the upper and lower surfaces is less sensitive than the Hurst and scaling parameters. The model is an improvement on previous methods and produces aperture ensembles that closely correspond with the natural aperture obtained from surface scans. A sub section of the sample is also taken and analysed, and input parameters based off restricted measurements were successfully used to generate up-scaled apertures. The model can generate apertures that are representative of natural fracture apertures and can be implemented in larger scale fracture network models allowing for numerical simulations to include representations of aperture internal heterogeneity. Impacts of the Hurst and scaling parameters on flow through the resulting aperture fields are also discussed.