Optimization of Oil Pipe Arrangement with Conditions of Compensation and Different Unit Cost

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Abstract. It is usually to see that oil pipelines usually pass through suburbs areas and urban areas. And it is necessary to pay compensation to private properties owners when the pipelines occupy some private properties. Meanwhile, the unit costs of different section pipelines are different because the production capacities of refineries are different. Hence, the optimal scheme of oil pipe arrangement is very complicated in such case. Hence, the oil pipe arrangement scheme with conditions of compensation and different unit cost of the oil pipelines is proposed to study the complicated case. The simulation shows that model can easily obtain the optimal scheme to construct oil pipe when given different compensation and different unit cost of the oil pipelines.

Introduction

An oilfield company plans to build two refineries on the one side of railway, and built a station in the railway to transport oil products as shown in Fig.1. The problems are complicated in some case. For instance, Moura A V reported that Brazilian Petrobras faces a very difficult over-constrained planning challenge: how to operate a large pipeline network in order to adequately transport oil derivatives and biofuels from refineries to local markets. [1]. Wei, D. and Lei, T. converted the problem of optimization gas or oil pipelines arrangement into Fermat problem of "Two points and One Line" [2]. In fact, Oil pipelines usually pass through suburbs areas and urban areas. Wei, D. and Lei, T. firstly study the simplest problem that the oil company does not need to pay the private properties owners when the pipeline occupies some private properties [3]. OAPSU-Model and OAPDU-Model is proposed to study the oil pipe arrangement scheme without compensation to private properties owners. However, it is usually to see that the oil company should pay the private properties owners when the pipeline occupies some private properties. Hence, it is quite necessary to study more complicated conditions that the company should pay compensation to private properties owners in urban or suburbs areas. Then the oil pipe arrangement scheme with compensation conditions (OPASCC-Model) is proposed Wei, D. and Lei, T [4]. Although OPASCC-Model can solve the problem better, it didn't consider that different section oil pipe has different unit cost because the production capacities of refineries are different. Hence, it is necessary to study oil pipe arrangement scheme with more complicated conditions including compensation in urban areas and different unit cost of different oil pipe section.

Notations

k_1 : The unit cost of pipelines AP

k_2 : The unit cost of pipelines PF

k_3 : the unit cost of pipelines BF

k_4 :The unit cost of pipelines PE

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k_3: The unit cost of pipelines in urban areas

F: The total cost of pipelines

a: The vertical distance from refinery A to the railway

b: The vertical distance from refinery B to the railway

l: The horizontal distance between refinery A and B

p: The Fermat point

Methodologies

Oil Pipe Arrangement Scheme without Compensation to private properties owners

The positions of A, B refineries and railway can be shown in Fig.1. Oil pipelines usually pass through suburbs areas and urban areas. The simplest problem is the oil company does not need to pay the private properties owners when the pipeline occupies some private properties. It is easy to see from Fig.1 that PE is the shared pipeline. AP and PB are non–shared pipeline. Wei, D. and Lei , T. proposed OAPSU-Model and OAPDU-Model to study the oil pipe arrangement scheme without compensation to private properties owners. OAPSU-Model is assumed that the unit cost of shared or non - shared pipeline is the same. OAPDU-Model is assumed that the unit cost of shared or non - shared pipeline different is different. They found that OAPSU-Model is the special case of OAPDU-Model when $k_1 = k_2$. Tab.1 shows the lowest cost of whole pipelines $F_{\min}$ with OAPSU-Model. Tab.2 shows the lowest cost of whole pipelines $F_{\min}$ with OAPDU-Model.

The relations of l, a and b	$0 < l < \sqrt{3}(b-a)$	$\sqrt{3}(b-a) \le l \le \sqrt{3}(b+a)$	$l > \sqrt{3}(a+b)$
$F_{\min}$ OAPSU-Model	$[a + \sqrt{l^2 + (a-b)^2}]k$	$\dfrac{a+b+\sqrt{3}l}{2} \cdot k$	$\sqrt{l^2 + (a-b)^2}$

Tab.1 $F_{\min}$ with OAPSU-Model

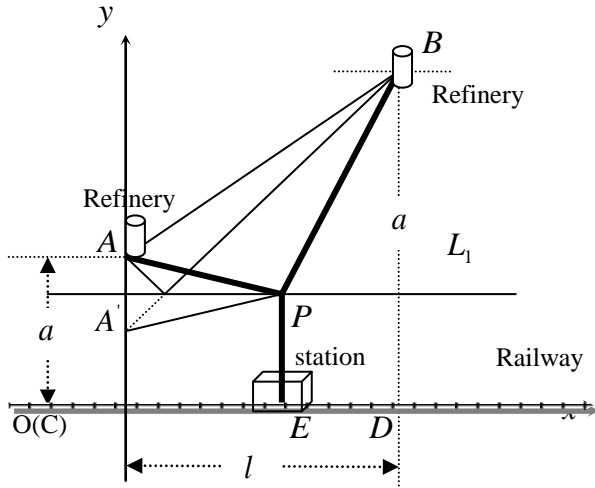| The relations of l, a and b	$0 \le l \le \dfrac{(b-a)\sqrt{4k_1^2 - k_2^2}}{k_2}$	$\dfrac{(b-a)\sqrt{4k_1^2 - k_2^2}}{k_2} \le l \le \dfrac{(a+b)\sqrt{4k_1^2 - k_2^2}}{k_2}$	$l > \dfrac{\sqrt{4k_1^2 - k_2^2}}{k_1}(a+b)$
$F_{\min}$ OAPDU-Model	$k_1\sqrt{l^2 + (a-b)^2} + k_2 a$	$\dfrac{1}{2}(a+b)k_2 + \dfrac{\sqrt{4k_1^2 - k_2^2}}{2}l$	$k_1\sqrt{l^2 + (a+b)^2}$

Tab.2 $F_{\min}$ with OAPDU-Model

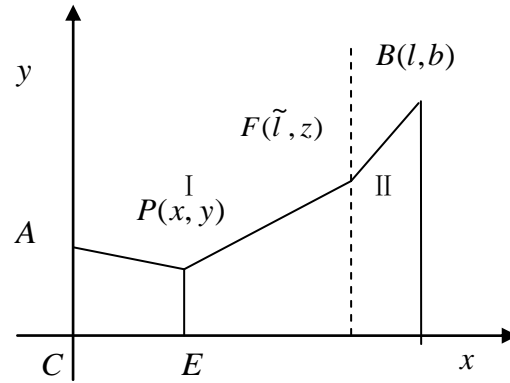Fig.1 The arrangement of pipelines without compensation to private properties owners

Fig.2 The arrangement of pipelines with compensation to private properties owners

Oil Pipe Arrangement Scheme with Compensation to private properties owners

Oil Pipe with the same unit cost

Oil pipelines usually pass through suburbs areas and urban areas. Fig.2 shows that area I is the suburbs and area II is the urban. There are many private properties in urban areas. However, OAPSU-Model and OAPDU-Model assumed that the oil company does not need to pay the private properties owners when the pipeline occupies some private properties. It is usually to see that the oil company should pay the private properties owners when the pipeline occupies some private properties. Hence, it is quite necessary to study more complicated conditions that the company should pay compensation to private properties owners in urban or suburbs areas. Wei, D. and Lei, T. proposed the oil pipe arrangement scheme with compensation conditions (OPASCC-Model) as following to study the complicated problem.

$$\min F = k_1\sqrt{\tilde{l}^{\,2} + (2y-a-z)^2} + k_1 y + k_3\sqrt{5^2 + (b-z)^2} \tag{1}$$

s.t $0 \le y \le a$

$0 \le z \le 8$

The OPASCC-Model shows that compensation cost can affect the pipeline arrangement very sensitively. The model can obtain the optimal scheme to construct oil pipe when given different compensation cost. The OPASCC-Model shows that pipe arrangement in Fig.1 change to AP, PE, PF, FB shown in Fig.2. However, OPASCC-Model also assumed that the unit cost of pipeline AP, PE, PF, FB is the same.

Different section oil pipe with unit cost

In fact, the unit cost of pipeline AP, PE, PF, FB is different because the production capacity of A and B refineries are different. Then OPASCC-Model is not suitable to obtain the optimal scheme for arranging the oil pipe in such case. So it is necessary to study oil pipe arrangement scheme with more complicated conditions including compensation in urban areas and different unit cost of different oil pipe section. k_1 is denoted as the unit cost of AP. k_2 is denoted as the unit cost of PF. k_3 is denoted as the unit cost of BF. k_4 is denoted as the unit cost of PE. Therefore, oil pipe

arrangement scheme with conditions compensation and different unit cost (OPASCCDUC-Model)can be described as following

$$\min F = k_1 \sqrt{x^2 + (y-a)^2} + k_2 \sqrt{(15-x) + (y-z)^2} + k_3 \sqrt{5^2 + (8-z)^2} + k_4 y \tag{2}$$

$$s.t. \quad 0 \le x \le 15$$
$$0 \le y \le a$$
$$0 \le z \le 8$$

When $k_1 = 5.6, k_2 = 6, k_3 = 27, k_4 = 7.2$, it is easy to obtain the optimal solution by the method of multiple-variable calculus [5] that $x = 6.7424, y = 0.1327, z = 7.2659, F = 249.4422$. Similarly, it is not difficult to calculate the optimal solution of OPASCCDUC-Model by MATLAB program [6] when given three different compensation cost shown in Tab.3.

	The unit cost of pipeline	The Fermat point p		Point	The total cost
	k_3	y	x	F	F_{min}
Firm 1	27	0.1327	6.7424	7.2659	249.4422
Firm 2	30	0.1667	6.6952	7.3406	264.586
Firm 3	26	0.1195	6.7606	7.2370	244.3865

Tab.3 The optimal pipeline arrangement with different compensation cost and different unit cost

Note: k_3 is the unit cost of Pipelines in urban areas+ compensation cost

According to Table 3, it can design three options oil pipeline arrangement plan as following:

1) **Plan I:** In the case of Firm 1, the Fermat point is $P(6.7424, 0.1327)$. The turning point is $F(15, 7.2659)$. The station is located at $E(6.7424, 0)$. The pipelines of $PA = 8.3157$ km, $PE = 0.1327$ km, $PF = 10.9119$ km, $FB = 5.0536$ km. The total cost of pipelines is 2,494,422 RMB.

2) **Plan II:** In the case of Firm 2, the Fermat point is $P(6.6952, 0.1667)$. The turning point is $F(15, 7.3406)$. The station is located at $E(6.6952, 0)$. The pipelines of $PA = 8.2575$ km, $PE = 0.1667$ km, $PF = 10.9743$ km, $FB = 5.0433$ km. The total cost of pipelines is 2,645,862 RMB.

3) **Plan III:** In the case of Firm 3, the Fermat point is $P(6.7606, 0.1195)$. The turning point is $F(15, 7.2370)$. The station is located at $E(6.7606, 0)$. The pipelines of $PA = 8.3382$ km, $PE = 0.1195$ km, $PF = 10.8879$ km, $FB = 5.0579$ km. The total cost of pipelines is 2,645,862 RMB.

Conclusions

This paper assumes that the company should pay compensation to private properties owners in urban or suburbs areas when the pipeline occupies some private properties. It is also assumed that the unit cost of different section pipeline AP, PE, PF, FB is different because the production capacities of refineries are different. Then the oil pipe arrangement scheme with conditions of compensation and different unit cost (OPASCCDUC-Model) is proposed to study the complicated case. Finally, the simulation of OPASCCDUC-Model gives three different optimal plans to construct oil pipe when given three different compensation cost.

Acknowledgements

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