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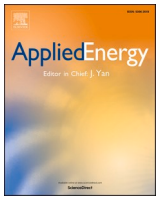

Energy saving and consumption reduction in the transportation of petroleum products: A pipeline pricing optimization perspective☆

Renfu Tu [a], Yingqi Jiao [a], Rui Qiu [a,b], Qi Liao [a,*], Ning Xu [a,c], Jian Du [a], Yongtu Liang [a,c]

[a] Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China
[b] School of Business, Society and Engineering, Mälardalen University, Västerås 721 23, Sweden
[c] China University of Petroleum-Beijing at Karamay, Anding Road No.355, Karamay District, Karamay City, Xinjiang 83400, PR China

HIGHLIGHT

- Propose an integrated framework for the pipeline pricing strategy.
- Utilize a logistics optimization model to guide multi-scheme analysis.
- Contribute to increasing pipeline carriers' revenue by 11.41 million *CNY* per month.
- Reduce energy consumption by 272 *tce* per month.
- Provide recommendations to policymakers in China.

ARTICLE INFO

Keywords:
Multi-product pipeline
Pricing strategy
Low-energy
Multi-scheme analysis
Policy recommendations

ABSTRACT

Pipeline transportation is a low-energy and economical mode of transporting petroleum products in the downstream supply chain, however, there is almost no theoretical research on its pricing strategies. The unreasonable pricing strategy has resulted in low utilization of multi-product pipeline capacity as well as high energy consumption of petroleum products transportation. Therefore, this paper aims to improve pipeline turnover and promote the low-carbon transportation market from the perspective of pipeline pricing optimization. We propose an integrated framework for multi-product pipelines that couples pricing strategy and logistics optimization model. This framework simulates the pricing behavior of the pipeline carrier and the corresponding logistics planning behavior of the oil shipper. We apply the framwork to 10 pipeline pricing schemes for two regions in China with different logistics structures, and analyze the economic and environmental benefits of the new strategy. The results show that the well-performing scheme can increase pipeline carriers' revenue by 11.41 million *CNY* per month, significantly improve the competitive advantage of long-distance pipelines, and reduce energy consumption by 272 *tce*. Based on these findings, we provide recommendations for policymakers at four levels. In conclusion, the new pricing strategy will help reverse the disadvantageous situation of the pipeline in the competitive market and promote energy conservation in the petroleum products logistics industry.

1. Introduction

1.1. Background

In the context of energy conservation and emission reduction, renewable energy sources such as biomass, hydrogen, and geothermal energy have developed in recent years, but petroleum products still dominate the primary energy consumption at present, accounting for nearly-one-third of the total. And this situation will persist for a long time. To satisfy the market demand, the oil shipper usually chooses the transportation mode, including pipeline, rail, ship, and truck, based on the logistics cost as the criterion [1]. These modes are collectively called carriers and compete with each other. The shipper and carrier together form the downstream supply chain of petroleum products, as shown in

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* Corresponding author.
E-mail address: qliao@cup.edu.cn (Q. Liao).

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Pipeline sharing: Potential capacity analysis of biofuel transportation through existing pipelines

Renfu Tu [a], Qi Liao [a,*], Ning Xu [a], Xuemei Wei [a], Yi Wang [a], Yongtu Liang [a], Haoran Zhang [b]

[a] Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing, 102249, PR China

[b] School of Urban Planning and Design, Peking University, 100871, PR China

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ABSTRACT

In response to resource depletion and tightening carbon emissions policies, the product oil is gradually being substituted by biofuels and faced with falling demand. A large number of studies have been done on the optimization of the biofuel supply chain, but few of them have considered the existing petroleum pipelines for policy reasons. Market-based reforms in the oil and gas industry have provided the possibility of pipeline sharing, whereby pipeline owners can use the remaining delivery capacity to transport other liquid fuels that are allowed into the pipeline, such as biofuels, thereby increasing pipeline benefits and reducing biofuel logistics costs. This paper develops a logistics optimization model considering multi-product pipeline scheduling from the perspective of biofuel suppliers and proposes a pipe-rail transportation mode to assess the optimization potential of logistics costs. Finally, this paper verifies the feasibility of the proposed approach using a logistics system in a region of China as a practical case study and conducts a sensitivity analysis on whether changes in the demand for product oil and biofuels affect the choice of pipeline opening location, concluding that there is no effect within a 4-fold increase in biofuel production and a 0.78-fold decrease in product oil demand.

1. Introduction

1.1. Background

With the promulgation of carbon emission policies in various countries, the use of traditional fossil fuels has received a certain degree of impact. At present, there is a consensus that the carbon emissions of using biofuels are less than those of traditional fossil fuels. Biofuels are highly similar to conventional product oil and can be a direct replacement for non-renewable primary energy sources without changing existing consumption patterns to achieve low carbon. The engines or other components of the corresponding consumption facilities would require only a relatively small portion of modifications. Several international oil companies are also involved in this business through retrofitting, acquisition, and new biorefineries.

On the one hand, under the pressure of carbon emission policy for some time to come, the consumption of traditional fuel is bound to decrease, and biofuels will gradually expand the market to play an alternative role in the future (Forsberg et al., 2021). In recent years, with the support of relevant policies, the rapid development of bioenergy accounts for about one-tenth of the total primary energy supply in the world today. Fig. 1 shows the annual production of global biofuels since 2016 (data from IEA), both ethanol and biodiesel show an overall upward trend, except for a decrease in production in 2020 due to COVID-19. On the other hand, the independence of oil and gas pipelines from oil company operations has become a sign of marketization in the industry, and pipeline-sharing services will put biofuel producers on par with other refinery companies as new participants compete for pipeline delivery capacity. As the demand for product oil decreases, the remaining capacity of multi-product pipelines will gradually expand, and to cope with the potential economic losses from this event, pipeline companies will have to actively seek alternatives to provide consignment services for them to maintain operations.

In the past, biofuel producers could only use rail or road transportation to sell their products to target markets. Because pipelines were monopolized by refinery companies, they had no right to use pipelines unless they built pipelines under their ownership. Providing shared services by opening up the transportation capacity of pipeline facilities, not only facilitates biofuel producers to save logistics costs through rational routing but also allows multi-product pipeline companies to

* Corresponding author.
E-mail address: qliao@cup.edu.cn (Q. Liao).

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Pipeline sharing: Boosting multi-product pipeline transport biofuels in the shift to low-carbon energy

Renfu Tu [a], Hao Zhang [a], Siyuan Xu [b], Guangtao Fu [a], Zhengbing Li [a], Qi Liao [a,**], Jian Du [a], Yongtu Liang [a,*]

[a] National Engineering Laboratory for Pipeline Safety, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing, 102249, PR China
[b] Petrochina Planning and Engineering Institute, CNPC, Zhixin West Road No.3, Haidian District, Beijing, 100086, PR China

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ABSTRACT

Under the dual pressures of oil depletion and low carbon transition, biofuels are considered effective alternatives for fuel oil due to their renewable nature and environmental friendliness. However, oil demand remains high, which indicates that biofuels and fuel oil will coexist for a long time to come. While pipelines offer an efficient means of transporting liquid fuels, the initial investment required is substantial. Therefore, this paper proposes a comprehensive framework that focuses on sharing already existing multi-product pipelines with biofuels, thus evaluating the pipeline remaining potential to transport biofuels. The core component of this framework is the evaluation method for determining the multi-product pipeline remaining capacity. We coupled fuel oil consignment contracts into the remaining capacity evaluation method and developed a model for evaluating the multi-product pipeline transport biofuels potential, aiming to maximize biofuels pipeline transport volume. The objective of this model is to optimize the transportation volume of biofuels through pipelines. Various constraints are taken into account, such as product batch movement, prohibited sequences, operational constraints, delivery time frames, and inventory levels. Moreover, this study evaluates and discusses the benefits of biofuels transportation capacity using eight real-world multi-product pipeline systems without impacting fuel oil consignment contracts. The findings indicate that pipelines are capable of transporting 49,849 m^3 of biofuels per week, increasing revenue by 1.78 million *CNY*. Simultaneously, the low energy consumption for pipeline transportation can lead to a weekly reduction of 34.6 tons in carbon emissions. The evaluation model anticipatively provides the ability to respond to future market developments.

1. Introduction

1.1. Background

The global fossil resources are facing depletion and extraction challenges, as evidenced by various indicators (Khan et al., 2016). In response to this, more than 140 economies worldwide have set different levels of carbon neutrality goals, implying that governments will further tighten their carbon emission regulations (Alola et al., 2023; Zhao et al., 2022). However, energy consumption is essential for social functioning, and thus energy systems are undergoing transformation to tackle these two issues. Besides the well-known wind and solar energy, other clean energy sources such as bioenergy, hydrogen, and geothermal energy are gaining more attention from governments (Iyke, 2024). Liquid biofuels, a form of bioenergy, play a vital role in the decarbonization of the transportation sector and pose a strong threat to conventional fuel oil alternatives (Gonçalves et al., 2023). Due to the renewable and eco-friendly characteristics of biomass production and processing, its development potential is high (Kongto et al., 2021; Reid et al., 2020). As shown in Fig. 1 (a), the International Energy Agency (IEA) statistics reveal that the global biofuel demand was 966 million barrels in 2021, an increase of 22 million barrels relative to 2019, and is projected to rise by 26% in 2026. In the meantime, oil demand has bounced back after the initial impact of the COVID-19 epidemic, and is anticipated to hit 37.96 billion barrels in 2026 (Khan et al., 2022; Raza and Siddiqui, 2024). Despite the huge gap between biofuels and oil in terms of total

* Corresponding author.
** Corresponding author.
E-mail addresses: qliao@cup.edu.cn (Q. Liao), liangyt21st@163.com (Y. Liang).

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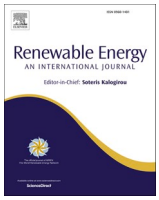

Pipeline sharing: Optimal design of downstream green ammonia supply systems integrating with multi-product pipelines

Renfu Tu [a], Chunying Liu [a], Qi Shao [a,b], Qi Liao [a,**], Rui Qiu [a,***], Yongtu Liang [a,*]

[a] Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing, 102249, PR China

[b] South China Branch, PipeChina Co., Ltd, Linjiang Avenue No.1, Tianhe District, Guangzhou City, Guangdong, 510623, PR China

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Supply system
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ABSTRACT

Green ammonia is a promising energy storage form with extremely high efficiency of hydrogen storage. Although the construction of green ammonia production facilities is rapidly progressing, there is still a lack of comprehensive consideration of the optimal design for supply systems. This paper prospectively explores a framework for the ammonia supply system under four scenarios considering multimodal transportation. Different mathematical models are developed, which incorporate special constraints such as pipe diameter, broken loops, etc., aiming at minimizing costs of transportation, construction and carbon treatment. In this framework, the economic, energy and environmental performance is evaluated to optimize the design of the supply system. The case study in China shows that different transportation modes can reduce economic costs by 60.93~77.45 %, energy consumption by 18.4 ~67.7 ktce, and carbon emissions by 23.3~60.7 kt per year. A further novel finding is that the simultaneous usage of new liquid ammonia pipelines and multi-product pipelines for supply systems proves to be the most effective transportation mode. Sensitivity analyses are also conducted on regional production capacity expansion, liquid ammonia pipeline planning, and multi-product pipeline utilization. The results confirm that the scheme is stable under certain conditions. Finally, some recommendations are provided for the development of green ammonia industry.

1. Introduction

1.1. Background

All over the globe, people are pursuing green lifestyles with low carbon and energy to cope with environmental deterioration. According to the United Nations Intergovernmental Panel on Climate Change (IPCC), carbon dioxide (CO_2) emissions need to decline by about 25 % from 2030 to 2010 and achieve net zero around 2070, limiting global warming to 2 °C [1]. By the end of 2022, 138 countries or regions have announced their "carbon neutrality" goals. Hydrogen energy has gained popularity as a potential clean energy. The "new energy power generation → water electrolysis → hydrogen combustion" scheme has drawn interest from all sides. However, a major challenge facing large-scale energy substitution is that hydrogen has only one-third of the energy density of natural gas, increasing difficulty of hydrogen storage and transportation. Currently, there are three main methods for hydrogen transportation: pipeline, high-pressure storage tank, and ultra-low temperature liquefaction. Among them, pipeline transportation faces the problem of hydrogen embrittlement due to small molecular diameter, low molecular weight and density, as well as its wide explosion limit range, which makes it more likely to leak and cause accidents than natural gas. High-pressure storage tanks rely on long-tube trailers as a mature technology for transportation, while its disadvantage lies in a pressure of 35~70 MPa usually needed and a low hydrogen storage density per unit volume. Additionally, ultra-high pressure also puts

Abbreviations: ASD model, the design model of ammonia supply system; ASCD model, the design model of ammonia supply system considering capacity planning; TK, truck; AP, ammonia pipeline; MP, multi-product pipeline; EAP, the average annual production; EAU, the average annual usage; EAPI, the EAP increase; EAPI-R, the EAP increase ratio; EAUI-R, the EAU increase ratio.

* Corresponding author.
** Corresponding author.
*** Corresponding author.
E-mail addresses: qliao@cup.edu.cn (Q. Liao), qiurui1996@126.com (R. Qiu), liangyt21st@163.com (Y. Liang).

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Pipeline sharing: Remaining capacity estimation of multiproduct pipelines

Renfu Tu[a], *Qi Liao*[a,*], *Liqiao Huang*[b], *Yingqi Jiao*[a], *Xuemei Wei*[a], *Yongtu Liang*[a]

[a] *China University of Petroleum-Beijing, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, Fuxue Road No.18, Changping District, Beijing 102249, PR China*

[b] *Graduate School of Engineering, University of Tokyo, 7-3-1 Hongo, Bunkyo-ku, Tokyo 113-8654, Japan*

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Multiproduct pipeline
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ABSTRACT

Accurate estimation of remaining capacity is crucial for pipeline companies to improve their service quality and economic benefits. Considering the delivery of multiple batches in long-distance pipelines, the remaining capacity is affected by technical capacity, delivery time, booked capacity, injection location, transmission and so on. Taking the maximum revenue as the objective, this paper develops a mathematical model for the multiproduct pipeline containing dual-purpose nodes to obtain its optimal remaining capacity at different injection nodes during different periods. The proposed model is validated by a real-world pipeline in China, and the sensitivity analysis is also conducted to identify the driving factors of the optimal remaining capacity. The comparison reveals that the tightness of delivery time has a major impact on the optimal remaining capacity, especially at downstream nodes of the pipeline. Finally, relevant suggestions are put forward based on the results to help pipeline operators make decisions.

1. Introduction

1.1. Background

Over the past few decades, multiproduct pipeline systems have become more complex, evolving from a single source and single sink to multiple sources and multiple sinks. Furthermore, to reduce pipeline construction investment and make full use of pipeline transportation capacity, different products are usually transported in multiple batches to consumer markets (MirHassani, 2008). Driven by the marketization of oil and gas industry, pipeline companies have decided to open up the capacity of pipeline facilities to provide third-party services (Ren et al., 2020; Yuan et al., 2020). Pipeline companies are only responsible for transporting products from sources to consumer markets on time and charging certain pipeline transportation fees (Kazemi and Szmerekovsky, 2015). Therefore, carriers must transport as many products as possible to increase their profitability. This indicates that traditional petrochemical companies no longer have absolute control over pipelines, and new liquid energy sources represented by biofuels can be smoothly entrusted to pipeline companies for transportation. Besides, long-term shippers and temporary shippers need to be considered when signing transportation contracts. Usually, long-term shippers have large shipments that take up most of the transport capacity, whereas temporary shippers have no stable shipment plan and are highly variable. To ensure basic pipeline revenues, long-term shippers have priority and their transportation contracts are usually determined in advance.

Abbreviations: MRC, The maximum remaining capacity of multiproduct pipeline; ORC, The optimal remaining capacityof multiproduct pipeline; RC, The remaining capacityof multiproduct pipeline

* Corresponding author.
E-mail address: qliao@cup.edu.cn (Q. Liao).

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Pipeline sharing: A supplementary strategy to enhance 3E performance of multi-product pipelines in China

Renfu Tu[a], *Guangtao Fu*[a], *Wenxi Da*[b], *Peng Li*[c], *Rui Qiu*[a,*], *Qi Liao*[a], *Yongtu Liang*[a,*]

[a] *Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China*

[b] *Marketing Department, China Oil & Gas Pipeline Network Corporation, Dongtucheng Road No. 5, Chaoyang District, Beijing 100013, PR China*

[c] *Central China Branch, PipeChina Co., Ltd, Qingnian Road No. 369, Jianghan District, Wuhan City, Hubei 430024, PR China*

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3E analysis

ABSTRACT

Single-rate pipeline prices have resulted in low competitive flexibility and have led to high costs and consumption in China's refined oil logistics system. This study aims to propose a framework for multi-product pipelines supplementary pricing strategy that creates a win-win situation for both shippers and pipeline carriers while quantifying economic, energy and environmental performance. Based on the objective of cost minimization, a lower limit constraint on pipeline transportation quantity is added, and a discount coefficient is introduced for pipeline prices, thus improving the transportation optimization model. Moreover, this paper develops an implementation approach for a supplementary pricing strategy that can ensure that the discounted price is not lower than the sum of cost and minimum profit. This framework usability is confirmed using a Chinese oil company as an example. The results show that the optimal scheme can increase pipeline revenue by ¥79.8 million while reduce shipper's logistics costs by ¥1.68 million during the practice cycle. Meanwhile, this work reduces energy consumption by 1.37 tce, CO_2 emission by 444 tons, SO_2 emission by 5.65 tons, and NO_X emission by 7.07 million tons for the logistics system. Compared with past studies, this study is more economical or more in line with market-oriented behavior.

1. Introduction

Following the announcement of China's "2030 carbon peak" goal means that fossil energy consumption will peak before 2030 (Shi et al., 2023). In response to the government's call, a large number of sustainable energy projects have emerged, such as wind power, photovoltaic power, hydrogen energy, biofuels, etc. Recently, affected by the new energy market, the demand growth of the traditional energy market has slowed down, and the storage and transportation capacity of refined oil energy facilities is oversupplied, especially the pipeline utilization rate is generally low (Liao et al., 2022a; Zhang et al., 2023). At the end of 2019, after the establishment of the National Oil and Gas Pipeline Network Group (referred to as PipeChina), multi-product pipelines play the role of carrier and

* Corresponding authors.
E-mail addresses: qiurui1996@126.com (R. Qiu), liangyt21st@163.com (Y. Liang).

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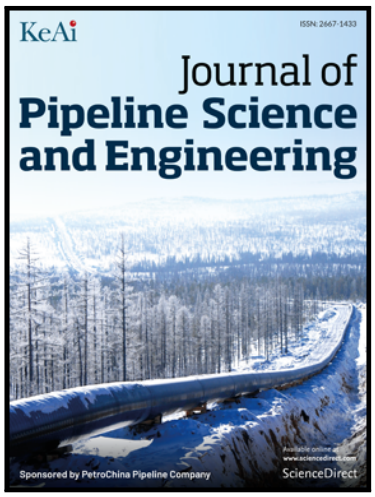

Machine learning application in batch scheduling for multi-product pipelines: A review

Renfu Tu , Hao Zhang , Bin Xu , Xiaoyin Huang , Yiyuan Che , Jian Du , Chang Wang , Rui Qiu , Yongtu Liang

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Low carbon transport for petroleum products: A pipeline pricing optimization perspective

Renfu Tu[1*], Rui Qiu[1,2], Yingqi Jiao[1], Qi Liao[1], Ning Xu[1], Jian Du[1], Yongtu Liang[1*]

1 Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China

2 School of Business, Society and Engineering, Mälardalen University, Västerås 721 23, Sweden
(Corresponding Author: turenfu@foxmail.com, liangyt21st@163.com)

ABSTRACT

The pipeline is a low-carbon and economical transportation mode in the downstream supply chain of petroleum products. At present, due to the lack of research on multi-product pipeline pricing strategies, the unreasonable pricing strategy has resulted in low utilization of pipeline capacity. This phenomenon causes the problem of high energy consumption of petroleum products transportation. Therefore, this paper aims to improve pipeline turnover and promote the low-carbon transportation market from the perspective of pipeline pricing optimization. We propose an integrated framework for multi-product pipelines, coupling the pricing strategy and logistics optimization model. This framework is used to simulate the pricing behavior of the pipeline carrier and the corresponding logistics planning behavior of the oil shipper. We simulate and display 10 pipeline pricing schemes for two regions in China with distinctly different logistics structures, and analyze the benefits of the new strategy in both economic and environmental terms. The results show that the well-performing schemes can increase pipeline carriers' revenue by 11.41 million CNY per month, significantly improve the competitive advantage of long-distance pipelines, and reduce carbon emissions by 272 tons. In turn, recommendations for policymakers are provided at four levels. In conclusion, the new pricing strategy will help reverse the disadvantageous situation of the pipeline in the competitive market and promote the petroleum product logistics industry to reduce carbon emissions.

Keywords: Multi-product pipeline, pricing strategy, low carbon, multi-scheme analysis, policy recommendations

NONMENCLATURE

Abbreviations	
MP-PIP	The multi-product pipeline
OS	Oil shipper
PC	Pipeline carrier
PipeChina	National Oil and Gas Pipeline Network Company
PPLOM	Petroleum product logistics optimization model

1. INTRODUCTION

In the context of energy conservation and emission reduction, although renewable energy sources such as biomass, hydrogen, and geothermal energy have made development in recent years, petroleum products are still the mainstay of primary energy consumption at present, accounting for nearly one-third of the total. And, such a situation will continue to maintain for a long time. To meet the market demand, the oil shipper usually chooses the transportation mode, including pipeline, rail, ship, and truck, based on the logistics cost as the judging indicator [1]. These modes are collectively referred to as carriers and compete with each other. The shipper and carrier together constitute the downstream supply chain of petroleum products. The pipeline has the characteristics of high volume and continuity in the transportation process, and is also the mode with the lowest carbon emissions [2]. Under the combined influence of unreasonable pipeline pricing and the lack of decarbonized transportation, the capacity utilization of multi-product pipelines is reduced, and cannot adapt to the new situation in the future.

Until 2020, in China, oil shippers have a monopoly in the market and pipelines are their subsidiary facilities. This also meant that shippers would give preference to the multi-product pipeline (MP-PIP) when choosing a transportation mode, as there were no transportation costs to be paid within the companies. However, in an attempt to improve infrastructure utilization and reduce carbon emissions, the Chinese government has undertaken a deepening reform of its oil and gas storage

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成品油一次物流优化与协调方法研究进展

涂仁福[1]　张雪琴[2]　邱睿[1]　许丹[3]　廖绮[1]　徐宁[1]　梁永图[1]
1. 中国石油大学(北京)机械与储运工程学院·城市油气输配技术北京市重点实验室·油气管道输送安全国家工程研究中心；
2. 国家管网集团科学技术研究总院分公司；3. 国家管网集团华中分公司

摘要：成品油一次物流优化与协调方法研究对提高运输效率、降低运营成本具有重要意义。基于中国成品油物流体系特征，从物流优化与协调两大视角对国内外研究现状、方法进行了分析与总结。在成品油一次物流优化研究方面，就战略层与战术层而言，现有研究仍无法有效解决资源分布不匹配、供需结构不匹配的矛盾；优化方法仍以数学规划法为主，少量研究引入启发式方法或机器学习算法以应对规模庞大的难题；利用线性加权法、ε-约束法等解决多目标规划问题，有效实现了多个主体的协同优化；采取随机规划、鲁棒优化改进模型，可解决不确定性优化问题。在成品油一次物流协调研究方面，中国仍停留在定性分析阶段。为适应复杂的物流系统结构，协调方法的研究从单一契约向组合契约发展，并扩充至企业内、企业间两方面。研究成果可为成品油一次物流优化与协调方法的进一步探索提供参考，对促进理论模型与实际业务融合、多主体集中决策模型开发、收益共享协调机制建立有积极作用。(图 2，表 1，参 68)

关键词：成品油；一次物流优化；协调方法；多目标规划；不确定性优化
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Research progress on optimization and coordination methods for primary distribution of refined oil

TU Renfu[1], ZHANG Xueqin[2], QIU Rui[1], XU Dan[3], LIAO Qi[1], XU Ning[1], LIANG Yongtu[1]
1. College of Mechanical and Transportation Engineering, China University of Petroleum (Beijing)//Beijing Key Laboratory of Urban Oil and Gas Distribution Technology//National Engineering Research Center for Pipeline Safety; 2. PipeChina Institute of Science and Technology; 3. PipeChina Central China Company

Abstract: Efficient methods for optimizing and coordinating the primary distribution of petroleum products are crucial for enhancing transportation efficiency and reducing operational costs. This paper provides an analysis and summary of current domestic and international research and methodologies, focusing on the distribution system for refined oil in China, from two perspectives: optimization and coordination. Regarding strategic optimization of the primary distribution of refined oil, problems exist such as uneven resource distribution and unbalanced supply and demand, necessitating further research. Current optimization methods primarily rely on mathematical programming, with some studies incorporating heuristic methods or machine learning algorithms to address problems that come in large-scale. Approaches such as linear weighted sum and ε-constraint methods have demonstrated success in addressing multi-objective programming problems and facilitating enhanced collaboration among multiple operating entities along the primary distribution. Additionally, incorporating stochastic planning and robust optimization techniques can mitigate the impact of uncertainty. In terms of coordinating the primary distribution of refined oil, China is in a qualitative analysis phase. Research on coordination methods has transitioned from single contracts to multiple contracts, encompassing operations within and between enterprises. The findings of this study serve as a reference for further exploration of optimization and coordination methods in the primary distribution of refined oil. They can also facilitate the practical application of theoretical models, the development of multi-agent centralized decision-making mechanisms, and the establishment of profit-sharing coordination mechanisms. (2 Figures, 1 Table, 68 References)

Key words: refined oil, primary distribution optimization, coordination methods, multi-objective planning, optimization under uncertainty

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考虑运行平稳性的成品油管道调度方法

涂仁福[1]，徐宁[1*]，刘静[2]，黄晓茵[2]，廖绮[1]，梁永图[1]

1 中国石油大学(北京)油气管道输送安全国家工程实验室/石油工程教育部重点实验室/城市油气输配技术北京市重点实验室，北京 102249
2 国家石油天然气管网集团有限公司华南分公司，广州 510620
* 通信作者，xn11235@163.com

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摘要　成品油管道调度计划是管道完成输送任务的重要运行依据，除了要保障按时、按量地将油品输送到沿线站场外，还应尽量维持管道的平稳运行，提高管道调度整体服务质量。目前，对于采用集中分输工艺的成品油管道，已有国内外调度计划制定研究尚无法将管道运行平稳性因素纳入考虑范围。而且，部分文献证实，若仅以水力约束的方式控制管道流量，会引起管段流量在某一范围内波动频繁的问题，进而会削弱管道运行安全性，致使研究成果脱离工程实际，鲜有落地应用。本文针对单源多汇的成品油管道，在现有研究的基础上，引入了流量波动系数、操作次数上限等适应于集中分输工艺的关键参数，并基于离散时间表达方法提出优化策略。此后，对站场分输工艺、管段运行流量、批次跟踪、预估下载量、下载偏差以及流量偏差等约束进行考虑，并以下载偏差和运行流量波动最小为目标函数，结合现场在相邻站场操作时间节点上改变本站下载流量的人工编制计划经验，构建了管道调度计划自动编制模型，实现了考虑运行平稳性的成品油管道调度计划的快速制定。所建模型应用于我国包含 9 座站场的某实际成品油管道，在 2 分钟内能够准确求解出该管道月调度计划；调度计划充分考虑了该管道全分输工艺、一次性下载要求，满足通用性要求；求解结果在运行过程中的正常流量波动占比 90%，油品需求偏差控制在 −3.23%~3.65% 以内，具有较强的工程实用性。本研究成果对于采取集中分输工艺的成品油管道运行企业，在制定调度计划时具有一定的指导意义。

关键词　成品油管道；调度计划；运行平稳性；集中分输；MILP 模型

A scheduling method for products pipeline considering operation stability

TU Renfu[1], XU Ning[1], LIU Jing[2], HUANG Xiaoyin[2], LIAO Qi[1], LIANG Yongtu[1]

1 National Engineering Laboratory for Pipeline Safety, Ministry of Education Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Beijing 102249, China
2 PipeChina South China Company, Guangzhou 510620, China

Abstract　The pipeline scheduling plan is an important operation basis for the multi-product pipeline to complete its transportation tasks. In addition to ensuring the delivery of products to the stations along the route on time and in the right quantity, it should also maintain the stability of the pipeline as much as possible and improve the overall service quality of the pipeline scheduling. At present, for the multi-product pipeline with centralized distribution process, the domestic and foreign studies

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Auction design for capacity allocation in the petroleum pipeline under fair opening

Qi Liao [a,**], Renfu Tu [a], Wan Zhang [b], Bohong Wang [c,*], Yongtu Liang [a], Haoran Zhang [d]

[a] National Engineering Laboratory for Pipeline Safety/Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China
[b] Pipechina South China Branch, Guangzhou, 510620, PR China
[c] National & Local Joint Engineering Research Center of Harbor Oil & Gas Storage and Transportation Technology/Zhejiang Key Laboratory of Petrochemical Environmental Pollution Control, Zhejiang Ocean University, No.1 Haida South Road, Zhoushan 316022, PR China
[d] School of Urban Planning and Design, Peking University, 100871, PR China

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ABSTRACT

Auction is a dominant way to allocate transport capacities for the aim of profit, fairness, and transparency. Previous related work focuses on the natural gas pipeline and cannot be applied to the petroleum pipeline for its special technique of transporting multiple batches. This paper designs a bi-level model for capacity auction of the petroleum pipeline, which facilitates fair competition and free flow of petroleum products in market. The upper-level model simulates the decision-making process of pipeline company, and the lower-level one determines if shippers bid up prices for capacities somewhere. A real-world pipeline is taken as a case to explore the impact of different auction designs and proration on capacity allocation. New shippers obtain all the nominations of 18,700 m^3 by auction but lost the capacities of 3,523 m^3 by proration. Compared to proration, auction leads to a profit growth of 181,545 *CNY* and 150,019 *CNY* to pipeline company and new shippers respectively but a decrease of 4,586 *CNY* to regular shippers. Different orders of offering price lead to different outcomes regarding fairness and revenue. Letting new shippers offer price first is suggested as a base to design auction for capacity allocation since it generates a reduction of 0.2% to regular shippers but an increase of over 12% to others.

1. Introduction and motivation

As a kind of economic and efficient carrier, the pipeline is the key link that connects the upstream and downstream petroleum products. Typically, petroleum pipelines are operated in three ways, including market- oriented mode, state monopoly mode, and enterprise monopoly mode [1]. Because the monopoly pattern limits the competition in the energy market, the pipeline companies in Europe and America have implemented market-oriented liberalization reform early. For a liberalized petroleum pipeline, its transport capacities are taken as the commodities sold to interested petroleum companies on a long- and short-term basis, which provides convenient conditions for effective connection and fair competition among upstream and downstream market players [2]. In contrast, giant petroleum companies in China constructed many pipelines and dominated decision-making procedures for transport capacity. Although this enterprise monopoly mode is conducive to integration management inside enterprises, it leads to duplicated construction and inefficient utilization of infrastructure. Learned from the successful experience of Europe and America, China carried on deepening liberalization reform in petroleum industries, separating pipeline transportation from production and sales business. Since 2019 the pipelines previously owned by petroleum companies have been handed over to a start-up company called China Oil & Gas Pipeline Network Corporation [3].

From the point of development, liberalization reform is gradually preferred by most countries worldwide as it facilitates competition and the free flow of petroleum resources in the market [4]. Defining distinct "shipper" and transport capacity trading rules enables the fair and efficient use of pipeline infrastructure and increases market participation. Specifically, transport capacities are the volume of petroleum products that can be conveyed from a source to a destination through a pipeline at any given time [5]. Besides, every pipeline is constructed

* Corresponding author.
** Corresponding author.
E-mail addresses: qliao@cup.edu.cn (Q. Liao), wangbh@zjou.edu.cn (B. Wang).

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Pipeline pricing and logistics planning in the refined product supply chain based on fair profit distribution

Rui Qiu [a,b], Qi Liao [a,*], Renfu Tu [a], Yingqi Jiao [a], An Yang [c], Zhichao Guo [d], Yongtu Liang [a,*]

[a] National Engineering Laboratory for Pipeline Safety/Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No. 18, Changping District, Beijing 102249, PR China
[b] School of Business, Society and Engineering, Mälardalen University, Västerås 721 23, Sweden
[c] Marketing Department, China Oil & Gas Pipeline Network Corporation, Dongtucheng Road No. 5, Chaoyang District, Beijing 100013, PR China
[d] Sinopec Engineering Incorporation, No.21, Anhui North Li'an Garden, Chaoyang District, Beijing 100101, PR China

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Refined products
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ABSTRACT

The pipeline is an economical, safe and environmentally friendly way to deliver refined products, but the uncoordinated decisions of the pipeline carrier and the oil shipper can lead to low pipeline turnover and high cross-regional logistics costs. This paper intends to remedy this problem through pipeline pricing and logistics planning. First, a framework is designed to coordinate the operational decisions of the pipeline carrier and the oil shipper. Then, a bi-level programming model is customized to characterize the decentralized decision-making process of both stakeholders, including pipeline pricing and logistics planning. The upper-level model maximizes the transportation revenue of the pipeline carrier, and the lower-level model minimizes the logistics cost of the oil shipper. The model constraints supply and demand capacity, transportation capacity, transportation network structure and mass balance. Next, to realize the coordination of both stakeholders, a negotiation mechanism based on fair profit distribution is customized. Ultimately, the method is tested on a large-scale logistics system of refined products in China. The results reveal that: (1) the pipeline turnover is increased by 127 million ton-kilometers, (2) the economic benefits of both stakeholders are maximized with an increase of 13 million CNY, (3) a fairer profit distribution is provided compared with the centralized decision-making. It is proved that the proposed method has a satisfactory coordination effect on the pricing of the pipeline carrier and the logistics planning of the oil shipper.

1. Introduction

1.1. Background

The Statistical Review of World Energy 2021 claims that oil and natural gas account for more than 55 % of primary energy consumption in 2020, with oil accounting for 31.2 % and natural gas accounting for 24.7 % (BP, 2021). Fossil fuels continue to play an important role in the global energy system despite a substantial increase in countries' ambitions for decarbonization (Alnaqbi, Dweiri, & Chaabane, 2022). Nowadays, petroleum companies are forced to seek optimization from the overall supply chain to maintain viability and competitive advantage (Sahebi, Nickel, & Ashayeri, 2014). In the real world, each company acts as an independent entity, making operational decisions driven by individual interests regardless of the reactions of other entities. This will lead to inconsistent decision-making among different entities, and even cause conflicts and contradictions, reducing the overall efficiency of the supply chain. More and more managers and researchers raise awareness of inter-firm cooperation (Alnaqbi et al., 2022). However, due to the lack of a rational coordination mechanism, the cooperation cannot be carried out smoothly in practice.

This paper focuses on logistics optimization and coordination in the refined product supply chain. Refined products are the outputs of a petroleum refinery, which are also known as petroleum products, oil products and finished products. A typical refinery processes crude oil into a variety of high-value light products, such as gasoline, jet fuel and diesel. The pipeline is regarded as an economic, safe and environmentally friendly way to deliver refined products over long distances. However, uncoordinated decisions by oil shippers and pipeline carriers may lead to low pipeline turnover and high cross-regional logistics costs

* Corresponding authors.
E-mail addresses: qliao@cup.edu.cn (Q. Liao), liangyt21st@163.com (Y. Liang).

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Review article

Innovations of carbon-neutral petroleum pipeline: A review

Qi Liao [a,*], Yongtu Liang [a], Renfu Tu [a], Liqiao Huang [a], Jianqin Zheng [a], Guotao Wang [a], Haoran Zhang [b]

[a] Beijing Key Laboratory of Urban oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No. 18, Changping District, Beijing 102249, PR China
[b] Center for Spatial Information Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan

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ABSTRACT

As one of the major energy-intensive industries, petroleum pipelines are facing with huge pressure from carbon-neutral policies. Conforming to green development, the traditional pipeline industry should advance intelligent transition and take the reduction of carbon emissions as a strategic priority. Focusing on effective and low-carbon operation of petroleum pipelines, this review elaborates the challenges and solutions covering four aspects, including the system reform, intelligent monitoring and control, intelligent operation management and integrating with the clean energy transmission network. The related literature and industrial practices have been systematically reviewed to conclude with general guidelines and examples for competitiveness enhancement, energy saving and emission reduction. Future directions are also proposed on the basis of the research gaps.

Contents

* Corresponding author.
E-mail address: qliao@cup.edu.cn (Q. Liao).

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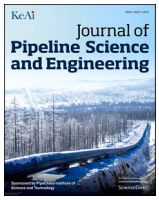

Evaluation and optimization of pipeline pricing strategies on oil product logistics in China

Rui Qiu, Renfu Tu, Xuemei Wei, Hao Zhang, Mengda Gao, Qi Liao *, Yongtu Liang *

National Engineering Laboratory for Pipeline Safety/Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, China

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ABSTRACT

In the early stage of pipeline network reform in China, it is still controversial to formulate an appropriate pipeline freight pricing strategy. Focusing on this issue, this paper puts forward an integrated framework to analyze the impact of different pipeline pricing strategies on the economic-environmental benefits of China's oil product logistics. A basic mathematical programming model is developed to simulate the planning of nationwide oil product logistics at the tactical level. On this basis, five pipeline pricing strategies are customized for comparative analysis, including pricing as usual (PAU), pricing by benchmarking railway (PBR), pricing by discounting on excess (PDE), tiered pricing by mileage (TPM), and tiered pricing by volume (TPV). Then, the basic logistics optimization model is upgraded accordingly. The real-world case study in China in 2019 is carried out in detail and the results demonstrate that (i) Except for TPM, the other pricing strategies can achieve coordination between oil shippers and pipeline carriers compared with PAU; (ii) Ranked by economic performance as follows: PDE >PBT>TPV> PAU>TPM; (iii) As for PDE, it also helps to reduce carbon emissions by 0.5% annually. The proposed method can be a theoretical guide for oil and gas logistics managers and decision-makers within and beyond China.

1. Introduction

The energy development trend around the world is evolving from high-carbon to low-carbon and then to carbon-free (Wei et al., 2022). According to the Statistical Review of World Energy 2022 (BP, 2022), the share of oil and gas in primary energy in the year 2021 accounts for 31.0% and 24.4%. It can be seen that in this energy transition process, oil and gas will still play an important role in primary energy for a long time (Zhou et al., 2019). As the largest energy consumer and producer, China is actively promoting the reform of the oil and gas system to meet the country's increasing energy demand and respond to the call for sustainable energy development (Dong et al., 2018). On December 9, 2019, a new state-owned China Oil & Gas Pipeline Network Corporation (PipeChina) was officially established, which is a key step in China's ongoing reform of the oil and gas system (Yuan et al., 2020). PipeChina integrated the pipeline assets of three major state-owned energy giants, that is China Petrochemical Corp (Sinopec), China National Petroleum Corp (PetroChina), and China National Offshore Oil Corp (CNOOC), which marks the separation of the large-scale oil and gas pipeline network from the above enterprises.

However, in this early stage of pipeline network reform, it is still controversial to formulate an appropriate pipeline pricing strategy that suits China's national conditions and stimulates the fair participation of oil and gas shippers. Several Opinions on Deepening the Reform of the Petroleum and Natural Gas System (The Central People's Government of the People's Republic of China, 2017) pointed out the reform direction for oil and gas pipeline pricing strategy in China. However, there is no specific guidance on freight pricing for oil product pipelines, and the pricing method of oil product pipeline follows that of natural gas pipeline, that is, the freight rate is uniformly calculated according to the method of "permitted cost plus reasonable income". Compared with natural gas pipeline, oil product pipeline faces fierce competition from other transportation modes. For oil product pipelines, few quantitative studies have been carried out and the current pricing strategy performs poorly in economic-environmental benefits of oil product logistics, and there is room for further optimization. The difficulties of this issue lie in reconciling strategic pricing and tactical operational plans, in reconciling the interests of oil shippers and oil carriers, and in considering a diverse and flexible distribution process for oil products. Under this background, the intention of this research is as follows:

* Corresponding authors.
E-mail addresses: qliao_cup@outlook.com (Q. Liao), liangyt21st@163.com (Y. Liang).

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成品油管道智能化批次调度研究现状及思考*

廖绮[1]　涂仁福[1]　徐宁[1]　段志刚[2]　梁永图[1]

[1]中国石油大学（北京）油气管道输送安全国家工程实验室·石油工程教育部重点实验室·城市油气输配技术北京市重点实验室

[2]中油国际管道公司

摘要：智能化批次调度是智能油气管道建设的一项重要内容，其主要任务是在管道安全运行基础上，基于历史运行数据，采用实时算法制定出满足现场需求的调度计划。为此，以梳理成品油管道批次调度方法的发展历程为出发点，从信息和决策两个方面分析成品油管道批次调度的技术支持，归纳出智能化批次调度内容，包括趋势预测、主动调度和实时算法；以趋势预测和主动调度为重点，并结合实时算法，对成品油管道智能化批次调度的研究现状进行论述，依次介绍油品托运量预测方法、管道动态调度方法、分解算法及自学习求解算法；最后，对成品油管道智能化批次调度发展进行总结并作出展望，以期能够为其发展提供参考。

关键词：成品油管道；智能批次调度；趋势预测；主动调度；实时算法

Research Status and Discussion on Intelligent Batch Scheduling of Product Oil Pipelines

LIAO Qi[1], TU Renfu[1], XU Ning[1], DUAN Zhigang[2], LIANG Yongtu[1]

[1]National Engineering Laboratory for Oil and Gas Pipeline Transportation Safety · Ministry of Education Key Laboratory of Petroleum Engineering · Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum (Beijing)

[2]China Petroleum International Pipeline Co., Ltd.

Abstract: Intelligent batch scheduling is an important element in the construction of intelligent oil and gas pipelines. Its main task is to develop a scheduling plan based on historical operation data, using real-time algorithms to meet field requirements on the basis of safe pipeline operation. This paper takes the development history of batch scheduling methods for product oil pipelines as the starting point, analyzes technical support for batch scheduling of product oil pipelines in terms of information and decision making, and summarizes the contents of intelligent batch scheduling, including trend prediction, active scheduling, and real-time algorithm. Then, focusing on trend prediction and active scheduling, and combined with real-time algorithms, the research status of intelligent batch scheduling for product oil pipelines is explained, and the oil consignment prediction method, pipeline dynamic scheduling method, decomposition algorithm, and self-learning solution algorithm are introduced in turn. Finally, the development of intelligent batch scheduling for product oil pipeline is summarized, and further considerations are made, so as to provide a reference for its development.

Keywords: product oil pipeline; intelligent batch scheduling; trend prediction; active scheduling; real-time algorithm

为应对成品油管道批次调度问题，从工程实际出发，以特定管道为研究对象开发了人机交互形式的计划编制软件。随着油气长距离输送管道向“互联互通”方向发展，管道系统结构日趋复杂，托运方对管输服务质量要求也不断提升。管道企业若想保证管道安全、高效运行，必须改变人机交互编制

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市场化改革背景下成品油管网运营关键技术及展望

梁永图[1]　廖绮[1]　邱睿[1]　涂仁福[1]　邵奇[1,2]　沈亮[1,3]
1. 中国石油大学(北京)机械与储运工程学院·城市油气输配技术北京市重点实验室·油气管道输送安全国家工程研究中心；
2. 国家管网集团华南分公司；3. 国家管网集团油气调控中心

摘要：随着国家石油天然气管网集团的成立，成品油管网逐步形成“全国一张网”的管理模式和“X+1+X”的市场体系，运营市场化、用户多元化等发展趋势给成品油管网市场化运营带来巨大变革和挑战。围绕成品油管网市场化运营的关键技术，总结了管网系统布局与资源配置优化、输送价格与输送路径协同优化、输送能力评估与分配机制 3 方面的核心问题，综述了国内外相关技术的研究进展并指明了发展方向。未来，成品油管网改革将持续深化，更健全的运营机制能更好地促进管网公平开放和节能减排。建议从清洁能源灵活输送、综合立体交通多网融合、公共信息服务平台搭建 3 方面深度发展，进一步完善管网运营机制，提升管网能源集约输送和公平服务能力，从而保障国家能源供应安全。(图 2，参 49)

关键词：成品油管网；运营机制；市场化；公平开放；资源配置；节能减排
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Key operation technologies and prospects to product oil pipeline network under market-oriented reform

LIANG Yongtu[1], LIAO Qi[1], QIU Rui[1], TU Renfu[1], SHAO Qi[1,2], SHEN Liang[1,3]
1. College of Mechanical and Transportation Engineering, China University of Petroleum (Beijing)//Beijing Key Laboratory of Urban Oil and Gas Distribution Technology//National Engineering Research Center for Pipeline Safety; 2. PipeChina South China Company;
3. PipeChina Oil & Gas Control Center

Abstract: With the establishment of China Oil & Gas Pipeline Network Corporation, the management mode of “a unified national network” and the “X+1+X” market system are gradually developed for the product oil pipeline network. Meanwhile, the development trend of operation marketization and user diversification brings about great changes and challenges to the market-oriented operation of the product oil pipeline network. Herein, the core issues concerning the layout and resource allocation optimization of the product oil pipeline network system, the collaborative optimization of transportation price and route, and the assessment & allocation mechanism of transportation capacity were summarized focusing on the key technologies for market-oriented operation of product oil pipeline network. Moreover, the progress of research on the relevant technologies at home and abroad was overviewed, and the development direction was pointed out. In the future, the reformation of the product oil pipeline network will be deepened continuously, and the sounder operation mechanism will better promote the open-access, energy saving and carbon emission reduction of the pipeline network. Hence, deep development is recommended for the flexible transportation of clean energy, multi-type network integration of comprehensive three-dimensional transportation and establishment of public information service platform, so as to further improve the operation mechanism of pipeline network, enhance the intensive energy transportation and fair service capability of pipeline network, and thus ensure the nationwide energy supply security. (2 Figures, 49 References)

Key words: product oil pipeline network, operation mechanism, marketization, open-access, resource allocation, energy saving and emission reduction

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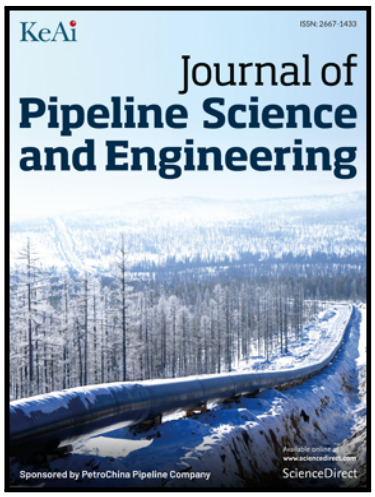

A decision-making framework for scheduling of multiproduct pipeline under the fair opening

Zhengbing Li , Qi Liao , Bin Xu , Renfu Tu , Lichao Li , Youfa Wang , Yongtu Liang

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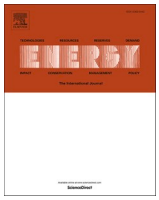

A knowledge-enhanced graph-based temporal-spatial network for natural gas consumption prediction

Jian Du [a,1], Jianqin Zheng [a,*,1], Yongtu Liang [a], Bohong Wang [b], Jiří Jaromír Klemeš [c], Xinyi Lu [a], Renfu Tu [a], Qi Liao [a], Ning Xu [a], Yuheng Xia [a]

[a] National Engineering Laboratory for Pipeline Safety/ MOE Key Laboratory of Petroleum Engineering/ Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No. 18, Changping District, Beijing, 102249, PR China

[b] National & Local Joint Engineering Research Center of Harbor Oil & Gas Storage and Transportation Technology/Zhejiang Key Laboratory of Petrochemical Environmental Pollution Control, School of Petrochemical Engineering and Environment, Zhejiang Ocean University, No. 1 Haida South Road, Zhoushan, 316022, PR China

[c] Sustainable Process Integration Laboratory – SPIL, NETME Centre, Faculty of Mechanical Engineering, Brno University of Technology - VUT BRNO, Technická 2896/2, 616 69, Brno, Czech Republic

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Natural gas consumption
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Domain knowledge
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ABSTRACT

The accurate prediction of natural gas consumption plays a central role in long-distance pipeline system production and transportation planning, and it becomes even more important during present political situation. The existing prediction methods for natural gas consumption barely consider spatial correlations and domain knowledge. As a result, the study proposes a novel deep learning prediction method (knowledge-enhanced graph-based temporal-spatial network, abbreviated to KE-GB-TSN) for predicting natural gas consumption by integrating domain knowledge into association graph construction and capturing temporal-spatial features via a hybrid deep learning network. This study first applies the domain knowledge that analyses the operation technique of the natural gas pipeline network and combines the historical data to establish an association graph. Subsequently, the historical data and association graphs are input to a hybrid deep learning network to predict natural gas consumption. The comparative experiments are conducted by taking real-world cases of natural gas consumption as examples. At last, a sensitivity analysis of different components combination is carried out to exhibit the significance of each component in the proposed model. The results prove that the proposed model is capable of achieving more accurate and efficient predicted results compared to the advanced models, such as decision trees and gated recurrent units. The Mean Absolute Relative Errors and Root Mean Squared Relative Errors gotten by the proposed model are less than 0.11 and 0.14 in all cases, indicating an improvement compared to previous works. Additionally, it is also suggested that domain knowledge and temporal-spatial correlations are crucial for the excellent performance of the prediction model.

1. Introduction

1.1. Background

With the development of the global economy, energy consumption has shown a rapid growth rate in the past decades [1]. According to the BP statistical review of world energy 2021 [2], the highest top 10 energy consumer countries have consumed primary energy exceeding 10 EJ [3]. As depicted in Fig. 1, the primary energy consumption of the highest top 10 energy consumer countries increased from 212 EJ in 1990 to 330 EJ in 2020, with an increase of 56%. Notably, the energy consumption of China accounts for 26.11% of the world's energy consumption. In China, traditional primary energy resources, such as coal, supply the considerable majority of energy consumption of most heating and generating electricity system [4], which has inevitably caused the intensification of air pollution [5]. While natural gas, as a cleaner and safe energy source, can satisfy the demands of daily heating and generating electricity in cities, it has aroused increasingly wide attention [6]. The average growth rate of primary energy consumption in the past 20 years in China is shown in Fig. 2. Natural gas consumption has risen from 0.89 EJ in 1990 to 11.9 EJ in 2020 [2]. Proving that natural gas has become one of

* Corresponding author.
E-mail address: 2018214074@student.cup.edu.cn (J. Zheng).
[1] Both authors contributed equally to this work and should be considered co-first authors

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Deeppipe: An intelligent framework for predicting mixed oil concentration in multi-product pipeline

Jian Du [a], Jianqin Zheng [b], Yongtu Liang [a,**], Yuheng Xia [a], Bohong Wang [c], Qi Shao [d], Qi Liao [a], Renfu Tu [a], Bin Xu [a], Ning Xu [a,e,*]

[a] National Engineering Laboratory for Pipeline Safety/ MOE Key Laboratory of Petroleum Engineering/ Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No. 18, Changping District, Beijing, 102249, PR China
[b] China Petroleum Planning and Engineering Institute, Xinxi Road No 3, Haidian District, Beijing, 100083, PR China
[c] National & Local Joint Engineering Research Center of Harbor Oil & Gas Storage and Transportation Technology/Zhejiang Key Laboratory of Petrochemical Environmental Pollution Control, School of Petrochemical Engineering and Environment, Zhejiang Ocean University, No. 1 Haida South Road, Zhoushan, 316022, PR China
[d] PipeChina South China Company, Linjiang Avenue No 1, Tianhe District, Guangzhou, 510623, PR China
[e] China University of Petroleum-Beijing at Karamay, Xinjiang, 834000, PR China

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Multi-product pipeline
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ABSTRACT

Accurately predicting mixed oil concentration distribution exerts a core effect on the optimization of pipelines and the quality of oil. Due to the neglect of mechanism features, high-dimensional complex feature correlations, and insufficient feature information on small batch data, the current methods cannot predict mixed oil concentration accurately. This work proposes a hybrid intelligent framework to provide an accurate and effective monitoring tool for mixed oil concentration of multi-product pipelines. In the proposed framework, the development mechanism of mixed oil is analyzed to select and reconstruct holistic features to explore the influencing mechanism of mixed oil concentration. Then, a parameterization and nonlinear transformation module is designed to acquire the accurate and concise representation of mixed oil concentration, thus decreasing the complexity of feature space and promoting the approximating ability of the prediction model. Eventually, a novel virtual samples generation module is established to obtain high-quality samples of mixed oil concentration, aiming to extract more comprehensive correlations of feature variables and improve the prediction performance. Cases from real-world multi-product pipelines suggest more accurate prediction results of mixed oil concentration compared to other advanced methods, with RMSE and R^2 being 0.0500 and 0.9688. Furthermore, it is also proved that acquiring more holistic and accurate feature variables of mixed oil development and fully exploring comprehensive correlations between feature variables are crucial for the performance enhancement of the prediction model.

1. Introduction

1.1. Background

As an inseparable and strategic energy resource [1], refined oil accounts for 12.9% of China's energy consumption [2]. Among all the transportation approaches, the pipeline is the most efficient and economical method to transport refined oil from refineries to delivery stations over a long distance [3]. To manage the multi-product pipeline networks more efficient and encourage marketing competition [4], the PipeChina corporation was established in 2019, the multi-product pipelines turn to marker-oriented [5]. Considering that constructing a pipeline is expensive, the multi-product pipelines adopt sequential transportation, that is, delivering different refined products to multiple depots by sharing a pipeline, to improve the economy [6].

During the process of multi-batch transportation, a mixed oil segment will inevitably form [7]. Due to the formation of mixed oil, the pure products are contaminated by each other, causing quality declines

* Corresponding author. National Engineering Laboratory for Pipeline Safety/ MOE Key Laboratory of Petroleum Engineering/ Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No. 18, Changping District, Beijing, 102249, PR China.
** Corresponding author.
E-mail addresses: liangyt21st@163.com (Y. Liang), xn11235@cup.edu.cn (N. Xu).

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Scheduling-based method for estimating remaining capacity of oil product pipeline under the fair opening

Liqiao Huang[a], Qi Liao[a,*], Renfu Tu[a], Yongtu Liang[a], Haoran Zhang[b]

[a] Beijing Key Laboratory of Urban oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China

[b] Center for Spatial Information Science, The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8563, Japan

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ABSTRACT

The remaining capacity of oil product pipeline network is the most basic information required for third-party service of oil storage and transportation, determining the opening ability of pipeline facilities. This paper fully discusses the remaining capacity of long-distance oil pipelines and develops an estimation model for unidirectional pipelines with single injection combining its characteristics of multi-batch transmission. The model contains different download constraints from the perspective of pipeline companies and third-party users with separate information required by both sides, so that the company is able to allocate the remaining capacity reasonably and the third-party users have access to the consignment information they need. Based on this model, a method is proposed for optimally negotiating with long-term shippers when the remaining capacity cannot meet the demand of third-party users. Data from a real pipeline is used to verify this model, the law of remaining capacity is analyzed, and relevant suggestions for future research are put forward.

1. Introduction

1.1. Background

As the process of industrialization and urbanization continues to advance worldwide, the growth rate of energy demand continues to accelerate (Jiang and Lin, 2012; Li et al., 2020). The production and consumption of oil and gas have surpassed all previous periods due to their roles as important primary energy sources, with the consumption of major oil products exceeded 3.91 $\times$ 10^6 kt. Oil products are widely utilized in vehicles, factories, and households, the stable supply of which is of great importance to the development of the economy and the daily life of residents.

Among various approaches to deliver oil products, pipeline transportation has taken a dominant position due to its advantages of low price, large throughput, and small environmental impact (Gao and Wang, 2014). For a long time, the oil and gas pipe networks in many regions had been monopolized by large state-owned oil companies (Dong et al., 2018), facing the problems of single service subject, large regional differences, low interoperability, and openness, etc. With the rise of economic level and global trade, many countries have opened up the right to import and use oil, making local and foreign refineries show a strong impact and competitiveness and become an important part of the refining industry. The comparison between monopoly-operated pipelines and market-oriented pipelines is shown in Fig. 1. Therefore, pipe network reform came into the public scene, advocating fair and open supervision of oil and gas pipeline networks and auxiliary facilities, and pipeline corporations are now independent of state-owned enterprises to provide services to all users equally (National Development and Reform Commission, 2019).

With the establishment of individual pipe companies, large oil and gas pipe networks are now capable of opening up their market transparently, providing access to third-party customers who have the demand to deliver products. The fair and open reform of the pipe network has laid a good foundation for improving the utilization efficiency of oil and gas pipeline facilities and promoted competition in the oil and gas market (Chen et al., 2020). The competition of petroleum enterprises in the same industry will bring benign results, such as the competition of production technology, which is conducive to improving the quality of products and reducing costs. In this case, it is pipe companies' duty to ensure the safe and stable supply of oil and gas resources, and undertake the responsibilities of operation and dispatching, regularly disclosing the remaining capacity to users and developing a reasonable trading mechanism (Yuan et al., 2020). Therefore, the determination of remaining capacity is the core link in the course of opening to third-party users.

* Corresponding author.
E-mail address: qliao@cup.edu.cn (Q. Liao).

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Multimodal Transportation Optimization of Refined Oil Logistics Considering Daily Scheduling: Case from China

Zhiwei Wei[1]; Mengda Gao[2]; Renfu Tu[3]; Jiawen Chang[4]; Xu Zhang[5]; Meng Du[6]; XiaoXin Yang[7]; and Wu He[8]

Abstract: With the rapid development of global industrialization, the consumption of refined oil is at a high level. The scale of refined oil transportation is huge. For refined oil sales enterprises, determining a method for making reasonable transportation plans and reducing transportation cost has become an important means to improve competitiveness. The current method of developing a primary logistics plan does not consider the characteristics of various transportation modes, which can lead to an increase in overall costs. The logistics system in this case has multiple transportation modes, including road, rail, and pipeline. In addition, a multiproduct pipeline has multiple injection points. For such a complex system, this work unifies the time dimension of continuous transportation by pipeline and discrete transportation by rail and road based on the idea of multimodal transportation. This paper couples a pipeline scheduling submodel and a logistics optimization submodel to construct a daily scheduling model for refined oil which is close to the actual operation in the field. This model was validated using a refined oil logistics system in China, and the results show that the optimized logistics solution decreased total transportation costs by 14.5% compared with the actual cost. This model can serve as a guide for actual operations. **DOI: 10.1061/JPSEA2.PSENG-1590.**

Author keywords: Refined oil; Logistics optimization; Multimodal transportation; Multiproduct pipeline; Daily scheduling.

[1]Senior Engineer, Laboratory of Oil and Gas Business Chain Optimization, PetroChina Planning and Engineering Institute, China National Petroleum Corporation (CNPC), Zhixin West Rd. No. 3, Haidian District, Beijing 100086, PR China. Email: weizhiwei@petrochina.com.cn

[2]Master's Student, National Engineering Laboratory for Pipeline Safety, Ministry of Education (MOE) Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China Univ. of Petroleum (Beijing), Fuxue Rd. No. 18, Changping District, Beijing 102249, PR China. Email: 1433696193@qq.com

[3]Ph.D. Student, National Engineering Laboratory for Pipeline Safety, Ministry of Education (MOE) Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China Univ. of Petroleum (Beijing), Fuxue Rd. No. 18, Changping District, Beijing 102249, PR China (corresponding author). ORCID: https://orcid.org/0000-0002-5657-4084. Email: turenfu@foxmail.com

[4]Senior Engineer, Laboratory of Oil and Gas Business Chain Optimization, PetrChina Planning and Engineering Institute, China National Petroleum Corporation (CNPC), Zhixin West Rd. No. 3, Haidian District, Beijing 100086, PR China. Email: changjiawen_wl@petrochina.com.cn

[5]Senior Engineer, PetroChina Marketing Company, China National Petroleum Corporation (CNPC), Ande Rd. No. 16, Dongcheng District, Beijing 100086, PR China. Email: zhangxu2015@petrochina.com.cn

[6]Senior Engineer, PetrCchina Marketing Company, China National Petroleum Corporation (CNPC), Ande Rd. No. 16, Dongcheng District, Beijing 100086, PR China. Email: dmxs@petrochina.com.cn

[7]Senior Engineer, PetroChina Marketing Company, China National Petroleum Corporation (CNPC), Ande Rd. No. 16, Dongcheng District, Beijing 100086, PR China. Email: xjyxx@petrochina.com.cn

[8]Senior Engineer, PetroChina Marketing Company, China National Petroleum Corporation (CNPC), Ande Rd. No. 16, Dongcheng District, Beijing 100086, PR China. Email: wuhe@petrochina.com.cn

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Introduction

Background

Refined oil logistics is an organic system combining storage, loading and unloading, transportation, and information processing of gasoline, diesel, and other products in refined oil sales enterprises (Lima et al. 2021; Wang et al. 2021a). In China, refined oil logistics is divided into primary logistics transportation and secondary logistics distribution, mainly according to the different management subjects (Qiu et al. 2022; Wang et al. 2019). At present, China's primary logistics system of refined oil still has problems such as imperfect management system, geographical imbalance in production and sales, unreasonable transportation structure, low pipeline operating load, and poor collaboration ability of regional sales system (Tu et al. 2023b). After the impact of new energy on refined oil, the profit margin of refined oil sales enterprises also gradually becomes smaller. As a result, refined oil sales companies have turned their attention to logistics optimization in order to improve competitiveness.

China's refined oil production sites are located mainly in the northeast and northwest regions, where refined oil consumption is relatively low. In contrast, the economically developed regions of East China, South China and Central China, which produce less refined oil, are the consumption centers (Jiao et al. 2022). The difference between the production and consumption areas forms the logistics pattern of long-distance transportation of refined oil. Due to the different types of refined oil and the wide distribution range, strong transportation and distribution capabilities are required. To ensure the smooth transportation of refined oil, a strong logistics system for refined oil is required (Lima et al. 2021). In China, four main modes of transportation are used for transporting refined oil: pipeline, railroad, waterway, and road. Each of the four modes has its own advantages and disadvantages. Pipeline transportation has

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Integration optimization of production and transportation of refined oil: A case study from China

Yingqi Jiao[a], Rui Qiu[a,b,*], Yongtu Liang[a,**], Qi Liao[a], Renfu Tu[a], Xintong Wei[a], Haoran Zhang[b,c]

[a] National Engineering Laboratory for Pipeline Safety/Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China

[b] School of Business, Society and Engineering, Mälardalen University, Västerås 721 23, Sweden

[c] Center for Spatial Information Science, The University of Tokyo, 5–1-5 Kashiwanoha, Kashiwa-shi, Chiba 277–8568, Japan

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ABSTRACT

The logistics management of refined oil under a separation of production and transportation leads to high logistics costs and a mismatch between the supply and demand sides. This paper intends to develop a general framework to assess the impact of the integration of the production and transportation in terms of economic, environmental, and energy benefits. Firstly, this paper proposes a tactical-level mathematical model for optimizing the integration of production and transportation of refined oil to minimize the total cost. In the model, several factors, such as level of market demand, production capacity limits, transportation modes, and transportation capacity, are taken into consideration. Then, the energy, economy, and environment analysis method are applied to assess the impact of the integration on the field of refined oil logistics. Four scenarios are set up and a comparative analysis is carried out in detail in China. The optimal resource allocation scheme and production adjustment scheme for each scenario are obtained. The results show that after the integration, the logistics cost is reduced by 6.8 %– 11 %, the greenhouse gas emission is reduced by 7.3 %– 17.7 %, and the energy consumption per unit turnover is reduced by 4.4 %– 7.4 %. This proves that the integration of production and transportation guided by the proposed method performs positive economic, environmental, and energy benefits. Finally, policy implications are provided.

1. Introduction

The consumption growth rate of petroleum products has been significantly reduced due to the impact of the COVID-19 epidemic and the global energy transition. At the same time, oil refining capacity continues to grow. In 2020, China's oil refining capacity has reached 900 million tons per year, making it the world's second-largest oil refining country. The oversupply of refined oil is becoming more and more serious. In addition, for refined oil sales companies, the competitive

* Corresponding author at: National Engineering Laboratory for Pipeline Safety/Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing, Fuxue Road No.18, Changping District, Beijing 102249, PR China.
** Corresponding author.
E-mail addresses: qiurui1996@126.com (R. Qiu), liangyt21st@163.com (Y. Liang).

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ASCE

Scheduling of Straight Multiproduct Pipelines Considering the Contamination Control

Yulei Xu[1]; Bin Xu[2]; Jinzhou Song[3]; Zhengbing Li[4]; Yi Guo[5]; Renfu Tu[6]; Yongtu Liang[7]; Hongyang Gao[8]; and Hengyu Wang[9]

Abstract: Batch interface tracking and contamination control are the key technologies for the operation and management of multiproduct pipelines. Existing studies only focused on sequence arrangement or segment stoppage to control the generated contamination, and few considered this problem comprehensively and systematically. This study fully considers the contamination control process and develops a scheduling model for straight pipelines to minimize the cost of contamination loss caused by segment stoppage. The objective of this model is to minimize the restart cost of idle segments and the penalty cost due to improper interface placement during segment stoppage. Three types of constraints for contamination control are proposed, namely operation control, flow rate control, and stoppage control. Three real-world multiproduct pipelines are used as examples to validate the proposed method. Compared with the actual operation schemes, the method helps to reduce the number of stoppage operations by 20%–50%, and decrease the probability that the interface is improperly located by 40%–67%. Therefore, this work can reduce the cost of contamination treatment and bring greater benefits to pipeline operators.
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Author keywords: Multiproduct pipeline; Scheduling; Contamination loss; Contamination control; Stoppage condition.

[1]Senior Engineer, Pipechina Oil and Gas Pipeline Control Center, Dongtucheng Rd. No. 5, Chaoyang District, Beijing 100007, PR China. Email: xuyl@pipechina.com.cn

[2]Master's Student, National Engineering Laboratory for Pipeline Safety, Ministry of Education Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China Univ. of Petroleum (Beijing), Fuxue Rd. No. 18, Changping District, Beijing 102249, PR China. Email: 1563432417@qq.com

[3]Senior Engineer, Pipechina Oil and Gas Pipeline Control Center, Dongtucheng Rd. No. 5, Chaoyang District, Beijing 100007, PR China. Email: 1625083239@qq.com

[4]Ph.D. Student, National Engineering Laboratory for Pipeline Safety, Ministry of Education Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China Univ. of Petroleum (Beijing), Fuxue Rd. No. 18, Changping District, Beijing 102249, PR China. Email: cup_lzb@163.com

[5]Senior Engineer, Pipechina Oil and Gas Pipeline Control Center, Dongtucheng Rd. No. 5, Chaoyang District, Beijing 100007, PR China. Email: 13959389502@163.com

[6]Ph.D. Student, National Engineering Laboratory for Pipeline Safety, Ministry of Education Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China Univ. of Petroleum (Beijing), Fuxue Rd. No. 18, Changping District, Beijing 102249, PR China. Email: turenfu@foxmail.com

[7]Professor, National Engineering Laboratory for Pipeline Safety, Ministry of Education Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China Univ. of Petroleum (Beijing), Fuxue Rd. No. 18, Changping District, Beijing 102249, PR China (corresponding author). Email: yongtuliang@126.com

[8]Senior Engineer, Pipechina Oil and Gas Pipeline Control Center, Dongtucheng Rd. No. 5, Chaoyang District, Beijing 100007, PR China. Email: 2842343301@qq.com

[9]Engineer, Pipechina Oil and Gas Pipeline Control Center, Dongtucheng Rd. No. 5, Chaoyang District, Beijing 100007, PR China. Email: 965679058@qq.com

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Introduction

Background

Multiproduct pipelines are the bridge connecting upstream refineries with downstream markets, along which there are initial station, injection stations, delivery stations, pump stations, and related equipment (Harjunkoski et al. 2014; Magatão et al. 2004). Batches of different refined products and grades are pumped back-to-back in the same line without any separation device (Liao et al. 2018b). Due to the difference in physical properties, the interface between two adjacent batches of different products (also called a trans-mix) generates a contaminated volume influenced by convection and turbulent diffusion. Therefore, it is important to track the position of the interface in the line and control the volume of the interface between such consecutive batches during pipeline operation (Mostafaei et al. 2016; Zhang et al. 2017).

The volume of the interface will gradually develop with products migrating in the line, and it may also increase when stoppage operations occur. When the flow pattern is laminar flow, the convective transfer caused by the velocity difference of the product on the cross section is the main factor of contamination development. Diffusion transfer has an impact on contamination generation when the flow pattern is turbulent flow, but the volume is greatly reduced compared with laminar flow. Existing experiment have shown that the volume of the interface decreases rapidly with the increase of Reynolds number when the flow pattern is turbulent flow. Therefore, it is necessary to control the segment flow rate to make the flow pattern in a turbulent state during pipeline operation. When the pipeline is idle, the density difference between adjacent batches in the line can lead to a great increase in the interface volume. In this case, the size of the contamination between products will increase dramatically when a high-density product is located above a low-density product in steep pipe sections.

Current studies on the scheduling of multiproduct pipelines have focused on controlling the interface volume generated as products migrate through the pipeline. The following two approaches

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成品油管铁联运物流优化

许少新[1] 涂仁福[2] 徐宁[2] 李舒丹[1] 黄丽燕[1] 梁永图[2]

1. 中国石化销售股份有限公司华南分公司；2. 中国石油大学（北京）·油气管道输送安全国家工程实验室·石油工程教育部重点实验室·城市油气输配技术北京市重点实验室

摘要：成品油物流优化研究大多关注油库库存优化，决策中通常缺乏对运输方式的合理选择以及批次输送对管输方案的影响。基于此，在满足油库各油品需求的前提下，以总体运输费用最小为目标函数，考虑油库需求、库容、运输能力等约束，构建了成品油物流优化模型；以管道沿线各分输站实际分输油品量与需求量偏差之和最小为目标函数，考虑批次跟踪、批次分输、节点流量等约束，构建了成品油管道调度优化模型。将上述两个模型耦合成考虑管道、铁路联合运输的成品油物流优化模型，迭代求解物流方案与管道调度计划，最终得到满足管道运输能力的成品油物流方案。将所构建模型应用于某区域成品油物流方案的制定，优化结果相对于传统编制方案管输量得到提升，铁路运输里程相应缩短，整体物流成本降低了 4.18%，对于成品油销售企业制定合理的物流计划具有参考作用。（图 5，表 8，参 21）

关键词：成品油；一次物流；管道调度；管铁联运

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Optimization of refined oil logistics considering pipeline-rail combined transportation

XU Shaoxin[1], TU Renfu[2], XU Ning[2], LI Shudan[1], HUANG Liyan[1], LIANG Yongtu[2]

1. SINOPEC Marketing South China Company; 2. China University of Petroleum (Beijing)//National Engineering Laboratory for Pipeline Safety//MOE Key Laboratory of Petroleum Engineering//Beijing Key Laboratory of Urban Oil and Gas Distribution Technology

Abstract: The optimization of oil depot inventory is focused in most of the previous researches on the optimization of refined oil logistics, but the reasonable choice of transportation mode and the influence of batch transportation on pipeline transport plan are not considered during decision-making. On this basis, an optimization model of refined oil logistics was constructed under the premise of satisfying the demand of oil products at the oil depot, establishing the objective function of minimizing overall transportation cost and considering the constraints of oil depot demand, storage capacity and transportation capacity. Meanwhile, a pipeline scheduling optimization model was also constructed by setting up the objective function of minimizing the sum of deviations between the actual delivery volume of oils and the demand of the delivery stations along the pipeline, with consideration to the constraints of batch tracking, batch delivery and node flow. Finally, a refined oil logistics plan satisfying the transportation capacity of pipeline was obtained by coupling the above two models into an optimization model of refined oil logistics, considering the pipeline-rail combined transportation, and iteratively solving the logistics plan and pipeline scheduling plan. Specifically, the constructed model was applied to the formulation of a regional logistics plan for refined oil. The optimization results show that the pipeline transportation volume is improved, the mileage of railway transportation is shortened, and the overall logistics cost is reduced by 4.18% compared with the site plan. The research results have some guiding significance for the refined oil marketing enterprises to develop a reasonable logistics plan. (5 Figures, 8 Tables, 21 References)

Key words: refined oil, primary logistics, pipeline scheduling, pipeline-rail combined transportation

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美国成品油管道管输能力分配机制及其启示

王果涛[1,2]，廖绮[1,2]，梁永图[1,2]，张浩然[3]，倪玮隆[1,2]，涂仁福[1,2]

（1.中国石油大学（北京）机械与储运工程学院；2.中国石油大学（北京）城市油气输配技术北京市重点实验室；3.日本东京大学空间信息科学研究中心）

摘　要：以用户分类模式、长期托运方及新托运方管输能力分配机制为着眼点，以美国巴克艾伙伴公司和科洛尼尔管道公司为例，详细剖析美国成品油管道的管输能力分配机制。中国成品油管道的公平开放尚处于初期阶段，在深化成品油管道市场化进程中，首先应保证油气设施信息的公开和透明，制订标准的公平开放制度，而后根据中国油气市场行业实际情况逐步细化开放机制。借鉴美国成品油管道管输能力分配机制，对于中国成品油管输能力分配机制，建议：制订全国统一的成品油管网准入制度；搭建统一的管输能力交易平台；考虑地区差异，在统一按历史运输量进行用户分类的模式下，不同地区可根据具体情况对用户分类的具体阈值进行一定程度调整；在管道发生拥塞时，针对长期托运方采取基于历史运输量按比例进行分配的方式；新托运方的管输能力分配采取抽签的方式；监管体系透明化。

关键词：油气管网；成品油管道；公平开放；管输能力；分配机制

The allocation mechanism of U.S. multiproduct oil pipeline transmission capacity and the enlightenments

WANG Guotao[1,2], LIAO Qi[1,2], LIANG Yongtu[1,2], ZHANG Haoran[3], NI Weilong[1,2], TU Renfu[1,2]

(1. School of Mechanical and Storage and Transportation Engineering, China University of Petroleum-Beijing; 2. National Engineering Laboratory for Pipeline Safety, Ministry of Education Key Laboratory of Petroleum Engineering, Beijing Key Laboratory of Urban Oil and Gas Distribution Technology, China University of Petroleum-Beijing; 3. Center for Spatial Information Science, the University of Tokyo)

Abstract：This study focuses on the user classification model, the long-term shipper, and the new shipper's pipeline transportation capacity allocation mechanism, explores the detailed multiproduct pipeline transportation capacity allocation mechanism in the United States by taking Buckeye Partners and Colonial Pipelines as examples. The fair opening of China's refined oil pipeline is still in the early stage and China should ensure the openness and transparency of oil and gas facilities information, formulate the standards of a fair and open system, and then refine the opening mechanism according to the actual situation in the process of deepening the marketization of refined oil pipelines. Drawing on the allocation mechanism of the pipeline capacity of the refined oil pipeline in the United States, combined with the actual situation of marketization of the Chinese oil and gas industry, it is suggested for the allocation mechanism of Chinese pipeline capacity in the future formulating a unified national access system for the refined oil pipeline network, building a unified trading platform for the ability, adjusting the specific threshold of user classification for different regions according to the specific situation under the unified mode of user classification according to historical traffic volume by considering regional differences. A prorated allocation based on historical traffic could be used for long-term shippers when there is existing of pipeline congestion, the allocation of the new shipper's capacity for transmission shall be by lottery, and the transparent regulatory system should be kept.

Key words：oil and gas pipeline network; refined oil pipeline; fair opening; transportation capacity; allocation mechanism

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