Katarina Simon*, Nediljka Gaurina-Međimurec*, Davorin Matanović*, Zdenko Krištafor*

CLEANING CAPABILITY OF DIFFERENT FLUID SYSTEMS USED IN COILED TUBING DRILLING

1. INTRODUCTION

Coiled tubing drilling applications are becoming more widely used because of their major advantages over the conventional jointed pipe drilling methods. Some of the advantages are:

- drilling and trip under pressure,
- continous circulation while tripping,
- slimhole and thru tubing capability,
- small location footprint.

Before using coiled tubing (CT) for drilling practice, serious engineering considerations have to be taken into account because of coiled tubing limitations such as:

- small diameters,
- limited reach in horizontal wells.
- hydraulic limitations etc.

Cuttings transport during drilling (either conventionally or with coiled tubing) has a major impact on the economics of the drilling process. Inefficient hole cleaning can lead to numerous problems such as stuck pipes, reduced weight on the bit and reduced rate of penetration, lost of circulation, additional costs because of adding additives in the drilling fluid, wasted time for wiper tripping etc.

One of the major challenges still is how to achieve efficient cuttings transport in such wellbores because drillstring rotation during drilling is not possible. This limits mechanical agitation of cutting beds, so flow rates need to be increased to compensate for this. There are many studies which agreed that the major effective drilling parameter on cuttings trans-

* Faculty of Mining, Geology and Petroleum Engineering, University of Zagreb, Petroleum Engineering Department, Pierottieva 6, 10000 Zagreb, Croatia

port in high-angle wells is the annular velocity. When the flow regime in annulus is turbulent, a significant reduction in cuttings bed development is observed. Better cuttings transport ability has been reported for low-viscosity fluids, because turbulent flow for such fluids can be much more easily obtained. But there are many other factors that have impact on cuttings transport in case of coiled tubing drilling such as fluid and cuttings properties, rate of penetration, well inclination, tubing eccentricity, etc.

So, when designing a fluid's rheology and hydraulics for coiled tubing drilling operations the following points must be considered:

- pressure drops through the coiled tubing and up the annulus limit maximum flow rate,
- downhole motor and drilling assemblies have a flow rate range (maximum and minimum) that often limits the drilling fluid flow rate,
- some directional assemblies have limitations on solids that can be pumped through them (e.g. LCM such as calcium carbonate).

2. DRILLING FLUID SELECTION

The drilling fluid selection process is principally based on the lithology and pore pressures anticipated over wellbore section to be drilled. Drilling fluid density is generally specified for each wellbore section and represents a compromise between the anticipated pore pressure and the fracture gradient of the formation being drilled. Fluid selection must also take account of high friction losses encountered in the CT string and the difficulties of cutting transport. Other critical design criteria for CTD fluid include minimizing formation damage, fluid loss, cooling and lubricating bit, motor and CT, shale stability etc.

The most common CTD fluid composition includes:

- brine based liquid for inhibition,
- bio-polymer,
- interfacial tension reducer and lubricant,
- a biocide,
- additive for pH control.

It is obvious that fluid is "solids free" and if needed adding of sodium or potassium chloride can increase fluid density. There are different opinions about fluid viscosity. One school of thought supports the use of visco-elastic fluids that possess very high values of LSRV (Low Shear Rate Viscosity). The other points out that thin fluids (low-viscosity fluids) in turbulent flow provide superior hole cleaning [1–6]. The problem is how to achieve adequate flow rate in annulus with wider clearance.

3. LABORATORY WORK

We prepared and tested two different polymeric "solids free" fluids (Tab. 1). The only difference in their composition was in the type of biopolymer. In one fluid, clarified XC polymer was used, while in the other, a new biopolymer named diutan was used.

Table 1

Composition of tested fluids

Composition	Additive	Quantity, g/dm^3
Viscosity control	Clarified XC polymer or Diutan	3
Filtration control	Starch	6
Inhibition and density	KCl	35
pH value	KOH	As needed for pH 8.5–9

Fluids for laboratory testing were prepared on a Hamilton Beach mixer. Potassium chloride is dissolved in tap water. Then the polymer was initially dispersed in salt water at 3000 min^{-1} for about 1 min. After that the mixing speed was increased to 11 000 min^{-1}. Both fluids were mixed for 30 min. Specific gravity of prepared fluids was 1025 kg/m^3. Rheological measurements at ambient 50°C and 75°C temperatures were performed using Model 900 viscometer. This is a digital, fully automated system with speed range from 0,006 to 1000 min^{-1} and Couette coaxial cylinder geometry (R1B1) for measuring fluid viscosity. The instrument can perform standard API tests.

The rheological behaviour of tested fluids at different temperatures (ambient, 50°C and 75°C) is shown in Figure 1. It is obvious that for the same polymer concentration, diutan has higher viscosities in low range of shear rate than XC polymer fluid. There is no difference in viscosity for higher shear rates.

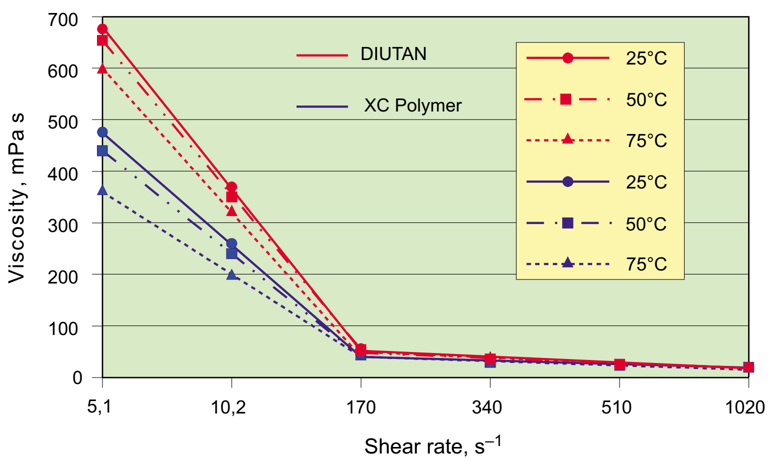

Fig. 1. Comparison of viscosity for tested fluids

LSRV viscosity was also determined by the Model 900 viscometer at the rotational speed of 0.037 min^{-1}. Results are shown in Figure 2. It can be seen that fluid with diutan has higher LSRV values at all testing temperatures. Also, LSRV values of the fluid with diutan are stable at all temperatures. LSRV values of XC polymer fluid are decreased with temperature increasing.

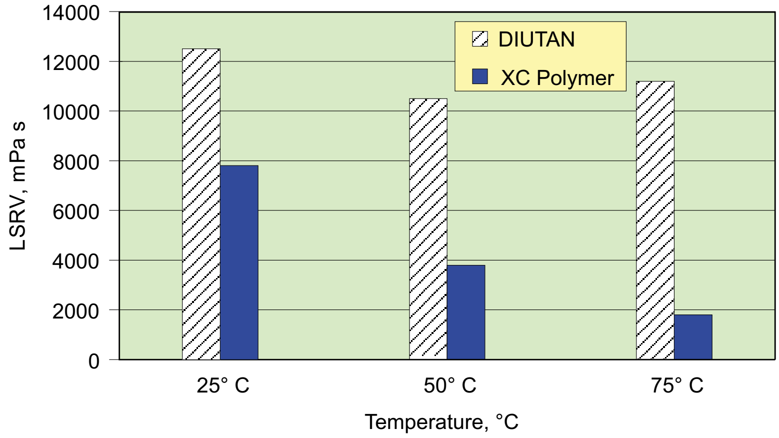

Fig. 2. LSRV values of tested fluids

Fluid loss testing of both fluids was performed by standard API filter press. Results are shown in Figure 3. Both fluids have high spurt loss and constant filtration with time.

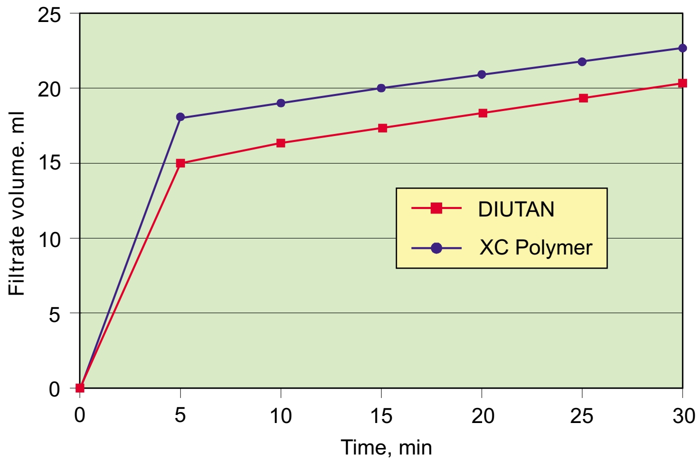

Fig. 3. Filtration of tested fluids (API standard filter press)

4. HYDRAULICS SIMULATION

Typical horizontal wellbore geometry in case of coiled tubing drilling is shown in Figure 4. There are two characteristic areas [2]:

1) CT and BHA in openhole annulus – near the bit and usually at a high inclination,
2) CT in casing annulus – farther up the well and at a lower inclination,

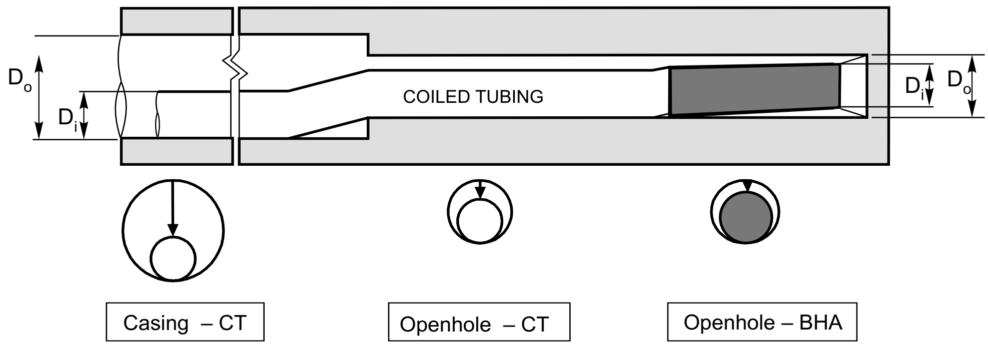

Fig. 4. Typical horizontal wellbore geometry during coiled tubing drilling

We used MTI software apllication to calculate critical flow rates and pressure profiles for tested fluids. Results of modelling confirm that chosen coiled tubings can withstand imposed pressures. Rheological fluid parameters used in calculations are presented in Table 3.

Table 3

Power – law's model rheological parameters values of the tested fluids (at 75°C)

	DIUTAN	**XC Polymer**
Flow behaviour index (n), –	0.221	0.323
Consistency index (K), $Pa \cdot s^n$	1.98	1.09

Rheological parameters for both fluids were calculated based on six characteristic data pairs shear rate/shear stress. Two commonly used coiled tubing drillstring configurations were anticipated for critical velocity/flow rate modelling (Tab. 4). The results of modelling are shown in Table 5.

Table 4

Drillstring configuration (from the bottom)

Drillstring component	**Drillstring 1**	**Drillstring 2**
	Outer diameter, mm (in)	**Outer diameter, mm (in)**
Bit	114.3 (4.5)	95.25 (3.75)
BHA	88.9 (3.5)	73.025 (2.875)
Coiled tubing	73.025 (2.875)	60.325 (2.375)

Inner casing diameter for both configurations is 127.3 mm

Table 5

Results of critical velocity/flow rate modelling

Wellbore area	XC Polymer				DIUTAN			
	Drillstring 1		Drillstring 2		Drillstring 1		Drillstring 2	
	v_c, m/s	Q_c, l/min	v_c, m/s	Q_c, l/min	v_c, m/s	Q_c, l/min	v_c, m/s	Q_c, l/min
Openhole – BHA	1.916	454.3	1.916	337.7	1.816	441.7	1.846	325.2
Openhole – CT	1.7	619.4	1.756	449.6	1.71	622.9	1.75	447
Casing – CT	1.6	826.4	1.554	917.9	1.652	846.4	1.61	953.4

In the case of drillstring configuration 1, turbulent flow is achievable only in the openhole – bottom hole assembly part of annulus. The flow rates needed for turbulent flow in other parts of annulus are too high because of downhole motor capacity limitations (anticipated positive displacement motors (PDM) have flow rate limitations in the range of 341 to 606 l/min). In drillstring configuration 2, both fluids can be pumped in turbulent flow in openhole part of the annulus (PDM limitations range 303 to 473 l/min). Turbulence cannot be achieved around coiled tubing in casing neither for drillstring 1 nor for drillstring 2 configuration. Because of higher LSRV value which means better cleaning possibilities in larger annuli and lower observed pressure losses [6], fluid with diutan is a better choice for cleaning both "wells".

5. CONLUSIONS

Hole cleaning is more efficient if a low-viscosity fluid is pumped in turbulent flow but such conditions are usually limited by the pressure at the surface and the flow rate limitation of the downhole motor/assembly.

Diutan used in tested "solids free" polymer fluids is more efficent viscosifier than xanthan (higer LSRV values at all testing temperatures) and is abetter choice for using in coiled tubing drilling operations.

Hydraulics modelling should be done during the wellbore design phase especially in complex operations such as coiled tubing drilling. It can help in the selection of appropriate drilling fluid.

REFERENCES

[1] Walton I.C.: *Computer Simulator of Coiled Tubing Wellbore Cleanouts in Deviated Wells Optimum Pump Rate and Fluid Viscosity*. Paper SPE 29491, presented at the 1995 Productions Operations Symposium, Oklahoma, USA, 2–4 April 1995

[2] Leising L.J., Walton I.C.: *Cuttings Transport Problems and Solutions in Coiled Tubing Drilling*. Paper IADC/SPE 39300 presented at the 1998 IADC/SPE Drilling Conference, Dallas, USA, 3–6 March 1998

[3] Li J., Walker S.: *Sensitivity Analysis of Hole Cleaning Parameters in Directional Wells*. Paper SPE 54498. Presented at the 1999 SPE/ICoTA Coiled Tubing Roundtable, Houston, USA, 25–26 May 1999
[4] Walker S., Li J.: *The Effects of Particle Size, Fluid Rheology and Pipe Eccentricity on Cuttings Transport*. Paper SPE 60755, presented at the 2000 SPE/ICoTA Coiled Tubing Roundtable, Houston, USA, 5–6 April 2000
[5] Chao H., Shah S.N., Osisanya S.O.: A *Three Layer Modeling for Cuttings Transport with Coiled Tubing Horizontal Drilling*. Paper SPE 63269, presented at the 2000 SPE Annual Technical Conference and Exhibition, Dallas, USA, 1–4 October 2000
[6] Navarrete R.C., Shah S.N.: *New Biopolymer for Coiled Tubing Applications*. Paper SPE 68487, presented at the 2001 SPE/IcoTA Coiled Tubing Roundtable and Exhibition, Houston, 7–8 March 2001