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The Influence of Temperament on the Conveying Efficiency of UCG High Temperature Gathering Network

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Abstract: Due to the particularity of its gas source area and transportation medium, the factors affecting the efficiency of UCG pipeline transportation are also more complex than those of conventional natural gas. The dendriform UCG pipeline network model is designed through pipe network simulation software, aiming at different component conditions such as moisture, coal tar and dust, and aiming at different pressure and pressure drop changes of wellsite, branch line and trunk line respectively for quantitative analysis. The results show that the increase of the proportion of CH_4 and H_2 can improve the transport efficiency. With the increase of the proportion of H_2O components, the transport efficiency will decrease. Tar in the group does not increase the transportation efficiency, and if the component is large, it will lead to liquid phase in the pipeline and reduce the transportation efficiency; The appearance of dust will reduce the efficiency of transportation.

Keywords: UCG; Medium; Gathering Network; Pipeline Transport Efficiency.

1. Introduction

With the adjustment of energy structure and the implementation of national environmental protection policies, the underground carbon gasification (UCG) industry has received more extensive attention. UCG is an environmentally friendly energy development technology that conforms to the sustainable development strategy and contributes to the transformation and development of coal energy structure and the improvement of the low carbon utilization level of coal resources [1]. During the international energy crisis in the 1980s and 1990s, the United States vigorously developed UCG technology and carried out six series of UCG pilot tests [2]. Wiatowski Marian [3], Kapusta Krzysztof [4] and other relevant experiments focused on UCG production and process optimization. Good results have been achieved. However, there are few researches on UCG gathering and transportation.

In recent years, relevant domestic research work is also in full flow [5-9]. Yi Tongsheng et al. [10] proposed that strengthening targeted research is the urgent task to deepen the economic evaluation of UCG in China, and systematically analyzing the existing UCG field test cases is an objective way to solve the current problem of understanding differences. In this paper, the transportation efficiency of UCG gathering network is studied, and the influence of different media on the transportation efficiency and the degree of influence is deeply explored. Through comparison and analysis, the influence of water, tar, dust and other components on the transportation efficiency is determined, which provides a theoretical basis for future research on the engineering design and economic evaluation of UCG gathering network.

2. Parameter Design

The large-scale change of molar components of different media such as CH_4, H_2O and tar will have a corresponding impact on the gathering and transportation efficiency of UCG. The control variables are analyzed for different influencing factors, to determine the influence of each influencing factor on the transportation efficiency and the change trend.

2.1. Pipe Network Modeling

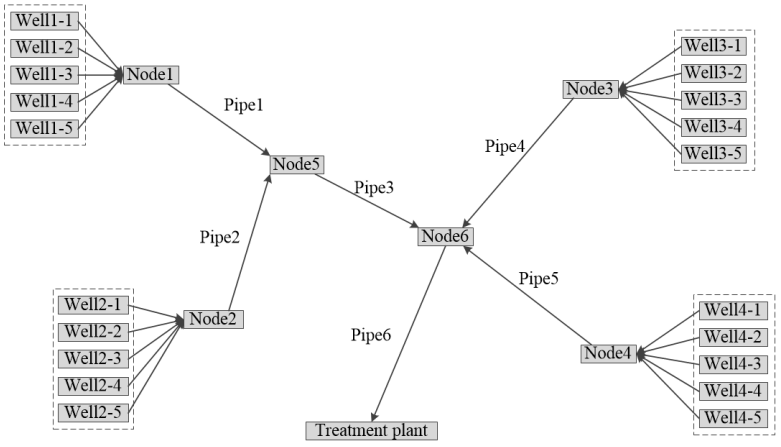


Figure 1. Pipe network diagram

In order to more accurately explore the impact of large-scale changes in different media such as CH_4, H_2O and tar on UCG transportation efficiency, a UCG gathering and transportation pipeline network model diagram as shown below is designed using pipe network simulation software:

The condition boundary of the pipe network model is as Fig 1:

The pipe network consists of 4 well sites, each with 5 identical wellheads, each with a flow rate of 300,000 square meters/day (600,000 square meters/day for wet gas, of which 300,000 square meters is water), which is collected to the well site through a single well pipeline with an inner diameter of 100mm and a pipe length of 1km, and then to the treatment plant through 2 gathering points.

The inner diameter of the gathering and transportation pipeline from the gathering point to the well site is 450mm, the pipe length is 2-5km, the pipeline roughness is set to 0.04mm, and the inlet pressure of the treatment plant is controlled to 1MPa. The wellhead temperature is 350°C; The ambient temperature is 20°C. Gathering lines 1 and 2 are 3km, gathering lines 3 are 2km, and gathering lines 4, 5 and 6 are 5km. Well 1-1, well 3-1 and gathering and transportation lines 1, 3, 5 and 6 are taken as analysis objects.

2.2. Basic Parameters of Dry Gas and Wet Gas

It is stipulated that the dry gas flow is 300,000 cubic meters/day, and the dry gas + water flow is 600,000 cubic meters/day (H_2O accounts for 50%). The composition is shown in Table 1:

Table 1. Constituent

Medium	dry gas (%)	Wet gas (%)
CH_4	30	15
CO	8	4
H_2	16	8
CO_2	43	21.5
N_2	0.5	0.25
O_2	0.5	0.25
C_2H_4	0.2	0.1
C_2H_6	0.8	0.4
C_3H_6	0.1	0.05
C_3H_8	0.5	0.25
i-C_4	0.2	0.1
n-C_4	0.2	0.1
H_2S	0.02	0.01
H_2O		49.45
Dust		
Tar	0.011	0.011

The relevant results of wellhead pressure calculation based on the model are as follows Table 2:

The pipeline states of dry gas and wet gas calculated by the simulation model are shown in the following table 3:

Table 2. Wellhead pressure

Terminal point	Dry gas (MPa)	Wet gas (MPa)
Well 1-1	3.87	4.83
Well 3-1	3.81	4.62

Table 3. Dry gas pipeline status

Pipe	Total pressure (MPa)	Unit pressure drop ($MPa \cdot km^{-1} \cdot 10^{-4}m^3$)	Liquid hold up
Pipe 1	0.04	0.00004	0
Pipe 3	0.10	0.00017	0
Pipe 5	0.07	0.00005	0
Pipe 6	1.42	0.00095	0

Table 4. Wet gas pipeline status

Pipe	Total pressure (MPa)	Unit pressure drop ($MPa \cdot km^{-1} \cdot 10^{-4}m^3$)	Liquid hold up
Pipe 1	0.07	0.0008	0
Pipe 3	0.22	0.0037	0
Pipe 5	0.01	0.0008	0
Pipe 6	2.91	0.0194	0

After doubling the volume of gaseous water, the wellhead pressure increases obviously, while the total pressure and unit pressure drop of each gathering and transportation pipeline increase, and the liquid holdup is 0.

3. Medium Change Analysis

By changing the boundary conditions of relevant components, the total pressure drop and unit pressure drop are observed under the condition that the flow rate is unchanged and the wellhead temperature is set to 350°C. The pressure drop is smaller, the corresponding pipe transport efficiency is greater.

3.1. CH_4

The CH_4 content was 15%; 20%; 25% under the design moisture condition. studied the change of gathering process parameters of wellhead and gathering pipeline under different CH_4 content.

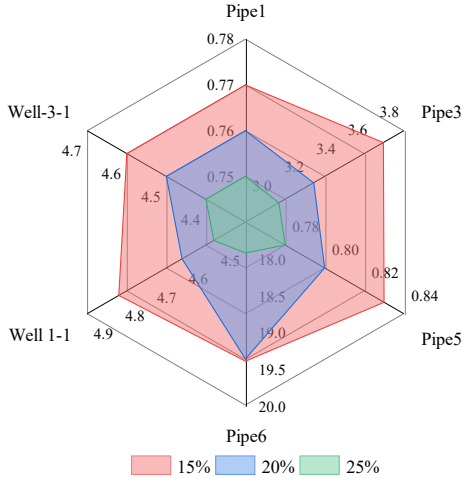


Figure 2. Unit pressure drop of gathering line ($kPa \cdot km^{-1} \cdot 10^{-4}m^3$) and wellhead pressure (MPa) under different CH_4 content

It can be observed from the above table that with the increase of CH_4 content, the unit pressure drop and wellhead pressure of the gathering pipeline gradually decrease. In addition, it is calculated that the liquid holdup at the outlet of the gathering pipeline is 0 under different CH_4 content. Therefore, the variation of unit pressure drop can be seen that the transport efficiency increases with the increase of CH_4 content.

3.2. H_2

The content of H_2 is 8%; 10%; 20% under the design moisture condition., study the change of gathering process parameters of wellhead and gathering pipeline under different H_2 content.

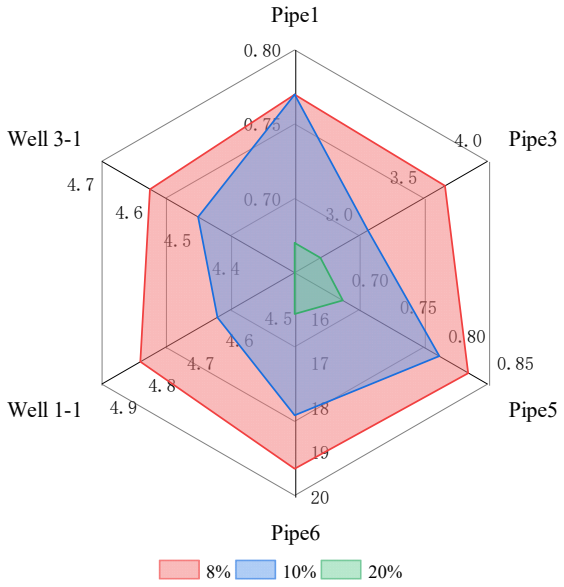


Figure 3. Unit pressure drop of gathering line (kPa·km^{-1}·10^{-4}m^3) and wellhead pressure (MPa) under different H_2 content

It can be observed from the above table that with the increase of H_2 content, the pressure drop of the gathering line and the wellhead pressure gradually decrease. The liquid holdup is still all 0. In summary, it can be seen that with the increase of H_2, the pressure drop of gathering and transportation pipeline decreases, and the pipeline transportation efficiency increases.

3.3. H_2O

The H_2O content was 40% under the design moisture condition. 50%; 60%, study the change of gathering process parameters of wellhead, single well pipeline and gathering pipeline under different H_2O content.

It can be observed from the above table that with the increase of H_2O content, the pressure drop of the gathering pipeline and the wellhead pressure both increase gradually. It can be seen that with the increase of H_2O content, the pressure drop of the gathering pipeline decreases, and the liquid holdup is 0, there is no phase change, and the pipeline transport efficiency decreases.

3.4. Tar Oil

Under the different temperature condition, t Design tar content is 0.001%; 0.01%; 0.1%, The change of gathering process parameters of wellhead, single well pipeline and gathering pipeline under different tar content was studied.

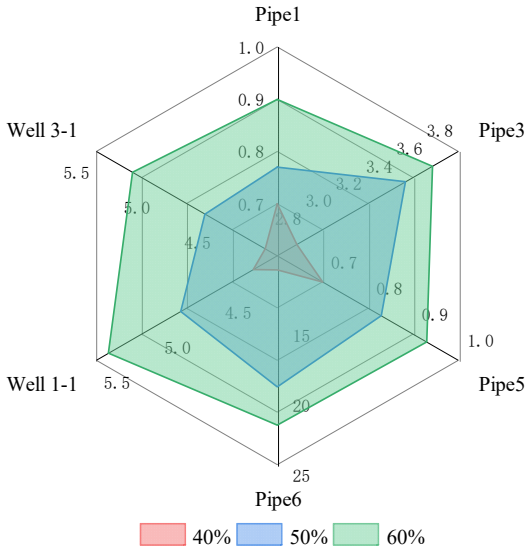


Figure 4. Unit pressure drop of gathering line (kPa·km^{-1}·10^{-4}m^3) and wellhead pressure (MPa) under different H_2O content

3.4.1. Change of Gathering and Transportation Process Parameters at T=350℃

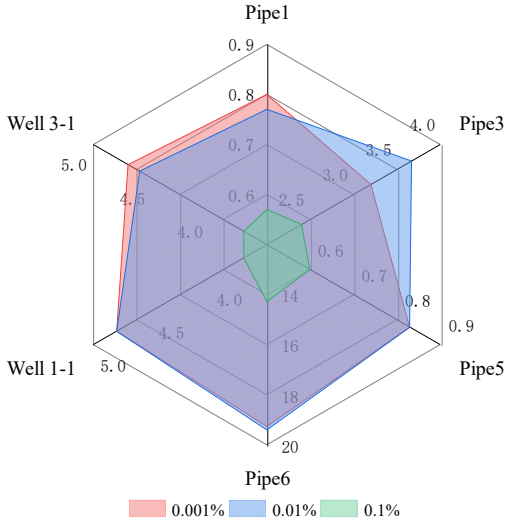


Figure 5. Unit pressure drop of gathering line (kPa·km^{-1}·10^{-4}m^3) and wellhead pressure (MPa) under different Tar oil content

Table 5. Liquid holdup at the outlet of gathering and transportation pipeline under different tar content

Tar content	Pipe1	Pipe3	Pipe5	Pipe6
0. 001%	0	0	0	0
0. 01%	0	0	0	0
0. 1%	0.014	0.011	0.0012	0.014

It can be observed from the above table that at 350℃, the pressure drops of gathering line and wellhead pressure gradually decrease with the increase of tar content. The value of liquid holdup appeared when the tar content increased to 0.1%. It can be seen that with the increase of tar, the pressure drops of the gathering and transportation pipeline decreases, indicating that the pipeline transportation efficiency will be improved, but the phase state appears liquid when the tar content reaches 0.1%, which will lead to the decrease of the pipeline transportation efficiency. Taking these phenomena into account, the pipeline transportation efficiency will be

slightly improved under this working condition, but with the continuous increase of tar, the influence of liquid holdup will be greater, and thus the pipeline transportation efficiency will be reduced.

3.4.2. Change of Gathering and Transportation Process Parameters at T=300℃

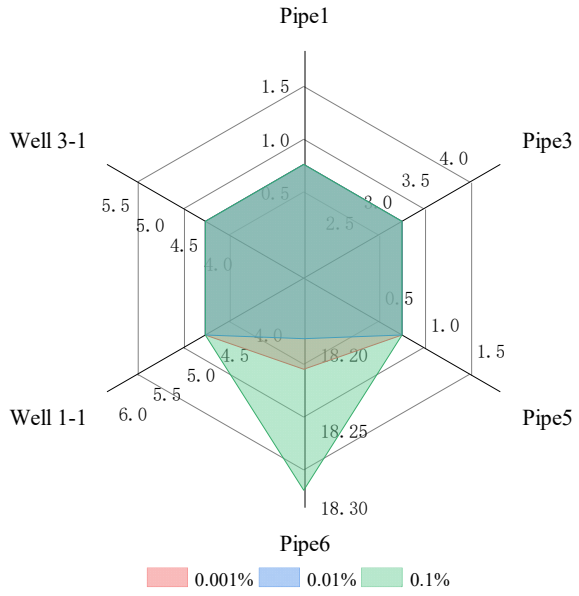


Figure 6. Unit pressure drop of gathering line (kPa·km^{-1}·10^{-4}m^3) and wellhead pressure (MPa) under different Tar oil content

Table 6. Liquid holdup at the outlet of gathering and transportation pipeline under different tar content

Tar content	Pipe1	Pipe3	Pipe5	Pipe6
0.001%	0	0	0	0
0.01%	0	0	0	0
0.1%	0	0	0.00002	0.00002

It can be observed from the above table that at 300℃, the pressure drop of the gathering line and the wellhead pressure hardly change with the increase of tar content. The value of liquid holdup appeared when the tar content increased to 0.1%. It can be seen that with the increase of tar, the phase state appears liquid. In summary, it can be seen that tar will not improve the efficiency of pipeline transportation, and with the increase of its content, the efficiency of pipeline transportation will even decrease.

In addition, by comparing the pressure changes of each pipeline and well site at 350℃ and 300℃, it is found that the unit pressure drop, wellhead pressure and liquid holdup of the gathering and transportation pipeline at 300℃ are smaller than those at 350℃, and the variation trend of pressure drop and wellhead pressure at 300℃ is also smaller.

3.5. Dust

The dust content is 1.75kg/m^3, and the dust content in the pipeline is 0.01% according to the conversion of medium flow and density. The analysis is divided into dry gas+water+0.01% tar component:

It can be seen that the pressure drops of gathering line and wellhead pressure increase after adding dust. The value of liquid holdup appeared after adding dust. It can be seen that with the addition of dust, the pipeline transport efficiency will be reduced.

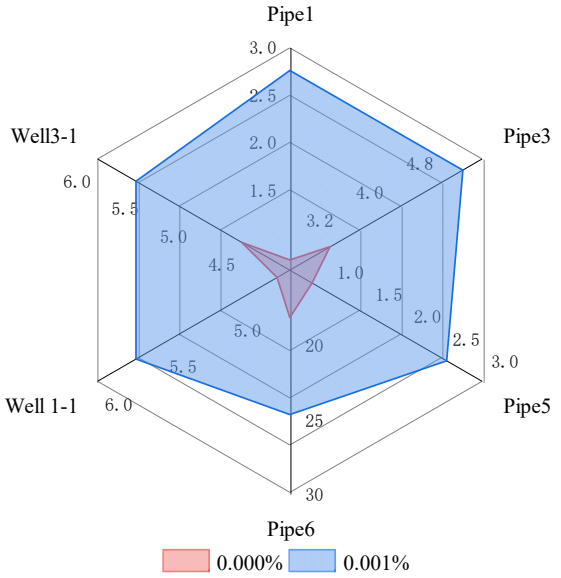


Figure 7. Unit pressure drop of gathering line (kPa·km^{-1}·10^{-4}m^3) and wellhead pressure (MPa) under different Dust content

Table 7. Liquid holdup at the outlet of gathering and transportation pipeline under different tar content

Dust content	Pipe1	Pipe3	Pipe5	Pipe6
0.000%	0	0	0	0
0.001%	0.00001	0.00001	0.00001	0.000006

4. Conclusion

This paper studies the transportation efficiency of complex coalbed methane pipeline network through pipe network simulation software, analyzes the influence of different influencing factors and boundary conditions on pipe transportation efficiency, compares the influence weights of different influencing factors, and draws the following conclusions when the wellhead flow rate is determined to be 600,000 square meters/day (50% of which is water) and the wellhead temperature is 350℃, Draw the following conclusions:

(1) The increase of the ratio of CH4 and H_2 can effectively improve the transportation efficiency;

(2) The increase of the proportion of H_2O components will directly lead to the reduction of transportation efficiency.

(3) When the tar content in the group is less than 0.01%, the transportation efficiency will not increase, but when the tar content is more than 0.1%, the transportation efficiency will increase.

(4) When the wellhead temperature is lower than 300℃, the tar has little effect on the transportation efficiency, and when the oil component exceeds 0.1%, the downstream transportation efficiency is significantly reduced.

(5) The appearance of dust will greatly reduce the transportation efficiency.

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