Mixed oil control and solution of mountain product oil pipeline

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Abstract. At present, the mixing oil will be produced in the sequential transportation of various refined oil inescapable. The mixing oil is not qualified product which is needed to be dealt with. The Volume of mixing oil is less the better. How to reduce the volume of mixing oil in the transportation of product oil is the key to reduce the cost and improve pipeline efficiency. This paper discusses the cause and mechanism of mixed oil in refined products and the characteristics of mixed oil in mountain pipelines. Then, it is providing a calculation method of mixed oil quantity, and a detecting method of mixed oil section, and a treatment method after receiving mixed oil.

1 Instruction

With the rapid development of China's economy, the consumption of refined oil is growing faster. The common transportation mode of refined oil is pipeline transportation, road transportation, railway transportation, ship transportation, etc. The pipeline transportation has the characteristics of low cost, high safety, high continuous operation rate and little influence by climate. Especially in the mountainous area of southwest China, it has obvious advantages which is comparing with other transportation modes, except that there is high investment in construction\(^\text{[1]}\). In order to improve the utilization rate of refined oil pipeline, sequential transportation is often adopted. However, in mountainous areas, the pipeline is mainly located in mountains and deep valleys, and the oil mixture produced by the pipeline in sequence is large, and the oil mixture treatment seriously increases the pipeline transportation cost.

Combined with the situation of refined oil in Yunnan province in recent years, this paper analyzes the cause and mechanism of mixed oil transported sequentially by mountain refined oil pipeline, and studies the calculation method of mixed oil quantity, detection of mixed oil section and treatment method after receiving mixed oil.

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2. The cause of mixed oil in mountain product pipeline

During the sequential transportation of mountain refined oil pipeline, mixed oil will occur at the first station, the middle station, the last station and along the route, and it is also affected by density difference, temperature difference, viscosity difference and other physical properties\(^2\). At the origin station, the main causes of oil mixing are oil changing and the rotation of the oil pump. In the middle station, it is mainly for the stirring of the oil pump, and the oil mixture of blind pipe and branch pipe. In the terminal station, it is mainly for oil to switch into different oil tanks, blind pipe and branch pipe oil mixture. At the final station, mixing oil mainly occurs when the oil enters into different oil tanks, blind pipes and branch pipes. The oil mixture is mainly produced during pipeline transportation. The mixing oil produced along the process is mainly formed at the junction of two kinds of oil products, and the mixing oil along the process is the main mixing way. At the same time, density difference, temperature difference, viscosity difference, elevation difference and other factors in the whole process of product oil transportation will lead to oil mixing.

2.1 The influence of flowing state

When two kinds of product oil are transported between two stations, the amount of mixed oil in different flow states is also different. In laminar flow state, the flow rate at the center of the pipe is larger than that near the pipe wall, which is about twice the average flow rate. The product oil at the back end of the interface forms a wedge head, enters the product oil at the front end of the interface, and mixes with each other to form oil mixture. In turbulent condition, the oil flow velocity in the center of the pipeline is similar to the average flow velocity, which is about 1.18~1.25 times according to relevant data\(^3-4\). Therefore, there is no obvious velocity difference at the back end of the interface between the two oil products, and less oil mixing and laminar flow are produced. It is laminar flow When the Reynolds number is smaller than the critical Reynolds number, but it is turbulent When the Reynolds number is larger than the critical Reynolds number. Therefore, in order to reduce the amount of mixed oil along the process, the product oil should be guaranteed to be turbulent.

2.2 The mixed oil in the origin station

The first stage mixed oil can also be called the initial mixed oil that is produced when it is transported from the original station. When different product oil are transported at the original station, different oil transfer processes need to be changed frequently. When the oil transfer process is changed each time, the external valve of the planned oil storage tank should be opened first, and then the external valve of the planned oil storage tank should be closed. In the process of transferring oil, the pipeline capacity between storage tank and transferring pump, the time of process changing, which determines the amount of mixed oil and directly affects the quality of product oil.

In view of the above problems, there are generally some solutions to control the generation of mixed oil. First, in the pipeline design stage, the pipe capacity and pipe length between all kinds of oil storage tank and pump should be fully considered. On the premise that the pipe capacity cannot be adjusted, the position of the pump should be close to the valve of process changing as closer as possible, so as to reduce the pipe capacity by shortening the pipe length between the storage tank and pump, and then to reduce the mixing of oil\(^5\). Second, optimize the flow of the first station and shorten the time of process changing, so that the amount of initial mixing which produced in the process changing is reduced to a minimum. In the process changing, the short operation time can
greatly reduce the mixing oil. For example, the general switching time of the electric valve is 120s~180s, and the switching time of the electro-hydraulic linkage valve is 10S~15S. The selection of the electro-hydraulic linkage valve can effectively reduce the time of mixing oil, so as to reduce mixing oil. Third, reducing refined oil delivery batches. According to the requirements of "Operation Specification for Refined Oil Pipelines" (SY/T 6695-2014), the annual batches of should not be less than the minimum batch quantity, but the batch quantity should be increased as much as possible. Through reasonable optimization is aim to reduced the the number of annual batch, so as to reduce the amount of mixed oil. As the sales situation of downstream refined oil market is difficult to control, this measure needs to be adjusted dynamically based on the sales situation of refined oil.

Table 1. Comparing the difference of mixed oil amount between before and after the annual batches optimization in one product oil station.

<table>
<thead>
<tr>
<th>Year</th>
<th>Batches of Diesel</th>
<th>Batches of 92# Gasoline</th>
<th>Batches of 95# Gasoline</th>
<th>Total of mixed oil (m3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2020</td>
<td>30</td>
<td>20</td>
<td>15</td>
<td>4807.372</td>
</tr>
<tr>
<td>2021</td>
<td>25</td>
<td>16</td>
<td>12</td>
<td>3365.160</td>
</tr>
<tr>
<td>Comparison</td>
<td>-5</td>
<td>-4</td>
<td>-3</td>
<td>-1442.212</td>
</tr>
</tbody>
</table>

2.3 The mixed oil in the intermediate stations

By analyzing the flow direction, flow rate, pressure and other factors of the intermediate stations, it is found that there are many ways to produce mixed oil. In the actual situation, when the product oil enters the intermediate stations, there will generally be changes in flow direction, pressure and flow rate. If the interface of two kinds of oil passes through the intermediate station, mixed oil will be generated due to the above reasons. The main reasons for the change of flow direction are the change of pipeline direction in the station and the change of elevation between the two stations. The velocity changing is the changing of pipe diameter in the station and the control of flow regulating equipment. The pressure changing are the pressurization of the pump and the function of pressure regulating valve. At the same time, intermediate station oil loading, valve switch, blind pipe, branch section mixing and other factors will increase the amount of mixing oil.

2.4 The mixed oil in the terminal stations

After the product oil arrives at the terminal station, in addition to being affected by similar factors such as flow direction, flow rate and pressure in the intermediate station, there is also mixed oil caused by the process changing of different oil products entering the storage tank. According to the practice of conventional product oil transportation, the mixed oil is generally transported to the terminal mixed tank for storage, and some intermediate stations will also put part of the mixed oil into the mixing tank during the downloading of refined oil. Mixed oil is generally transported to the refinery for refining, as shown in Figure 1. Alternatively, the mixture is cut in different proportions and transported to different kind of tanks. For example, the mixture containing more diesel oil is cut into the diesel tank, and the mixture containing more gasoline is cut into the gasoline tank, as shown in Figure 2. Product oil with strict quality requirements, such as jet fuel, which cannot be mixed, must be transported to the refinery or other special units for treatment.
Fig. 1. Mixed oil is collected by mixing tank.  Fig. 2. Mixture is mixed into different tanks.

A high precision and high resolution online of density monitoring equipment is installed in the pipeline of the first station, the sub-pumping station, the intermediate pumping station and the terminal station. The density monitoring equipment is used to monitor the oil interface between different density oil products. In addition, sequential transportation simulation software can be used to calculate and track the interface of oil products in the pipeline. It is monitored by the dispatch control center, the density monitoring equipment is monitored by the station control, and the batch tracking is realized by the control center. Therefore, improving the precision of oil density detection components and the speed of process changing, which can effectively reduce the amount of mixed oil.

2.5 The mixed oil during transportation

When the product oil is transported in the pipeline, the amount of mixed oil generated at the adjacent interface of the two oil products will be affected by many factors, the main factors are viscosity difference, temperature difference, pipe diameter change, mountain pipeline elevation difference, etc. The viscosity difference will not only directly lead to the mixing of two kinds of oil at the interface, but also the oil with different viscosity will produce different mixing amount in the transportation sequence. The main reason is that the high-viscosity refined oil sticks to the inner wall of the pipeline. When the low-viscosity product oil passes through this area, the high-viscosity product oil will be washed off by the low-viscosity product oil, which is resulting in oil mixing. For example, the diesel which has a higher viscosity than petrol, will produce 10 to 15 per cent more blend when delivered in front of petrol than when petrol is delivered in front of diesel. Therefore, as far as possible to arrange the density and other physical and chemical properties of the oil together, can effectively reduce the mixing of oil.

Fig. 3. Elevation map of pipeline.

At the same time, during intermittent shutdown, pipeline maintenance and accident shutdown, the pipeline needs to be shut down for a long time, and the two oil products will
produce a lot of mixed oil at the mixing interface. The transportation situation of refined oil products in a mountainous area was investigated. Due to the influence of mountain terrain height difference, the height difference of some pipelines would be nearly 1000m within 10 km of the pipeline, and the oil products at rest would be affected by gravity and merged with each other to increase the amount of mixed oil. In addition, due to the influence of friction along the process, the velocity of the product oil gradually decreases, and when the flow state of the product oil changes from turbulent to laminar flow, the amount of mixed oil will increase. Therefore, during the transportation of refined oil, it is necessary to ensure that the refined oil is in a turbulent state.

Fig. 4. Gasoline is delivered behind diesel.  
Fig. 5. Diesel fuel is delivered behind gasoline.

3 Calculation of mixed oil quantity of product oil

According to the Code for Engineering Design of Oil Pipelines (GB 50253-2014), the critical Reynolds number \( R_{elj} = 2000 \). The formula for calculating Reynolds number \( Re \) is as follows.

\[
Re = \frac{4Q}{\pi d \nu}
\]

(1)

\[
Re_{lj} = 10000e^{2.72d^{0.5}}
\]

(2)

d--Pipe diameter, Q--Volume flow rate at average temperature, e--Constant, e=2.718, \( \nu \)--The kinematic viscosity of each 50% mixture at conveying temperature, the calculation formula is as follows.

\[
\log(\nu \times 10^6 + 0.89) = 0.5 \log(\nu_A \times 10^6 + 0.89) + 0.5 \log(\nu_B \times 10^6 + 0.89)
\]

(3)

\( \nu_A \)--Kinematic viscosity of the oil which is transported ahead, \( \nu_B \)--Kinematic viscosity of the oil which is transported behind.

When the product oil is in laminar flow state, \( Re < Re_{lj} \), the mixing quantity \( Q_h \) is calculated as follows.

\[
Q_h = 4596.25\pi d^2 (dL)^{0.5} e^{2.18d^{0.5}}
\]

(4)

d--Pipe diameter, L--Pipe length. When the product oil is in turbulent state, the \( Q_w \) of \( Re > Re_{lj} \) mixture is calculated as follows.

\[
Q_w = 2.9375\pi d^2 (dL)^{0.5} Re^{-0.1}
\]

(5)
The flow velocity of \( \nu_{lj} \) in turbulent and laminar critical states can be calculated when \( \text{Re} = \text{Re}_0 (\text{Re}_0 = 2000) \). To reduce the amount of mixed oil, the flow rate of refined oil must be greater than \( \nu_{lj} \). According to formula (1) and (5), it can be calculated that the flow rate of refined oil \( \nu \) is larger, \( \text{Re} \) is smaller, and \( Q_w \) of mixed oil is smaller.

However, due to the flow of product oil in the pipeline, friction between liquid molecules and between liquid and pipe will generate static electricity, and excessive static electricity will generate discharge, which will lead to fire and explosion in serious cases. In the process of oil pipeline transportation, electrostatic voltage is positively correlated with oil flow rate and friction intensity, and the greater the friction of the inner wall of the pipeline, the higher the electrostatic voltage\(^6\).

According to the related standards such as Static Electricity Safety Regulations for Liquid Petroleum Products, General Guidelines for Preventing Static Accidents, Basic Requirements for Safety Technology of Oil Terminals and so on, in order to prevent static electricity hazards during the transportation of refined oil, it is required that the flow rate of the inlet pipe of light oil tank should be less than 4m/s and the maximum should not exceed 7m/s. The flow rate can be increased if an electrostatic eliminator is installed near the outlet of the pipe, but not more than 10m/s.

As above, the amount of mixed oil during pipeline transportation is directly related to the flow rate \( \nu \) and conveying batches without considering other factors such as pipeline route, elevation, temperature and viscosity. Therefore, the following conclusions can be drawn. The conclusion is as follows:

- Within a reasonable speed range, the amount of mixed oil between two kinds can be effectively reduced by controlling the flow rate of finished oil.
- By reasonably reducing the number of different oil batches, the total amount of mixed oil can be effectively controlled.
- Under the condition that the pipe size and the distance between the two pipelines are constant, the mixture quantity of the product oil can be detected and controlled.
- Oil with similar viscosity is transported adjacent to reduce the conveying times of oil with larger viscosity difference.

### 4 The solution of mixed oil treatment

At present, there are two common ways of processing refined oil. The one is to collected the mixed oil into the fixed storage tank, and then transport it to the refinery by the storage tank truck for refining and refining treatment. This method can effectively ensure the quality of each batch of oil, but a large amount of mixed oil can only be treated as waste oil, resulting in large loss of refined oil. At the same time, storage tank truck transportation costs, refinery mixed oil processing costs are huge. The second is to cut the mixed oil into different storage tanks, and then back mixing processing\(^7\). In this method, the mixture of oil products with similar properties is cut into the same mixing tank and mixed in the next batch of conveying. For example, during the conveying batch of 92# gasoline, the mixture of 95# and 92# gasoline is injected through the mixing system.

In order to improve the efficiency of mixing back, the slip points of 92# gasoline and 95# gasoline in the same batch at the first station and the receiving station can be detected respectively. The difference of pipeline transport quality between the two stations was compared. On the premise of determining the transport volume of 92# gasoline in each batch, the proportion and volume of mixed oil injection were calculated. Under normal circumstances, the mixed oil injection system uses the injection pump to inject the mixed oil in the mixed oil tank into the pipeline, and controls the injection ratio by controlling the speed of the mixed oil pump through the frequency converter. The data control table of refined oil blending of a pipeline company is shown in Table 1.
Table 1. The ratio reference of 92# Gasoline mixed into 95# Gasoline.

<table>
<thead>
<tr>
<th>Original Production of Temperature(℃)</th>
<th>Temperature Reduction Index(℃)</th>
<th>Terminal Production of Temperature(℃)</th>
<th>Proportion(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>196</td>
<td>2</td>
<td>198</td>
<td>0.20</td>
</tr>
<tr>
<td>195</td>
<td>2</td>
<td>197</td>
<td>0.22</td>
</tr>
<tr>
<td>194</td>
<td>2</td>
<td>196</td>
<td>0.24</td>
</tr>
<tr>
<td>193</td>
<td>2</td>
<td>195</td>
<td>0.26</td>
</tr>
<tr>
<td>192</td>
<td>2</td>
<td>194</td>
<td>0.28</td>
</tr>
<tr>
<td>191</td>
<td>2</td>
<td>193</td>
<td>0.30</td>
</tr>
</tbody>
</table>

*When the temperature is below 191 ℃, the injection rate is 0.3%.

In addition, 0# diesel can also refer to the above method for mixing treatment, each mixing, need to combine 0# diesel flash point and other key parameters for control, to ensure that the quality of the mixing oil still meet the trade handover requirements.

5 Conclusion

In the process of sequential transportation of long distance pipeline of mountain products, a large amount of mixed oil is produced due to the influence of terrain height difference, pipeline length, roughness, density difference, viscosity difference and other factors, which increases the quality risk of refined products, oil loss and pipeline operation cost. The mixed oil injection method can effectively deal with mixed oil, reduce oil loss and reduce production cost. This paper summarizes the operation characteristics of mountain refined oil pipeline, and the following methods can be adopted to solve the problem of mixed oil:

- Optimize the transportation order of product oil, arrange adjacent transportation of oil with similar density, viscosity and other physical and chemical properties.
- Optimize the transportation process of different refined oil products, shorten the process switching time and reduce the initial mixing amount.
- Improve the precision of density, pressure, temperature and other monitoring components, improve the calculation and control accuracy of mixing oil.
- The flow rate of the pipeline is controlled by regulating the pressure to avoid transportation in laminar flow and avoid electrostatic accumulation and accidents caused by excessive speed.
- When pipeline intermittent transmission, maintenance and maintenance, accidents, etc., lead to shutdown, use the front and back stopper valve to cut off the mixed oil, so as to reduce the production of mixed oil during shutdown.
- Mixed oil injection system is set up at the refined oil receiving station to deal with mixed oil.
- Reasonable arrangement of each batch of returnable finished oil to ensure the maximum reinjection of mixed oil.

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