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Turbulent - laminar transition in the propagation of height-contained hydraulic fracture.

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Fluid flow is usually assumed to be laminar in the modelling of hydraulic fracture propagation. This approximation can however break down in certain cases where a low viscosity fluid (e.g. water) is injected at a high rate resulting in Reynolds numbers well into the turbulent flow regime. This is notably the case of hydraulic fracture propagation at glacier beds where Reynolds numbers above 100,000 are expected (Tsai and Rice 2010). Recent trend of high injection rate slickwater treatment for the hydraulic fracturing of oil and gas wells has also called the validity of the laminar flow assumption into question. Ames & Bunger (2015) recently investigated the effect of fully rough turbulent flow on the propagation of a height contained hydraulic fracture (Perkins & Kern 1961, Nordgren 1972). They have shown via dimensional analysis that the characteristic pressure should be larger and length shorter in the fully turbulent-rough regime compared to the laminar case. However, in practice, the range of Reynolds numbers for a typical slickwater treatment is expected to be from 1000 to 100,000 which coincides with the transition range from the fully laminar to fully turbulent-rough flows. Moreover, the Reynolds number is also expected to drop significantly in the tip region of a hydraulic fracture as the fracture width tends to zero. We present a numerical model that accommodates the complete laminar-turbulent transition of the flow and its impact on the propagation of a height contained hydraulic fracture. The numerical model is based on an explicit non-oscillatory central scheme for the solution of the coupled system of equations governing fluid flow and fracture elastic deformation. A volume of fluid method is used for tracking of the fracture front. The accuracy of the scheme is validated against the classical solution for the laminar flow regime. The relevance of the different limiting approximations (i.e. fully laminar versus fully turbulent regime) to simulate typical industrial hydraulic fracturing treatments in unconventional reservoirs is then discussed.