Fracture Permeability of Gas Shales: Effects of Roughness, Fracture Offset, Proppant, and Confining Pressure

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Domestic gas shale production is made economic through new completion practices which include horizontal wells and multiple hydraulic fractures. The performance of these fractures is improved through the injection of proppant. Success has largely been based on empiricism through field experiments. We attempt to remove some uncertainty in this empiricism through a series of laboratory controlled experiments. We have measured the permeability of fractured rock as a function of effective stress, proppant, proppant distribution and fracture offset. Our findings indicate that fracture offset is as effective as propping a fracture; both increase initial permeabilities more than 1000 fold over initial fracture values. However, the pressure dependence of the propped fracture is stronger, i.e. the permeability is reduced more per increment of pressure than the offset fractures. Neither obeys the simple cubic pressure dependence law proposed by Walsh. A simple monolayer of proppant is as effective as a fairway distribution of proppant in enhancing permeability. Initial fracture permeability is dependent on surface roughness, quantified as root mean square asperity heights. Pressure dependence of permeability of these fractured surfaces does obey the Walsh permeability models. SEM observations of surfaces and proppant suggest a new approach to proppant design.