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Studies of the unavoidable exergy loss rate and analysis of influence parameters for pipeline transportation process

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ABSTRACT

According to the exergy balance relationship among the various items in the crude oil transportation process system, the exergy balance equation is established and each exergy loss is calculated. In a sense, the essence of exergy analysis method relies on the calculation and the analysis of system exergy loss. The unavoidable exergy loss is defined based on the required minimum exergy loss from the technology standpoint during the pipeline conveying process. In order to truly reflect the degree of effective energy utilization, this article puts forward the unavoidable exergy loss rate as evaluation index, which is based on the exergy analysis criterion consisted by exergy loss coefficient and exergy loss rate. Taking an oil pipeline as an example, the changes of the unavoidable exergy loss are studied under different designed parameters. And the unavoidable thermal exergy loss is the dominant position. Change situations of the unavoidable exergy loss rate are explored. Through analysis, the trend and the regularity of the unavoidable total exergy loss rate are identical with the unavoidable thermal exergy loss rate. Then the orthogonal experiment method is used to compare the different influence degrees to the pipeline unavoidable exergy loss rate. The results are as follows: diameter, insulation thickness and buried depth, which can provide the reference for the energy-saving transportation of crude oil pipeline.

1. Introduction

Chinese oil utilization efficiency is significantly lower compared with the developed countries, and some questions about the resource constraint, the irrational structure, backward production technology and industry system have also plagued the petrochemical industry development.

In the primary stage, the fundamental method to identify the energy weak link of oil pipeline is based on the parameters of system exergy analysis results which has the ability to respond energy condition sensitively. It can be properly handled to form an index system that can identify weak links, which generally uses the exergy loss to analyze. The external exergy loss is always accompanied by the energy loss, and always harmful. The internal exergy loss is caused by the energy transfer and the irreversibility of the conversion process. These processes often occur in the system, such as heat transfer with temperature difference, mechanical friction, throttling and chemical reaction etc [1,2].

In fact, any thermodynamic process requires a certain potential difference as the driving force. These potential differences include temperature difference, pressure difference and chemical potential difference. The potential difference would lead to the exergy loss,

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and the greater the potential difference, the larger exergy loss. But if you intend to ensure the thermodynamic process smoothly, it is unavoidable to have a minimal potential difference, so the concept of the unavoidable exergy loss is put forward. Qinsheng Fu [8] divided the loss into avoidable loss and unavoidable loss which can determine the recoverable energy potential in the thermal cycle. According to mechanical analysis of the irreversible loss caused by heat transfer temperature difference in internal reversible Kano cycle, a formula for calculating the unavoidable loss between the working medium and the heat source was derived. Thereby it can reduce the avoidable loss, improve circulation and increase the cycle efficiency. Starting from the thermal analysis and the pressure energy analysis in hot oil pipeline transportation process, Zhe Li [3] pointed out the energy analysis that aimed at solving the contradiction between energy consumption and energy supply along the pipeline. It referred that a part of internal exergy loss is unavoidable based on expounding the external and internal exergy loss. It must be consumed, and the pipeline exergy flow is classified in accordance with the property of avoidable and unavoidable in the process.

However, exergy loss is an absolute number, it cannot be used for energy situation comparison in different conditions. Therefore, the concept of "exergy efficiency" has been widely used in exergy analysis. Donghua Yang [4] summed up the general rules of the exergy efficiency definition, and put forward four kinds exergy efficiencies from different evaluation aspects of equipment thermodynamic performance. After a comprehensive induction, a simplified model was proposed to defined the exergy efficiency by Mingshan Zhu [5]. Two definitions of common energy efficiency and purpose energy efficiency were given. Yixiang [7] Luo used this method to establish the mathematical model, which showed that the exergy loss and exergy efficiency of heat exchanger flow changed with the ratio between the water T and the heat units NTU number. If the two parameters can be selected reasonably, the exergy efficiency reaches an optimum value. External exergy loss rate and internal exergy loss have been proposed in depth which uses exergy loss coefficient and exergy loss rate as indicators. Foreign researchers have also put forward different exergy efficiency expressions in different forms. In addition to establish the energy balance equation from the exergy analysis, the energy efficiency and energy loss have been gotten together by Kamran Taheri et al. [6], which highlighted the low efficiency of the system energy, and further determined the energy analysis criteria.

Frank Cziesla [13] et al. explained that the system actual thermodynamic efficiency was associated with exergy loss, and the minimum exergy loss rate was restricted by the physical, technical and economic conditions. The avoidable cost rate has been put forward which are associated with the exergy loss and capital investment. It can be seen that the avoidable exergy loss has great effects on the cost benefit energy conversion system. Based on the above method, it is necessary to put forward the unavoidable exergy loss rate as the evaluation index for oil pipeline, that's, the pipeline energy consumption level is reflected scientifically and comprehensively, and the effective utilization degree can be truly embodied. The unavoidable exergy loss rate is analyzed with the variation law of design parameters, which provides theoretical basis for energy saving transportation of crude oil pipeline.

2. Exergy analysis method

2.1. Exergy balance equation

Exergy analysis method is based on the system exergy balance principle. For the system exergy analysis, we need to establish the energy balance model primarily. According to the exergy balance relationship among the various system items, exergy balance equation is established and each system exergy loss is calculated. Set the system input energy as $E_{x,in}$, system exergy loss as $E_{x,loss}$, and the remaining part is the effective output exergy $E_{x,ef}$. The relationship is shown in Fig. 1:

From this we can see that the general formula of the system energy balance equation is:

$$E_{x,in} = E_{x,loss} + E_{x,ef} = E_{xl,in} + E_{xl,out} + E_{x,ef} \quad (1)$$

where,

$E_{xl,in}$—Exergy dissipation in the internal system;
$E_{xl,out}$—Exergy dissipation in the external system.

The composition and distribution of exergy loss in the process can be calculated by exergy balance equation. This is the main content of exergy analysis method to study the weak link of system energy consumption process, which can provide the basis for improving the situation.

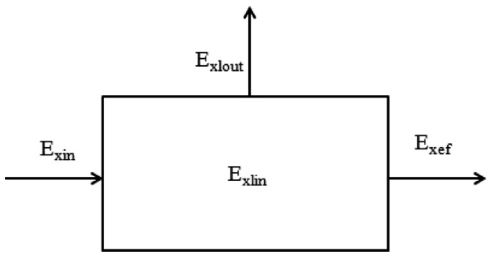

Fig. 1. system exergy balance model.