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Application of HYSYS software in hydraulic calculation of natural gas pipeline

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Abstract

In the construction of natural gas pipelines, pipeline hydraulic calculation is a very important part. Only by accurately calculating pipeline hydraulic parameters can the feasibility and rationality of pipeline design be ensured. In this paper, the pipeline unit in HYSYS software is used for pipeline design, the hydraulic calculation of natural gas long-distance pipeline is carried out, and the traditional teaching equation is used for checking calculation. The calculation results of the two are approximately equal.

Keywords

Natural gas pipeline; hydraulic calculation; HYSYS software.

1. Introduction

Driven by the development of natural gas resources and the rapid development of the market, my country's natural gas pipelines have exceeded 70,000 kilometers, forming a pipeline network that spans the northeast and runs through the north and south, connecting China and foreign countries [1]. The establishment of the National Petroleum Pipeline Network Group Co., Ltd. on December 9, 2019, marked that China's natural gas pipeline network will enter a new stage of market-oriented independent operation. The reliable and efficient operation of the natural gas pipeline network is facing unprecedented opportunities and challenges. Changes such as the interconnection of natural gas pipelines and the market-oriented operation of the pipeline network are intertwined with pipeline network technology, resulting in an increase in the complexity of the structure and dynamics of the natural gas pipeline network system. This not only improves the flexibility of pipeline network resource allocation but also puts forward higher requirements for the operational efficiency and security of the pipeline network, forcing natural gas pipeline operation technology to innovate [2].

The hydraulic calculation of the natural gas long-distance pipeline is an important link before the pipeline design. Only accurate design parameters obtained through accurate hydraulic calculations can ensure that the pipeline construction meets the design requirements, and the pipeline has a certain degree of economy.

The accuracy of natural gas pipeline process design calculation directly affects the quality of pipeline construction. Sometimes, even a slight error may cause major quality and safety issues, which not only increase the cost of pipeline construction but also threaten people's lives and property. For natural gas pipelines, factors such as the flow pattern of natural gas and the roughness of the pipeline will have a great impact on the flow of the pipeline. In this context, some developed countries have proposed several hydraulic friction coefficient calculation formulas based on the Nicholas test, Prandtl theory, and Quorbrook formula, taking Reynolds number and pipe wall roughness as variables. According to the different Reynolds numbers, the flow pattern of the flowing fluid in the natural gas pipeline can be divided into three categories: laminar flow zone, critical zone, turbulent flow zone (including resistance square zone, hydraulic smooth zone, and mixed friction zone). In general, for long-distance natural gas

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pipelines, the fluid flow pattern is mainly based on the square resistance area of the turbulent flow zone. Therefore, in the construction of long-distance natural gas pipelines, an effective resistance square area friction coefficient should be adopted. Formula to calculate the hydraulic friction coefficient [3].

Aspen HYSYS is a process simulation software for simulation, design, and performance testing of oil, and gas production parts, gas processing and refining industries, with steady-state simulation and dynamic simulation functions. HYSYS was originally a product of Canadian Hlyprotech. Founded in 1976, Hyprotech is the first multinational company in the world to develop industrial simulation and simulation technology in the petroleum and chemical industries. Its technology is widely used in petroleum exploration, storage and transportation, natural gas processing, and petroleum Chemicals, fine chemicals, pharmaceuticals, refining, and other fields, occupy a leading position in the world of petrochemical simulation and simulation technology. HIYSYS has more than 17,000 users in 80 countries. The number of registered users exceeds that of any other process simulation software company in the world. HYSYS is currently used by major petrochemical companies in the world, including the top 15 oil and gas companies in the world, 14 of the top 15 petroleum refining companies, and 13 of the top 15 chemical companies [4].

Aspen HYSYS software is divided into two parts: steady-state and dynamic. One is mainly used for oilfield surface engineering construction design and petroleum and petrochemical refining engineering design calculation analysis, and its dynamic part can be used for dynamic analysis of crude oil production and storage and transportation systems.

For oilfield ground construction, the software can solve the following problems:

•Evaluation, design, and program optimization of various gathering and transportation processes;

• Design of pipeline network, long-distance pipeline, and pumping station in the station;

• Temperature drop prediction of pipeline shutdown;

• Pigging ball receiving and dispatching and prediction of slug flow;

• Calculation of oil and gas separation;

• Calculation of the three-phase separation of oil, gas, and water;

•Design calculation of oil and gas separator;

•Prediction of natural gas hydrate;

•Drawing of the oil-gas phase diagram and prediction of oil and gas back-precipitation points;

• Crude oil dehydration design;

• Crude oil stabilization device design and optimization;

• Design and optimization of natural gas dehydration (glycol or molecular sieve) and desulfurization equipment;

•Design and optimization of natural gas light hydrocarbon recovery equipment

• Calculation and selection of pumps and compressors;

For petroleum and petrochemical refining, the software can solve the following problems:

• Design and optimization of atmospheric and vacuum systems;

• Design and optimization of FCC main fractionation tower and other refining equipment;

•The design and optimization of the air treatment device.

2. Use HYSYS software for hydraulic calculation

The Pipe Segment in HYSYS is used to simulate a series of different types of piping systems or large-capacity closed pipe network systems and can perform rigorous heat transfer calculations on single-phase or multi-phase pipe networks.

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The pipe section provides four calculation modes: pressure drop, length, flow, and diameter. HYSYS automatically selects the appropriate calculation mode according to the data information provided by the user. No matter which model is used, the user must specify the number of pipe sections. HYSYS performs calculations in each section of the pipe one by one. For example, in order to calculate the pressure drop, the energy and mass balance calculations are performed in each section, and the outlet pressure of each section is used as the inlet pressure of the next section, so iterative calculation Until the outlet pressure of the pipeline is calculated. The pipe section can be solved forward or backward, and the solving procedure generally starts from the end where the temperature is known. HYSYS uses the specified pressure value or estimated value to perform iterative calculation step by step in the pipeline at the starting point. If the exit is the calculation starting point, HYSYS can also perform regression calculation. Table 1 lists the necessary data information for each calculation model.

Table 1 Four calculation modes and necessary data of the pipe section

Calculation mode	Required parameters
Pressure drop	Flow rate, pipe length, diameter and height difference, heat transfer data, the temperature of at least one stream, and pressure of one stream
Length	Initial estimates of flow rate, heat transfer information, pipe section diameter, inlet and outlet pressure, the temperature of one end of the stream, and length
Flow rate	Length and diameter of the pipe section, heat transfer information, inlet, and outlet pressure, the temperature of one end stream (or end stream pressure and pressure drop), flow estimation
Diameter	The length of the pipe section and other data are the same as the length calculation. The initial estimate of the diameter is provided by the design option of the calculation page

The specific flow of the simulation is shown in Figure 1 below.

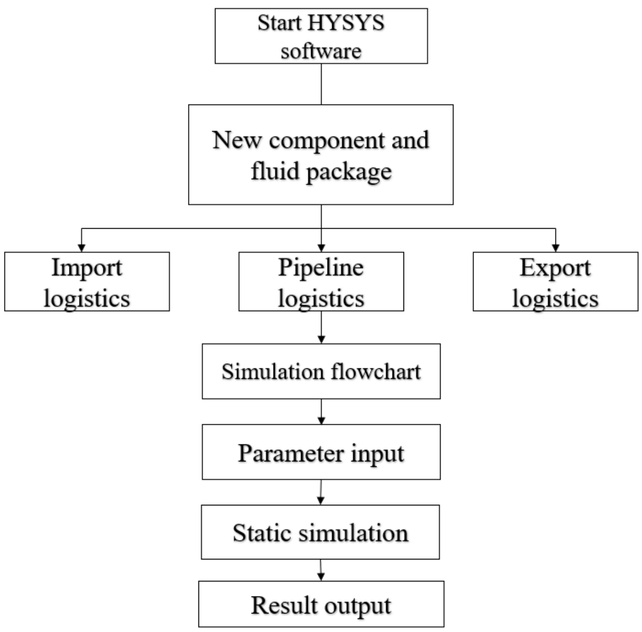

Figure 1 Operation flow chart

It can be seen from the above figure that the components and mole percentages of natural gas are added first, and then physical property equations are selected to prepare for subsequent simulations. Add logistics and unit originals in Simulation, enter the parameters and complete the design. Table 2 shows the composition of natural gas components.

Table 2 Natural gas components

Components	Mole fraction
Methane	0.623000
Ethane	0.280000
Propane	0.016300
i-Butane	0.004330
n-Butane	0.008210
i-Pentane	0.004160
n-Pentane	0.004050
n-Hexane	0.006590
C7+	0.009920
H2S	0.015400
CO2	0.022500
Nitrogen	0.005540

Enter the parameters of Table 2 into logistics 1, select the PR equation as the physical property calculation equation, and the operation interface is shown in Figure 2 below. After completing the basic component input and physical property equation selection, the pipeline unit can be simulated, and the imported raw material parameters can be input in stream 1. The pressure is 5300kPa, the temperature is 40°C, and the flow is 17422.5m^3. In the pipeline design, according to the engineering requirements, the inner diameter is greater than 273.1, so the pipeline with a diameter of DN300 is selected. The specific piping design is shown in Figure 4. The simulation software can directly calculate the pressure at the end of the pipeline, and the output result is 5289kPa.

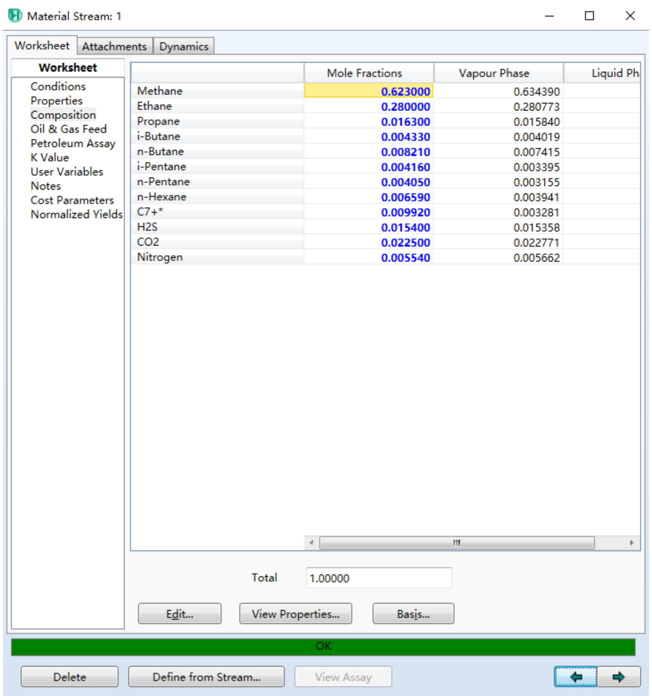

Figure 2 Component input interface

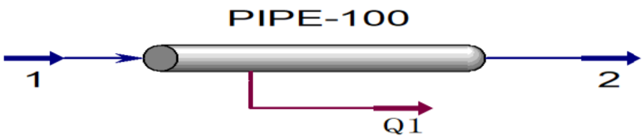

Figure 3 Simulation process of natural gas pipeline

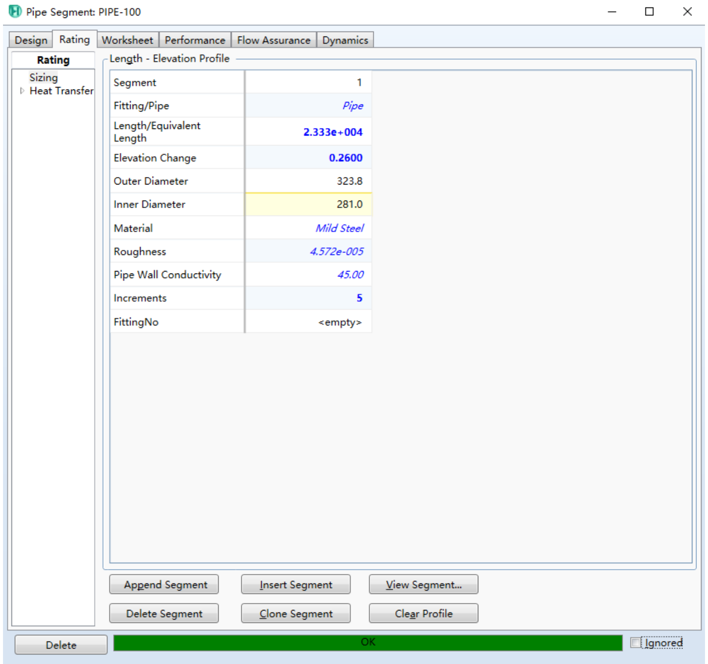

Figure 4 Piping design diagram

3. Verification of hydraulic calculation results

Traditional hydraulic calculations start with the establishment and analysis of the motion equation, continuity equation, and gas state equation of natural gas flow in the pipeline [5], forming a nonlinear deviation that can be used to calculate the motion parameters of natural gas at any time and any position in the pipeline. Differential equations, but the nonlinear partial differential equations obtained from this are often difficult to obtain their analytical solutions. For the purpose of engineering application, after ignoring the inertia, convection, and gravity terms in the equation of motion, the simplified equation can be used to obtain an approximate solution. Considering the pressure level of the gas in the pipeline and the different partitions of the Reynolds number, the equation is further simplified into a calculation equation suitable for a specific working condition, and the hydraulic calculation for this working condition is realized. At the same time, the gas pipeline hydraulic calculation chart is provided for table lookup calculations.

The calculation formula for low-pressure gas pipeline is:

$$\Delta P=P_1-P_2=0.81\lambda\frac{Q_0^2}{d^5}\rho_0\frac{T}{T_0}\frac{Z}{Z_0}L \tag{1}$$

The hydraulic calculation formula for high and medium pressure natural gas pipelines is:

$$\frac{P_1^2-P_2^2}{L}=1.27\times10^{10}\lambda\frac{Q_0^2}{d^5}\rho_0\frac{T}{T_0} \tag{2}$$

Use customary common units, and consider that the pressure of city gas pipelines is generally below 1.6MPa, and when the compression factor is approximately equal to 1, the basic formula for hydraulic calculation of low-pressure gas pipelines is:

$$\Delta P/L=6.26\times 10^{10}\lambda \frac{Q_0^2}{d^5}\rho_0 \frac{T}{T_0} \tag{3}$$

In the formula: P_1 and P_2 are the absolute pressures at the start and end of the gas pipeline, kPa; L is the calculated length of the gas pipeline, in km; Q_0 is the calculated flow rate of the gas in the pipeline, in Nm3/h; d is the inner diameter of the pipeline, in mm; $\triangle P$ is the pressure loss of the gas pipeline, Pa; Z is the compression factor of the gas; T is the absolute temperature of the gas, K; λ is the frictional resistance factor of the gas pipeline.

It is known that the density of natural gas in this paper is ρ0=0.7kg/Nm3, the kinematic viscosity υ=25×10-6m2/s, the outer diameter of the medium-pressure gas steel pipe is 300mm, the length is 23.33km, and the starting pressure is P_1=5300kPa. The gas flow rate is Q_0=66666.7Nm3/h. Find the specific value of the pressure P_2 at the end of the pipe section at 40°C.

This question uses a theoretical formula to calculate, using formula 2 to calculate the end pressure, the formula is as follows.

$$\frac{P_1^2-P_2^2}{L}=1.4\times 10^9 \left(\frac{\Delta}{d}+192.2\frac{dv}{Q_0}\right)^{0.25}\frac{Q_0^2}{d^5}\rho_0 \frac{T}{T_0} \tag{4}$$

Substitute data available:

$$\frac{5300^2-P_2^2}{23330}=1.4\times 10^9\left(\frac{0.17}{281}+192.2\frac{281\times 25\times 10^{-6}}{66666.7}\right)^{0.25}\frac{66666.7^2}{281^5}\times 0.7$$

The theoretically calculated end pipeline pressure is 5298kPa.

4. Conclusion

After the above simulation calculation and analysis, the following conclusions can be obtained:

(1) The choice of natural gas components and physical property equations directly determines whether the subsequent simulation can be carried out correctly.

(2) The result of hydraulic calculation using HYSYS simulation software is similar to the calculation result of actually established motion equation, continuity equation, and gas state equation.

(3) HYSYS can meet the hydraulic calculation of basic natural gas pipelines under certain conditions and has a guiding role in the actual pipeline laying and optimization.

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