Evaluation of temperature resistance of gelatinized modified starch drilling fluid

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Abstract. This chapter evaluates and compares the indoor performance of different concentrations of non gelatinized starch and gelatinized starch in drilling fluid, gelatinized modified starch at 80℃, and then aged at high temperature. Taking the plastic viscosity (PV) and filtration loss (FL) as the main evaluation indexes, a formula with better performance was selected as the main additive and used as the follow-up study. At the same time, the inhibition of gelatinized starch in water-based drilling fluid was investigated.

Keywords: high temperature, modified starch, drilling fluid.

1. Introduction

Gelatinization is one of the basic physical and chemical properties in starch modification processing. With the heating of the starch suspension, the starch particles first start to absorb water and expand, and the volume becomes larger. Then the amylose molecules in the amorphous region are partially leached. After reaching a certain temperature, the starch particles suddenly expand rapidly, the starch particles lose birefringence, the crystal structure disintegrates, and continue to rise. The volume of the starch particles expands to dozens or even hundreds of times, The starch water suspension system finally becomes a translucent colloidal solution, which is the gelatinization of starch. The whole gelatinization process of starch can be roughly divided into three stages: the first is the reversible water absorption stage, in this reaction stage, only a small amount of water molecules enter the starch particles, and the particle volume expansion is very small; Then it enters the irreversible water absorption stage. In this process, a large amount of starch particles absorb water, the volume expands rapidly, the internal structural skeleton of starch is destroyed, some amylose molecules will leach out of the particles, the viscosity increases rapidly, and the transparency of starch solution also increases; The third is the particle disintegration stage, especially under the action of shear force, after the starch particles are broken and disintegrated, the starch molecules are finally dispersed in the solution [1].

The potato starch, corn starch and cassava starch used in this experiment showed irreversible water absorption in the process of fully heating with water, and the water molecules gradually entered the crystalline area in the starch particles. Some chemical bonds in starch molecules become unstable due to the increase of external temperature, which is conducive to the fracture of chemical bonds in starch molecules. With the breaking of these chemical bonds, the crystalline region in the starch particles gradually changes from the original closely arranged state to the loose state. In this process, the water absorption of the starch increases rapidly, and the volume of the starch particles expands rapidly. Its volume can expand to 50~100 times of the original volume, that is, the starch is modified by gelatinization; It can not only reduce viscosity in drilling fluid, but also effectively adjust the rheological properties of drilling fluid. The production method is simple, the synthesis technology is relatively mature, the source of raw materials is wide, and the cost is low. Gelatinized modified starch has the advantages of environmental protection, no pollution and easy degradation, and can be applied to environmental protection drilling fluid system.

2. Experiment

2.1 preparation of drilling fluid

Pre hydration of drilling fluid:350ml water+0.7g sodium carbonate+14g bentonite, 1600r/min, stirring for 120 minutes, aging under closed conditions for 1 day, ready for use.

2.2 performance evaluation of starch drilling fluid

According to GB/t16783.1-2006, the plastic viscosity (PV, mPa•s), filtration loss (FL, ML) and other performance parameters of drilling fluids with different concentrations of cassava, potato and corn starch after hot rolling at different temperatures are evaluated. From four different amounts of starch selected in the experiment: 0.5%, 1.0%, 1.5% and 2.0%, the amount with the best temperature resistance (low filtration) and good lubricity (low plastic viscosity) was selected as the experimental standard of gelatinization modification [2,3].

2.3 comparative analysis of performance characteristics of starch gelatinized modified drilling fluid

The starch with the best performance was used as the experimental standard of gelatinization modification, and the starch: distilled water = 1:4 was mixed and stirred Gelatinized starch was prepared by fully gelatinizing in a water bath at 80℃ for 5 minutes. It was added to the drilling fluid solution, stirred at 1600r/min for 120 minutes, and aged under closed conditions for 1 day. This paper mainly evaluates the plastic viscosity, filtration loss and other performance parameters of three starch gelatinized modified drilling fluids after hot rolling at different temperatures, and selects the gelatinized starch with the best temperature resistance.

2.4 linear expansion rate of Bentonite

According to sy-t6335-1997, the inhibition performance of distilled water, KCl solution with the same concentration and gelatinized starch drilling fluid treatment mud with the best temperature resistance are evaluated respectively, the expansion amount of bentonite of drilling fluid treatment mud at different times is evaluated, compared with distilled water and KCl solution, and the expansion rate is calculated according to the expansion amount to draw the curve .

3. Results and Discussion

3.1 Characterization of starch

Different concentrations of potato, corn and cassava starch were added to the fresh water base mud at room temperature. The plastic viscosity PV(mPa•s), dynamic shear YP(PA), apparent viscosity AV(mPa•s), filtration loss FL(ML) and other performance parameters of the treated mud at room temperature were tested. When 0.50% ~ 2.0% cassava starch was added, compared with 4% fresh water base mud, the filtration loss decreased with the increase of starch dosage, The plastic viscosity basically did not change with the increase of the amount of starch, which was 3mPa•s. when 2.0% cassava starch was added, the filtration rate decreased to 28ml; When 0.50% ~ 2.0% potato starch was added, compared with 4% fresh water base mud, the filtration loss decreased with the increase of starch dosage, and the plastic viscosity basically did not change with the increase of starch dosage, which was 3mPa•s. when 2.0% potato starch was added, the filtration loss decreased to 20.6ml. When 0.50% ~ 2.0% corn starch was added, compared with 4% fresh water base mud, the filtration loss decreased with the increase of starch dosage, and the plastic viscosity basically did not change with the increase of starch dosage, which was 3mPa•s. when 2.0% corn starch was added, the filtration loss decreased to 20.6ml. Through the screening of three kinds of starch, it was found that when 2% potato and corn starch were added, the performance was better, among which 2% corn starch had the best performance, the filtration loss was reduced to 20.6ml and the plastic viscosity was 3.5mPa·s. In conclusion, through the performance evaluation of drilling fluid with three different types and different concentrations of starch, it is found that compared with 4% fresh water base mud, the three starch treated mud can increase the apparent viscosity and plastic viscosity of drilling fluid, reduce the filtration loss and increase the friction coefficient Tg of sliding block. This is because the starch added at room temperature is still small particles without gelatinization modification and does not form polymer glue [4-6].

Table 1. Results of treated pulp with different starch concentrations at room temperature

Mud	consumption/ %	PV /mPa•s	YP /Pa	AV /mPa•s	YP/PV /Pa/mPa•s	G10s Pa	G10min Pa	FL mL	tg
Base mud	/	3.0	0.50	3.50	0.167	0.50	0.25	33.0	0.0963
Base mud + cassava starch	0.50%	3.0	0.50	3.50	0.167	0.50	0.25	31.0	0.1228
	1.00%	3.0	0.50	3.50	0.167	0.50	0.25	29.8	0.1763
	1.50%	3.0	0.50	3.50	0.167	0.50	0.25	28.8	0.2217
	2.00%	3.0	0.50	3.50	0.167	0.50	0.25	28.0	0.1763
Base mud + potato starch	0.50%	3.0	0.25	3.25	0.167	0.75	0.50	27.2	0.1051
	1.00%	3.0	0.50	3.50	0.167	0.50	0.50	25.6	0.1405
	1.50%	3.0	0.50	3.50	0.167	0.50	0.50	23.8	0.2217
	2.00%	3.5	0.25	3.75	0.083	0.50	0.50	20.6	0.1763
Base mud + corn starch	0.50%	3.0	1.00	4.00	0.330	0.50	0.50	26.8	0.1139
	1.00%	3.0	1.00	4.00	0.330	0.75	0.50	24.8	0.1405
	1.50%	3.0	1.00	4.00	0.330	0.50	0.50	24.0	0.1584
	2.00%	3.5	0.25	3.75	0.083	0.50	0.50	20.6	0.1763

Compared with 0.5% ~ 2.0% treated pulp at room temperature, after aging at 130 ℃ for 16 hours, the filtration of 0.5% cassava starch treated pulp decreased by 76.77% and the plastic viscosity increased by 1.66 times; The filtration of 0.5% potato starch treated pulp decreased by 69.12%, the plastic viscosity increased by 0.5 times, the filtration of 0.5% corn starch treated pulp decreased by 80.59%, and the plastic viscosity increased by 1 time. The filtrate loss of 1.0% cassava starch treated pulp decreased by 46.3%, and the plastic viscosity increased by 1.83 times; The filtrate loss of 1.0% potato starch treated pulp decreased by 68.75%, and the plastic viscosity increased by 1.5 times; The filtration of 1.0% corn starch treated pulp decreased by 82.26%, and the plastic viscosity increased by 2 times. The filtrate loss of 1.5% cassava starch treated pulp decreased by 42.36%, and the plastic viscosity increased by 3 times; The filtration loss of 1.5% potato starch treated pulp decreased by 74.79%, and the plastic viscosity increased by 2.83 times; The filtration of 1.5% corn starch treated pulp decreased by 90% and the plastic viscosity increased by 2.5 times. The filtrate loss of 2.0% cassava starch treated pulp decreased by 48.57%, and the plastic viscosity increased by 4.83 times; The filtration of 2.0% potato starch treated pulp decreased by 90.29%, and the plastic viscosity increased by 2.83 times; The filtration of 2.0% corn starch treated pulp decreased by 68.93%, and the plastic viscosity increased by 2.83 times. The results showed that the comprehensive properties of 2.0% corn starch were the best at 130℃, the filtration of 2.0% corn starch treated pulp was 2ml and the plastic viscosity was 12MPa·s.

Table 2. Results of starch treated pulp with different concentrations at 130 ℃

model	consumption/ %	PV /mPa•s	YP /Pa	AV /mPa•s	YP/PV /Pa/mPa•s	G10s Pa	G10min Pa	FL mL	tg
Base mud + cassava starch	0.50%	8.0	0.75	8.75	0.094	0.50	0.50	7.2	0.5206
	1.00%	8.5	1.50	10.00	0.176	0.50	0.50	16.0	0.4663
	1.50%	12.0	2.00	14.00	0.167	0.75	0.50	16.6	0.4348
	2.00%	17.5	2.75	20.25	0.157	1.00	0.75	14.4	0.3839
Base mud + potato starch	0.50%	4.5	1.00	5.50	0.220	0.25	0.25	8.4	0.3541
	1.00%	7.5	0.75	8.25	0.100	0.25	0.25	8.0	0.3443
	1.50%	11.5	1.50	13.00	0.130	0.50	0.50	6.0	0.3443
	2.00%	11.5	3.75	14.25	0.330	0.75	0.50	5.6	0.3839
Base mud + corn starch	0.50%	6.0	2.50	8.50	0.420	1.00	0.75	5.2	0.1317
	1.00%	9.0	2.00	11.00	0.220	1.00	1.00	4.4	0.1493
	1.50%	10.5	3.25	13.75	0.310	0.75	0.75	2.4	0.1673
	2.00%	12.0	3.00	15.00	0.250	1.25	1.25	2.0	0.1763

Compared with 0.5%~2.0% treated pulp at room temperature, after aging at 140°C for 16 hours, the filtration of 0.5% cassava starch treated pulp decreased by 73.55% and the plastic viscosity increased by 1.67 times; The filtration of 0.5% potato starch treated pulp decreased by 55.89%, the plastic viscosity increased by one time, the filtration of 0.5% corn starch treated pulp decreased by 69.4%, and the plastic viscosity increased by 1.17 times. The filtrate loss of 1.0% cassava starch treated pulp decreased by 39.6%, and the plastic viscosity increased by 2.42 times; The filtration loss of 1.0% potato starch treated pulp decreased by 44.53%, and the plastic viscosity increased by 1.67 times; The filtration loss of 1.0% corn starch treated pulp decreased by 61.29%, and the plastic viscosity increased by 1.67 times. The filtrate loss of 1.5% cassava starch treated pulp decreased by 37.5%, and the plastic viscosity increased by 3.83 times; The filtrate loss of 1.5% potato starch treated pulp decreased by 56.3%, and the plastic viscosity increased by 3.33 times; The filtration of 1.5% corn starch treated pulp decreased by 66.67%, and the plastic viscosity increased by 3.17 times. The filtration of 2.0% cassava starch treated pulp decreased by 46.43%, and the plastic viscosity increased by 5 times; The filtration loss of 2.0% potato starch treated pulp decreased by 52.43%, and the plastic viscosity increased by 3.29 times; The filtration loss of 2.0% corn starch treated pulp decreased by 63.11%, and the plastic viscosity increased by 4.71 times. It is concluded that the comprehensive performance of corn starch is the best at 140°C. Although the filtration of 2% corn starch treated pulp is only 7.6ml, its plastic viscosity is 20MPa·s, which is obviously high, poor lubricity and weak practicability. After hot rolling at 140°C, the temperature resistance, filtration reduction and lubricity of the three Starch Treated pulps decreased significantly.

Table 3. Results of starch treated pulp with different concentrations at 140 ℃

model	consumption/ %	PV /mPa•s	YP /Pa	AV /mPa•s	YP/PV /Pa/mPa•s	G10s Pa	G10min Pa	FL mL	tg
Base mud + cassava starch	0.50%	9.5	0.5	10.0	0.21	1.00	1.00	10.4	0.3057
	1.00%	10.5	1.5	12.0	0.24	1.00	1.00	17.0	0.3153
	1.50%	14.5	0.5	15.0	0.21	1.50	1.00	18.0	0.2962
	2.00%	18.0	2.5	20.5	0.25	2.00	1.50	15.0	0.4040
Base mud + potato starch	0.50%	6.0	1.0	7.0	0.25	0.50	0.50	12.0	0.2867
	1.00%	8.0	3.0	11.0	0.13	0.50	0.50	11.2	0.3057
	1.50%	13.0	2.0	15.0	0.23	0.75	0.50	10.4	0.3346
	2.00%	15.0	1.5	16.5	0.53	1.00	0.75	9.8	0.3443
Base mud + corn starch	0.50%	6.5	2.5	9.0	0.54	1.50	1.00	8.2	0.3640
	1.00%	8.0	2.0	10.0	0.25	0.50	0.50	9.6	0.3346
	1.50%	12.5	4.0	16.5	0.32	0.75	0.50	8.0	0.3839
	2.00%	20.0	7.0	27.0	0.35	1.50	1.00	7.6	0.4142

In conclusion, the following conclusions can be drawn through the characterization of the concentration gradient properties of the three starches: The best starch content of 0.5%, 1.0%, 1.5% and 2.0% was 2%, which was used as the standard of subsequent gelatinization modification experiment. The highest temperature resistance of the three starches without gelatinization modification can only reach 130℃, and corn starch and potato starch are better than cassava starch in temperature resistance, filtration reduction and lubricity, among which corn starch is the best.

3.2 Comparative analysis of gelatinization properties of three kinds of starch

It can be seen that the filtration loss of the three gelatinized starch treated slurries decreases significantly during the temperature rise from room temperature to 110℃, and gradually increases at 110 ~ 150℃. The temperature resistance, filtration reduction and lubricity of the gelatinized corn starch drilling fluid system are better than those of potato and cassava starch treatment agents. The temperature resistance and lubrication of the three gelatinized starch treated slurries after hot rolling at 140℃ The performance of fluid loss reduction and lubricity are significantly reduced, so the high temperature resistance can only reach 130℃. The lubricity of 2% gelatinized corn starch treated pulp is obviously better than that of corn starch treated pulp without gelatinization modification at the same concentration, but the temperature resistance and filtration reduction need to be further improved by adding other modifiers.

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Table 4. Results of three starch 2% gelatinized pulps at different temperatures

Temperature ℃	model	PV /mPa•s	YP /Pa	AV /mPa•s	YP/PV /Pa/mPa•s	G10s Pa	G10min Pa	FL mL	tg
	potato	6	1.5	7.5	0.25	0.50	0.50	15.0	0.1584
25	Corn	2	1.0	3.0	0.50	0.25	0.25	5.6	0.1405
	cassava	2	1.5	3.5	0.75	0.25	0.25	17.0	0.1228
	potato	9	3.5	12.5	0.39	0.50	0.50	6.0	0.2126
90	Corn	5	3.0	8.0	0.60	0.25	0.25	5.6	0.2217
	cassava	4	1.5	5.5	0.35	2.00	2.00	5.8	0.2586
	potato	14	3.5	18.0	0.25	1.00	1.00	5.6	0.2401
110	Corn	9	3.0	10.0	0.33	0.50	0.50	5.2	0.2493
	cassava	6	3.0	9.0	0.50	1.00	1.00	5.5	0.1944
	potato	19	3.5	22.5	0.18	1.00	1.00	11.2	0.1763
130	Corn	13	3.0	16.0	0.23	0.50	0.50	7.0	0.4142
	cassava	7	4.0	11.0	0.57	0.50	0.50	9.0	0.4348
	potato	17	1.0	18.0	0.06	1.00	1.00	16.0	0.1584
140	Corn	10	2.0	12.0	0.20	0.50	0.50	14.0	0.1405
	cassava	6	2.0	8.0	0.33	0.50	0.50	18.0	0.1317
	potato	20	4.0	24.0	0.20	2.50	2.00	15.0	0.1584
150	Corn	14	4.0	18.0	0.29	2.00	2.00	16.0	0.1495
	cassava	10	6.0	16.0	0.60	1.50	1.00	19.0	0.1317

3.3 Linear expansion rate of Bentonite

The inhibitor in the drilling fluid system mainly plays the role of stabilizing the wellbore and is one of the important treatment agents of water-based drilling fluid [7]. In the experiment, 2% potassium chloride inhibitor with low cost and good environmental protection performance was selected for comparative experiment, and 2% gelatinized corn starch with the best temperature resistance was selected to verify the inhibition. The linear expansion rate of bentonite with the same dosage of two inhibitors was evaluated.

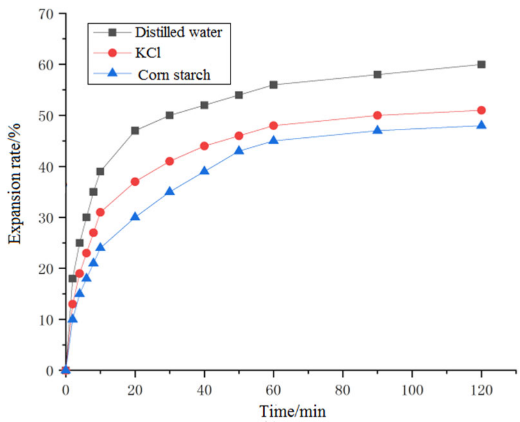

Fig. 1 Effect of 2% gelatinized corn starch solution on linear expansion rate of bentonite

The influence of the two treatment slurries on the linear expansion rate of bentonite is shown in Fig. 1. It can be seen from Fig.1 that the expansion rate of bentonite tablet after 2h in distilled water is 59.23%; The swelling rate of bentonite tablet after 2h in gelatinized corn starch treated pulp is 46.68%, and the inhibition effect of 2.0% potassium chloride treated pulp with the same concentration is the second. The experiment shows that gelatinized corn starch has a certain inhibition effect on the hydration and dispersion of bentonite, because the crystal forming area in starch particles changes from the original closely arranged state to the loose state, The water absorption of starch increases rapidly. Starch is a hydrocarbon polymer with many hydroxyl groups in its branched chain, which will combine with clay molecules due to van der Waals force, so as to reduce the dispersion and expansion of clay particles; It can be seen that gelatinized corn starch can inhibit the expansion of bentonite [8-9].

4. Conclusion

(1) Through the characterization of the concentration gradient properties of the three kinds of starch, it can be concluded that the best concentration of the four different starch concentrations of 0.5%, 1.0%, 1.5% and 2.0% is 2%. The high temperature resistance of the three kinds of starch without gelatinization modification can only reach 130℃, among which corn starch is better than potato and cassava starch in temperature resistance, filtration reduction and lubricity.

(2) Through the performance evaluation of three kinds of gelatinized starch treated mud, it is selected that the gelatinized corn starch gelatinized drilling fluid has better performance. After aging at room temperature for 24 hours, the temperature resistance and filtration reduction of the three gelatinized starch treated pulps were not obvious. After hot rolling at 90℃, 110℃, 130℃, 140℃ and 150℃, the performance was evaluated. The results showed that the filtration loss of the three gelatinized starch treated slurries decreased significantly from room temperature to 110℃, and gradually increased at 110 ~ 150℃. The temperature resistance, filtration reduction and lubricity of the gelatinized corn starch drilling fluid system were better than those of the gelatinized potato and cassava starch treated slurries, However, the highest temperature resistance can only reach 130℃, and its lubricity is significantly better than that of corn starch treated pulp without gelatinization modification at the same concentration. It is necessary to further optimize and improve the temperature resistance by adding other modifiers [10].

(3) Through the linear expansion rate experiment of bentonite, it is concluded that the gelatinized corn starch can inhibit the hydration expansion of bentonite and inhibit the hydration dispersion of bentonite. Its inhibition effect is stronger than fresh water mud and slightly stronger than 2% KCl solution. The inhibition of the system can be improved by adding other suitable environmental friendly modifiers.

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References

1. R.J. Zhang, Y. Bai, Y. Sun, W.C. Du, C.S. Pu, J. Zhang, G. Chen, Preparation of ammonium-oleic salts and evaluation as shale swelling inhibitors in water-based drilling fluid, Tenside Surfactants Detergents, 58 (2021) 311-316.
2. W.J. Ni, W.L. Wang, Q.C. Wang, W.C. Du, G. Chen, Modification and application of waste shaddock peel as a green additive for water-based drilling fluid, Journal of Biobased Materials and Bioenergy, 15 (2021) 380-384.
3. W.C. Du, X.Y. Wang, T.F. Bi, Man Liu, J. Zhang, G. Chen, Synthesis and inhibitive mechanism of a novel clay hydration inhibitor for water-based drilling fluids, Materials Science-Medziagotyra, 27 (2021) 128-142.
4. X.X. Liu, L. Gao, Q.C Wang, W.C. Du, X.F. Gu, J. Zhang, G. Chen, Evaluation and application of PEG as lubrication in water based drilling fluid for horizontal well in Sulige Gas Field, Polymer International, 70 (2021) 83-89.
5. Materials Research; Universidad del Zulia Researchers Update Current Study Findings on Materials Research (Modified Starch as a Filter Controller in Water-Based Drilling Fluids), Journal of Technology, 12 (2020) 97-113.
6. Z.H. Wang, Design and New Product Development of Drilling Fluid chemicals. Northwest University Press, Xi'an, 2006, pp. 210-212.
7. J.J. Xiao, H.G. Zeng, J. Han, Z.W. Sun, Y. Zhao, Application of high temperature resistant and environment-friendly drilling fluid in Henan Oilfield, China Petroleum and chemical industry standards and quality, 41 (2021) 47-58.
8. F.T.G. Dias, R.R. Souza, E.F. Lucas, Influence of modified starches composition on their performance as fluid loss additives in invert-emulsion drilling fluids, Fuel, 140 (2015) 140-152.
9. Y. Kong, Z. Yang, Z.F. Wang, X.H. Yang, Study on modification of starch and its application in drilling fluid, Energy Weekly News, Applied chemical industry, 11 (2016) 78-93.
10. W.Y. Guo, B. Peng, Synthesis and characterization of starch-graft-polyacrylamide copolymers and their application as filtration control agents in drilling fluid, Journal of Vinyl and Additive Technology, 4 (2012) 261-263.