Virtual Isomorphism Oil Pipeline Transportation Energy Efficiency Management Platform

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Abstract: Pipeline transportation is one of the most important oil transportation methods at present. However, in pipeline transportation, pipeline transport distance is long. Oil pump units, heating furnaces, boilers and storage tanks as the main energy-consuming equipment, years of operation, will consume a lot of energy, but the existing oil pipeline management method does not take into account the oil transport task quantity, task time, ambient temperature and other dynamic factors, resulting in energy waste. The project proposes to establish a set of energy efficiency management platform for oil pipeline transportation with the goal of improving energy efficiency, task requirements and all-weather constraints, and virtual isomorphism as the rendering form. Oil pipeline transportation energy efficiency management platform includes 3D pipeline transportation virtual scene model, energy optimization mathematical model, data display and analysis visualization model which can help managers to develop pipeline transportation energy saving scheme.

1. Introduction
The platform uses visualization technology to complete the virtual isomorphism of pipelines. Drawing on the concept of digital twin, and by combining simulation analysis model data and actual real-time detection data, the platform can quickly and accurately simulate the real transportation of pipelines and visualize them in VR virtual reality devices. According to the oil transportation task quantity, pump machine and other equipment parameters, and the weather change during the task time to plan the future operation mode of energy dissipation equipment, it can calculate its theoretical optimization point in advance, so that the subsequent actual optimization can be optimized in the number of short iterations to achieve rapid optimization. At the same time, a database is established to record the relationship between pipe wall temperature, oil transportation efficiency and weather change in operation, and to introduce database as empirical parameters in subsequent optimization planning so that the optimization model can further approximates the actual situation, accurately optimize the point, and finally reasonably allocate energy consumption equipment, reduce the energy consumption of oil in the conveying unit, and achieve the goal[1].

2. Material and Methods

2.1 Hypothesis conditions before the establishment of energy saving optimization model
The oil pipeline system is mainly composed of pipelines, pumping stations, storage tanks and other parts, because the optimization problem of conveying operation is more complex, affected by many factors, it is necessary to make the following assumptions before establishing the optimization model of
the energy saving scheme of conveying operation, in order to ensure the feasibility and economic rationality of the process technology of the established mathematical model:

- The oil in the system pipeline is a one-dimensional single-phase (liquid phase) homogeneous flow;
- The whole line of the use of closed transport, transport flow is consistent;
- The whole line of thermal, hydraulic conditions stable;
- The oil density does not change with the pressure;
- If you want to consider the temperature change of oil in the tube, only the axial temperature change is considered[2].

2.2 Energy consumption Cost model establishment

The main energy-consuming component in the oil transmission system is oil pump, and the following model is established for the power cost of oil pump.

\[ P = \frac{q_v \rho H}{102 \eta_p} \]  

\[ N_e = K \times \frac{P}{\eta_e} \]

In the formula: \( P \)—oil pump shaft power, kw; 
\( N_e \)—oil pump with motor power, kw; 
\( H \)—the head provided by the pump, m; 
\( q_v \)—corresponding to the conveying flow rate at the conveying temperature, m³/s; 
\( H_p \)—efficiency of the pump unit; 
\( H_e \)—motor efficiency, take 0.85; 
\( K \)—motor safety rating of the rated power, take \( K=1.1 \);

Available from equations (3-1) and (3-2):

\[ N_e = K \times \frac{q_v \rho H}{102 \eta_b} \]

among them:

\[ \eta_b = \eta_p \eta_e \]

\( H_b \)—the overall efficiency of the pump unit

The power cost of a pumping station with a total throughput of \( Q \) and a pipeline length of \( L \) is:

\[ C_p = K \times \frac{q_v \rho H}{102 \eta_b} \times r \times t \]

In the formula \( r \)—electricity price, yuan / degree, take 1.0 yuan / kWh; 
\( H \)—the head provided by the pump station, m; 
\( L \)—full length of the oil pipeline, km 
\( T \)—the time required to complete the entire transport process, h.

2.3 Selection of optimization scenarios

The viscosity and density of oil are greatly affected by temperature, the temperature of oil is measured by temperature sensor, and the viscosity of oil varies by temperature change.

\[ \mu_t = \mu_1 \cdot e^{-\xi(t-t_1)} \]

Where: \( \mu_t \), \( \mu_1 \) - the viscosity of the oil at a temperature of \( t \), \( t_1 \), m²/s; 
\( \xi \)—viscosity index, 1/°C. can be obtained from two known viscosity values \( \mu_1 \), \( \mu_2 \), 

\[ \xi = \frac{1}{t_2 - t_1} \ln \frac{\mu_1}{\mu_2}, t_1 < t < t_2 \]

Oil density changes with temperature

\[ \rho_t = \rho_{20} - \varepsilon(t - 20) \]

Where \( \rho_t \), \( \rho_{20} \)—the density of the oil at a temperature of \( t \)°C and 20°C, kg/m³; 
\( \varepsilon \)—Temperature Coefficient, \( \varepsilon=1.825-0.001315 \rho_{20}, k g / (m^3 * ^\circ C) \).

Known flow \( Q \), through the formula
Re = $\frac{4Q}{\pi dv}$

(2-8)

Where $Re_{\rho 20}$—Reynolds number;

$Q$—volume flow of oil in the pipeline, m³/s;

$\nu$—The kinematic viscosity of the oil, m²/s;

d—the inner diameter of the pipe, m.

Calculate the Reynolds number and judge the flow state according to the Reynolds number. The basis of judgment using China's current national standard is shown in table 3-1. Then the corresponding parameters $m$, $A$ and beta values in different flow states are found on the basis of flow state, which is brought into the calculation formula of hydraulic slope of pipeline.

\[ i = \beta \frac{Q^2 - m}{d^2} \]

(2-9)

In order to obtain the hydraulic slope of the system. The $M$, $A$, beta values and calculation patterns along the friction in each flow zone are shown in table 3-2. The total hydraulic slope of the system is composed of along the friction and local friction resistance. When calculating the local friction, the friction resistance loss of the pipe fittings can be converted to the equivalent length of the local friction, which is equivalent to the loss of the same diameter pipe length along the path. The total hydraulic slope calculation formula.

\[ H = i (L + L_d) \]

(2-10)

$h$—total hydraulic slope, m;

$L$, $L_d$—the length of the pipe, the equivalent length of the local friction of the pipe, m.

At the same time, based on obtaining the parameters $A$ and $B$ values corresponding to the pump model, in order to obtain the lift that the pump unit can provide under different connection conditions, according to the pump's lift formula

\[ H = a - bQ^2 - m \]

(2-11)

Where $a$, $b$—the corresponding parameters of the pump;

$m$—the corresponding parameter in different flow states;

$Q$—flow, m³/s.

Since oil pump is connected in series, the total lift that the pumping station can provide:

\[ H_{oil} = n * H \]

(2-12)

In the formula: $n$—the number of pumps open;

$H$—the head of a single pump.

Compare the total lift corresponding to the number of open pumps with the total hydraulic slope, find out the lowest number of open pumps, and the unit oil consumption of the fuel transmission:

\[ Ne = \frac{N_{el}}{Q_m} \]

(2-13)

$Q_m$—actual delivery flow when the pipeline is running, t/h.

Because the oil pump is connected in series, the output power consumption of the oil pump is also the lowest when the minimum open pump number that can meet the total hydraulic slope is obtained, that is, the minimum required lift. Therefore, the minimum number of pumps corresponding to the scheme is the lowest energy consumption of the oil transmission program.

Through the preliminary data and the above formula, the energy consumption of the pump group under the current system is evaluated, which provides the operator with the Energy Saving optimization scheme under the current task condition.

3. Expected application Prospects

The construction of this system can be combined with the actual oil pipeline transportation system, real-time monitoring of operating parameters, when the flow changes, can be pushed to the operator reliable Energy consumption optimization program, auxiliary management personnel to make decisions. During the operation of the system, a large amount of actual pipeline data can be accumulated, according to the relevant temperature, density, flow rate and other parameters of the change, to predict the pipeline transport pump Unit Energy-saving work mode, provided to the management personnel. Managers will feedback the specific situation after the implementation of the program to the system, to help improve
the system, to facilitate the self-learning of the system. The more detailed 3d max modeling of some important parts of the pipeline, the training of the system operators in the way of VR, reduce the cost of learning. At the same time, the system and security assessment and other auxiliary systems can be combined to form a set of practical work in the combination of a variety of systems integrated optimization system[4].

4. Discussion

4.1. Establish a visual virtual simulation model
Use 3DMax and Unity3d to establish a visual virtual simulation model and management platform equivalent to the actual oil pipeline to realize the scene visualization and data visualization of the remote oil pipeline.

4.2. Initial establishment of management platform
Realize real-time monitoring of the parameters such as flow rate, ambient temperature, temperature of conveying oil, pressure and energy consumption of pump group, put it into the virtual simulation model for trial operation, and carry out Dynamic Data storage, establish database, and initially establish management platform.

4.3. Data refinement and data visualization of virtual simulation models through system comparison
The deviation between the virtual system and the actual operation is recorded and corrected by using the fictitious two systems in parallel, the data refinement and data visualization of the virtual simulation model are realized, in order to complete the precise fictitious isomorphism and lay the operating foundation for the establishment of the Energy Efficiency management platform of the oil pipeline transportation.

4.4. Dynamic transfer of energy efficiency through mathematical calculations in an energy efficiency management platform
According to the parameters of real-time monitoring, combined with fluid characteristics, all-weather and task requirements, as well as the empirical data accumulated in the database, through mathematical model calculation in the Energy efficiency management platform, the dynamic transmission of energy efficiency information is obtained, which provides an optimization scheme for long-term oil transportation[5].

5. Conclusion
It is proposed to establish a set of oil pipeline transportation energy efficiency management platform with the goal of improving energy efficiency, task requirements and all-weather constraints, virtual isomorphism as the form of presentation, and ultimately reasonable allocation of energy consumption equipment, reduce the energy consumption of oil transportation units and achieve the goal of energy conservation and emission reduction.

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