

# Establishment of General Oil Pipeline Scheduling Model and Research on Interface Tracking Calculation Method

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**Abstract.** In order to understand the establishment of oil pipeline scheduling model and interface tracking calculation method, a research on the establishment of a universal product oil pipeline scheduling model and interface tracking calculation method has been proposed. Establish an automatic formulation and optimization model for the scheduling plan of finished oil pipelines with the objective of minimizing the consumption cost of the entire pump unit. The model mainly adopts a centralized distribution method, considering the hydraulic constraints of the pipeline, and adopts a genetic algorithm to optimize and solve the model. This article provides a detailed introduction to the encoding method of genetic algorithm for optimizing the scheduling plan of finished oil pipelines, the selection of main operators in the algorithm, the establishment of fitness functions, and the introduction of penalty functions. Based on the established mathematical model, an automatic programming and optimization program for product oil pipeline scheduling plan was developed using C language in Windows 7 environment. Secondly, through practical applications, the actual pipeline operation data is basically consistent with the software calculation results, with an error of no more than 5%; As the running time changes, the pump cost fluctuates greatly; Using a larger throughput can reduce the amount of mixed oil; Therefore, this mathematical model can better meet the actual needs of pipeline operation, facilitate the rapid identification of the most sensitive parameter indicators, and adjust the scheduling plan in a timely manner, reduce operational economic losses, and improve the efficiency of product oil pipeline scheduling and operation.

## 1 Page Layout

With the continuous growth of global oil demand, the scheduling and operational efficiency of finished oil pipeline systems, as an important component of oil transportation, is particularly crucial. In order to improve the transportation efficiency of finished oil pipeline systems, reduce operating costs, and meet complex and changing market demands, it is urgent and important to study a universal finished oil pipeline scheduling model and interface tracking calculation method. In previous studies, many scholars have proposed various pipeline scheduling models and interface tracking calculation methods to cope with different types of pipeline transportation systems[1]. Goudarzi, F. K. et al. improved the scheduling formula for multi product pipelines. The main goal is to minimize operating costs, including inventory and shortages, interfaces, and labor. Considered batch size limitations, inventory carrying costs, backlog, and settlement periods. In addition, due to the lack of relevant historical data, certain parameters are classified as uncertainty types based on confidence. As a solution strategy, three independent conversion methods were used. The effectiveness and reliability of the model, as well as the proposed method, were verified through numerical calculations. Sensitivity analysis shows that the

value of the objective function is highly dependent on changes in confidence levels, thus achieving the best technique [2]. Some of these models focus on optimizing scheduling schemes to maximize the transportation efficiency of pipeline systems; Other studies focus on interface tracking calculation methods for real-time monitoring and adjustment of system operation status. Some typical assembly line scheduling models include: discrete event models, which model various key events of the finished oil pipeline system to achieve a discrete description of system scheduling, thereby improving the control of system operation status. Optimize the model by using mathematical tools such as linear programming and integer programming to optimize the transportation, warehousing, and distribution of finished oil pipelines, in order to minimize total costs or maximize transportation efficiency. A simulation model is established to simulate the operation process of a pipeline system, evaluate the impact of different scheduling schemes on system performance, and provide scientific basis for decision-making.

In this context, this article will combine the above-mentioned product oil pipeline scheduling model and interface tracking calculation method, and explore the establishment of a universal product oil pipeline scheduling model and the study of interface tracking

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calculation methods by introducing advanced technologies and methods. Through in-depth research on these issues, we aim to provide theoretical support and practical guidance for the efficient operation and sustainable development of finished oil pipeline systems.

## 2 Oil Properties and Interstation Interface Tracking Calculation Method

The process of online real-time batch tracking algorithm is as follows: Firstly, pipeline information, station information, oil product information, equipment information and batch information from the software database are passed into the program, and flow rate and pressure information are analyzed through the pipeline hydraulic model established. It is calculated and stored, and the location of the mixed oil section is tracked by the mixed oil diffusion and extension model. On the other hand, the real-time density data retrieved from the field server is used to identify the oil passing through the station and obtain the real oil concentration distribution curve[3]. The actual data is compared with the calculated data for batch information correction, and the calculation information is returned to the database for storage and update. As shown in Figure 1:

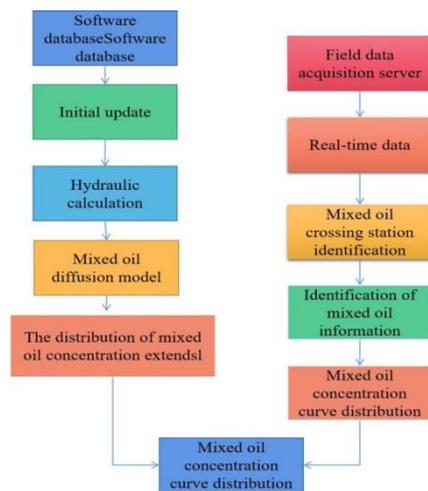


Figure.1. Tracking algorithm flow

Pipeline hydraulic model, Hydraulic transient model Formula (1):

$$\begin{cases} \frac{\partial p}{\partial t} + V \frac{\partial p}{\partial x} + \frac{a^2 \rho}{A} \frac{\partial Q}{\partial x} = 0 \\ \frac{1}{A} \frac{\partial Q}{\partial t} + \frac{V}{A} \frac{\partial Q}{\partial x} + \frac{1}{\rho} \frac{\partial p}{\partial x} + g \frac{dz}{dx} + f|Q|^{1-m} g = 0 \end{cases} \quad (1)$$

The hydraulic model can be converted to the head form by  $p = \rho gh - \rho g z$  Formula (2) :

$$\begin{cases} \frac{\partial H}{\partial t} + V \frac{\partial H}{\partial x} + \frac{a^2}{gA} \frac{\partial Q}{\partial x} = 0 \\ \frac{1}{gA} \left( \frac{\partial Q}{\partial t} + V \frac{\partial Q}{\partial x} \right) + \frac{\partial H}{\partial x} + f|Q|^{1-m} = 0 \end{cases} \quad (2)$$

The model coupling solution method is as follows:

(1) Based on the initial boundary setting, the steady-state pressure, flow rate and oil mixture distribution in the pipe section are calculated;

② Determine the hydraulic and oil mixing calculation time;

(3) According to the hydraulic state of the mixed oil section, the mixed oil transport calculation is carried out;

(4) The current mixed oil distribution state is used for hydraulic calculation;

(5) According to the hydraulic calculation results, the relevant calculation of the development of mixed oil diffusion;

⑥ Repeat step ③- until the termination condition is reached.

Solution: Improved feature line method

On the characteristic line  $dx/dt = V \pm a$ , the hydraulic transient model in the form of water head can be combined into the ordinary differential form, that is, the original characteristic equation 3:

$$\begin{cases} \frac{dx}{dt} = V \pm a \\ \frac{a}{gA} dQ \pm dH + af|Q|^{1-m} dt = 0 \end{cases} \quad (3)$$

The original characteristic equation is derived based on the form of water head, which can be better applied to the single medium conveying situation with no change in density. However, for the sequential conveying situation, the water head will also have changes caused by non-flow rate and friction due to the density change in the oil mixing region. Therefore, when the characteristic line method in the form of water head is used to calculate the sequential conveying, It needs to be simplified to some extent and segmented at the oil mixing interface, which is more complicated. Since the pressure in the oil mixing zone is not affected by the density change, the characteristic equation in the form of pressure can characterize the entire pipe segment, and there is no need to perform segmentation processing at the oil mixing interface, and the overall calculation logic will be clearer[4].

The derivation process of the characteristic equation in the form of pressure is similar to that in the form of water head. The basic idea is to convert the partial differential equation in the hydraulic model into a total differential equation. Based on this, the continuity equation in Equation 3 is multiplied by the undetermined coefficient  $\xi$  and combined with the equation of motion to obtain the following equation Formula (4):

$$\frac{1}{A} \left[ (V + a^2 \rho \xi) \frac{\partial Q}{\partial x} + \frac{\partial Q}{\partial t} \right] + \xi \left[ \left( V + \frac{1}{\rho \xi} \right) \frac{\partial p}{\partial x} + \frac{\partial p}{\partial t} \right] + g \frac{dz}{dx} + f|Q|^{1-m} g = 0 \quad (4)$$

Under the condition  $V + a^2 \rho \xi = V + 1/\rho \xi = dx/dt$ , Equation 4 can be converted into an ordinary differential equation, that is, a characteristic equation in the form of pressure Formula (5):

$$\frac{a}{A} dQ \pm \frac{1}{\rho} dp + g dz + af|Q|^{1-m} dt = 0 \quad (5)$$

In this case,  $a^2 \rho \xi = \frac{1}{\rho \xi} \Rightarrow \xi = \pm \frac{1}{a\rho}$  therefore, the feature line is also Formula (6):

$$\frac{dx}{dt} = V + a^2 \rho \xi = V \pm a \quad (6)$$

Since the frictional resistance term contains multiple square integrations, it is complicated to calculate, so the characteristic equation can be reduced to the following finite difference form by simplifying it to some extent, and its characteristic plane is shown in Figure 2, Formula (7), Formula (8)

$$C^+ : \begin{cases} \frac{dx}{dt} = V + a \\ \frac{a_A}{A}(Q_P - Q_A) + \frac{1}{\rho_A}(P_P - P_A) + g(Z_P - Z_A) + a_A g f Q_P |Q_A|^{1-m} \Delta t = 0 \end{cases} \quad (7)$$

$$C^- : \begin{cases} \frac{dx}{dt} = V - a \\ \frac{a_B}{A}(Q_B - Q_P) - \frac{1}{\rho_B}(P_B - P_P) - g(Z_B - Z_P) - a_B g f Q_P |Q_B|^{1-m} \Delta t = 0 \end{cases} \quad (8)$$

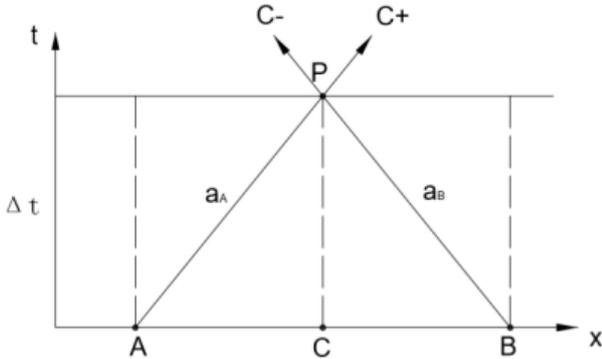


Figure 2. Fluid transient characteristic

After the combination, the solution of  $Q_p$  and  $P_p$  can be obtained and sorted into the following form Formula (9):

$$P_P = R'_A - S'_A Q_P = R'_B + S'_B Q_P$$

$$Q_P = \frac{R'_A - R'_B}{S'_A + S'_B} \quad (9)$$

Among them Formula (10-13) :

$$R'_A = P_A + \frac{\rho_A a_A}{A} Q_A + \rho_A g (Z_A - Z_P) \quad (10)$$

$$R'_B = P_B - \frac{\rho_B a_B}{A} Q_B + \rho_B g (Z_B - Z_P) \quad (11)$$

$$S'_A = \frac{\rho_A a_A}{A} + \rho_A g a_A f |Q_A|^{1-m} \Delta t \quad (12)$$

$$S'_B = \frac{\rho_B a_B}{A} + \rho_B g a_B f |Q_B|^{1-m} \Delta t \quad (13)$$

### 3 Refined Oil Transportation Structure

The pipeline transportation process of refined oil is shown in Figure 3. The design and use of pipeline transportation system should be combined with the actual situation of refined oil transportation in this area, and the primary and secondary costs of refined oil transportation should be clear. Based on the trial operation data of various flow schemes, a set of practical pipeline transportation scheduling and operation model should be established [5-6].

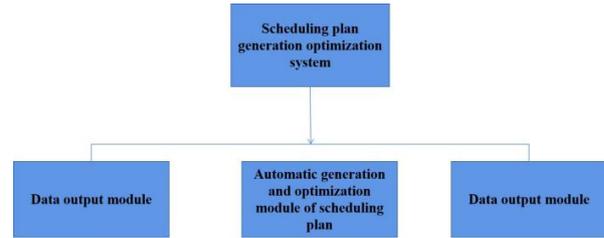


Figure 3. Main structure of program

### 3.1 Scheduling operation model

The expenses incurred in the pipeline transportation process include: ① Electricity charges for pump operation; ② Mixed oil depreciation fee; ③ Pipeline maintenance fee; ④ Personnel management fee. Among them, the first two expenses are the main sources of expenses. Therefore, taking the minimum sum of mixed oil depreciation loss expenses and pump operation electricity charges as the objective function, a pipeline scheduling and operation model is established on the basis of model constraints[7-8].

Formula of mixed oil depreciation loss (14):

$$S_h = \sum v_h(m) \cdot cm(i, j) \quad (14)$$

### 3.2 Constraints

(1) Formula (15) for constraint conditions of conveying capacity:

$$T_{plan} = \sum T_2(m) \quad (15)$$

Pressure constraint formula (16):

$$P_{ks} + P_p = P_1 + P_z + P_{in} + P_j + P_{js} \quad (16)$$

### 4 Example Application

The established model is programmed with software to realize digital and interface operation, so as to achieve the purpose of fast calculation and obtaining results. Sensitive indicators can be adjusted at any time according to the change of operation parameter data of the operation interface, the whole scheduling and operation system can be revised in time, and the corresponding scheduling plan can be formulated. Taking the pipeline transportation of a refined oil product in the west as an example, the actual operation historical data and software calculation data are compared and analyzed, and the difference between the two groups of data is small, both of which are within a reasonable range of change, as shown in Table 1.

Table 1. Comparison between Actual Data and Operating Data

project	unit	real data	operating data
Operating flow	m <sup>3</sup> /h	386	398
Forward oil transportation time	h	80	79
Subsequent oil delivery time	h	160	156
Total cycle time	h	240	240
Mixed oil quantity	m <sup>3</sup>	106	108
Mixed oil depreciation loss	×104 yuan	2.04	2.20
Pump operation cost	×104 yuan	20.25	20.07
operating cost	×104 yuan	23	22.48

The cost incurred in that pipeline transportation of product oil are: ① the electricity fee for pump operation; ② mixed oil depreciation fee; ③ pipeline maintenance fee; ④ personnel management fee. Among them, the first two expenses are the main sources of expenses. Therefore, taking the minimum sum of mixed oil depreciation loss expenses and pump operation electricity charges as the objective function and considering various constraints of the model, the pipeline dispatching and operation model is established, and the established model is compiled with software to realize digital and interface operation and quickly calculate the results, so as to achieve the goal of minimizing the total operation expenses[9-10].

## 5 Conclusion

There are many costs in the pipeline transportation of refined oil, and the scheduling and operation are more complicated. In order to solve this problem, the cost sources of each link are analyzed in detail from the composition of the total operation cost. The research shows that the main costs in the operation process are the depreciation loss of mixed oil and the pump operation electricity fee. Based on the objective function and constraints, an optimization model of scheduling and operation is established, and the model is digitized to realize fast operation.

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