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An Inward and Outward Growing Shell Model in Water-in-Oil Mud

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Abstract: When gas kick occurs in deepwater drilling, solid hydrate particles are easily formed during the gas bubble rising in the wellbore under low temperature and high pressure conditions, which not only affects the flow characteristics of the mud, but also may lead to wellbore blockage and increase the difficulty and risk of well control treatment.

In this paper, based on water-in-oil drilling fluid, a comprehensive model of hydrate shell growing on droplet surface is established, including an inward growth model and an outward growth model of hydrate shell. The main factors considered in this model are: (i) mass transfer rate between free gas and dissolved gas in oil-based drilling fluid; (ii) intrinsic conditions for hydrate formation; (iii) mass transfer rate in hydrate shell, including diffusion rate of dissolved gas into hydrate shell and permeation rate of water outside hydrate shell; (iv) the change in the pore roar radius during hydrate shell growth. The calculated results of this comprehensive model are in good agreement with Shi's experimental results. Using this model, the effects of gas consumption and rate, variation in the hydrate shell thickness and impact of sensitivity parameters on the thickness of hydrate shell were studied.

The calculation results showed that the hydrate film would form quickly on the droplet surface in the initial stage once the intrinsic conditions of hydrate are satisfied. With the increase in the thickness of hydrate shell, the radius of pore roar in hydrate shell decreases gradually, which decreases the diffusion rate of dissolved gas and the permeation rate of water. In addition, the sensitivity analysis results showed that the radius of droplets, shear rate and diffusion coefficient all had great influence on the radius and growth rate of hydrate shell, while the hole roar have little influence on the radius and growth rate of hydrate shell. This study can provide theoretical support for quantifying hydrate shell formation and growth behavior under water-in-oil drilling fluid conditions.

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