Energy Engineering and Environmental Engineering

Part 2

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Cuttings Characteristics and Mechanics Behavior in Horizontal Wells of Liaohe Oil Field

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Keyword: cuttings transport; well profile; particles settling; cuttings mechanics behavior

Abstract. Cuttings transport of drilling and washing process in horizontal well is a typical two-phase (liquid-solid) or three-phase (gas-liquid-solid) flow phenomena. In this paper, it analyzes the flow characteristics of Huan 127-Lian H2 horizontal wellbore , then uses experimental method to study the behavior of the particle size distribution and the mechanics. This study provides an important way to master cuttings settling in fluid medium, it can explain how the cuttings bed is generated and cleared, and why the procession of cuttings of migration is stopped. In addition, measurement and analysis of drill cuttings is the basis erosion and abrasion analysis of BHA.

Introduction

Buried reservoir in Liao he Oilfield is very shallow, sandstone is unconsolidated and diagenesis is poor. It needs to inspect sand pump approximately 3,200 every year, which causes to consume a large amount of operating funds. Research and analysis about Huan 127-H1, Huan 127-Lian H2, Mian 2-Ping1, Qi 2-H3 and other horizontal wells shows that the heavy oil sand production is relatively frequent, sand column is more than 200 m generally. It needs to wash sand and when to inject steam every time. So it chooses drilling cuttings collected in Huan 127-lian H2 well, which is typical of Liao he Oilfield horizontal wells to carry out screening experiments.

Wellbore Profile Analyzing and Debris Particles Sampling

In this paper samples are from the 1# rock sample of 1250m section, 2# rock sample of the 700-1244m whipstocking section, 3# rock sample of 0-700m vertical section of Huan-127-Lian H2.

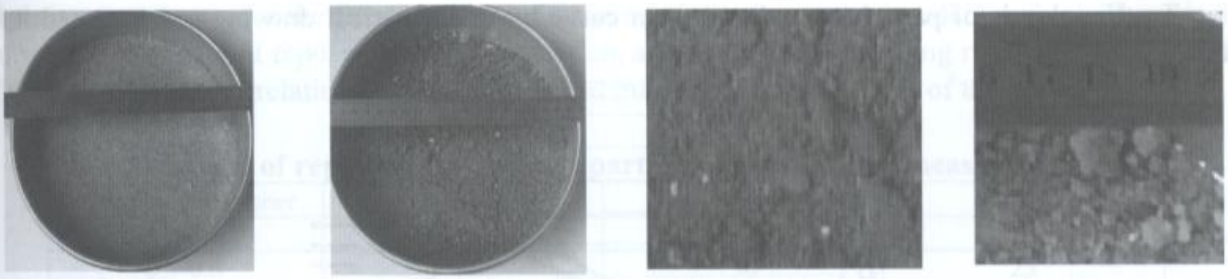
Test section

Primary Instrument. Scales: weighing range 1000g, a sense of weight less than 0.1g. It refers national standards (GB6003.1-1997), which prescripts the diameter is 200mm and it is a kind of standard screening. Hole diameter is 0.075mm, 0.30mm, 0.60mm, 1.18mm separate; scale (precision 0.1mm); small shovel; shallow dish; brush; beaker; hopper and so on.

Experiment Preparation. Firstly, use the camera to take shape of sand and physical size of it as shown in Fig. 1. At last to observe particle samples, analyze cuttings size and shape, nature of the rock formation, the rock breaking tools, etc.

Experimental Procedure. Sand sample screening experimental steps:

Weigh accurately certain quality of air-dried sample, the accurate cause 0.5g (to carry out experiment separately) , 1.18mm diameter sieve is placed on the top. To close the upper cover, hand shake sieve for 15 minutes, and then remove the sieve set. Shake continuously, according to sieve opening size sequence, and start from the largest sieve, until every screen content does not exceed the residual amount of 10%. To weight the residual mass of the sieve, accurate to 0.5g, and it will be screened out. Sift together, according to the order, until all procedure is completed. Compared to the sum of the remaining amount of the sample before screening, classification of all remaining amount and total samples in the chassis, the difference should not be more than 1%.

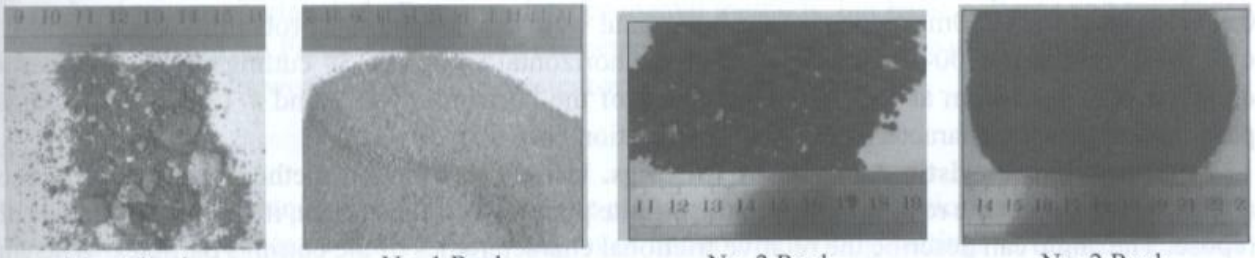


(a) No. 1 rock particles (b) No. 2 rock particles (c) Local shape of No. 2 rock particles (d) Local shape of No. 3 rock particles

Figure 1 Experimental rock samples after air-dried, indoor air-dried

Test Results and Analysis

Results Observation and Analysis of Sand Particles. (1) Cuttings sizes of the same formation is different, sheet characteristics is obvious, color and composition are similar;(2) Drilling cuttings size is very large when using the cone bit to drill the upper well section, characteristics of the sheet is obvious; When using diamond bit to drill in deep well, drilling cuttings sizes is small. Cuttings particle size and shape is directly related to rock properties, rock-breaking tool and other factors. (3) Partial enlarged picture in No.2 in Fig. 1-(c) shows the cuttings are bonded together, this will affect the migration speed of cuttings when returning to the ground, when it attaches to the shaft wall, it will affect the cuttings clean-up. (4) A chunk of large polygon rock exists in No.3 cuttings in Fig. 1-(d) should belong to the borehole wall after shedding; Particle shapes after screening are shown in Fig. 2.



No. 1 Rock (D>1.18mm) No. 1 Rock (D=0.03~0.06mm) No. 2 Rock (D>1.18mm) No. 2 Rock (D=0.03~0.06mm)

Figure 2 Rock shape after screening D=200mm)

Fig. 2 shows that cuttings after grading shows obvious characteristics.

Size Distribution Analysis of Cuttings Particle.

Refer to the representation of particle size analysis results belongs to Chinese Standard (GB/T 15445. 2-2006/ISO 9576-2.2001), the average particle size of cuttings samples is expressed as: $x=\frac{1}{2}\sum_{i=1}^{n}\Delta Q_i(x_i+x_{i-1})$. Where x represents the average particle size of the debris; x_i represents the particle size interval ceiling, x_{i-1} represents the lower limit of the particle size interval; ΔQ_i represents relative amount of particle size interval. Mass and size levels distribution of the rock sample is listed in Table 2 [2][3].

Table 2 Mass distribution of 3 kinds of rock particles at all levels of mesh size

rock sample number			1#	2#	3#
sieve diameter (mm)	0.0088	<0.0175mm, square opening	0.0116	0.0544	0.0536
	0.1625	0.175~0.15mm, square opening	0.0349	0.0816	0.0670
	0.2250	0.15~0.3mm, square opening	0.0997	0.1224	0.0965
	0.450	0.3~0.6mm, square opening	0.1179	0.2585	0.2010
	0.8900	0.6~1.18mm, square opening	0.7085	0.3197	0.3246
	>1.18	>1.18mm, square opening	0.0274	0.1633	0.2560
percentage of total quality, %			1	1	1

To draw kinds of particle size distribution curve by mathematical drawing software and it is shown in Fig. 3:

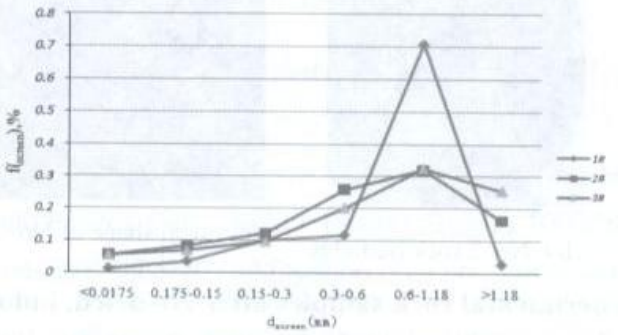


Figure 3 Particle size distribution

To curve fit the particle size, it approximately gets the 1 #, 2 #, 3 # cuttings particle size distribution.

$$1\#:\ y=-0.0098x^5+0.1303x^4-0.593x^3+1.0773x^2-0.6193x, R^2=0.9521;$$

$$2\#:\ y=-6E-05x^5-0.0031x^4+0.0355x^3-0.1058x^2+0.1316x, R^2=0.9934;$$

$$3\#:\ y=-0.0007x^5+0.006x^4-0.0088x^3-0.0267x^2+0.0843x, R^2=0.9999。$$

x represents the diameter size of the debris, y represents the particle size distribution. R^2 represents the degree of correlation after cuttings diameter fitting. Wherein the value 0.9521, 0.9934, 0.9999 are respectively close to 1, so the use of 5-order polynomial fitting can reflect the Huan 127-Lian H2-wells particle size distribution well. The 1# cuttings probability has a diameter of 0.6-1.18mm at the 1250m segment of the horizontal well; The 2# cuttings probability has a diameter of 0.6-1.18mm at the700-1244m segment of the horizontal well; The 3# cuttings probability has a diameter of 0.3-1.18mm at the 0-700m segment of the horizontal well; And # 1, # 2, # 3 cuttings particle size gets the characteristics of X2 distribution basically.

Friction Characteristic Analysis of Cuttings. Using the injection method to measure repose angle that is to inject the rock sample into the infinite plane at a certain height, it will form the angle of repose. The angle can describe the relative frictional characteristics of the cuttings particles. Wherein processed data is shown in Table 3 and Table 4.

Table 3 Original data of particle packing cone with injection method (mm)

rock sample number		1#		2#		3#	
sieve diameter (mm)	0.0750	88	28	46	16	38	10
	0.2250	107	35	89	32	74	21
	0.8900	97	32	95	35	101	34

Table 4 The angle of repose measured with injection method

rock sample number		1#	2#	3#
sieve diameter (mm)	0.075	32.471	34.825	27.759
	0.2250	33.193	35.720	29.578
	0.8900	33.417	36.384	33.951

And then according to formula: $a_{in}=atan[\frac{2H_a}{D_a}]$ to calculate the angle of repose and then draw a graph related the angle of repose and sieving diameter with graphics software and to analyze flow properties of the cuttings(Fig 4). F illustrates that as sieving diameter increases, angle of repose of the rock sample becomes large, the fluidity descends, that fits completely internal friction characteristics of the powder. Average angle of repose of 2 # is greater than 36°, which shows that the # 2 is the illiquid powder type.

Using the Tilt Method to Measure and Analysis Angle of Repose α_{dip}. Container filled with the powder is placed horizontally, and then open the end, so that the powder can flow out freely. the angle formed on the powder surface and the horizontal plane namely, is defined as the angle of repose. This

angle is representative of the characteristics of static friction between the powder particles. Three rock samples in the angle of repose of experimental data and analytical processing results is list in Table 5.Then to draw the correlation curve as Fig. 5, and make necessary analysis of the curve.

Table 5 The angle of repose of the cuttings particles by inclination measurement method

rock sample number	1#	2#	3#
0.15-0.3	40	29	22
0.3-0.6	42	30	25
0.6-1.18	50	34	30
>1.18	61	35	34

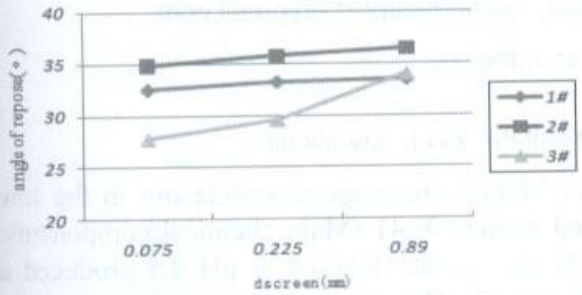


Figure 4 The angle of repose of the particle

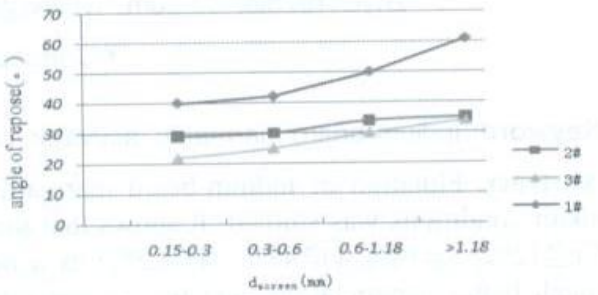


Figure 5 Cuttings angle of repose of injection method

For irregular cuttings, mobility of the particles is poor, with a strong compressibility and reunion, Its angle of repose is related to the size and experimental methods, but basic patterns and trends are the same. Known from Figure 6, as sieving diameter increases, repose angle of the cuttings becomes large, the fluidity gets worse, which is consistent with the injection trend.

Summary

This paper studies sand characteristics and the powder mechanical behavior of Huan 127-Lian H2 horizontal well. It indicates that size distribution of horizontal drilling cuttings is related with rock properties, and cuttings has a certain characteristic in certain probability distribution of the range.

Sandstone sample of horizontal wells after screening shows obvious shape feature. It needs to consider the difference between sheet cuttings and approximate square then to correct the shape and particle size distribution, in order to reflect the real debris characteristics more accurately. Study the particles settling of different size, concentration of particles. Then to simulate and analyze fluid cutting carrying capacity of different tilt angle wellbore after Huan 127-Lian H2 well cuttings particle characteristics and mechanical behavior are determined.

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