Volumetric Changes of an Open Wellbore Due to Elastic Deformation

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Certainly, three processes can cause volumetric changes to the active drilling system, these process are:

- Kick: A flow of formation fluids into the wellbore during drilling operations,
- Loss: The leakage of the liquid phase of a drilling fluid, slurry or treatment fluid containing solid particles into the formation matrix,
- Borehole breathing (ballooning).

Borehole ballooning or breathing is a phenomenon, which can be described as a reversible process of active drilling fluid volume gain and loss during drilling operations. It is very crucial to understand the major mechanisms and factors controlling the ballooning phenomenon to avoid confusion with conventional losses or formation kick. Therefore, misinterpretation of the consequences of this phenomenon can lead eventually to excessive non-productive time[1].
So far five processes are known as the main causes of the borehole ballooning, they can be grouped as following [2&3]:

- Drilling fluid related processes:
  - Thermal expansion and contraction of the drilling fluid due to change in system temperature.
  - Compression and expansion of the drilling fluid due to change in wellbore pressure.
- Wellbore related processes:
  - Radial elastic deformation of the borehole and the cased hole wall.
  - The opening and closing of induced fractures at the near wellbore region.
  - The opening and closing of natural fractures [pre-existing] intersected during drilling.

By estimating the overall change in volume of the wellbore caused by above mentioned processes, we can avoid confusion with conventional losses or formation kick, consequently nonproductive time is reduced.

According to the studies which has been performed by Bjørkevoll et al (1994) and Aadnøy (1996), the volumetric change of an active mud system caused by the elastic deformation of the borehole and the cased hole does not excess 10% of the total volume variation[3]. Helstrup et al (2001) stated that change in borehole volume due to elastic deformation can be significant and it is mainly driven by wellbore radius, well pressure and Poisson's ratio. Their results show that the change in volume can be as high as 1 bbl for 100 meter depth interval[5]. Al-Tahini et al (2008) performed experimental studies in order to identify a correlation between the far field stresses with introduced stresses, displacement and breakout stresses, their concluded that the wall displacement of the tested rock is less than 0.01 inch with 3000 psi applied pressure[6].

On beginning of 2016 Asad et al performed sensitivity study using syntactic data in order to investigate the effects of different parameters on volumetric deformation of the open borehole. The outcome of the study clearly shows that the volume variation is insignificant and mainly controlled by the drilling fluid weight and temperature, based on the outcomes of the sensitivity study; they classified the parameters which have impact on the deformation into two groups, controllable and uncontrollable[7] (See Figure 1).

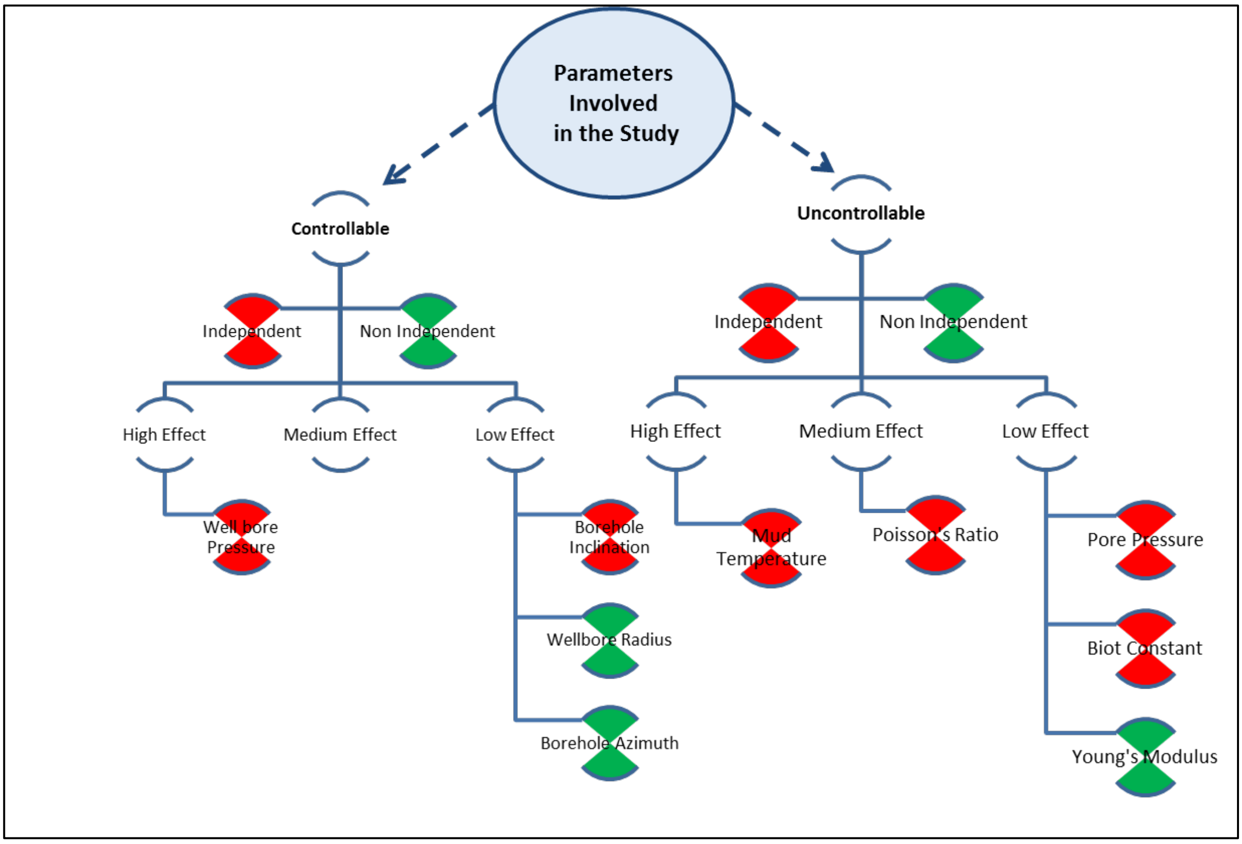

Figure 1: Classification of the parameters involved in the sensitivity study[7]

Late 2016 Asad et al developed standalone software (built on Matlab) in order to estimate and quantify the volumetric change of the active drilling fluid system. Two case studies were performed using historical data belonging to two wells. The main objectives of the study were to measure the effects of different controllable and uncontrollable parameters on the volumetric changes of the open borehole section and to evaluate any expected changes which would occur to equivalent circulation density (ECD) accordingly. They concluded the following points[8]:

- The elastic deformation of an open borehole section wall certainly occurs and its severity depends on geotechnical properties of encountered formation, magnitude of the in situ principle stresses , induced stresses, well geometry, well profile and the operational margin between dynamic and the hydrostatic pressure.

- The volumetric change of the open borehole section and change in ECD increase with increasing the pump flow rate.
- The static condition [pump off] of an open borehole section in terms of contraction and expansion is mainly driven by the status of the in situ principal stresses and the drilling fluid weight.
- The changing magnitude of ECD depends mainly on the open borehole static [Pump off] condition, if the borehole is under contraction status when the pump is off, two cases could exist once the pump is started:
  - The borehole could continue to be under contraction status; in this case the change in ECD will be positive [the predicted ECD will be higher than the theoretical ECD].
  - The second possible situation occurs if the open borehole condition changes from contraction to expansion, in this case the predicted ECD will be less than the theoretical ECD and consequently the change in ECD will be negative.

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