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喷射火焰对海洋平台立管的影响

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摘　要　将喷射火焰能量与钢材的性能相结合,采用简化处理的办法,建立在火灾荷载作用下平台立管温度的变化模型,将分析结果与文献的有关试验结果做了对比,吻合较好。分析了立管随温度变化破坏的可能性,为平台立管的防护提供了依据。

关键词　风险评估　海洋平台　火灾荷载　喷射火焰

在海洋油气田开发项目中,海洋平台及其设施投资巨大;海上作业的环境恶劣,风险程度很高。风险主要来自因设施本身的缺陷及人为失误造成的设施、设备油气泄漏,遇明火燃烧、爆炸,对人、设施、设备、环境造成伤害及损失的事故。平台的安全风险评估和上述风险因素下设施的安全计算都是相当重要的内容。在海洋平台上,尤以油气生产、处理舱室和出油、气立管受到损坏后产生的危害后果最为严重。本文旨在建立事件升级时油或气立管对火灾的响应模型及破坏模型。

要建立遭受火灾侵袭的物体的响应模型,就要求解物体的三维能量平衡关系式。这些平衡关系式是基于火源与物体之间通过对流和热辐射以及物体内部温差引起的热传导传递热量这样一个概念,而温度计算则是基于物体随温度变化的材料特性。这样,在按上述方法解决问题时,就要用到复杂的数值计算技术,如有限元方法,并需要计算机软、硬件方面的有力支持。为取得简单易行的模型,对海洋平台输油、气立管在火灾作用下的影响进行分析,对复杂的机制进行了简化,忽略了立管内热传导造成的热传递,假定热荷载沿所研究的立管竖向和环向是常量,分析并建立了影响模型,描绘出立管在给定温度下的温度变化趋势。

1　理论基础和简化

1.1　喷射火焰的产生和作用理论

在距燃料释放点一定距离处,用简单的喷射模型计算出位于喷射轴线上的体积分数及速度,以及垂直于轴线的体积分数剖面。在喷射冲力支配混合过程处,可计算出卷流特性,判断出受压作用泄出物呈各种喷射形状。

在大多数情况下,蒸汽喷射物质并不是一流出就处于环境条件下,其温度比四周温度低,如果流动受阻,压力就会比四周高。要模拟的喷射,应是与真实出流具有同样释放量的等效喷射,只是出流的周围条件不同。这种流动被认为是瞬间达到了周围条件要求,故等效孔口可看作与真实孔口一样。

这种等效喷射是出自一等效直径 D_{eq} 的孔口:

$$D_{eq} = D_o\sqrt{\frac{\rho_{goa}}{\rho_{ga}}};$$

式中:D_o 为出流中所用真实孔口的直径;ρ_{goa} 为出流条件下的气体相对密度,即气体刚一释出时与周围空气密度的比值;ρ_{ga} 为周围条件下的气体与同样条件下空气密度的比值。

距孔口 x 处在喷射轴线上的体积分数为

$$C_m = \frac{\dfrac{b_1 + b_2}{b_1}}{0.32\dfrac{x}{D_{eq}}\dfrac{\rho_{ga}}{\rho_{goa}^{1/2}} + 1 - \rho_{ga}};$$

式中 b_1 和 b_2 是与 ρ_{goa} 和 ρ_{ga} 有关的分布常数。

输入燃料的流量或输入时间、喷射长度、受体的位置,利用辐射公式确定出辐射热的强度,估计出火焰附近位置所受到的热通量,就可以计算出火焰的大小和可能的火灾损失。用于估算因喷射火焰造成热辐射作用的模型,是用于喷射扩散包括风的影响的一种扩展模型。火焰是被模拟成沿喷射中心线分布的,具有和全部辐射源辐射的热量 Q_p 相等的一系列点辐射源。

对释放量 Q 和 n_p 个点源的辐射热量 Q_p,可由下式求得:

$$Q_p = \eta Q H_c。$$

式中:η 为效率系数,保守地取为 0.35;H_c 为焓。

由前面的喷射模型可求得喷射值。对喷射长度最合理的选择,可能是从喷口到最小的火焰层面的轴线长度。不过就火焰表面的热流量而言,将低到其1/1.5的浓度包括在火焰之内是比较合适的。n_p的选择是相当随便的,通常在危险分析时有5点就足够了。在距火焰某一距离处的总热通量是火焰每点产生的辐射总和。从火焰中某一个别点到受体相距r处的辐射作用I可由下式求得:

$$I=\frac{x_g Q_p}{4\pi r^2};$$

式中x_g是发射系数,它取决于燃烧着的物质,对于喷射起火,x_g可取为0.2。

应注意风对高压燃烧源的喷射的影响是微不足道的,因为喷射的速度要比风速快得多。不过由低压燃烧源喷射的形状,明显地会受到风的作用而改变,同时热通量的分布也会随着风力的改变而发生变化。风的这种影响将使顺风向的受体增加入射的辐射作用。

1.2 火灾对立管的危害

通过对火源进入物体的热能和物体向外传递的热能的计算,同时结合热力学第一定律,以及针对热辐射的程度,视大多数物体随波长与温度的发散率为常数;最后用物体的温度升高表示能量变化,并依此建立物体在给定火灾中温度的变化模型:

$$\int\frac{L}{A}\left(\frac{\rho c_p}{\sigma\alpha_s(\varepsilon_f T_f^4-T_s^4)+h(T_f-T_s)}\right)\mathrm{d}T_s=\int_0^t \mathrm{d}\tau。$$

式中:σ是Stefen Boltzman常数,取为5.67×10^{-8} $\mathrm{W\cdot m^{-2}K^{-4}}$;$\alpha_s$为物体的吸收率;$\varepsilon_f$为火源的发散率;$T_f$为火源的热力学温度;$T_s$为物体的温度;$h$为热传递系数;$L$为物体的受热周长;$A$为物体的截面积;$c_p$为比热容;$\rho$为工程钢的密度。

求解上式要用到数值积分方法,可以用辛普森规则或四阶龙格—库塔方法。后者可以为较大的时间步长产生稳定结果,通过编制简单的FORTRAN程序,可对此进行计算分析。

2 计算结果和试验结果对比

2.1 试验对象和结果

G.K.Schleyer和D.Campbell曾利用长9 m、直径1.1 m、壁厚35 mm的钢管作过火灾试验。试验时,钢管上装备了热电偶,将管柱置于一系列高速燃烧的烃类火焰之中,由此得到了热传导效应变化和截面的温度变化结果(表1~3)。

表1 管柱外表面温度变化结果

t/min	T/K	t/min	T/K	t/min	T/K	t/min	T/K
1.0	91	3.0	256	5.0	381	7.0	507
1.5	136	3.5	291	5.5	424	7.5	537
2.0	181	4.0	326	6.0	458	8.0	559
2.5	222	4.5	360	6.5	488	9.0	591

表2 管柱中线处温度变化结果

t/min	T/K	t/min	T/K	t/min	T/K	t/min	T/K
1.0	89	3.0	253	5.0	378	7.0	504
1.5	134	3.5	288	5.5	420	7.5	535
2.0	178	4.0	324	6.0	455	8.0	558
2.5	220	4.5	356	6.5	486	9.0	589

表3 管柱内表面温度变化结果

t/min	T/K	t/min	T/K	t/min	T/K	t/min	T/K
1.0	55	3.0	213	5.0	341	7.0	457
1.5	106	3.5	249	5.5	378	7.5	487
2.0	147	4.0	280	6.0	412	8.0	507
2.5	188	4.5	312	6.5	439	9.0	535

由得到的遭遇火灾荷载作用的柱子上同一截面处随厚度变化的结果可见,温度随厚度的变化是非常小的。

2.2 数值模拟计算结果及讨论

用上述试验对象进行数值模拟来考察热传导效应沿钢管柱的变化,将模型建立为有限元软件包。由试验结果可见,温度从柱外表面到中面的变化是很小的,从中面到内表面的变化稍大一些(因为热向内部空气传递所致),这在计算模拟时都可以忽略。对沿长度变化的计算,为简化起见,在模型中假设温度沿厚度没有变化;模型中热荷载的输入可以通过确定管柱接受的初始热荷载来建立。输出的结果用来确定温度因热传导在未加热截面的升高值。典型的工程钢,随温度变化的比热容和热传导率如表4所示。

表4 典型工程钢随温度变化的比热容(c_p)和热传导率

T/K	c_p / $\mathrm{J\cdot(kgK)^{-1}}$	热传导率 / $\mathrm{W\cdot(mK)^{-1}}$	T/K	c_p / $\mathrm{J\cdot(kgK)^{-1}}$	热传导率 / $\mathrm{W\cdot(mK)^{-1}}$
273	460	52	873	750	35
373		51	973	850	31
473	550	49	993	1 000	
573		46	1 003	1 200	
673	610	43	1 073	800	
773		39			

表 5　在给定火荷载情况下的计算结果

t/min	T/K	t/min	T/K	t/min	T/K	t/min	T/K
1.0	96	3.5	301	6.0	470	10	642
1.5	139	4.0	334	6.5	490	20	733
2.0	185	4.5	365	7.0	514	30	837
2.5	226	5.0	388	8.0	559	40	897
3.0	261	5.5	433	9.0	601	50	914

简化计算结果与试验管柱外表面测试结果吻合较好,因此可用于海洋平台生产立管热荷载的分析。由钢材受温度影响的机制可知,达到一定温度时,钢材强度就会丧失,所以对立管来讲,必须采用有效的防火措施来避免失效。

3　结束语

简化的近似计算方法对预测结构在热荷载下的效应是非常有效的,尤其对大型的海洋工程结构来说,这不仅有利于进行结构响应的探讨,也为寻找结构抗灾防灾的量化指标提供了思路。近似理论结果与试验结果的对比表明,二者吻合较好。

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海洋石油工程常用计量单位换算

1 in = 25.4 mm
1 ft = 0.304 8 mm
1 mile = 1.609 km
1 n mile = 1.852 km
1 kn = 1 n mile·h^{-1} = 1.852 km·h^{-1}
1 ft^3 = 28.3 L = 0.028 m^3
1 bbl = 158.987 L = 0.158 988 m^3
1 gal(US) = 3.785 L = 0.003 78 m^3
1 lb = 0.45 kg
1 kgf = 9.8 N
1 lbf = 4.448 N
1 kgf·m = 9.8 N·m
1 lbf·ft = 1.355 8 N·m
1 Pa = 1 N·m^{-2}
1 lbf·ft^{-2} = 47.88 Pa
1 kgf·cm^{-2} = 98 kPa
1 bar = 0.1 MPa
1 atm = 101.325 kPa = 0.101 325 MPa
1 mmHg = 133.322 Pa
1 psi = 1 lb·in^{-2} = 6.89 kPa
1 bl·ft^{-3} = 16.02 kg·m^{-3}
1 blf·ft^{-3} = 157.08 N·m^{-3}
1 gf·cm^{-3} = 9.8 kN·m^{-3}
1 kgf·m^{-3} = 9.8 N·m^{-3}
1 cP = 1 mPs·s
1 cSt = 1 mm^2·s^{-1}
1 Hp = 735.499 W
1 N·m = 1 J
1 kW·h = 3.6 MJ
1 cal = 4.186 8 J
1 Btu = 1.055 kJ
1 bbl·d^{-1} = 1.84 × 10^{-6} m^3·s^{-1}
1 D = 1 μm^2
1 mD = 1 × 10^{-3} μm^2

with phase fractions derived from physical property measurements. The operating principles of velocity and phase fractions measurements were discussed. Its uncertainties were analyzed in detail. Most multiphase flowmeters can provide phase flow rate measurements with uncertainties of ± 10% relative to the actual flow rate within a limited range of flow rate. For well testing purpose their accuracy may be sufficient. The selection of the most appropriate type must be determined by the conditions to be measured.

Key Words: multiphase flow meter, velocity measurement, phase fractions measurement, selection of type

Abstract: In winter, the air temperature is chilly, the climate is very bad and the ice on the sea is serious. These bring effect on the production of the whole oil fields in Bohai sea very serious. It's very important that how to strengthen the management on production and facilities of every oil field and make oil field product steadily in winter. Taking JZ 9 − 3 oil field as an example, this article introduces some experiences on management in winter.

Key Words: winter management, prepare work, wind ice, loading

·MANAGEMENT·

Abstract: the basic design for Wenchang 13 − 1/13 − 2 oilfield, the first large-scale integrated oilfield, was completed independently by China Offshore Oil Research Center. The design project was divided four stages and went through thirty months. This paper describes the organization and management of design project for this oilfield.

Key Words: Wenchang oilfield, design project, organization and management

Abstract: Owing to successful launching of heavy derrick/lay barge "Lanjiang" and its sound engineering activity, we made a conclusion that "the parallel project", which to be used successfully on the "Lanjiang", is to be implemented on our offshore oil platform design and construction. It means the client and manufacture should be invited to take part in the Think Tank from the beginning; the designer client and manufacture should coordinate in the engineering project from A to Z; and the hull and equipment research is to be coordinate as well.

Key Words: parallel project, strategic crisis idea, playing rule

Abstract: This article briefly introduced the procedures, methods and main point of bidding work of engineering projects from tender preparation to tender appraisal. The article will help you to understand the important points of bidding work.

Key Words: engineering project, invitation for tender, assessment of bids

·SAFETY·

Abstract: Simplified method was adopted to analyze the temperature model of vertical pipeline under jet fire loading in marine platform by combing the fire energy with material properties. Satisfied correlation was achieved by comparing the analytical results with the experimental ones. At the same time, the breakage probability of pipeline because of temperature variation was considered. This dissertation would be used to determine the protection measures for pipeline.

Key Words: risk assessment, offshore platform, fire loading, jet fire

Abstract: The main process of applying the GDM (gray dynamic model) to predict the event is to build up gray system differential equation model, Gray Model (GM). In this paper, in terms of staff casualty accident, the author uses the gray system predicting method put forward by Deng Julong etc, to build up industrial injury accident (lost man-hour) performance model GM (1,1). Therefore the results show that the matching degree is high, and the GM can be used in industry safety production.

Key Words: gray dynamic model, characteristic data