Effect of loading rate and in-situ stress anisotropy on fracture patterns in a tight formation

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Abstract

Hydraulic fracturing has been the most common approach to stimulate tight formations. The geometry of the wellbore and the time history of the hydraulic loading play important roles in induced fracture patterns. For example, generating multiple perforations in a wellbore to enhance its hydrocarbon recovery is nowadays attracting more attention. The increased number of fractures can potentially enhance the yield of a reservoir by increasing the regions affected by hydraulic fractures. However, in practice many of the initial perforations do not result in any substantial hydraulic crack propagation. Dynamic stimulation methods are often associated with explosive or propellant methods. These approaches are typically performed without any initial perforations. However, recent studies show that by using a hybrid approach, in which similar to hydraulic fracturing there are some initial perforations but for these high loading rate conditions, all perforations can be activated, thus affecting larger areas of the reservoir.

We study the conditions for which the initial perforations become effective and propagate in rock. We combine the asynchronous spacetime discontinuous Galerkin method with an interfacial damage model in our fracture simulations. Mesh adaptive schemes are used to align crack trajectories with inter-element boundaries. We consider loading rates ranging from 10 microseconds to 1 second. The first few high loading rates are hypothetical and are included to better demonstrate the effect of fracture strength randomness on fracture response. The loading rates from 1 to 100 milliseconds correspond to the aforementioned hybrid methods, while lower rates can be associated with very early stages of hydraulic fracturing. Our numerical results show that at low loading rates only a few of the initial perforations become active. As the loading rate increases, more perforations become active until ultimately all result in crack propagation. Moreover, higher loading rates affect larger zones for each of the initial perforations by dynamic fracture features such as microcracking and crack bifurcation. In-situ stress anisotropy has an adverse effect in that it prohibits activation of more perforations even at higher loading rates. Finally, we study the effect of spatial inhomogeneity of fracture strength on generated fracture patterns; as the loading rate increases a deterministic model, which assumes fracture strength is spatially uniform, starts to induce more microcracking and crack branching events. Accordingly, these studies imply the high impact of local material inhomogeneities on fracture response, particularly at high loading rates.