Fundamental research on the role of differential stress in hydraulic fracturing in strength-anisotropic medium

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Hydraulic fracturing is a technique to enhance the permeability around the borehole to create fracture networks in oil and natural gas reservoirs. Since the performance of hydraulic fracturing is not fully predictable beforehand, it is important to pre-estimate the extension and the connectivity of artificial fractures for a given condition such as in-situ stress and various mechanical properties of reservoir rock. It, therefore, has been drawing attention to achieve this with a method of numerical simulation in recent years.

Although microscopic failures and propagation of cracks are known influenced by the ratio of the maximum to the minimum radius of spherical elements, the viscosity of injected fluid, the existence of natural fractures, etc., the propagating direction of hydraulic fractures is in the direction of horizontal maximum stress in an isotropic medium. Since reservoir rock of shale oil or gas is anisotropic in the mechanical properties inferred from several laboratory tests, the propagating direction of hydraulic fractures is known strongly affected by the direction of anisotropy axis. Since there is few researches conducted on the numerical simulation of hydraulic fracturing in strongly anisotropic media with the existence of differential stress towards the borehole, it is necessary to examine the role of the differential stress. We give mechanically anisotropic properties such as uniaxial compressive strength, uniaxial tensile strength, permeability, etc., based on the calibration of microscopic parameters of DEM to represent macroscopic parameters of the reservoir rock. The empirical assumption of macroscopic uniaxial tensile strength distribution is introduced into microscopic strength of the model. Contact and bond forces are given to neighboring particle elements in the model, and both tangential stresses from interstitial fluid are applied to each particle.

The result showed that if the differential stress is large, hydraulic fractures tend to propagate in the direction of maximum principal stress whereas hydraulic fractures tend to propagate in the direction of bedding plane under low differential stress.

Moreover, this information suggests that in the shale reservoir, which has mechanical anisotropy, the differential stress has important role in estimating the propagation direction of hydraulic fractures.

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