Mechanism Study of Gas Drilling Dust Removal of Water-Affusion

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Abstract: ***The prevention and control of debris particles is always a big problem in gas drilling for safety production. On the basis of the force analysis of the debris particles in sand pipeline is built up. Under some certain assumptions, the subsidence rules of the debris particles with different dimensions are analyzed and calculated. The result shows that the debris which's across are bigger than 25 micron can subsidence by themselves and which's across are smaller than 20 micron can't subsidence by themselves. These small particles will be a threaten to people's health and the environment. So it is needed to water injection and dust. In combination with the interaction mechanism between water and debris particles, some measures to improve the effect of water injection and dust in gas drilling are put forward, the methods that against the current direction, water at the eccentric position and add dustfall agent will be used to improve the effect.***

Keywords: debris; gas drilling; stress analysis; subsidence rules; water injection and dust

1. Introduction

Gas drilling adopts the under balanced drilling technology with the circulating fluid gas, separate the debris from the shaft bottom by the gas thrust, the big grains will be cut repeatedly near the drill till the the high pressure gas can take them out of the month, at last expel out from the ground draining sand pipelines[1,2]. After the debris enters in the draining sand pipelines, the gravity starts to be obvious, in general, the big debris grains can sediment in the draining sand pipelines, but the small ones will let out to the air with the airflow which will pollute the environment, so the dust removal of water-affusion will be processed at the end of the draining sand pipelines.

2. Stress of the Debris Grains in the Draining Sand Pipelines

In the gas drilling, the debris grains are subjected to aerodynamic resistance, gravity, buoyancy, Basset force, Szafman lift force, pressure gradient force, additional mass force, Magnus effect and pulse airflow and the mutual force crashed between grains to grains, grains to pipe walls[3-7], among those, the aerodynamic resistance, gravity and buoyancy make the main effects.

2.1 Aerodynamic resistance

Because of the different density, the flow of gas and debris grains in the draining sand pipelines exists the relative displacement. The aerodynamic resistance F_D affected on the grains is:

$$F_D = \frac{1}{2}\rho C_D A_D v_r^2 \quad \text{(N)} \tag{1}$$

In the formula: A_D — the meeting area of flowing of the debris grains (m^2); v_r — the relative speed of grains and gas (m/s); ρ — the gas density (kg/m^3); C_D — the aerodynamic resistance coefficient.

The aerodynamic resistance coefficient C_D is related to the shape of the debris grains and the gas flow conditions, which is the function of Reynolds number Re[7,8]. According to the different Reynolds number, the resistance coefficient C_D can be concluded the following three areas:

Laminar area

$$10^{-4} < Re < 1, \quad C_D = \frac{Re}{24} \tag{2}$$

Transition area

$$1 < Re < 500, \quad C_D = \frac{10}{\sqrt{Re}} \tag{3}$$

Turbulence area

$$500 < Re < 2\times10^5, \quad C_D = 0.44 \square 0.45 \tag{4}$$

2.2 Gravity

In the draining sand pipelines, the gravity suffered on the debris grains G is:

$$G = \rho_P g V_P \quad (5)$$

In the formula: ρ_P — the density of the debris grains (kg/m^3); g — the gravitational acceleration (m/s^2); V_P — is the volume of the debris grains (m^2).

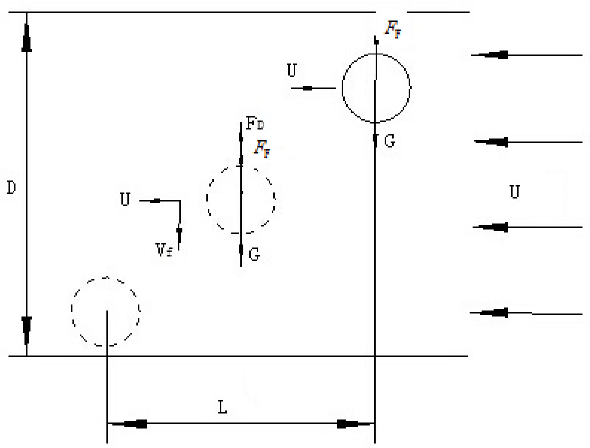
2.3 Buoyancy

In the draining sand pipelines, the buoyancy suffered on the debris grains F_F is:

$$F_F = \rho g V_P \quad (6)$$

3. Analysis of the debris grains deposition rule in the draining sand pipelines

The displacement simplified model of the debris grains in the draining sand pipelines is shown as figure 1.



D— the diameter of the draining sand pipelines; L— the horizontal displacement of the debris grains; U— the horizontal speed of the debris grains;

Figure 1: Schematic Figure of the debris grains deposition in the draining sand pipelines

In order to analyze and calculate quantitatively, make the following assumptions:

- The debris grains are the regular sphere;
- The flow in the pipeline doesn't consider the turbulent fluctuation and debris grains' Brownian displacement;
- The debris grains are deposited from the top of the pipelines;
- Don't consider the accelerated displacement time of the debris grains;
- The vertical deposition of the debris grains is the free deposition in the infinitely large space, that is Reynolds number < 1.

Under the above assumption conditions, the deposition speed, the deposition time and the horizontal displacement of the debris grains in the draining sand pipelines are respectively:

Deposition speed v_f :

$$v_f = \frac{\rho_p g d_p^2}{18\mu} \quad (10)$$

Deposition time t :

$$t = \frac{D}{v_f} = \frac{18\mu D}{\rho_p g d_p^2} \quad (11)$$

Horizontal displacement L :

$$L = \alpha t \frac{4Q}{\pi D^2} = \frac{72\alpha\mu Q}{\rho_p g d_p^2 \pi D} \quad (12)$$

In the above formulas: Q — the gas injection volume (m^3/s); α — the speed ratio of the debris grains and gas; the meanings of other symbols are the same as the above.

In the different gas injection volumes, after analysis and calculation, the relationships between the deposition speed, the deposition time of the debris grains and the grain diameter are shown as figure 2 and figure 3, the relationship between the horizontal displacement of the debris grains and the grain diameter is shown as figure 4, the relationship between the horizontal displacement of the debris grains and the gas injection volume is shown as figure 5.

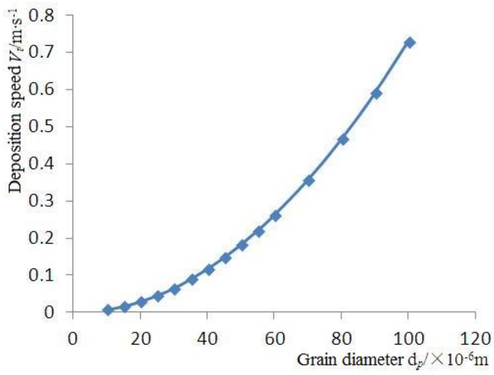


Figure 2: The relationship between the deposition speed of the debris grains and the grain diameter

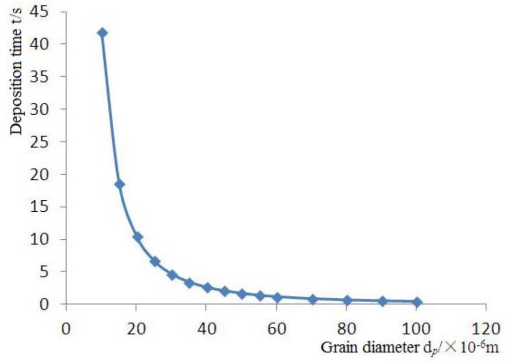


Figure 3: The relationship between the deposition time of the debris grains and the grain diameter

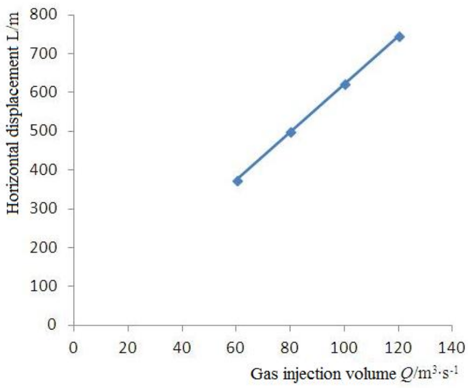


Figure 4: The relation curve between the horizontal displacement of the debris grains and the gas injection volume (dp=10μm)

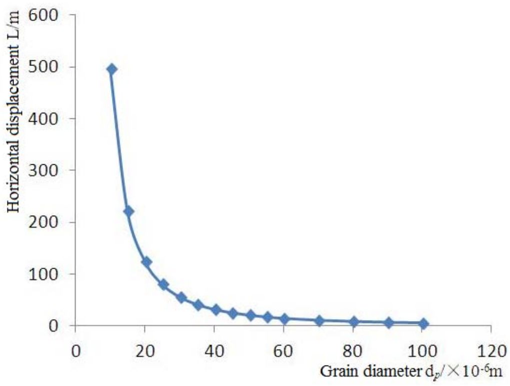
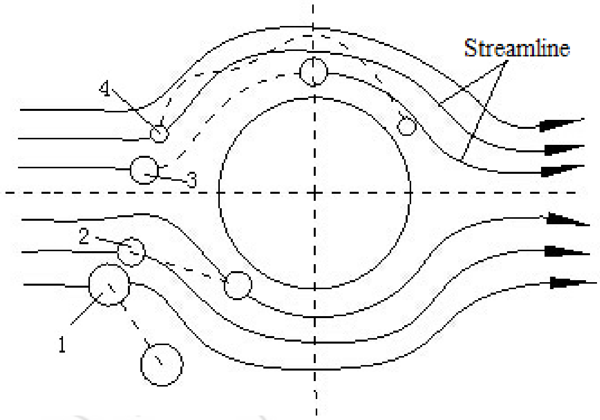


Figure 5: The relation curve between the horizontal displacement of the debris grains and the grain diameter (Q=80m^3/min)

From the above analysis and calculation, in the draining sand pipelines with 100m of the current gas drilling length, the diameter more than 25μm is the debris grain, which can deposit freely, but those less than 20μm can't deposit freely, therefore, the dust removal of water-affusion must be processed in the draining sand pipelines.

4. Mechanism study of debris grains' dust removal of water-affusion in the draining sand pipelines

The common dust removal mechanism studies are the gravity deposition, the inertia force deposition, the intercept capture and Brownian diffusion [9-], **which** is shown as figure6.



1— gravity deposition grains, 2— inertia force crack grains, 3— intercept grains, 4— Brownian diffusion grains

Figure 6: Typical dust removal mechanism study

4.1 The gravity deposition principle of the debris grains

The factors affected the debris grains deposition are: the physical property of the gas with dust, dynamic characteristic of the fluid, the diameter size of the debris grains and their distribution. Including the main factor affected the debris grains deposition efficiency is the diameter size of the debris grains. As for the larger debris grains, the deposition principle is mainly the gravity deposition.

4.2 The inertia force deposition principle

When the airflow with dust flows around the liquid drop, because the debris grains have larger inertia force than the gas molecule, the grains in the airflow will separate from the curve gas flow line, continue to move forward according to the imaginary line, and they will be captured after crashing with the fluid drops, this capture is the inertia force deposition.

4.3 The intercept capture effect

Based on the surrounded object surface, the process of the dust grains with a certain diameter and no quality among the captured gas is the intercept capture process. The intercept capture is the capture dust effect that ignored the grain quality and not considered the grain's inertia crash. When only considering the intercept capture effect, the grains moved along the gas flow line can not only deposit on the crossed surface of the flow line and the surrounded objects, but also capture all the grains which the distance between flow line and the capture surface equal or less than the grain radial.

4.4 Brownian diffusion effect

When the small dust grains move around the fluid drops by the carry-over effect of the airflow, because of Brownian diffusion effect, the dust grain displacement trail is not consistent with the airflow line so that it is deposited on the fluid drops. The smaller the dust grains are, the stronger Brownian diffusion is, when analyzing the dust grain deposition of $d_p < 2\ \mu m$, this principle is often considered.

5. The measures of improving the dust removal of water-affusion effect

In theory, the measures of improving the dust removal of water-affusion effect can be to increase the water injection volume and its speed rate, but there is no doubt that increasing the water injection volume will waste the water resource, however improving the water injection speed rate will increase a supercharging device, it must increase the drilling cost. So under the premise of not wasting the resource and not increasing the cost, in order to improve the dust removal of water-affusion effect, it can be considered to lay out the water injection position in the draining sand pipelines and to add the additives which is helpful of wetting the debris grains in water[16-19].

5.1 From the aspect of the water injection position in the draining sand pipelines layout

Start to install nozzles from 6-7m at the end of the draining sand pipelines, the nozzle quantity is 3-4 pieces in general, then inject water. The layout way is shown as figure7 and figure8.

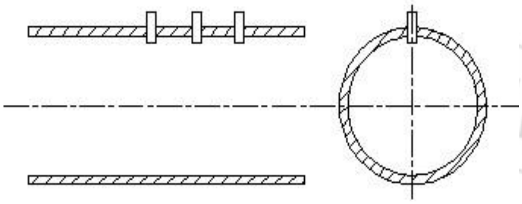


Figure 7: Layout along the pipeline's axis direction

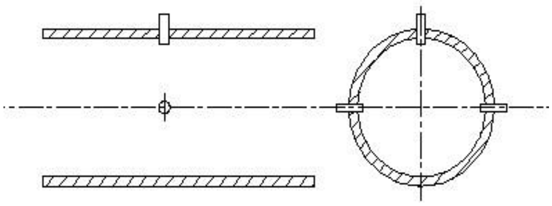


Figure 8: Layout along the pipeline's circumference

As for the water injection way of the axis layout, it makes the water drops and debris after efflux and atomization generated various crash chances, and increases the possibility that the debris is captured by the water drops largely. This capture principle of the layout way is to play the leading role of the single liquid drop's capture effect.

As for the water injection way of the circumference layout, it can generate a large water flow area in a position. When the debris reaches here with the airflow, the chance of contacting or crashing water drops will be higher than the former way. This capture principle of the layout way is to play the leading role of the effect that the debris immerses the bottom liquid flow.

Through the analysis of the above two water injection ways, we understand that the basic way to improve the dust removal effect is to increase the chance of wetting the water drops and debris and the crash combination capability. As for this opinion, we can improve the water injection layout way as follows, which is shown as figure9 and figure10.

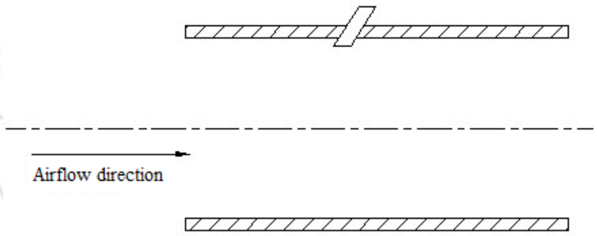


Figure 9: Layout in countercurrent direction

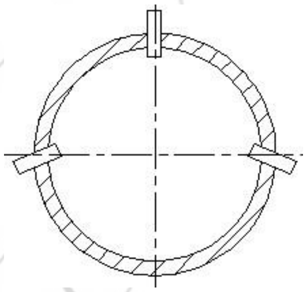


Figure 10: Eccentricity layout

The layout way of figure9 is an improvement of that in axis direction, it is mainly considered the water's countercurrent effect. That is under the condition of the same water injection volume, the relative speed between the efflux water drop speed and the airflow speed increases. So the impact force between them increases, the high-speed airflow speed can make the fluid or the fluid drop broken rapidly and generate many small liquid drops. Because the fluid drop amount increases in the draining sand pipeline sections, it obviously improves the crash and contacting rate of the fluid drops and the debris grains which will increase the debris wet amount, thus it provides the possibility of the adhesion and aggregation in the later flow. On the other hand, because the angle between the water injection pipeline and the draining sand pipeline is not 90^{o}, based on the mechanics knowledge, the water drop speed has horizontal and vertical direction components, compared with the vertical direction layout, the vertical speed component of the liquid drops reduces, so the time that the water drops reached the pipeline bottom will be increased relatively. In other words, the time of the fluid drops crashing the debris grains in the pipeline increases, also the capture capability of the water drop is improved.

The layout way of figure10 is mainly considered the problem of the uneven pressure distribution and the problem of the uneven water injection distribution. Because the grain diameter of the debris grains is not even in the draining sand pipelines, it can make that the larger debris are distributed near the bottom of the pipeline, the smaller ones are distributed above the pipeline. However the past water injection way can make the water injection amount distributed unevenly, it is lower at the top of the pipeline, even the water drops can't reach some dead corners, so some small debris at the top of the pipeline can't be wet, and by the eccentricity water injection, it can solve the problem of the uneven pressure distribution and the problem of the uneven water injection distribution, then it reaches the effect of improving the dust removal.

5.2 From the aspect of adding dust deposition agents

All the researches and practice indicate that the dust removal effect of the clear water is very poor, its rate of dust removal only reaches about 60%. So it needs to add a certain proportion of the dust deposition agents in the water, and it can improve the wetting capacity of the water to the debris largely and improve the dust removal effect.

When selecting the dust deposition agents, at first the capability of decreasing the water surface tensile, the wetting speed to the dust and the shortest deposition time of the dust need to be considered, these are the main parameters of measuring and judging the dust deposition agents performance. At present, they mainly select R-89 high efficient dust deposition agent and RJ-85 high efficient dust deposition agent. However selecting 1/1000 of the matched concentration of the dust deposition agent is the best, and its dust removal effect is also the best.

6. Conclusion

This research indicates that:

1) Through the analysis of the debris deposition rules in the gas drilling, it concludes the relation curve Figure between the debris grain diameter and the deposition speed, the deposition time and the horizontal displacement, thereby it concludes that the debris grains more than 25micron in the draining sand pipelines can be deposited freely; as for the debris grains less than 20 micron, they can't be deposited automatically, if let out these small grains into the air, it will affect people's health and pollute the environment, so dust removal with water-affusion is needed.
2) Dust removal with water-affusion is used for increasing the debris density and the grain diameter to increase the debris gravity and reach the purpose of the dust removal.
3) Improving the effect of the dust removal with water-affusion is to improve the crash and contacting rate between water and debris, improve the dust removal effect by the water injection ways of countercurrent direction and eccentricity layout and adding dust deposition agents.

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