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A Simple Thermal Dynamics Model and Parameter Identification of District Heating Network

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Abstract

The existence of time delay usually results in the mismatch between the heat source output and the users' heating load. In the research, a dynamic model is built to predict the supply water temperature in the substation and the heat loss from the heat source to the substation by identifying the time delay, α and β. α and β are parameters obtained by Regression. α is determined by the length of pipeline, velocity, heat transfer coefficient, etc., β is determined by outdoor air temperature besides those above elements. In the feasibility and prediction ability analysis of the model, two groups of tested supply water temperature in the substation are fitted well with the predicted supply water temperatures, respectively.

Results show that the proposed method can improve the prediction accuracy of the supply water temperature in the heating substation, and the prediction error of the supply line heat loss can be restricted within -10%-2%. This indicates that the model have great ability in the temperature prediction and heat loss calculation.

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Keywords: Simple Thermal Dynamics Model, Parameter Identification, the feasibility and prediction ability

1. Introduction

Due to the close relationship between heat loss to the surroundings and the time delays in the district-heating network, the dynamic research of heat loss cannot carry out without the influence of time delay. Stevanovic et al. (2007) developed a model of the Zemun DH grid in Serbia to investigate fluid time delays from source to consumers in the system. The model used the numerical solution of the transient energy equation with the numerical scheme of

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the third-order accuracy in space, and on the steady state hydraulic solution of pressure changed and flow rates within the network. [1]Grosswindhager et al. (2011) focused on the Tannheim DH grid in Austria. The study presented a fully dynamic physical model that was capable of tracking variable transport delays in the network pipes.[2] Jie et al. (2012) simulated the temperature wave from pipe inlet to outlet to analyze the lag time and relative attenuation degree. They found the two parameters could reflect the dynamic characteristics of the DH network. It has been proved that the time delay was approximately equal to the flow time of the heat medium.[3] Li and Zaheeruddin (2004) used the reduced-order dynamic model and implemented on the full-order model to identify the level of time delay. The calculated time delay could be dealt with the Smith predictor method and in this way 19%-31% of the heat will be saved.[4]Actually various demands with the changeable outdoor temperature and users' types, heat loss calculation should have high fitness of the actual operation situation. Research indicated that heat losses in the pipeline increase with the supply water temperature, the improvement of the network is to keep this temperature as low as possible on the premise satisfying the consumers' demands [5].

In this paper, a novel method is proposed to model the dynamic of supply water temperature of heating substation in terms of the given heat source supply water temperature. Firstly, the solution of partial differential equation, which describes the pipeline thermal dynamics, was simplified to obtain a linear equation with two unknown parameters： α and β. The two parameters are governed by the length of pipeline, velocity, heat transfer coefficient, outdoor temperature, etc. Then a heuristic technique called the peak-valley average method to determine the short-term time delay between the heat source and the substation is established. Identification of the two unknown parameters is conducted based on field test of the real-time supply water temperatures in heat source and substation. The simulation results are going to provide fundamental techniques for the calculation of the predicted supply water temperature in the heat source (which depends on the demand temperature in the substation, the time delay) and heat loss happened from the defined temperature point to any other point of the pipeline.

2. Methods

The dynamic model of district heating network has been simulated on the test data of heating period in 2015-2016, Tianjin. In order to analyze the dynamic thermal operation characteristics of the pipeline, the deductive process of the mathematical model is achieved in MATLAB.

2.1 Physical model of district heating pipeline

The circuit of pipeline is formed by heat source, supply-return pipeline and substation. Hot water is pumped out from the heat source and return after transferring in the substation. The heat transfer of hot water in the district-heating pipeline is shown in Fig. 1. And two-dimensional heat transfer is considered.

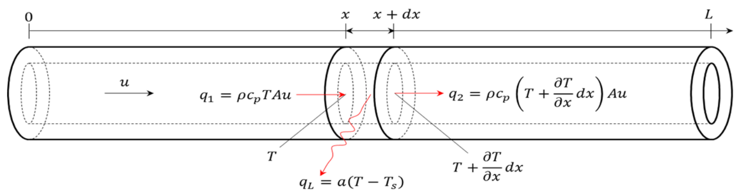

Fig. 1. Heat transfer in the district heating system pipeline.

The governing equation of the infinitesimal volume in the pipe can be derived by applying the heat balance principle:

$$q_1 - q_2 - q_L \quad (1)$$