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Optimal Design of Urban Pipe Network and Its Gas Supply Reliability Analysis

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Abstract

With the continuous development of urban scale, the types and number of gas users are growing rapidly, and the area of gas pipeline network is also gradually expanding. There are widespread problems such as unclear gas supply range, large accident emission area, and ineffective combination of design and operation management. Some large cities adopt a pressure level system with medium pressure, which is difficult to balance the stability and economy of gas supply under the condition of limited gas source points. In the process of urban development, construction operations such as road reconstruction and expansion are often accompanied, which will inevitably lead to active and passive transformation of urban gas pipeline network and increase the possibility of accidents. In this paper, the design, management, scheduling and other aspects of the gas system, find the specific method of urban pipe network optimization design, using TGNET software for hydraulic calculation, analysis of hydraulic reliability after pipe network optimization, provide a feasible scheme for the efficient operation of urban pipe network.

Keywords

Urban gas; gas pipeline network; hydraulic reliability; hydraulic calculation; accident condition.

1. Introduction

Urban gasification rate is one of the important symbols to measure urban modernization. Gas plays an important role in improving people ' s living standard, promoting economic development, energy saving and emission reduction.[1] In recent years, China's urban gasification rate has increased year by year, and the area of gas pipeline network has continued to expand.[2] By the end of 2008, the total length of urban gas pipelines in China reached 258,000 kilometres, with a gasification rate of 89.6%, and the demand for gas also tends to diversify from cooking and hot water production to power generation, transportation and many other fields.[3]

Regional metering zoning (DMA for short) is a series of physical boundaries for the gas network based on the topography of the area, administrative divisions and parameters such as pipe diameter and pressure, or according to certain mathematical algorithms, so that the entire ring network is artificially separated into separate areas to achieve sub-regional management of the gas network.[4] Currently, DMA partition methods mainly include algorithm automatic partition and artificial experience partition.[5] In 1999, the Shanghai Water Supply Company divided the urban water supply network into four sub-networks based on river basins to achieve effective leakage control.[6] In 2002, Tianjin Water Company introduced a "three-tier metering management system" to precisely control the water metering system.[7] In 2005, Changsha City Water Company took into account the geographical conditions and the existing layout of the pipe network, and zoned the water supply capacity of water plants, pressure demarcation, and the type of objects to be managed.[8] The research object of this paper is the artificial experience

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partition method, which makes an objective evaluation of the impact of experience partition on urban gas pipeline network.

2. Zoning cases

2.1. Zoning overview

According to the City G Urban Master Plan (2017-2035), as of 2022, the city centre of G covers an area of 231.04km^2, the planning area is 133.77km^2, the population density is 3527 people/km^2, the gas consumption quota is 2120MJ/person-per-year, the natural gas low calorific value is 35.81MJ/m^3, the annual domestic gas consumption of residents is 2793×10^{4}Nm^3, hourly gas calculation flow rate of 1.05×10^{4}Nm^3.The pipe network modeling and analysis process is shown in Figure 1.

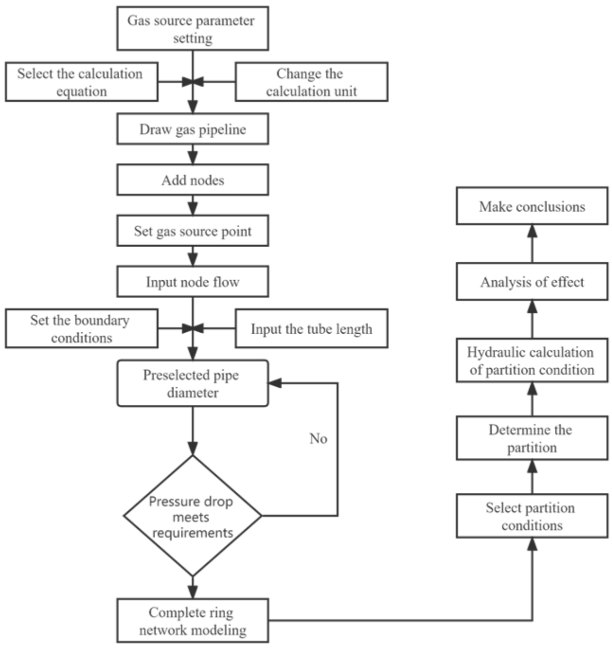

Fig. 1 Pipe network modelling and analysis process

2.2. Overview of pipe network layout before partition

Before DMA partition management, the city ' s gas pipeline network exists in an integral form. The city adopts medium pressure first-class pipeline network for gas distribution, and has two gate stations, which are located in the west and east of the city.

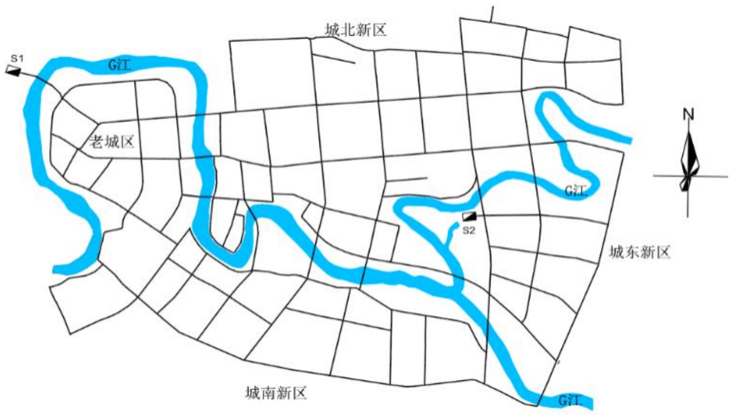

Fig. 2 Diagram of the G-City ring network

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3. Software Description

TGNET is proved to be an off-line pipeline simulation software with powerful computing ability. It is an essential calculation tool in the process of steady-state simulation and dynamic analysis of transmission and distribution pipelines, and has been widely used in the world.

In this paper, TGNET software is used to simulate the initial conditions and the gas pipeline network after partition.

4. Zoning basis

The pipe network zoning in this paper is based on the following.

Based on the unique geographical conditions of G city, the topography is used as the basis of pipe network partition. G River enters the urban area from the west of the city, and then is divided into two branches in the southeast of the city. One is outflow from the east of the city, and the other is outflow from the southeast of the city. G River divides the city into four relatively independent regions.

Pressure is one of the most important factors affecting the hydraulic reliability of gas pipeline network. Since the gas source point is located on the east and west sides of the urban area, the pressure of the pipe network in City G presents a distribution pattern of high before and after and low in the middle. The pipe network management by pressure partition can minimize the length of gas flow and the number of pressure regulation, save initial investment and operating costs.

5. Results of normal operation

5.1. Geographical conditions division

As can be seen from the calculation results, the pressure at the DMA1 and DMA4 nodes all dropped significantly after the pipe network was partitioned. The location of the highest and low pressure points of the partition pipe network is the same as that before the partition, with all operating pressures between 0.2-0.25 MPa. The new gas source S2 leads to the change of pressure distribution in DMA2 region. DMA3 accounts for 51 % of the total area of the ring network, and the gas consumption accounts for 30 %. The maximum pressure appears at node 90 directly connected to S3. Larger low voltage zones appear in DMA3. This is due to the large area of DMA3 and the fact that 52% of the pipe diameters are smaller than DN80, resulting in a rapid decrease in nodal pressure with gas flow.

5.2. Pressure condition zoning

Under the operating conditions divided by pressure conditions, DMA1 is similar to the geographically zoned conditions, with all node pressures in its area below the design pressure. The average operating pressure at the nodes has increased, with the majority of nodes between 0.25MPa and 0.3MPa, with the lowest pressure located at node 20 on the southwest side of the area. DMA2 adopts the dual-source gas supply mode, which supplies gas from the south and north sides of the city respectively. Therefore, the gas supply pressure at the south and north ends is large, the overall pressure in the region is stable, the pressure difference between nodes is small, and the lowest node pressure is located at node 44 on the southeast side. The area occupied by DMA3 and DMA4 and the gas supply scale are small, so the node pressure area is average. Among them, DMA3 is in the lowest pressure area of the original pipe network, and the pressure is significantly increased after partition. DMA4 is the high pressure area near the gas source point of the original pipe network, so the node pressure is reduced after partition.

Overall, dividing the network according to operating pressure maximises the use of pressure at the point of origin and reduces the flow distance of the gas, thus keeping the pressure drop in the pipe section within a reasonable range and equalising the pressure at the nodes, which is a better means of improving the reliability of the gas supply.

Fig. 3 Results by geographical condition (left) and by pressure condition (right)

Table 1 Hydraulic calculation results by geographical conditions

分区	S	Q	P_o^{max}/P_o^{min}	$P_{0.35-0.4}$	$P_{0.3-0.35}$	$P_{0.25-0.3}$	$P_{0.2-0.25}$	P_a
DMA1	12.84/9.60%	2104/20.04%	0.25/0.21	0	0	0	17	0.23
DMA2	33.9/25.34%	3156/30.06%	0.4/0.33	11	17	0	0	0.34
DMA3	68.23/51.01%	3156/30.06%	0.35/0.2	1	4	17	29	0.24
DMA4	18.8/14.05	2104/20.04%	0.27/0.22	0	0	1	12	0.23

Table 2 Hydraulic calculation results by pressure conditions

分区	S	Q	P_o^{max}/P_o^{min}	$P_{0.35-0.4}$	$P_{0.3-0.35}$	$P_{0.25-0.3}$	$P_{0.2-0.25}$	P_a
DMA1	30.9/23.1%	4190/39.90%	0.3/0.2	0	0	25	11	0.26
DMA2	72.69/54.34%	4210/40.10%	0.4/0.22	6	41	2	1	0.32
DMA3	8.46/6.32%	1050/10.00%	0.32/0.2	0	1	2	12	0.23
DMA4	21.72/16.24%	1050/10.00%	0.31/0.2	0	2	10	5	0.27

Note: S is the partition area(m^2) / proportion; Q is for partition gas supply (Nm^3/h) / proportion; P_a is the average pressure (Pa) for partition nodes; P_o^{max}/P_o^{min} is the maximum operating pressure / minimum operating pressure (MPa); $P_{0.35-0.4}$ is the 0.35 MPa < P ≤ 0.4 MPa node number / proportion; $P_{0.3-0.35}$ is the 0.3 MPa < P ≤ 0.35 MPa node number / proportion; $P_{0.25-0.3}$ is the 0.25 MPa < P ≤ 0.3 MPa node number / proportion; $P_{0.2-0.25}$ is the 0.2 MPa ≤ P ≤ 0.25 MPa node number / proportion.

6. Conclusion

This paper takes G city gas pipeline network as an example, using TGNET software to establish the pipeline network model. The model parameters are set and network zones are divided according to certain zoning principles and hydraulic calculations are completed. The hydraulic reliability of the pipe network under two accident conditions is analyzed. The conclusion of the gas supply reliability under the pipe network partition mode is as follows.

Under normal conditions, pipe network partition is an economic and reliable operation mode. The zoning conditions are easy to manage. The pipe network based on geographical conditions and pressure conditions reduces the workload of pipe network maintenance and management, and improves work efficiency.

When the position and diameter of the gas source station remain unchanged after the pipe network is divided, the position of the lowest pressure point in the region does not change.

Under the partition condition, the pipe network still has sufficient pressure to achieve normal operation. In contrast, when the pipe section fails, the hydraulic reliability under pressure zoning is better than that under geographical zoning.

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