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An Integrated Approach Towards Well Control under Hpht Environment

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Extended Abstract

The paper presents an approach on HPHT well control in narrow pressure margin wells. It includes theoretical evaluations and computer simulations. A special focus is directed towards gas diffusion during drilling operations; with its impact on a number of important parameters. Both theoretical and experimental work is presented.

The drilling of HPHT wells pose special challenges compared to standard wells, High pressures and temperatures impact mud properties in a dynamic way and can have effects on well control. Small margins between pore and fracture pressures will prevail in sections of the well. The conditions are above the critical point for the gas/oil/condensate influx; which means that the hydrocarbon influx is infinite soluble in the base oil of the mud. Hydrocarbon influx will totally mix with the base oil in oil based mud, and infinite amounts of gas can dissolve in the mud. Drilling of inclined and horizontal wells will make the consequences of barite sag serious. Significant quantities of gas can diffuse into a horizontal section of a well if Oil Based Mud is used even if the well is overbalanced.

Thus a simulator is developed for well control evaluations relevant for HPHT and other wells with small operating margins. Several benefits can be identified by modeling the well control which results into proper handling of well under such environment. It is observed most of the well control issues have taken place during completion. Thus following benefits are obtained by simulation. It provides more realistic kick tolerances compared to using simple single bubble models. Evaluate different kick scenarios. Evaluate and develop well control procedures.

In HPHT wells the pressure and temperature greater than 10000psi and 150^{o}C are experienced. Such conditions are basically observed in 5000m or greater depth wells. Under such extremely tough conditions many items of equipment and tools simply cease to function. Thus for primary well control the mud weight should be such that overbalanced condition is obtained. For the purpose of which Oil Based Mud is used, however due to high solubility of methane gas in such mud system results into detrimental effects in mud properties. The rheological properties of drilling fluid are often approximated to be independent of temperature and pressure. For shallow wells, the temperature changes are not so large and thus the rheological variations are small. Similarly in wells with large gap between pore pressure and fracture pressure, therefore errors in estimation of the dynamic circulation pressure have little consequences for well integrity or kick probability. The active mud volume may change significantly when circulation starts or stops even when there is no influx or lost circulation due to the expansion or contraction of mud due to variation in temperature or pressure. It may also occur due to borehole ballooning.

In HPHT wells severe challenges are faced in well control due to different reasons such as gas solubility and flashing in OBM, Exceeding fracture limits in the well, lack of expertise for the prevention and detection of borehole ballooning, handling of very large gas volumes at surface. Due to the solubility of influx in OBM it is difficult to detect an influx using pit gain since the gas is dissolved in mud and kick is detected when gas reaches surface. Thus rig crew has very short time to activate well control procedures. The kick in Oil Based Mud is dispersed thus a greater influx height is observed compared to Water Based Mud. This results into reduction in influx gradient and kick tolerance in OBM. In order to get realistic kick tolerance the dispersion of kick factor is to be included rather than using single bubble model.

In order to obtain realistic kick tolerance a simulator is developed which provides the result for both Oil Based Mud and Water Based Mud system. Influx gradient while circulation for non-dispersed kick can be evaluated using,

$$Gi = Gm - (SICP - SIDP)/Hi \qquad [1]$$

For dispersed kick it can be evaluated using,

$$Gi = Gm - \frac{Vmz*(SICP-SIDP)}{Vi*Hmz} \qquad [2]$$

Where:

Vmz= volume of mixed mud and influx, bbl
Vi= measured influx volume (pit gain), bbl
Qm= mud circulation rate, bbl/min
tk= time interval during entry of kick, min
Gm= current mud gradient, psi/ft
Gi= influx gradient, psi/ft
SICP= shut in casing pressure, psig
SIDPP= shut in drill pipe pressure, psig
Hmz= height of mixed or dispersed zone, ft

The rheology changes are investigated using modified HPHT rheometers. Mud and influx are mixed together before bringing them to HPHT conditions. With a suitable modified HPHT rheometer, the instrument can be pressurized with formation gas, in this way the effect of dissolved gas can be investigated. However, one should be aware that the measurements might become corrupted from the weight material sagging out of the fluid.

Dissolved gas or other formation fluids mixed into the drilling mud may degrade the mud’s carrying capacity, both for cuttings and for weight material. The effects of different mixtures of formation fluids can be investigated in a suitably modified HPHT rheometer.
Thus due to presence of so many challenges in using Oil Based Mud in HPHT wells, therefore a CsKformate mud (blend of cesium and potassium) is used to ensure stable density. It eliminated the risk of gas diffusion up to certain extent and improved the ROP. Thus using CsK, the kick tolerance is close to the one obtained using single bubble model and can be detected earlier than one detected in OBM. Providing time to rig crew to activate well control procedures, and safely remove the influx gained in well bore.

An integrated approach towards well control has been presented in this paper. The approach consist of

Theoretical evaluation
Numerical evaluation
Computer simulation
Procedures and operations

Thus realistic approach of the above will give an upper hand in HPHT well control.

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