Drilling optimization using dynamic multiphase Kick tolerance.

$$Hmax = \frac{MAASP - 0.052\ X\ (PP - MW)\ X\ TVD}{0.052\ X\ (MW - Kick\ Density)}$$

Volume of the influx at casing shoe,

Vshoe = *Hmax* X Casing capacity.

Then calculate volume of the influx on bottom (*Vbtm*) is calculated using Boyle's Law.

$Vbtm = Vshoe\ X\ \frac{Pshoe}{PP}$

Limitations of Conventional approach

In a single-bubble model, the kick is considered to have entered the wellbore as a single, continuous phase, displacing the drilling fluid, and with a clean influx (gas) and mud interface. The single-bubble model does not account for influx distribution, gas dissolution in the drilling fluid, and multiphase behavior based on pressure and temperature of the influx and the mud system. These simplified assumptions can lead to an erroneous calculated Kick tolerance volume. The difference in distribution of the influx in the annulus is shown in **Figure.5**

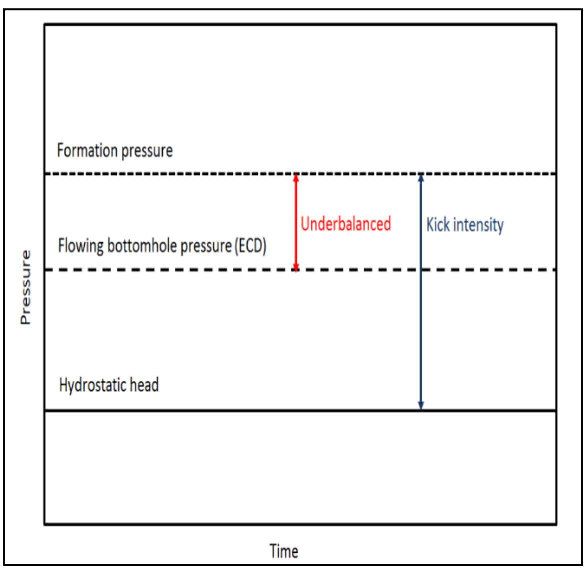

Figure 5: Definition of Kick Intensity.

Dispersed-bubble dynamic Kick tolerance approach

The dynamic simulations take influx, then follow the standard well control procedures of shutting down the pumps and closing the BOP's and allowing the bottom hole pressure to be balanced before circulating out the influx. By using the dispersed-bubble KT model, the full set of conditions and scenarios in a kick control situation could be simulated in the transient modeling software, allowing meaningful sensitivity analysis to be carried out, among others with respect to kick volumes, circulating rates, pit gain, crew reaction time, formation production potential, and choke operator error.

Using the dynamic Kick tolerance simulations several kick scenarios can be modelled, where a realistic distribution of the influx is accounted. The kick is then circulated out using Driller's method (or any other preferred method). The dynamic model calculates the pressure at the last casing shoe whilst keeping the bottom hole pressure constant during the circulation. The maximum pressure at the shoe is calculated as the top of the gas bubble reaches the shoe during well shut in and kick circulation. Gas expansion and breakout, and the specific interaction of the influx with the with the drilling fluid, which rheology is affected by pressure and temperature. The dynamic model provides a realistic kick margin when compared to the simplified single-bubble model for a drilled kick scenario and will often provide a better margin (**Figure.6**).

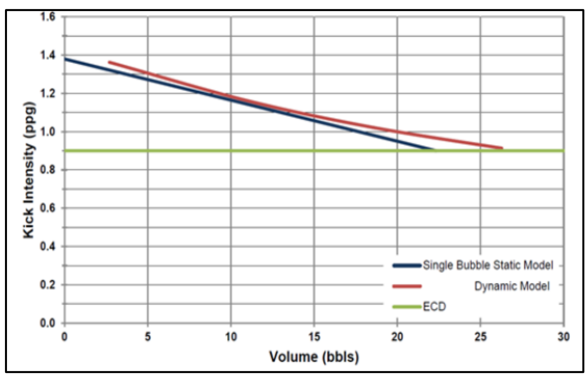

Figure 6: Comparison between single and dispersed bubble model Kick Tolerance.

Drilling optimization using dynamic multiphase Kick tolerance.

After the same analysis is done for all the well sections, an optimized casing design, setting depths and casing shoe characteristics will be available with the specific drilling. This in many cases results in the elimination of one or more casing strings from the original standard well design.

The Kick tolerance standard in the 12¼" hole for the subject well was 25bbl, and if single bubble kick tolerance calculation were to be used, it yielded Kick tolerance lesser than the required standard. Accordingly, during planning phase, the TD of 12¼" phase was planned as 2450m. In 12¼" section, dynamic Kick tolerance analysis were performed integrated with PPFG updates as drilling progressed and (as shown in Fig.4) allowed the section to extend until 2650m where drilling was stopped and called as well TD. An extension of 200m was done without splitting the section thereby requirement of extra intermediate casing was eliminated.

Conclusions

Dynamic Kick modelling applications assesses the following not commonly assessed by the single bubble model: Gas solubility of SOBM, Gas migration in WBM, Frictional pressure in annuls, Mud compressibility. Dynamic models provide more accurate Kick tolerance values results in more precise well designs which increases safety and potentially saves money through fewer casing strings. It can monitor the effect of Kick tolerance by adjusting mud weights, casing setting depths, formation types, etc. Also, it can track the solubility of gas kick in NADF which result in more detailed insight to the Kick tolerance dynamics and during well control.

Dynamic multiphase Kick tolerance is proposed to display changing Kick tolerance values through the entire hole section. Multiphase dynamic kick models can simulate well control events much more realistically when compared to single bubble static models therefore allowing drilling to be accomplished efficiently.
Well control simulations are expected to enhance the drilling safety margins by appending them in to the drilling companies well control procedures. Dynamic well control simulations will provide a higher Kick tolerance margin in comparison to a conventional single bubble static model when the top of influx is at the last casing shoe. This allows most of the time, the next casing to be set deeper than the conventionally defined target depth thus in many cases additional phases / casing will be eliminated. Dynamic Kick tolerance tools can better assess the risks associated with circulating out a certain amount of kick volume during well-control operations.

This case study showed the importance of real-time hydrodynamic monitoring and its respective realistic Kick tolerance estimations that comply customer standard, allowed drilling to proceed in the constraints of a very tight mud window, and pushed a 12¼" section deeper than planned. This eliminated an entire casing section and several rig days.

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