Role(s) of scale-dependent rough fracture topography in fracking: viscous flow resistance vs. solid toughness

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Under uniform stress conditions and in a macroscopically homogeneous solid, fracture tends to propagate about a nominally flat plane. However, generated fracture surfaces' topography is usually inherently rough, and can be quantified by a, "roughness" parameter r_z (standard deviation of the surface elevation from the mean propagation plane). Roughness is scale-dependent, approximately obeying a self-affine scaling $r_z(l > L_0) \sim L_0^{1-H}\, l^H$, with the Hurst exponent $0.5 < H < 0.8$, scale of observation l, bounded from above by the fracture length L and from below by the microstructural material length L_0. The scale-dependence of surface roughness leads to the growth of the apparent fracture energy (energy dissipated in generating a unit area of the *nominal* fracture surface) with fracture length L, $G(L) = G_0\, (L/ L_0)^{1-H}$ [e.g., 1-3].

On the other hand, fracture surface roughness, or more specifically, the roughness r_w of the fracture aperture (the combined topography of the two fracture surfaces, which are mismatched on the spatial scale of the fracture process zone), has been anticipated to lead to a dramatic increase on the viscous dissipation in the fluid flow near the fracture tip [4]. Since the fracture aperture roughness is linked to the scale of the fracture process zone, and thus, indirectly, to the fracture energy G(L), it appears that the increase of the viscous flow dissipation is also scale (fracture length) dependent.

In this talk, we will discuss the implication of these two scale-dependent energy sinks (in flowing the fluid and in breaking the solid) on the hydraulic fracture propagation within a semi-infinite steadily propagating fracture model.

References

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