顺序输送液体隔离塞最优长度的数值计算

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摘 要: 针对最小混油量问题, 对液体隔离塞在成品油顺序输送工艺中的应用进行了分析, 分析了不同长度的液体隔离塞对混油量的影响, 对隔离塞的最优长度进行了分析与数值计算, 编制了用于求解液体隔离塞最优长度的数值计算程序。计算实例的结果表明, 应用液体隔离塞时的混油量要低于两种油品直接接触交替输送时的混油量, 同时在最优隔离塞长度下的混油量为最小, 为求解顺序输送最优隔离塞长度提供了实用可靠的方法。

关键词: 管道; 顺序输送; 液体隔离塞; 最优长度; 数值计算

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0 引言

顺序输送工艺是指在一条管道内按一定顺序连续的输送多种不同油品的输送方法。这种输送方式可最大限度地提高长输管道的利用率, 同时也不可避免的因相邻油品的相互混合而形成混油, 由于形成的混油在物化性质上不同, 所以不能作为合格的油品出售, 会造成一定的混油贬值损失。

在顺序输送时采用液体隔离塞技术是减少混油的很有前途的措施之一。与交替输送油品之间的性质相比, 隔离液的性质与所输的每一种油品都更加相容, 所以, 可以掺入每种油品种的混油量增加了, 而不致损害油品质量, 这就相应的减少了混油罐内的非商品油的体积。此时, 每种油品中掺混物的数量将取决于隔离塞的初始长度以及与所输送油品间的相容性, 而隔离塞的长度则取决于隔离油品与所输油品间的相容程度及运输条件, 同时对混油量有很大影响, 若是隔离塞的尺寸过分小, 减少混油的效果就不明显, 若是应用长度过大的隔离塞, 由于隔离塞本身就是第三种油品这可能导致不符合标准的混油量的增加。因此, 有必要确定混油量最少时的隔离塞最优长度, 本文提出的顺序输送液体隔离塞最优长度的数值计算方法为采用液体隔离塞的顺序输送工艺提供了一定的参考和依据。

1 理论分析与计算

在紊流扩散作用下, 油品在管道内交替时会形成混油段, 根据紊流扩散理论, 混油段内各油品的浓度关系式为[1]:

对于后行油品:

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$$\theta_B = \frac{1}{2}\left(1 - \mathrm{erf}\frac{(l+X)}{2\sqrt{D_T t}}\right) \quad (1)$$

对于隔离液：

$$\theta_T = \frac{1}{2}\left(\mathrm{erf}\frac{(l-X)}{2\sqrt{D_T t}} + \mathrm{erf}\frac{(l+X)}{2\sqrt{D_T t}}\right) \quad (2)$$

对于前行油品：

$$\theta_A = \frac{1}{2}\left(1 - \mathrm{erf}\frac{(l-X}{2\sqrt{D_T t}}\right) \quad (3)$$

式中 θ_B, θ_T, θ_A ——分别为后行油品、液体隔离塞、前行油品的浓度；

$\mathrm{erf}(t) = \frac{2}{\sqrt{\pi}}\int_0^{\infty} e^{-u^2}\mathrm{d}u$ —— 为误差函数[2]；

l ——隔离塞长度的 1/2, m；

D_T ——紊流扩散系数, m^2/s；

x ——总管长 L 上的坐标, m；

$X = x - U_0 t$；

U_0 ——管中液体平均流速, m/s；

t ——运行时间, s。

混入前行油品的后行油品的量 $J_{B/A}$ 和混入后行油品的前行油品量 $J_{A/B}$ 分别为：

$$J_{B/A} = \pi R^2 \int_l^{\infty} \theta_B(L/U_0, x)\mathrm{d}x \quad (4)$$

$$J_{B/A} = \pi R^2 \int_l^{\infty} \theta_A(L/U_0, x)\mathrm{d}x \quad (5)$$

将式(1)、(3)分别代入(4)、(5)得：

$$J_{B/A}/V = J_{A/B}/V = \frac{1}{\sqrt{\pi}} Pe_d^{-0.5} F(w) \quad (6)$$

式中 $w = l/LPe_d^{0.5}$；

$F(w) = \exp\frac{w^2}{4} - \frac{\sqrt{\pi}}{2} w\left[1 - \mathrm{erf}\left(\frac{w}{2}\right)\right]$；

$Pe_d = \frac{U_0 L}{D_T}$ ——贝克莱准数[3]；

V ——$\sqrt{\pi}(z_1 - z_2) V_1$, m^3；

V_1 ——管道的总体积, m^3。

z_1, z_2 值与所选浓度 θ_1 和 θ_2 的界限相对应。

除了前行油品和后行油品间的相互掺混外，还有一些隔离液进入到两种油品中，其量值在每种所输油品中是相同的，且等于：

$$J_{T/A} = J_{T/B} = \delta V, \text{其中 } \delta = l/L \quad (7)$$

式中 $J_{T/B}$, $J_{T/A}$ 分别为隔离液进入后行油品和前行油品的量，掺混物是由部分所输油品和部分性质上与每种所输油品及加相容的隔离液所组成。设隔离液与前行及后行油品间的允许混入量分别是这两种油相互掺混容许量的 m 倍与 n 倍。

即混入前行油品 A 中的后行油品 B 的总量是：

$$J_{B/A}/V = \frac{1}{m}\delta + \frac{1}{\sqrt{\pi}} Pe_d^{-0.5} F(w) \quad (8)$$

相应的入后行油品 B 中的前行油品 A 的总量为：

$$J_{A/B}/V = \frac{1}{n}\delta + \frac{1}{\sqrt{\pi}} Pe_d^{-0.5} F(w) \quad (9)$$

利用 $J_* = \frac{1}{\sqrt{\pi}} Pe_d^{-0.5} V$ 代替 V。J_* 为无液体隔离塞时每种油品的混油体积，则进入油品 A 中的油品 B 的量为：

$$J_{B/A}/J_* = \sqrt{\pi}\beta_{T/A}^{B} w + F(w) \quad (10)$$

进入 B 油中的 A 油的量为：

$$J_{A/B}/J_* = \sqrt{\pi}\beta_{T/B}^{A} w + F(w) \quad (11)$$

式中 $\beta_{T/A}^{B}$ ——进入 A 油品中的 B 油品的容许含量与进入 A 油品中隔离油品 T 的容许含量的比值；

$\beta_{T/B}^{A}$ ——进入 B 油品中的 A 油品的容许含量与进入 B 油品中隔离油品 T 的容许含量的比值。

则得总的相对混油量为：

$$J_0 = \frac{J_{A/B} + J_{B/A}}{2J_*} = \frac{\sqrt{\pi}}{2}(\beta_{T/A}^{B} + \beta_{T/B}^{A}) w + F(w) \quad (12)$$

当总的混油量为最小时得出最优隔离塞长度：

$$2l = 2w_* Pe^{-0.5} L \quad (13)$$

式中 w_* ——使式(12)右侧部分取得最小值的 w 值。

2 数值求解及程序框图

利用 matlab 数学计算软件[4] 绘制的式(12)的图形在区间[0, +∞] 内为单谷函数。因此利用黄金分割法[5] 可以快速准确的求出最优解。在处理 erf 误差方程时利用龙贝格求积法[6]。编制的求解液体隔离塞最优长度的数值计算程序流程图如图 1。

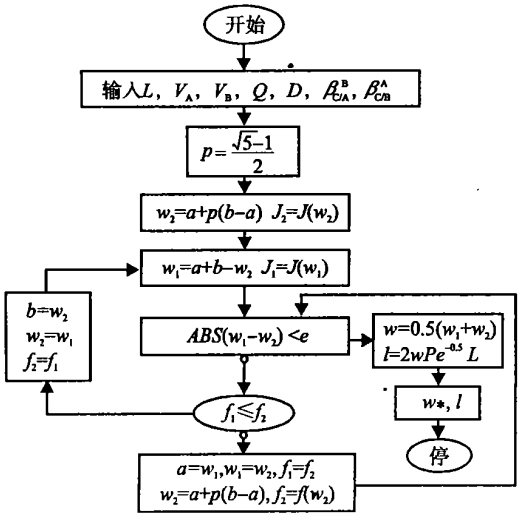

图 1　程序流程图

3　计算实例

某管道管径为 Ø404×6 mm, 管道长度 161 km 顺序输送柴油与汽油两种成品油, 隔离液选用 TC－1燃料油, TC－1 燃料油与汽油和柴油的允许混入量分别是这两种油彼此相互掺混允许量的 3 倍和 5 倍, 汽油与柴油的运动粘度与密度分别为 $\nu_{汽}=0.8\times10^{-6}m^2/s$, $\rho_{汽}=730\ kg/m^3$, $\nu_{柴}=4\times10^{-6}m^2/s$, $\rho_{柴}=840\ kg/m^3$, 管道输量为 500 m^3/h。

两种成品油在无液体隔离塞时的混油量为 103 m^3。

由图 2 可见, 当隔离塞的长度为零即两种成品油直接接触时, 相对混油量为 1, 当隔离塞长度增加时相对混油量逐渐减小, 当减小到一定值时又随隔离塞长度的增加而增大。由此可见最优液体隔离塞长度下的混油量是最少的。

用本文编制的计算程序计算得算例的最优隔离塞长度为 86 m, 混油量为94 m^3, 低于油品直接交替输送时的混油量。

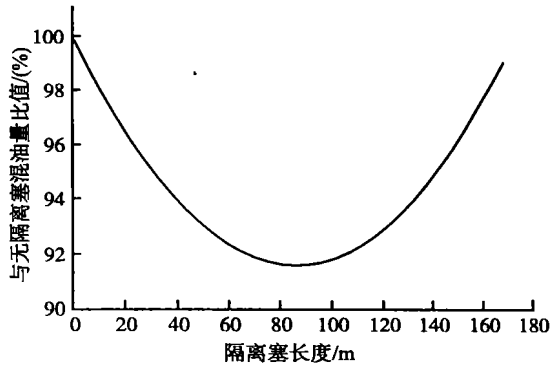

图 2　相对混油总量随隔离液长度的变化曲线

4　结论

在油品顺序输送中采用液体隔离塞技术可有效地减少混油量, 并且不同长度的液体隔离塞所产生的混油量是不同的, 在最优隔离塞长度下, 油品间的混油量为最小, 分析与计算结果表明, 本文提出的求取最优隔离塞长度的数值算法以及编制的程序是正确和实用的。

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SELECTED ABSTRACTS

OIL & GAS TRANSPORTATION AND STORAGE

Application of Hierarchical Analysis to Safety Evaluation on Oil Depot

Su Xin, Yuan Zongming et al. (Southwest Oil College, Chengdu, 610500, Sichuan, China) **NGO**, 2006, 24 (1): 1-4
ABSTRACT: Oil depot is a place for oil storage. Oil is dangerous because of its flammability and explosibility. The main work of objectively and correctly evaluating safe condition of oil depot is to determine weight of each factor affecting oil depot safety precisely. Determined are weights of main factors through hierarchical analysis. The analysis result shows that health conditions and professional skills of employees are main factors affecting oil depot safety. Therefore, it is necessary to improve health conditions and professional skills of employees to ensure oil depot safety.
KEY WORDS: Hierarchical Analysis; Safety evaluation of oil depot; Application

Application of Hydrate

Ou Jian, Yuan Zongming, He San (Southwest Oil College, Chengdu, 610500, Sichuan, China) **NGO**, 2006, 24 (1): 5-8
ABSTRACT: Described is current status of hydrate research and summarized is the existing hydrate application method. Analysis is made on hydrate transportation and storage technology, application status abroad and its industrial value. Forecasted are the future research prospect and direction of hydrate.
KEY WORDS: Hydrate; Hydrate transportation and storage; Natural gas; Application

Study on Pipeline Risk Management

Pan Hongli (PetroChina Pipeline Branch Co., Pipeline S&T Research Center, Langfang, 065000, Hebei, China) **NGO**, 2006, 24 (1): 9-14
ABSTRACT: Described are pipeline risk assessment, risk control, performance measure and response according to the pipeline risk management process. Based on current domestic pipeline industry situation, effective methods and mitigation measures are put forward for pipeline risk assessment. Addressed is an international acceptable risk criterion as a reference to prepare domestic pipeline risk assessment standard.
KEY WORDS: Pipeline; Risk management; Risk assessment; Acceptable risk criteria; Mitigation

Research on Motional Regularity of Pig in Oil Pipeline

Liu Hongbo, Wu Ming, Zhou Lifeng (Liaoning Petrochemical University Mechanical Engineering College, Fushun, 113001, Liaoning, China) **NGO**, 2006, 24 (1): 17-19
ABSTRACT: Paraffin sediment will occur after oil pipeline operates for a period. Initial sediment will form and flow will be stopped when paraffin layer in pipeline is thick. This phenomenon shall be noticed in operating pipeline. Pigging is the best way to prevent the phenomenon from occurring, maintain transportation capability and reduce operation cost. Research on motional regularity of pig is critical to oil pipeline management.
KEY WORDS: Pipeline; Pig; Mathematical model; Motional velocity; Motional time

Study on Compressor Station Operation Optimization Model Based on Black Box Method ——Pipe Segment Constraint Treatment

Wang Xiyong, He San, Yuan Zongming (Southwest Oil College, Chengdu, 610500, Sichuan, China) **NGO**, 2006, 24 (1): 20-23
ABSTRACT: Based on operation conditions of long-distant tree-shape gas pipelines, a new processing method is put forward, namely, long-distant tree-shape gas pipelines are divided into two parts: compressor station system and pipeline system, which are processed separately. Compressor station operation optimization model includes objective function and constraint conditions. Among the constraint conditions, pipeline segment constraint is very difficult to process. A new method is put forward to deal with pipeline segment constraint. Research results show that the method can be easily carried out through computer programming and can reflect structural algorithm thought.
KEY WORDS: Operation optimization; Tree-shape pipeline; Black box; Mathematical model; Compressor station

Application of DOW Analysis to Safety Evaluation on Oil Depot

Chen Xuefeng, Yu Qianxiu (Southwest Oil College, Chengdu, 610500, Sichuan, China) **NGO**, 2006, 24 (1): 24-28
ABSTRACT: In order to evaluate objectively the safety of storage and transportation system in oil depot, a method is put forward for evaluating the DOW's index of fire explosion and its evaluation procedure is discussed. It can quantitatively calculate risk extent and economic loss resulted from accidents. The method can provide a scientific basis for prediction of fire in oil depot.
KEY WORDS: Oil depot; Fire explosion; Safety evaluation; DOW's index method; Application

Formation and Prevention of Hydrate in Gas Pipeline

Wang Haixia, Chen Baodong, Chen Shujun (Liaoning Petrochemical University Oil & Gas Transportation and Storage Engineering College, Fushun, 113001, Liaoning, China) **NGO**, 2006, 24 (1): 29-32
ABSTRACT: During transportation by pipeline, a little natural gas may form hydrate due to landforms, weather and pipeline conditions, which can result in pipeline block and affect safe operation of pipeline. Analyzed are thermodynamic conditions and kinetic conditions of forming hydrate in pipeline. Described is the affect of water content in gas on hydrate formation and combined with the two conditions, introduced are common measures for preventing hydrate from forming.
KEY WORDS: Natural ges; Pipeline; Hydrate; Forming condition; Water content; Prevention

Numerical Value Calculation of The Optimum Length of Liquid Partition on Batch Transportation

Shi Yu, Wang Yue, Feng Yuguo (Liaoning Petrochemical University Mechanical Engineering College, Fushun, 113001, Liaoning, China) **NGO**, 2006, 24 (1): 33-35

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ABSTRACT: In view of the problem of the min. mixed oil volume, analyzed is the technology of liquid partition on the batch transportation and influence of different length liquid partition mixed oil volume. Calculated is the optimum length of the liquid partition using numerical value method and prepared is a program for calculating the optimum length of the liquid partition. The result of example shows that the mixed oil volume is less when using the liquid partition and the mixed oil volume is least under the optimum length of the liquid partition. A credible method is available to seek the optimum length of the liquid partition.
KEY WORDS: Pipeline; Batch transportation; Liquid partition; Optimum length; Numerical value calculation

Economic Evaluation Analysis on Failure of Pipeline

Li Shuang, Chen Liqiong, Zhang Peng(Southwest Oil College, Chengdu, 610500, Sichuan, China)
Li Miao(Kehong Gas Transportation Branch Co., Chengdu, 610215, Sichuan, China)
Zeng Yongjie(Sichuan Petroleum Administration Gas Transportation Branch Co., Chengdu, 610213, Sichuan, China)**NGO**, 2006, 24(1): 36-39
ABSTRACT: Failures of oil and gas pipeline will result in serious personnel death and injury, property loses and damage to environment. Aiming at pipeline failure sequent, correspondent effective maintenance measures may be adopted to reduce loss. However, a conclusion is not easy to be made due to non-consistency of measurement methods of direct economic loss, life loss and environment damage. A currency quantization method is put forward for dealing with non-consistency of measurement methods. This method is beneficial to pipeline operators for accident management.
KEY WORDS: Oil and gas pipeline; Failure sequent; Personnel injury and death; Economical loss; Currency quantization method

OIL & GAS TREATING AND PROCESSING

New Development of SDP Sulfur Recovery and Tail Gas Treatment

Pu Yuanyang, Zhu Lin et al.(Southwest Oil College, Chengdu, 610500, Sichuan, China) **NGO**, 2006, 24(1): 42-46
ABSTRACT: The SDP technology plays an important role in sulfur recovery and tail gas treatment. Summarized is recent development of sulfur recovery and tail gas treatment techniquess, especially described are technical characteristics, application and development of Clauspol, Clinsulf-SDP and MCRC techniques and discussed is the development trend of the SDP technology.
KEY WORDS: SDP technology; LT Claus; Sulfur recovery; Tail gas treatment; Process; Development trend

Development Trend of Domestic Gasoline and Engine Oil for Motorcycle

Wang Enyang, Sun Zongli, Zhang Ning et al.(Nanyang Paraffin Refining Plant, Nanyang, 473132, Henan, China) **NGO**, 2006, 24(1): 47-49
ABSTRACT: Along with improvement of people's living conditions continuously, China has the largest motorcycle productivity and consumption in the world, which has resulted in serious environment pollution due to tail gas. For purpose of protecting environment, motorcycles in China are gradually turned to 4-stroke from 2-stroke. High quality engine oil is required for special work environment of motorcycle engine.
KEY WORDS: Motorcycle; Gasoline and engine oil; Environmental protection; 2-stroke; 4-stroke

Technical Innovation on Delayed Coking Unit

Yuan Cunyu(General Petrochemical Plant of Shengli Oil field Co., Ltd. Dongying, 257000, Shandong, China)
Guo Aijun(College of Chemistry and Chemical Engineering, Petroleum University, Dongying, 257061, Shangdong, China) **NGO**, 2006, 24(1): 50-52
ABSTRACT: Described are the technical characteristics of tunable recycle ratio adopted in the industrial delayed coking unit and technical innovation on process flow of furnace pipe. The practical application in the process is then further analyzed. The technique innovation has resulted in recycle ratio reduction of 0.12, enlargement of the coking unit capacity, improvement of product distribution, liquid product increment of 2.10%, furnace pipe coking period prolongation of 1 multiple and large reduction of synthetic energy consumption. Some suggestions are put forward on future technical innovation of the unit. The experience in the technical innovation is beneficial to similar unit reformation.
KEY WORDS: Delayed coking; Technical innovation; Recycle ratio; Furnace; Industrial unit

INSTRUMENTATION AND AUTOMATATION

Application of Matrix Algorithm to Analysis on Failure of Instrumentation at Combined-station

Zhang Lin, Li Changjun(Southwest Oil College, Chengdu, 610500, Sichuan, China)
Tang Weili(Sichuan University, Chengdu, 610065, Sichuan, China) **NGO**, 2006, 24(1): 56-59
ABSTRACT: Major factors affecting reliability of instrumentation in the combined-station are analyzed synthetically. The fault tree is put forward. The min. cut sets and main failure types are obtained. Presented are some measures of improving reliability of the instrumentation.
KEY WORDS: Combined-station; Failure; Reliability; Matrix algorithm; Fault tree analysis

MACHINERY AND EQUIPMENT

Selection of Calculation Method for Wall Thickness of Cylinder Body in Pressure Equipment

Zhang Chunyan(China Petroleum Engineering Co., Ltd. Southwest Company, Chengdu, 610017, Sichuan, China) **NGO**, 2006, 24(1): 60-62
ABSTRACT: Calculate methods for wall thickness of the pressed cylinder in different operating conditions are different. Based on basic theory of strength design, common methods are analyzed and compared, formulas are selected to calculate the cylinder wall thickness to ensure that the pressed cylinder operate safely and reliably.
KEY WORDS: Cylinder; Thickness; Strength; Calculation method