Enhancement of the Gas Extraction for Reservoir Identification in a New Mud Logging System

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Summary

The TRU-Vision system, developed by Baker Hughes, analyzes the formation gas extracted from the drilling mud to estimate the hydrocarbons content in the drilled rock formation.

Several separation processes were surveyed in order to improve the gas extraction at the gas trap, namely, mechanical stirring, vacuum, air sparging, membranes, ultrasounds and cyclones. Stirring devices (a propeller, a flat-blade turbine, two baffles sets), a vacuum generator, and an air bubble generator were designed and assembled to increase the efficiency and stability of the TRU-Vision response.

Theory

Gas Extraction in TRU-Vision

The TRU-Vision, produced by Baker Hughes, consists of a compact system that continuously collects drilling mud samples, heats the mud, extracts the gases from the mud at a gas trap, conditions and analyzes them in a gas chromatograph. It is of paramount importance to enhance the gas extraction at the gas trap to sequentially increase the efficiency and stability of TRU-Vision response. Although TRU-Vision already yields high quality data, the following features may be further improved: higher and more stable efficiency of the gas extraction from the mud, less maintenance and utilities required, lower weight and economical.

The major physical mechanisms underlying the gas extraction (from liquids and/or solids) are the outgassing, degassing and desorption. Outgassing consists in the gas spontaneous release from a material. Degassing designates gas forced extraction. Desorption denominates the release of absorbed chemicals from a material surface (Paolo Chiggiato, 2006). As for the gas extraction from a drilling fluid, only the outgassing and degassing methods may be applied, because the gas is present in the fluid mainly as dissolved microbubbles.

The most common techniques for degassing are mechanical stirring, vacuum, heating, air sparging, membrane processes, ultrasounds, and cyclones.

Mechanical stirring

The mechanical stirring in the gas trap aims at providing a strong mud/gas mixing to release the entrained gas in the mud (Lucena, 2012), providing a high contact surface area between the air and the mud, yielding a fast mixing of the gas with fresh air such that the ditch line composition is representative of the gas/mud concentration, and maintaining a constant gas release despite mud level fluctuations inside the gas trap (Wright et al., 1993; Li et al., 2015).

For degassing, a high stirring velocity (Reynolds number $\sim 10^6$) is required to strongly promote the gas rise through the mud, as in von Kármán swirling flow (Zandbergen & Dijkstra, 1987). This high turbulence may be induced by given stirrer types, depending on the fluid viscosity (Doran, 1995).

Vacuum

The gas dissolved in a liquid under reduced pressure becomes less soluble, depending on the liquid area exposed to the vacuum (Van Slyke & Neill, 1924). On the other hand, a less soluble gas separates more easily from the liquid (Nourozieh et al., 2016).

Air sparging

According to Boyle's law, the volume and pressure of a bubble are inversely proportional at constant temperature (Shale Shaker Committee, 2005):

$$P_1 \times V_1 = P_2 \times V_2 \quad (1)$$

The continuous air injection at the gas trap bottom forces the air bubbles to collide with the methane microbubbles (Hu et al., 2010). The air bubbles volume should be higher than the methane microbubbles, because the lower internal pressure of the air bubbles promotes the Ostwald ripening effect. The methane microbubbles collide and easily coalesce with the air bubbles to equilibrate both bubbles pressures. The merged bubble volume increases and it rises faster to the surface, due to the buoyancy force, where the methane is finally released (Schmeizer & Schweitzer, 1987). A higher amount of methane will be removed with a turbulent air sparging.

Membranes

Certain membranes are only permeable to gases (Chen et al., 2015). In such a case, by circulating the drilling mud as the membrane feed and maintaining the membrane permeate side under vacuum, the dissolved gases pass through the membrane (Tonner et al., 2011; Separel, 2015).

Ultrasounds

Ultrasounds are commonly used to remove small bubbles and dissolved gases from a liquid (Pandey et al., 2017). The sound waves, while propagating through the liquid, alternate between high pressure (compression) and low pressure (rarefaction) cycles. In rarefaction, if many near-vacuum bubbles are created, a large contact surface area with the liquid is obtained. The dissolved methane may migrate to these low pressure bubbles, increasing their volume and inducing their fast rise. Ultrasounds has also the advantage of reduced gas redissolution, as the fast rise diminishes the contact time (Leighton, 1994; Wu et al., 2013).

Cyclones

In cyclone separators, the centrifugal force splits fluid components with distinct phases and/or densities. In a cyclone, the fluid and a carrier gas enter into a conical vessel, being projected tangentially to the wall (Kepa, 2013). The heavier compounds (higher densities) flow downwards along the wall and leave the vessel through the bottom outlet (Shields, 2015; ASCOMPTransAT, 2014). As the fluid and the air are propelled against the wall, small droplets are created, providing a large contact surface area between the fluid and the air, thereby facilitating the transference of methane to the air (Coker, 2007; Hoffmann & Stein, 2002).

Method

Mechanical stirring and vacuum were optimized in a previous work (Marum et al., 2019), but both methods may be further enhanced. In this work, various improved devices for mechanical stirring, vacuum generation and air sparging were designed, manufactured and assembled to intensify the gas extraction from the mud at the gas trap, and thereby increase the efficiency and stability of TRU-Vision response.

Mechanical stirring

Bearing in mind that the drilling mud viscosities were inferior to 10^2 cP, the impellers selected were a propeller and a flat-blade turbine. A three blade propeller generates an axial flow and it is commonly used at high rotational speeds (1750 rpm) with Reynolds number higher than 200. The flat-blade turbine is usually applied in small vessels for gas-liquid dispersions at low flow rates of gas (Walas, 1988). Both impellers were designed based on the thumb rules (Doran, 1995; Walas, 1988) and Table 1. Both impellers were printed in stainless steel in a 3D printer (Fig. 1).

Fig. 1 - Three dimensional (3D) printed impellers in stainless steel. On the left-hand side: propeller (blades assembled on the shaft

adaptor) and on the right-hand side: flat-blade turbine (only the blades).

Baffles prevent settling and stagnant zones throughout the stirring of viscous fluids and/or fluids containing-particles, such as drilling mud. They may be assembled (Doran, 1995). The current CVD gas trap has three straight baffles adjacent to the wall. As the mud viscosity, ca. 10^2 cP, is a low moderate viscosity, a three baffle set apart and perpendicular to the tank wall and a four baffle set adjacent to the tank wall were designed based on the thumb rules. Both baffle sets were printed in titanium in a 3D printer (Fig. 2).

Fig. 2 - 3D printed baffles in titanium. On the left-hand side: three baffle set far from the tank wall and on the right-hand side: four baffle set adjacent to the tank wall.

Vacuum

A set of devices were assembled to generate vacuum in the CVD gas trap (Fig. 3). A needle valve (*Parker* Series 9) was located at the air inlet hose of the gas trap, and electrically connected to a wave generator (*Agilent* 33210A) and a power supplier (*TDL-Lambda* X600). The wave generator controlled the valve opening time. Due to the valve restriction and the air flow, the continuous suction in the ditch line led to a pressure drop inside the gas trap.

A pressure sensor (*Keller* PR-23Ed) was assembled at the beginning of the ditch line to measure the pressure therein and estimate the gas trap pressure. It was connected to a media logger (*Graphtec* medi LOGGER GL220), in which the results were displayed and recorded.

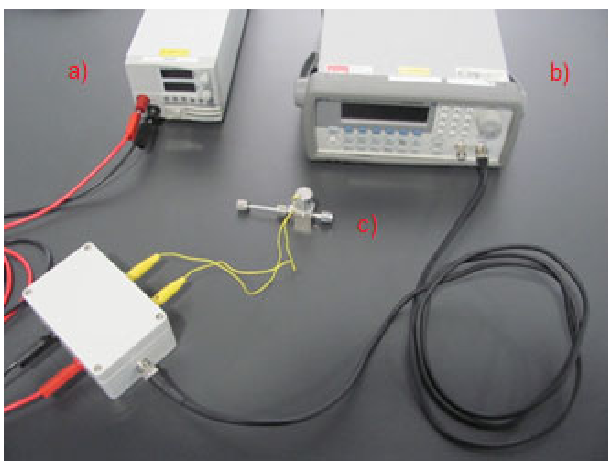

Fig. 3 - Gas trap vacuum generator: a) power supply, b) wave generator, c) needle valve.

Air sparging

To enhance the air sparging process, another bubble generator was inserted with the air flow rate controlled by a needle valve, connected to the facility pressurized air. A defensive publication from Baker Hughes mentions this technique (Ochoa et al., 2014).

Throughout this work, previously built bubbles generators were used but failed after a while, i.e., they did not produce microbubbles any longer (only macrobubbles). Their failure might be due to the porous material erosion by the high flow rates of mud crossing it.

Results & Conclusions

Although the current design of the CVD gas trap is a good compromise of simplicity, robustness and stability, as shown in a prior work (Marum et al, 2019), potential improvements of gas extraction were assessed.

The current mechanical stirring of the gas trap may still be enhanced regarding the gas extraction efficiency, and stability, the weight and utilities dismiss. The gas extraction takes longer for small contact surface areas, thus a vortex would be beneficial. Likewise for the application of vacuum and/or air sparging. The major handicap of vacuum creation is the mud aspiration into the ditch line at pressures inferior to the atmospheric pressure, damaging downstream equipment. Anyway, vacuum may be

applied together with other processes proposed here-in. The application of air sparging in TRU-Vision is unpractical. A bubble generator or another air bubble injector located at the gas trap bottom or mud inlet would be ruined by the drilling cuttings. A better option would be air sparging through the impeller but it would imply the gas trap redesign.
Though a gas permeable membrane would prevent the gas redissolution, it would require the gas trap redesign and vacuum implementation, as well. Furthermore, membranes cannot handle the drilling cuttings contained in the mud, and their frequent replacement and maintenance would be prohibitive. Although ultrasounds apparatus are efficient and fast, the gas trap redesign would be required, besides its maintenance and cost. As cyclones rely on the centrifugal forces in the vessel, the gas trap redesign and high flow rates of the mud would be required. The processes that would require a new design of TRU-Vision gas trap were dropped for the timeframe being.
The coupling of the potential processes that would enhance the gas extraction at the gas trap is represented in Fig. 4. It appears that the mechanical stirring is fairly more advantageous compared to the other processes. However, only experimental tests would absolutely rank the efficiency and stability of the various processes.

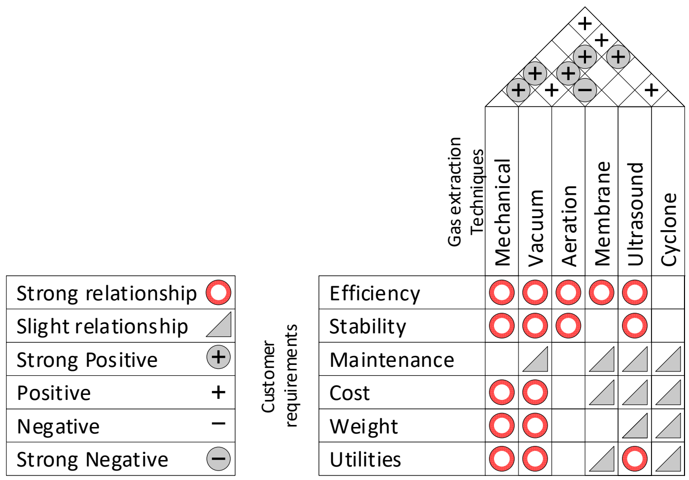

Fig. 4 - House of Quality diagram including customer requirements and gas extraction techniques.

Novel Information

The TRU-Vision is a new mud logging system to extract and analyze the formation gas from the drilling muds, in order to estimate the hydrocarbons content in the drilled rock formations. A TRU-Vision prototype comprised a methane bubble generator and a gas trap, the operational conditions of which were optimized in a previous work (Marum et al., 2019).
In this work, various processes were surveyed to increase the gas extraction efficiency in the gas trap, namely, mechanical stirring, vacuum, air sparging, membranes, ultrasounds and cyclones. As the three first ones did not require the gas trap redesign, extra devices were designed and assembled, viz., a propeller, a flat-blade turbine, two sets of baffles, a vaccum generator and an air bubble generator, which were not tested in the lab yet. From the surveyed methods, vacuum is the easiest to implement and surely will raise the gas extraction efficiency in the next model of TRU-Vision. The bubble generator requires enhancements to rise its lifespan. A method to monitor and control the bubbles sizes is also relevant. It is also pertinent to determine the composition ranges of the mud in which the gas microbubbles are entrapped in order to better understand the behavior of bubbles' entrapment in drilling fluids and access an inclusive extraction technique.

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