# 海底管道起吊时最佳吊点位置的选择

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帅　健：**海底管道起吊时最佳吊点位置的选择**，油气储运，1996(11)15，31～32。

**摘　要**　针对海洋管道的施工情况，提出了确定管中应力和吊点位置选择的两个问题。根据材料强度，认为起吊引起的管中应力不宜超过许用应力。为此，分析管子起吊的受力和变形，是选择海洋管道最佳起吊位置的保证。利用材料力学方法对此问题进行了分析。在应力分析中，研究了集中载荷单独作用、均布载荷单独作用和端口位移条件等问题，并给出了相应计算公式；对于最佳吊点位置，除给出计算公式外，还以曲线形式给出了管中最大应力、悬空长度和提升力随管端提升高度的变化。

**主题词**　水下管道　安装　位置　选择　最优化　计算

海底管道在安装期间，有时候需要将管子吊出海面进行焊接[1]。当管道从海底吊出海面进行焊接时，吊点位置的选择是重要的。一方面，从安装角度讲，管子吊出海面之后，要保证顺利对接，端口不能倾斜；另一方面，从强度上来考虑，起吊诱发的管中应力不宜超过许用应力。因此，要求分析管子的受力和变形。

图1表示管子在海底起吊时的典型状态。管子在海水中的重量为$q$，吊点在B点，它距离管端为$a$，需要将管子端口吊起的高度为$\Delta$，这一高度应高海面，需要确定吊点B吊起的高度$\Delta_B$及所需要的提升力$P$。起吊后，一段长度的管子要离开海底，设悬于海中的管子长度为$l$，A点是管子与海床的接触起点，A点和B点的距离为$b$，在接触段上，存在弯矩为零的边界条件。

为方便起见，分别考虑均布载荷和集中载荷单独作用时的挠度和转角方程[2]，选取如图1所示的坐标系。

（1）集中载荷单独作用时：

当$x=b$时的挠度和转角方程分别为：

$$y_P|_{x=b}=Pb^3/(3EJ) \quad (1)$$

$$\theta_P|_{x=b}=Pb^2/(2EJ) \quad (2)$$

当$x=l$时的挠度和转角方程分别为：

$$y_P|_{x=l}=\frac{Pb^3}{6EJ}\left(3\frac{l}{b}-1\right) \quad (3)$$

$$\theta_P|_{x=l}=Pb^2/(2EJ) \quad (4)$$

（2）均布载荷单独作用时：

当$x=b$时的挠度为：

$$y_q|_{x=b}=\frac{ql^4}{24EJ}\left[3-4\frac{b}{l}+\left(\frac{b}{l}\right)^4\right] \quad (5)$$

当$x=l$时的挠度和转角方程分别为：

$$y_q|_{x=l}=ql^4/(8EJ) \quad (6)$$

$$\theta_q|_{x=l}=ql^3/(6EJ) \quad (7)$$

在端口，应满足的位移条件为：

$$y=y_P-y_q=\Delta \quad (8)$$

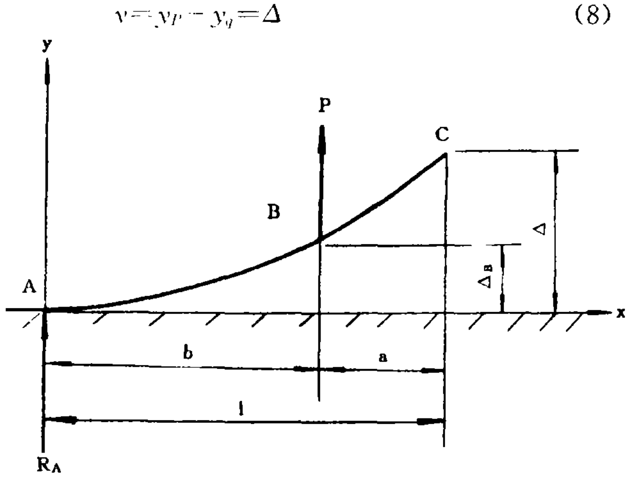


图1　起吊时管子的变形状态

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将式(3)和式(6)代入，得：

$$\frac{Pb^3}{6EJ}\left(3\frac{l}{b}-1\right)-\frac{ql^4}{8EJ}=\Delta \qquad (9)$$

在接触段上应满足弯矩为零的边界条件，因此，有静力平衡方程：

$$Pb=ql^2/2 \qquad (10)$$

将式(10)代入式(9)，得到确定 $l$ 的方程：

$$l^2(l^2-2al-2a^2)=24EJ\Delta/q \qquad (11)$$

有多种方法得到此式的数值解，一旦求出以后，可以得到管中的弯矩。

AB 段($0\leqslant x\leqslant b$)：

$$M(x)=-\frac{1}{2}qx^2+\frac{1}{2}qlx\left(1-\frac{a}{b}\right) \qquad (12a)$$

BC 段($b\leqslant x\leqslant l$)：

$$M(x)=-q(l-x)^2/2 \qquad (12b)$$

最大弯矩为：

$$M_{max}=\frac{1}{8}ql^2\left(1-\frac{a}{b}\right)^2 \qquad (13)$$

相应的应力为：

$$\sigma_{max}=M_{max}/W \qquad (14)$$

B 点应提起的高度为：

$$\Delta_B=\frac{ql^2}{24EJ}\left\{4b^2-l^2\left[3-4\frac{b}{l}+\left(\frac{b}{l}\right)^4\right]\right\} \qquad (15)$$

管端口 C 点的转角为：

$$\theta_C=\frac{Pb^2}{2EJ}-\frac{ql^2}{6EJ}=\frac{ql^2}{12EJ}(3b-2l) \qquad (16)$$

为了便于安装，管端口的转角应为零，以保持管端口竖直和其它管子对接。

令 $$\theta_c=\frac{ql^2}{12EJ}(3b-2l)=0 \qquad (17)$$

得： $$b=\frac{2}{3}l \qquad (18)$$

则： $$a=l/3 \qquad (19)$$

将上式代入式(11)得：

$$l^4=216EJ\Delta/q \qquad (20)$$

其余各量得：

$$P=3ql/4 \qquad (21)$$

$$\Delta_B=\frac{101}{1944}\frac{ql^4}{EJ} \qquad (22)$$

$$M_{max}=ql^2/32 \qquad (23)$$

管中最大应力、悬空段长度和提升力随管端提升高度的变化曲线示于图 2、图 3 和图 4。

为了应用于一般设计计算问题，图中均采用无量纲参数来表示。取特征长度、特征提升力和特征应力分别为：

$$L_C=(EJ/q)^{1/3} \qquad (24)$$

$$P_C=qL_C \qquad (25)$$

$$\sigma_C=ED/L_C \qquad (26)$$

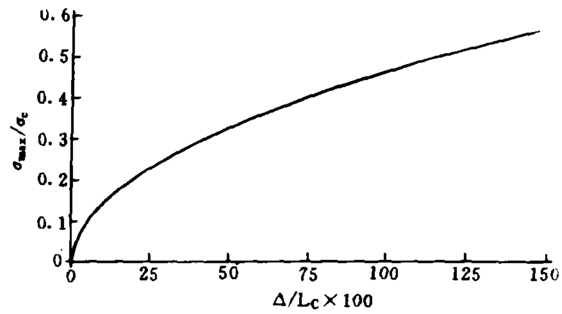


图 2 管中应力随提升高度的变化曲线

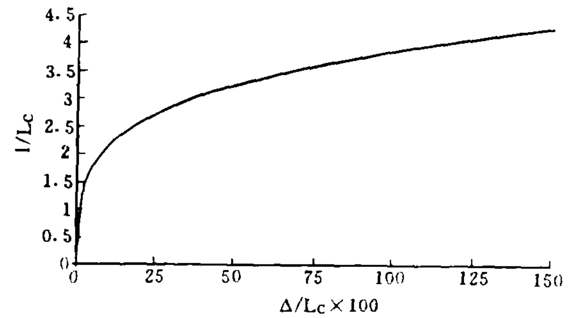


图 3 悬空长度随提升高度的变化曲线

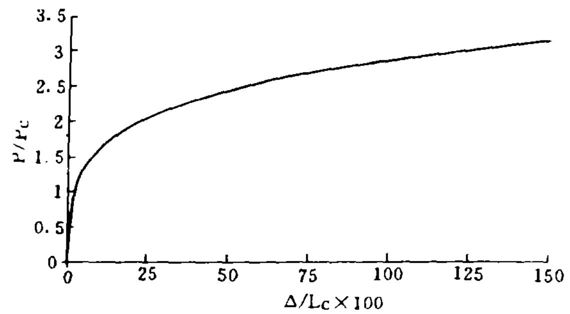


图 4 提升力随提升高度的变化曲线

从分析可以看出，由式(20)可以确定管子在海水中的悬空段长度 $l$，最佳吊点位置距管端 $l/3$ 的地方，吊点选在此处，管端的转角将为零。实际施工时，可在此点的附近配置数个吊点(一般为 3 个以下)。

## 参 考 文 献

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eral soil so as to ease vegetation growth and prevent the peat from igniting in dry seasons.

**Subject Headings**: pipeline crossing marshland, pipeline engineering, design, construction

## • CORROSION CONTROL & INSULATION •

Cao Dianzhen, Yang Huaiyu et al. **Control the Corrosion in the Water-Containing Part of Heat Medium-Water Heat Exchanger. OGST**, 1996(11)15,21~26.

The recycle water for the heat medium-water heat exchanger in oil transmission stations, featured by high contents of chlorion and dissolved oxygen, high hardness, and high flow velocity, gives rise to severe corrosion and scale buildup in the water piping. The corrosion control and scale arresting agent, IMC-50-S, is developed based on field investigations and analyses. Consisting of inorganic corrosion inhibiting component and organic phosphate which are prone to resistance to corrosive water, the agent can generates a protective film over metallic surface to effectively restrain metallic corrosion. In addition, because of its high thermal stability and adaptability to different pH values, IMC-50-S also has an excellent scale-arresting effect at high temperature and over a wide pH range. Analyzed are the test results about the corrosion of recycle water, the effects on corrosion rate in different concentrations of corrosion inhibitor, different soaking periods, and different pHs of solution. The tests show that, for A3 steel, IMC-50-S can control the corrosion rate down to less than 0.07 mm/a, and can achieve a scale-arresting rate of over 90%.

**Subject Headings**: heat exchanger, corrosion, corrosion inhibitor, scale arrester, analysis

## • MECHANICAL EQUIPMENT •

Chen Zhijun and Wang Fusheng. **Economical Comparisons for Centrifugal and Reciprocating Pumps.** ***OGST***, 1996(11)15,27~28.

**Subject Headings**: centrifugal pump, reciprocating pump, energy consumption, performance, economic benefit, comparison

## • CONSTRUCTION TECHNIQUE •

Sun Shengpu. **Points Worthy of Consideration in Pipeline Plugging.** ***OGST***, 1996(11)15,29~30.

**Subject Headings**: long distance pipeline, plugging, rush repair, method

Suai Jian. **Selection of the Optimal Lifting Point for Submarine Pipeline.** ***OGST***, 1996(11)15,31~32.

It is pointed out that two questions have to be answered in the submarine pipeline construction: the stresses in pipes and the location of the point to lift a pipe. The paper recommends that the stresses in pipe caused by lifting be below the allowable stress depending upon pipe strength, and that analysis on pipe stress and deformation during lifting operation be made to locate the most suitable point for pipe lifting. Analysis is made in the paper using the methods of mechanics of materials. In the stress analysis, such aspects are studied as the unaccompanied action of centralized loads, the unaccompanied action of uniform distributed loads and the conditions for pipe end displacement, with their calculation formula provided. For lifting point optimization, curves as well as formula are given, showing the maximum stress in pipe,



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the suspended length, and the variation of the suspended height of pipe end with the lifting force.

**Subject Headings**: underwater pipeline, installation, location, selection, optimization, calculation

# • SAFETY & FIRE PROTECTION •

Liu Dehai, Zhen Wanghua et al. **Applications of A Combined Lightning Protection Technique in Tank Farms.** ***OGST***, 1996(11)15, 33～34.

A new concept of lightning-protection engineering developed based on lightning-electricity mechanism, the combined unit consists of a lightning arresting tower and a lightning initiator. When thunder cloud approaches it, the lightning arresting tower will, actuated by electricity field, produce a large number of space charges powerful enough to change the field strength between the thunder cloud and the protected structure and increase the breakdown voltage, as a result, electrical discharge can be controlled. By contrast, when thunder cloud approaches the lightning initiator, the electricity field between them will increase to produce lead discharging followed by principal discharging. The initiator will keep unobstructed the channel for the discharge of thunder cloud, so that the charges in thunder cloud are neutralized and the protected structure comes out of the danger. With these two installations combined together, reliable protection can be achieved. Actual applications in the tank farm show that this technique is quite promising.

**Subject Headings**: tank farm, lightning protection, technique, application

Feng Haidong and Liu Tao. **Error Analysis and Error Reducing Measures for Dynamic Metering of Crude Oil.** ***OGST***, 1996(11)15, 35～37.

Dynamic metering is an important way to measure oil flow, and errors shall be reduced as much as possible to achieve accurate measurement. Analysis on the errors in dynamic metering is made based on the theory of error, and concludes that the main contributors to the errors come from densimeter, water cut meter as well as flow meter. Error reduction can be achieved by improving the precision of flow meter, thermometer, water cut meter and densimeter, by reducing sample oil's deviation, and by correcting flow meter with specific factors. It is suggested to adopt dynamic sampling and phyical examination, to realize continuous on line measurement of oil density and water cut, to choose proper sampling interval and to calibrate the flow meter on line.

**Subject Geadings**: crude oil, performance, metering, error, error analysis, method

# • EXPERIENCE EXCHANGE •

Wang Naihe. **Simple Davit Suitable for Modifying the Floating Roof of Floating Roof Storage Tanks.** ***OGST***, 1996(11)15, 38～39.

**Subject Headings**: floating roof tank, maintenance, davit

# • APPLICATION REPORT •

Yao Zhixiang. **Attempts to Protect the Bank Protection for Products Pipeline in Desert Area.** ***OGST***, 1996(11)15, 40～42.



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