单点系泊导管架疲劳分析

刘杰鸣
中海石油研究中心,北京,100027

摘　要　介绍单点系泊导管架在环境荷载和系泊船只运动作用下的疲劳分析方法。疲劳分析的重点是由系泊船只运动引起的导管架疲劳,因此需要把系泊船只运动引起的非规则循环外力与海流运动的概率分布结合起来进行该导管架的疲劳分析,然后把它与波浪荷载引起的疲劳分析叠加起来以得出最终结果。

关键词　单点系泊　导管架　疲劳分析

单点系泊导管架(以下简称单点导管架)的疲劳分析与常规平台导管架结构的疲劳分析不同。单点导管架除了受常规环境荷载的作用外,还要受到系泊船只传来的系泊力的作用;该作用力是作用在一个点上的循环荷载,并且作用方向、作用力大小与风、浪、流有着密切的关系:因此,对单点导管架要重点研究由系泊力引起的疲劳状况。

图 1 为系泊船只示意图。该船船艏通过钢臂系在导管架的系泊点(导管架的系泊柱)上。图 2 为单点导管架的三维示意图。系泊船只在风、浪、流的作用下围绕系泊点旋转。

图 1　系泊船只示意图

由于存在系泊力,对单点导管架进行疲劳分析时要分别分析 2 种疲劳状况: 1) 由船只系泊力引起的单点导管架疲劳; 2) 由波浪力引起的单点导管架疲劳。

首先要得到由船只受风、浪、流作用引起的系泊力的大小、作用的方向及其分布情况。这是计算系泊力引起的疲劳所必须掌握的基本数据。

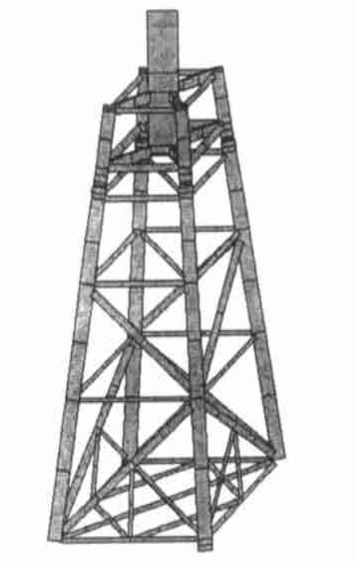

图 2　单点系泊导管架三维示意图

其次是计算单点导管架受波浪力作用引起的疲劳。因为结构的疲劳分析是进行导管架结构设计的常规工作,已被大家所熟知,所以需要重点解决的问题是如何计算系泊力对单点导管架引起的疲劳问题。目前导管架结构的疲劳分析普遍用谱分析计算方法进行,这也是 API RP 2A 推荐使用的方法[1]。

1　系泊力引起的单点导管架疲劳

进行由系泊力引起的单点导管架的疲劳分析,必须首先知道船只在风、浪、流作用下的运动响应,然后求出由船只运动引起的作用在单点导管架上的外力及其分布和作用次数。一般,设计基础数据中提供了一些数据用于计算由系泊力引起的单点导管架的疲劳。表 1 是渤海某海域海水流速在各个方向

上的概率分布值(累计了 8 个主方向的概率)。

图 3 为单点导管架系泊点上所受的水平力与循环次数的关系曲线。垂直力及弯距与循环次数的关系曲线与图 3 类似(此处略)。

表 1　海面以下 5 m 海水流速对应于各个方向的概率分布　%

流速/ (m·s^{-1})	流向								累计
	N	NE	E	SE	S	SW	W	NW	
0.01～0.10	1.17	1.12	1.01	2.35	2.80	1.46	0.72	0.71	11.34
0.11～0.20	3.69	3.21	2.94	3.60	2.97	4.97	3.89	3.39	28.66
0.21～0.30	2.22	1.51	3.94	4.37	0.47	1.36	4.71	5.37	23.95
0.31～0.40	0.48	0.23	2.88	5.16	0.08	0.11	3.20	4.82	16.96
0.41～0.50	0.12	0.03	1.47	4.94	0.03	0.02	1.63	2.99	11.23
0.51～0.60	0.02	0.01	0.50	3.67	0.01	0.00	0.65	0.99	5.85
0.61～0.70	0.00	0.00	0.11	1.22	0.00	0.00	0.15	0.36	1.84
0.71～0.80	0.00	0.00	0.04	0.06	0.00	0.00	0.00	0.04	0.16
0.81～0.90	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
0.91～1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
累计	7.70	6.11	12.89	25.40	6.36	7.92	14.95	18.67	100.00

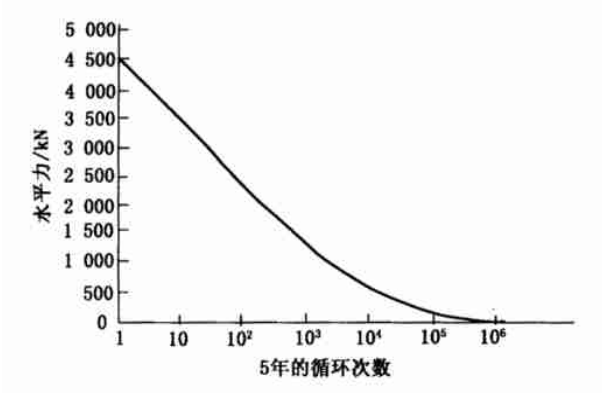

图 3　作用于导管架上的水平系泊力对应与其循环次数的长期分布曲线

图 4 为 $S-N$ 曲线热点应力与循环次数的对应关系。知道热点应力就能查出对应于疲劳破坏时的循环次数,因此通过图 3 纵轴上单点导管架系泊点上的外力与横轴循环次数的关系,用结构分析计算软件可计算出单点导管架各个节点的应力,进而求出热点应力,最后通过查 $S-N$ 曲线得到由系泊力引起的单点导管架的疲劳值。

图 3 上的曲线若按无限小的区间分解,可分成无穷多个点,计算工作量将非常大,且不现实;因此,仅需把曲线分解成有限个点,并使之符合表 1 所列 8 个方向的海水流速概率分布后,求得表 2 中各值。表 2 把曲线关系变成了表格关系,同时考虑了 8 个方向的海水流速概率分布。

由于表 2 所列是外力与循环次数的对应关系,此问题变成了确定型疲劳分析,可直接应用相关计算软件进行疲劳分析。

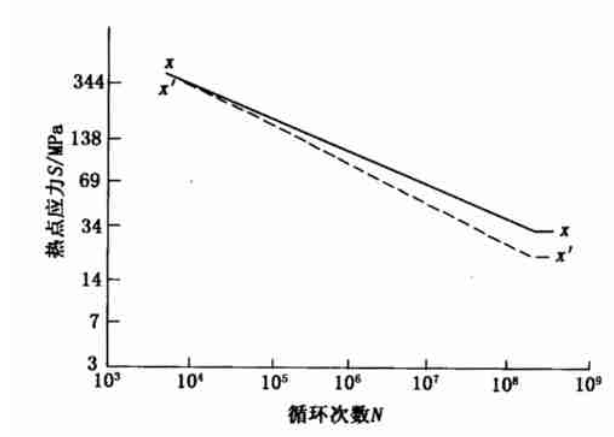

图 4　$S-N$ 曲线示意图

2　环境荷载引起的单点导管架疲劳

设该单点导管架是渤海的导管架,处于浅水海域,按规范要求仅需做简化疲劳分析,可直接应用相关软件进行简化疲劳分析。由于其计算结果为应力值,需要转换成疲劳分析所需的疲劳分析值。

3　系泊疲劳分析与常规疲劳分析叠加

2 种疲劳分析得到的结果的输出形式不同:系泊力引起的疲劳分析可直接得到疲劳寿命;简易疲劳分析得到的结果是管节点的冲剪应力值。这 2 种结果无法直接叠加,因此还需要把应力值换算成等效疲劳寿命。

设该单点导管架在新海域的服役期为 10 年,规格书要求其疲劳安全系数取 4。由系泊力引起的疲劳分析可直接考虑 4 倍的安全系数,而简易疲劳分析得到的是应力值,没有安全系数,因此其节点最终疲劳损伤等于由系泊力引起的疲劳损伤除以 10 加上简易疲劳分析得到的应力值除以 40 之和的倒数,这就是它的最终疲劳寿命,如图 3 所示。此计算结果扣除了 2 年由拖航引起的疲劳寿命。

表 2 水平外力与循环次数的对应关系

与平台 x 轴夹角/(°)	流向	流向概率	水平力循环次数										
			4 025 kN 时	求整后	2 925 kN 时	求整后	1 850 kN 时	求整后	1 000 kN 时	求整后	450 kN 时	175 kN 时	50 kN 时
112.5	N	7.70	0.770	1	6.930	7	69.30	69	693.0	693	6 930 *	69 300 *	2 233 000 *
67.5	NE	6.11	0.611		5.499	5	54.99	55	549.9	550	5 499 *	54 990 *	1 771 900 *
22.5	E	12.89	1.289	1	11.601	12	116.01	116	1 160.1	1 160	11 601 *	116 010 *	3 738 100 *
337.5	SE	25.40	2.540	3	22.860	23	228.60	229	2 286.0	2 280	22 860 *	228 600 *	7 366 000 *
292.5	S	6.36	0.636		5.724	6	57.24	57	572.4	572	5 724 *	57 240 *	1 844 400 *
247.5	SW	7.92	0.792	1	7.128	7	71.28	71	712.8	713	7 128 *	71 280 *	2 296 800 *
202.5	W	1495	1.495	2	13.455	13	134.55	135	1 345.5	1 346	13 455 *	134 550 *	4 335 500 *
157.5	NW	18.67	1.867	2	16.803	17	168.03	168	1 680.3	1 680	16 803 *	168 030 *	5 414 300 *
合计		100.00		10		90		900		9 000	90 000 *	900 000 *	29 000 000 *

说明:循环数量总计 30×10^6 次;带 * 号的值求整前后相同。

表 3 节点最终疲劳寿命

节点	管件	类型	疲劳损伤	计算位置	疲劳寿命	冲剪应力值	叠加后的疲劳损伤	节点最终疲劳寿命
107	107 - 207	TUB	2.793E - 05	TL	358 094.00	0.229	0.005 73	172.59
101	101 - 201	TUB	2.793E - 05	TL	358 094.00	0.229	0.005 73	172.59
107	123 - 107	TUB	1.531E - 05	T	653 260.30	0.229	0.005 73	172.63
101	101 - 121	TUB	1.531E - 05	T	653 260.30	0.229	0.005 73	172.63
107	107 - 207	TUB	1.066E - 05	TR	937 833.10	0.229	0.005 73	172.64
101	101 - 201	TUB	1.066E - 05	TR	937 833.10	0.229	0.005 73	172.64
107	122 - 107	TUB	5.785E - 06	T	1728 556.00	0.229	0.005 73	172.65
101	101 - 124	TUB	5.785E - 06	T	1728 556.00	0.229	0.005 73	172.65
205	205 - 305	TUB	0.000 886 8	T	11 276.81	0.207	0.005 26	187.98
203	203 - 303	TUB	0.000 886 8	T	11 276.81	0.207	0.005 26	187.98
707	707 - 709	BM1	0.025 920 6	BL	385.79	0.088	0.004 79	188.68
701	701 - 709	BM1	0.025 920 6	BL	385.79	0.088	0.004 79	188.68
205	205 - 307	TUB	0.000 681 8	T	14 667.85	0.207	0.005 24	188.72

4 结束语

单点系泊导管架疲劳分析的关键是分析和研究由系泊力引起的单点导管架的疲劳。波浪引起的船舶运动最后通过系泊点把作用力传到单点导管架上。这个力(水平力、垂直力和弯矩)仅是作用在一个点上的循环荷载,却引起所有管节点产生疲劳。这是与常规导管架结构由波浪引起的疲劳最大的不同点。其次是如何把给定的资料和数据转换成用现有程序能做疲劳分析的输入数据,随后解决 2 种类型的疲劳分析如何叠加,最终计算出单点系泊导管架各个管节点的疲劳寿命。从最终的叠加计算结果可以看出,简易疲劳分析结果对节点的疲劳贡献比较大,它是构成疲劳破坏的主要原因。

参考文献

[1] SY/ T 10030 - 2000 idt API RP 2A - WSD - 1993 海上固定平台规划、设计和建造的推荐做法 —工作应力设计法

(收稿日期:2002 - 12 - 04;编辑:张金棣)

Abstract: Fatigue life was calculated for the mooring jacket. The analysis induced by the mooring ship moving under the current was emphases at this time. The long term distribution of total horizontal mooring force on jacket, total vertical mooring force on jacket and radial moment on jacket were used for fatigue analysis. At same time the probabilities of occurrence of analysis results, the jacket normal fatigue analysis and fatigue induced by the mooring ship was combined by equivalent method.

Key Words: single point mooring, jacket, fatigue analysis

Abstract: The casing pipe against the water is important equipment in oil engineering. The vibration control equation of the casing pipe are set up as the casing pipe is modeled as the beam model which is fixed in the bottom and is simply supported at the lower deck, while considering Morison's nonlinear fluid damp and vortex loads. The nonlinear vortex-excited vibration responses of 170 m long cas ing pipe are obtained under the current and the wave-current employing the Galerkin method. This paper provides the analysis method for strength of a casing pipe.

Key Words: casing pipe, natural vibration characteristics, nonlinear vortex-excited vibration

Abstract: The general development and application environment of offshore private VSAT network is firstly presented. And then the principles of the VSAT communication design and the field application of VSAT equipment are described. The problems of design and application are illustrated with description of VSAT system, achievement of voice and data transmission, hot-standby design of equipment, microwave relay and application on the floating production facility. The problem-solving scheme is supplied, when VSAT is applied at the offshore environment.

Key Words: VSAT, satellite private network, voice and data transmission, field application

Abstract: Simulation test of group piles was conducted in accordance with the engineering situation of offshore drilling. The interaction of seabed clay in-group piling conduction was investigated, and the influencing tendency of cluster piling on the stress field of seabed clay was also revealed. The simulating test results were very important for directing the operation of offshore riser.

Key Words: stress field, group piles, riser, test

Abstract: The physical and mechanical properties of model ice, which is non-refrigerated breakable ice, are introduced. The facilities and testing methods on the model ice are also given. It shows that the technique of the model ice sheets acting on pile structures are reliable by comparison of measured ice forces on the pile structure with the empirical formulas presently used domestic and aboard.

Key Words: non-refrigerated breakable ice sheets, vertical pile structure, model test

·DRILLING AND PRODUCTION·

Abstract: The paper introduces the modern optimized fast drilling, which was applied in the QK17-2 oilfield in the Bohai Sea. With complicated structure complicated in geology, the oilfield was challenged to exploit two different areas with one wellhead platform. By application of the modern optimized fast drilling, the good results were achieved, drilling 27 wells in 152.8 days with total footage of 59910 m. By doing so, five new techniques were brought forth. The experience of drilling in the oilfield will be benefit for marginal well development in the future.

Key Words: Bohai Sea, drilling and completion, new techniques, reservoir protection well completion skill

Abstract: Through study of waxy crude oil influenced by VA content of EVE and melting index, EVE optimum addition on waxy crude oil and effect of different structure surfactant on anti-repeatedly heating ability and shear-resistant property of pour point depressant for crude oil, and relation of average molecule weight of BEM series pour point depressant have been used widely and successfully in many pipelines such as Luning pipeline, Zhongluo pipeline, etc.