

Heated Oil Pipeline Shutdown and Restart Simulation Software Development Using VB and MATLAB Hybrid Programming

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Abstract

During the operation of heated oil transportation pipeline, the shutdown is caused by some pipeline accidents or repairing. In order to ensure the safety operation of the pipeline, determine the temperature drop and restart pressure needed at different shutdown lasting time is important. This paper builds the heated oil pipeline shutdown and restart mathematic model based on heat transfer and fluid mechanics theory. The VB and MATLAB hybrid programming method which is on the basis of COM technical is utilized to develop heated oil pipeline shutdown and restart simulation software. The software application shows using of VB and MATLAB hybrid programming method can reduce the work of algorithm developing and enhance the reliability of heated oil pipeline shutdown and restart simulation software.

Index Terms: heated oil transportation pipeline; simulation software; Visual Basic; MATLAB; hybrid programming; Component Object Module

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1. Introduction

The oil transport pipeline is an important way to transport the oil from oil field and refinery to end-users. If the viscosity of the oil is high, the oil should be heated to decrease its viscosity. Then the transport friction can be decreased and the transport efficiency is enhanced. The heated oil pipeline is a kind of pipeline which is designed to transport heated oil specially [1]. Inevitably, during the operation process, the operation shutdown is caused by some pipeline accidents or repairing. The oil temperature decreases with the lasting of shutdown but the viscosity increases. Higher pressure at the pipeline entrance than the maximum operation pressure (MOP) may be needed to drive the high viscosity oil flow in the pipeline when the pipeline restarts after long shutdown lasting time. Consequently, in order to provide technical supports for safety operation of heated oil pipeline, it is important to investigate the temperature drop and restart pressure needed at different shutdown lasting time [2-3]. We can solve the problem by the method of numerical simulation and development of related software.

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The shutdown and restart simulation involves complicated matrixes. Corresponding simulation results are also need graphics output. MATLAB is an interactive, object-oriented programming language. MATLAB is intended primarily for numerical computing. It allows matrix manipulations, plotting of functions and data, implementation of algorithms, creation of user interfaces. Although MATLAB has powerful matrix and graphic processing functions, there are still some disadvantages such as the inconvenient user interface development. However, Visual Basic (VB) is a visual programming language developed by Microsoft. The advantages of VB are programming quick and simple, good interface, convenient development of software interface, which covers the shortage of MATLAB [4-6]. Combination of the two programming software provides an effective way to develop more professional, flexible numerical simulation software.

This paper develops heated oil pipeline Shutdown and Restart Simulation Software (SRSS) based on the hybrid programming technical. The SRSS can provide technical supports for determining the safety shutdown time and the restart pressure needed after shutdown.

2. Temperature drop model and restart model

2.1 Temperature Drop Model After Shutdown

For the temperature drop calculation of heated oil pipeline after shutdown, select the oil, pipeline, insulating layer, semi-infinite soil and air environment as the objects of research, the unsteady heat transfer model of the pipeline is presented in (1)-(3).

Heat transfer equation of heated oil pipeline:

$$\rho C \frac{\partial T}{\partial t} = \frac{1}{r} \frac{\partial}{\partial r} \left(\lambda r \frac{\partial T}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \theta} \left(\lambda \frac{\partial T}{\partial \theta} \right) \quad (1)$$

Heat transfer equation of pipeline wall:

$$\rho_n C_n \frac{\partial T_n}{\partial t} = \frac{1}{r} \frac{\partial}{\partial r} \left(\lambda_n r \frac{\partial T_n}{\partial r} \right) + \frac{1}{r^2} \frac{\partial}{\partial \theta} \left(\lambda_n \frac{\partial T_n}{\partial \theta} \right) \quad (2)$$

Heat transfer equation of soil:

$$\rho_s C_s \frac{\partial T_s}{\partial t} = \frac{\partial}{\partial x} \left(\lambda_s r \frac{\partial T_s}{\partial x} \right) + \frac{\partial}{\partial y} \left(\lambda_s \frac{\partial T_s}{\partial y} \right) \quad (3)$$

In order to form the definition problem of temperature drop model, the corresponding connecting conditions, initial conditions, and boundary conditions should be introduce into above equations. Then, conformal transformation is used to transform the semi-infinite region into finite region and then difference method is adapted to analyze the oil temperature variation with time along the pipeline after shutdown [2].

2.2 Restart Model

The restart of the pipeline is transient flow process. According to the theory of fluid mechanics, the continuity equation, momentum equation and energy equation can be used to describe the relationship among the fluid pressure, temperature and flow in pipeline.

Continuity equation:

$$\frac{\partial P}{\partial t} + V \frac{\partial P}{\partial x} + \rho a^2 \frac{\partial V}{\partial x} = 0 \quad (4)$$

Momentum equation:

$$\frac{\partial V}{\partial t} + \frac{1}{\rho} \frac{\partial P}{\partial x} + V \frac{\partial V}{\partial x} = -g \sin \theta - \frac{\lambda}{2D} V |V| \quad (5)$$

Energy equation:

$$\frac{\partial T}{\partial t} + \frac{T}{\rho C} \left(\frac{\partial P}{\partial T} \right)_\rho \frac{\partial V}{\partial x} + V \frac{\partial T}{\partial x} = \lambda \frac{|V|^3}{2DC} - \frac{4K}{\rho DC} (T - T_0) \quad (6)$$

Similar to temperature drop model, the corresponding connecting conditions, initial conditions, and boundary conditions should be introduced into (4)-(6). Then the method of characteristic (MOC) and Newton-Raphson method are utilized to obtain the numerical solution of the model. The restart pressure can be gained according to the highest pressure.

Where, ρ is oil density, kg/m^3 ; ρ_n is density of the n layer (pipeline wall, insulating layer, and), kg/m^3 ; ρ_s is the soil density, kg/m^3 ; c is oil heat capacity, $\text{J}/(\text{kg} \cdot ^\circ\text{C})$; C_n is the n layer heat capacity, $\text{J}/(\text{kg} \cdot ^\circ\text{C})$; C_s is the soil capacity, $\text{J}/(\text{kg} \cdot ^\circ\text{C})$; λ is oil thermal conductivity, $\text{W}/(\text{m} \cdot ^\circ\text{C})$; λ_n is the n layer thermal conductivity, $\text{W}/(\text{m} \cdot ^\circ\text{C})$; T is oil temperature, $^\circ\text{C}$; T_n is n layer temperature, $^\circ\text{C}$; T_s is soil temperature, $^\circ\text{C}$; T_w is surface temperature, $^\circ\text{C}$; α is heat transfer coefficient from oil to pipeline internal wall, $\text{W}/(\text{m} \cdot ^\circ\text{C})$; α_w is heat transfer from soil to air, $\text{W}/(\text{m} \cdot ^\circ\text{C})$; R_o is pipeline inside radius, m; R_n is outer diameter of n layer, m; P is pressure in pipeline, Pa; θ is pipeline slope, rad; t is time, s; V is instantaneous velocity, m/s; D is pipeline internal diameter, m; g is gravitational acceleration, m/s^2 ; x is pipeline position, m; K is overall heat transfer co-efficiency, $\text{W}/(\text{m}^2 \text{K})$; f is pipeline friction factor; D is external diameter, m.

As the powerful matrix manipulations of MATLAB, the iterative solving process can be realized convenient by MATLAB.

3. VB and MATLAB hybrid programming based on COM technology

The powerful numerical calculation and graphics processing functions of MATLAB can be fully used by VB call MATLAB. The main methods that can be used to implement the VB and MATLAB hybrid programming are: Dynamic Data Exchange (DDE), Activex Automation Server, Middle Files Transporting, Dynamic Link Library (DLL) and Component Object Module (COM). Not only the call procedures of first three methods are complicate but also run dependently with MATLAB. Thus the development and independent running of the software are dissatisfied. Although Mideva can run independently without MATLAB, the MathWorks has

stopped updating it. Fortunately, MATLAB's M-function files can be converted into a COM component applied in VB, which can not only take full advantages of VB and MATLAB, but also run independently without MATLAB [7-8].

A COM object is a software component that conforms to the Component Object Model. COM enforces encapsulation of the object, preventing direct access of its data and implementation. COM objects expose interfaces, which consist of properties, methods and events. A COM client is a program that makes use of COM objects. COM objects that expose functionality for use are called COM servers. Since MATLAB 6.5, the MATLAB has provided COM Builder for users. The COM Builder can convert MATLAB program into COM component which can be called directly by VB, VC++ and many other programming languages that support COM. COM building procedures in MATLAB are as summarized as follow:

- (1) Develop MATLAB program (M files);
- (2) Create a new project of COM;
- (3) Manage M files and MEX files;
- (4) Build COM object;
- (5) Deploy COM object.

4. Heated oil pipeline shutdown and restart simulation software development

With using of MATLAB 7.1, we develop the heated oil pipeline shutdown and restart mathematic model and numerical simulation program which is converted into COM named SRSS 1.0. In order to let the VB shell link to SRSS 1.0, we must check MWComUtil 7.1 Type Library and SRSS 1.0 Type Library in "Project - References" of VB. Then, we finish all the procedures of VB call MATLAB. VB mainly provides software operation functions which include parameters and commands input and COM implements the core calculation according the commands from VB. After the calculation is finished, COM plots the calculation results automatically and returns the results to VB. Principle of the whole hybrid programming procedures are illustrated in Fig.1.

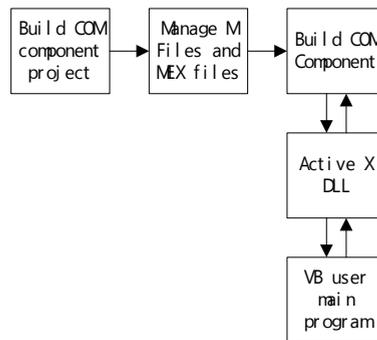


Fig 1. Principle of hybrid programming procedures

The program of VB call the simulation function in MATLAB is listed as follow:

```
Set aclass = New SRSS.SRSSclass
```

```
Call aclass.Simulation(6, H, Q, T, T11, Bk, Hmax, T0s, T00, Simt, Ko, Qds, Bv,Tas, Tst, Qfs, Djs, Hfs, Btm)
```

The programm of VB call the plot function in MATLAB as soon as calculation is over is listed as follow:

```
Set aclass = New SRSS.SRSSclass
```

```
Call aclass.PlotG(H, lk3)
```

Based on the mathematic model and software development method, we develop heated oil pipeline shutdown and restart simulation software (SRSS). An example of the parameters input interface is shown in Fig.2. Fig.3 and Fig.4 present the temperature drop graphic and restart pressure variation graphic plotted by COM respectively.

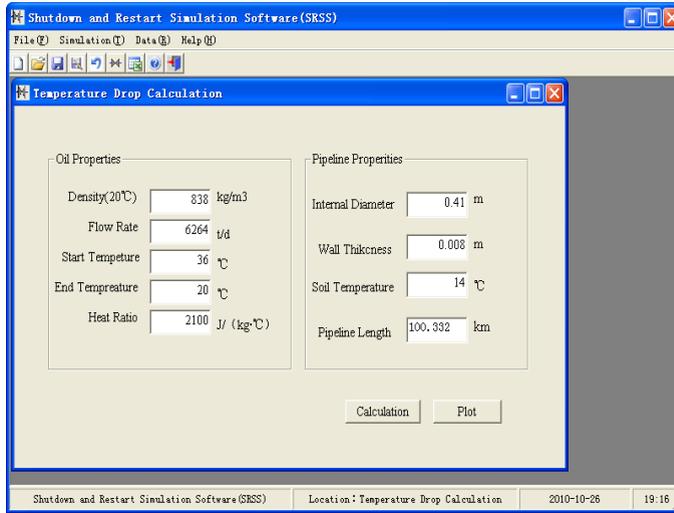


Fig 2. An example of software parameters input interface

As shown in Fig2-Fig.4, we can input related parameters and send calculation commands on the interface developed by VB. The simulation results are outputted as graphics as soon as the simulation is over. From the temperature drop graphic (Fig.3), we can learn the temperature along the pipeline at different shutdown lasting time (0 hour, 3hours, 6 hours et al). According to the restart pressure graphic, pressure variation at different sections of the pipeline (such as 0km, 11.5km et al) can be analyzed directly. The highest pressure in Fig.4 is the restart pressure needed which can be used to judge whether the pipeline can restart successfully after a certain shutdown lasting time.

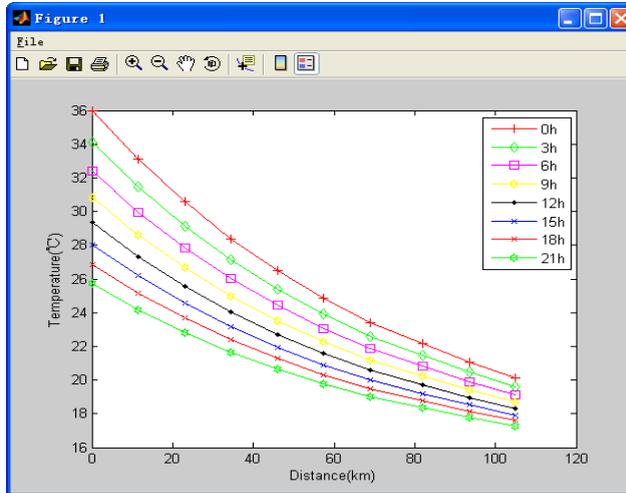


Fig 3. Temperature drop

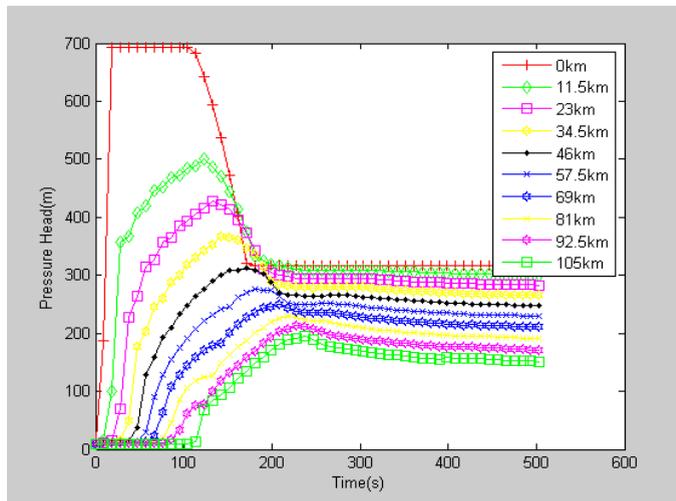


Fig 4. Restart pressure variation at different pipeline section

5. Conclusion

This paper builds the shutdown and restart mathematic model of heated oil transportation on the basis of heat transfer and fluid mechanics theory. Then, VB and MATLAB hybrid programming technical using COM is introduced. The hybrid programming method is utilized to develop heated oil pipeline shutdown and restart simulation software (SRSS).

The application of SRSS shows the powerful numerical calculation, graphic processing of MATLAB and the convenient interface development of VB can be fully used with using of VB and MATLAB hybrid programming. This software can run independently without VB and MATLAB and the reliability of the software is enhanced.

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