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Optimization of process parameters for pipeline CO_2 transportation with impurities

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Optimization of process parameters for pipeline CO_2 transportation with impurities

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Abstract. According to the actual engineering experience of many years of abroad, and impurities will have an impact on pipeline transportation parameters. This paper takes the 300,000 tons/year CCUS project of an oilfield in China as an example. The Pipe phase simulation software was used to simulate the supercritical dense phase carbon dioxide pipelines with different inlet diameters under the same inlet parameters, and analyze the most suitable pipeline transportation process parameters for impurities containing supercritical dense phase carbon dioxide. The feasibility plan of carbon dioxide pipeline transportation has laid a foundation for the comprehensive construction of carbon dioxide pipeline network in China.

1. Introduction

With the rise of CCUS technology, combined with foreign experience in supercritical-dense phase CO_2 transportation, pipeline transportation is considered to be the best transportation method [1, 3]. However, the research field of supercritical-dense phase CO_2 pipeline transportation in China is still in its infancy. Therefore, the research on supercritical-dense phase CO_2 pipeline transportation process has certain practical engineering significance, which can be used for providing the necessary basis and technical support for supercritical-dense phase CO2 pipeline transportation in China [4, 6].

1.1. Carbon dioxide phase diagram with impurities

The critical point of pure carbon dioxide is T_c=31.4°C, P_c=7.38MPa. In the supercritical region, carbon dioxide does not distinguish the gas phase and the liquid phase, and the supercritical phase and the dense phase have a common pressure interval. The presence of impurities changes the phase characteristics of carbon dioxide and affects the process of the pipeline transportation. Table 1 shows the gas components of carbon dioxide pipeline in a 300,000 tone/year CCUS project in an oil field in China [7, 9]. Figure 1 shows the phase diagram simulated by HYSYS software.

Table 1. Gas source component parameter list.

Gas component	Molar fraction content(%)
CO_2	98.8040
H_2	0.0435
CO	0.7675
CH_4	0.0135
N_2	0.3305
AIR	0.0033
H_2S	0.0006
CH_3OH	0.0365
H_2O	0.00002

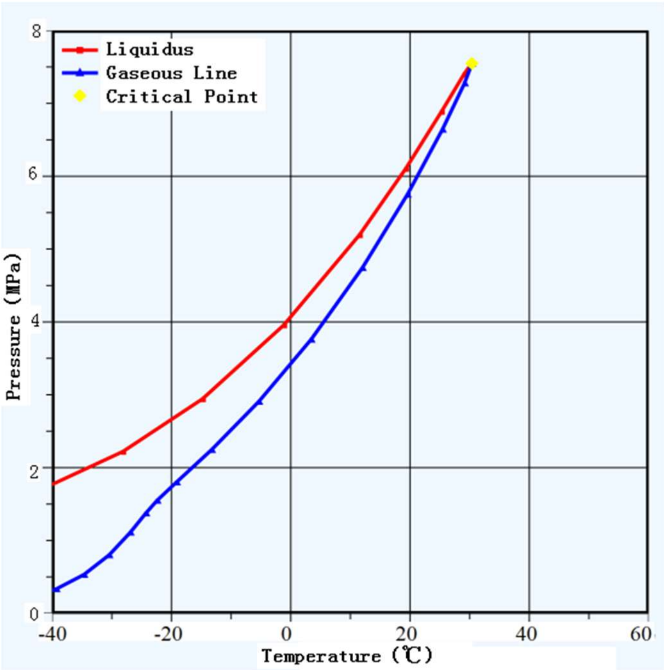

Figure 1. CO_2 phase diagram with impurity.

It can be seen from Figure 2 that the inclusion of impurities changes the critical point of carbon dioxide (Tc=30.37°C, Pc=7.55MPa), and two-phase zone appears in the phase diagram. Therefore, it is more difficult to transport carbon dioxide containing impurities. In the transportation process, not only the conveying temperature and pressure should be strictly controlled, but also the two-phase region in the transportation process should be avoided.

2. Determining the equation of state of carbon dioxide containing impurities

At present, the state equation for simulating the physical properties of carbon dioxide containing impurities is obtained by combining relevant literature and comparative evaluation of some valid experimental data. When the condition is 7MPa<P<15MPa, -3.15°C<T<96.85°C, the accuracy of the PR equation is higher than other equations of state. Therefore, this paper selects the PR equation for related simulation calculations [10, 11].

3. CO_2 pipeline design standard specification recommendations

There is no uniform delivery standard. at present, the main design and operation of carbon dioxide pipelines are related to European and American countries relevant experience and standards, such as

ASME B31.4-2016(Liquid Hydrocarbons and Other Liquid Pipelines) and BS EN 14161-2011(Oil and gas industry pipeline transportation system). China has no relevant standard specifications for carbon dioxide pipelines. the design standards of carbon dioxide pipelines in China mainly draw on the design of China's oil and gas pipelines and related oil and gas pipeline standards [12, 14].

4. Computational simulation exercise

Take a 300,000 tons/year CCUS project in an oilfield in China as an example, and transport it through pipelines with a length of 29km. The inlet pressure of the pipeline is 10 MPa, the inlet temperature is 60℃, the buried depth of the pipeline is 1.8 meters, and the ground temperature of the pipeline is 7.8℃. with 120,000 tones / year of CO_2 for transport to the storage site boost for oil displacement.

4.1. Simulation calculation and analysis of supercritical-dense phase CO_2 pipeline transportation process

The simulation calculates the variation of the pipeline parameters in different diameters. The results are shown in Table 2 and Figures3-6.

Table 2. Simulation results of Supercritical - dense phase CO_2 pipeline.

name	Simulation calculation result				
Nominal diameter(mm)	DN100	DN150	DN200	DN250	DN300
Pipeline size	Φ114×7	Φ168×8.0	Φ219×9.0	Φ273×10.0	Φ325×11.0
Outlet pressure(MPa)	6.6	8.951	9.811	9.943	9.977
Outlet temperature(℃)	23.24	20.79	18.73	17.31	16.28
Pressure drop(MPa)	3.4	1.049	0.189	0.057	0.023
Maximum flow rate(m/s)	4.26	2.08	1.09	0.69	0.48
Minimum flow rate(m/s)	3.81	0.78	0.40	0.25	0.17

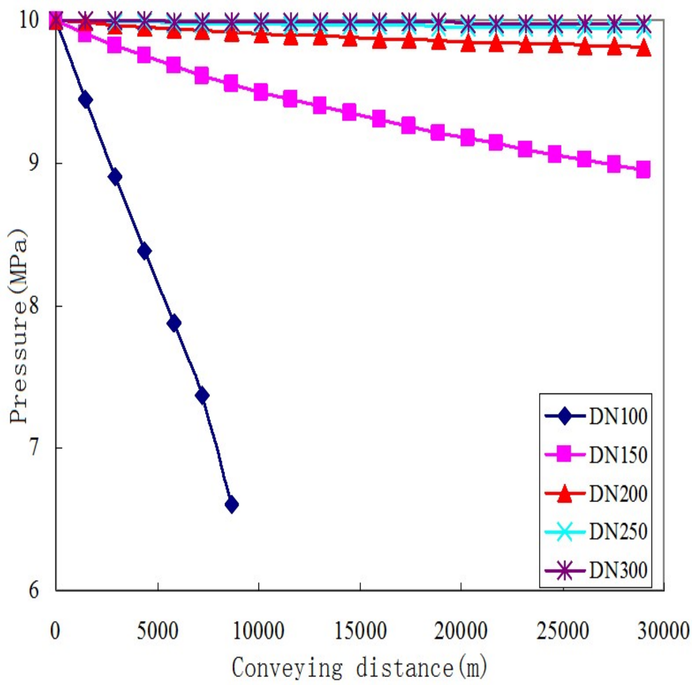

Figure 2. Pressure change in Supercritical - dense phase CO_2 pipeline

As can be seen from Figure 2: (1) Under the same conveying distance, the smaller the diameter, the larger the pressure drop; Compared with the other three pipelines, the DN150 pipeline has a larger pressure drop, while the DN200, DN250 and DN300 pipelines have similar pressure changes. (2) When the pipe diameter is DN100, the pressure decreases rapidly with the increase of the pipe transmission distance. At 8.7km, the CO_2 pressure in the pipeline drops below the critical pressure. Because the pressure is reduced more and the pipeline stops running, the DN100 pipeline is not suitable for supercritical— dense phase transportation;

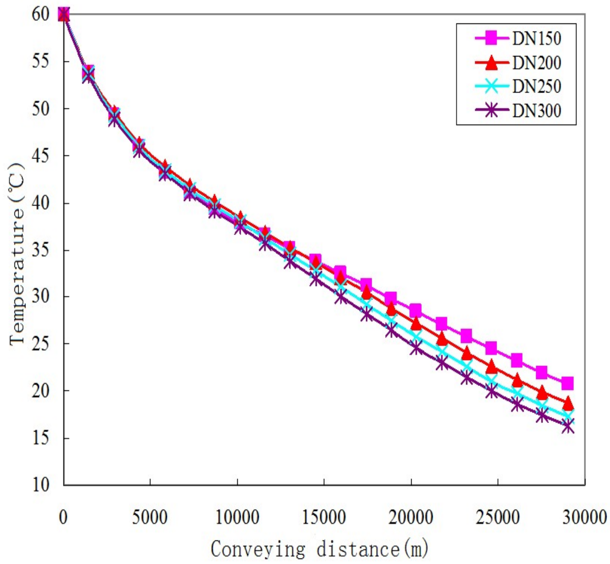

Figure 3. Temperature change in Supercritical - dense phase CO_2 pipeline

As can be seen from Figure 3: (1) With the increase of pipeline length, the CO_2 temperature gradually decreases, but the degree of decrease gradually decreases. At the same time, different pipe diameters have little effect on the degree of temperature decrease; (2) During the transport process, the temperature of CO_2 gradually decreases below the critical temperature, at which time CO_2 will be transported in a dense phase.

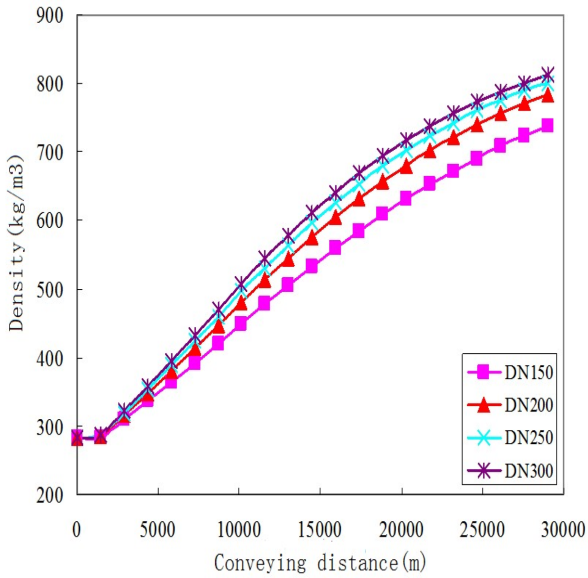

Figure 4. Density change in Supercritical - dense phase CO_2 pipeline

As can be seen from figure 4: The CO_2 density in the pipeline is affected by two factors, temperature and pressure. As the pipeline distance increases, the CO_2 density in the pipeline increases parabolically, and the CO_2 density increases with the increase of the inner diameter of the pipeline.

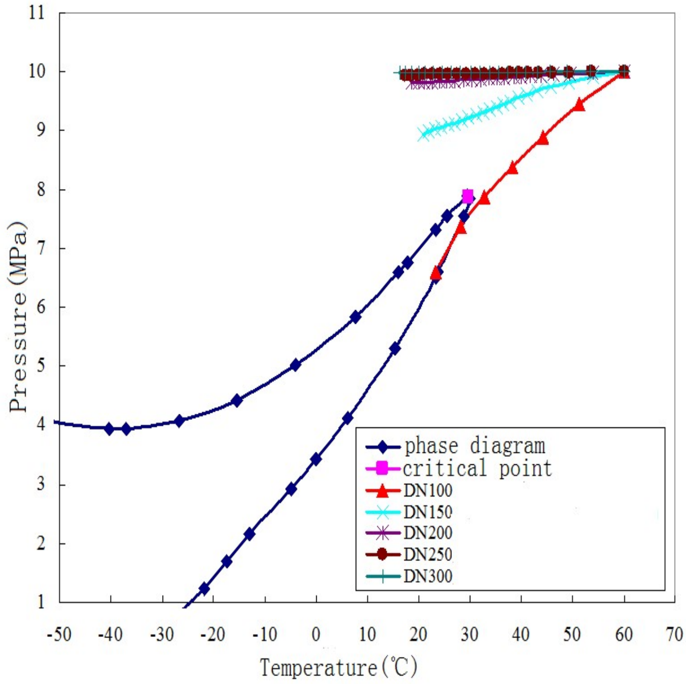

Figure 5. Phase transition of Supercritical - dense phase CO_2 pipeline

As can be seen from Figure 5: In addition to the DN100 pipeline entering the two-phase zone during transportation, the other four pipelines maintain the phase in the supercritical-dense phase throughout the transportation. Therefore, except for the DN100 pipeline, the remaining diameter pipelines meet the supercritical-dense phase transportation requirements.

4.2. Determination of the best diameter of supercritical-dense phase CO_2 transportation

According to the simulation, the other four pipe diameters can meet the process requirements of supercritical-dense phase CO_2 pipeline transportation in addition to the DN100 pipe diameter, sorting the entire conveying process comprehensively, the state of the CO_2 at the outlet of the pipeline determines the amount of power injected into the compressor at the storage site. When the cost of the pipeline is not considered, the higher the pressure of the CO_2 at the outlet of the pipeline, the lower the power required by the compressor. Compare the pressure drop of four pipelines, DN150 has a large pressure drop, so it is not suitable for pipeline supercritical-dense CO_2 transportation; and the pipe pressures of DN200, DN250 and DN300 have the same trend. Therefore, considering the pipeline infrastructure, DN200 is the best supercritical-dense phase transport pipe diameter for the CCUS project pipeline.

5. Conclusion

At present, supercritical-dense phase CO_2 pipeline transportation is a key link affecting the implementation of CCUS engineering projects. However, China's supercritical-dense phase CO_2 pipeline transportation is still in its infancy, and basic research and process technology research are relatively lacking. There are certain research blind spots in this field. This paper takes the 300,000 tons/year CCUS project of an oilfield in China as an example. The optimal pipe diameter parameters of supercritical-dense phase CO_2 under the different conveying distance are determined by simulation calculation, which provides theoretical basis and technical support for the subsequent large-scale development of CCUS projects. With the success of the experiment and the development of industrial application, it is hoped that the government and related enterprises should further consider the planning and construction of supercritical-dense phase CO_2 pipeline with impurities. On the basis of point-to-point transportation, research on CO_2 pipe network transportation should be carried out, and more specific and widely applied process parameters can be obtained.

Acknowledgments
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