

屏蔽泵汽蚀原因的分析及对策

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摘 要:结合屏蔽泵的结构特点, 分别从泵体和屏蔽电机两个方面, 对屏蔽泵汽蚀原因进行了分析, 并提出了相应的对策。

关键词:屏蔽泵; 汽蚀; 原因分析; 对策

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蒸汽与空气混合形成爆炸性混合物, 遇明火、明火极易引起燃烧和爆炸, 且苯蒸气有毒, 苯溅在皮肤上会使皮肤干燥, 大量苯蒸气吸入会引起人体内白血球降低, 因此为减少苯的泄漏, 在装置的设计选型时, 特将 C-401 的塔底流程泵选用屏蔽泵。其工艺流程见图 1。

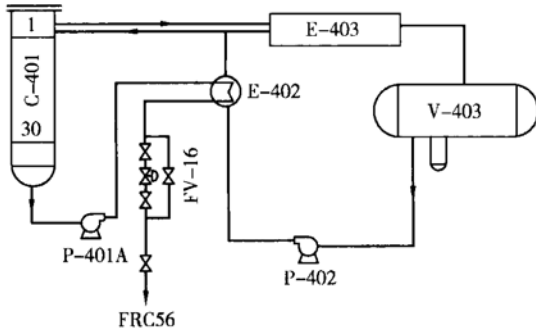


图 1 C-401 工艺流程

C-401 塔的操作参数: 塔压(绝) 0.13MPa, 操作温度 93℃。

2 屏蔽泵结构特点

屏蔽泵是一种无泄漏泵, 它将泵和电机连在一起, 电机的转子和泵的叶轮固定在同一根轴上, 利用屏蔽套将电机的转子和定子隔开, 转子在被输送的介质中运转, 其动力是通过定子磁场传递

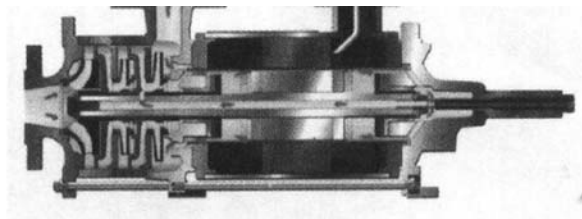


图 2 屏蔽泵结构

3 问题的提出

塔底屏蔽泵 P-401A/B, 为大连海密梯克密封泵有限公司生产, 其屏蔽套选用 Hastilloy C 合金材料加工而成, 轴承采用晶体碳化硅 SSIC 材料制成, 设计使用寿命为 10 年。该泵在正常投用一个月的时间内, 多次出现严重汽蚀现象, 前、后侧轴瓦破碎, 轴套、推力盘严重磨损, 不得不停车进行大修, 严重影响到装置的正常生产。P-401A/B 的性能参数如下:

- 型号为 CAM3/6;
- 流量为 6.95m³/h;
- 扬程为 186m;
- 泵必需汽蚀余量 $NPSH_r$ 为 1.1m;
- 转速为 2950r/min;

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功率为 21kW。

4 故障分析

由于屏蔽泵结构由离心泵加屏蔽电机组成,分析屏蔽泵汽蚀发生的机理,就要对离心泵和屏蔽电机两部分同时进行故障分析。

4.1 对离心泵部分进行分析

从屏蔽泵的结构可以看出,泵体部分发生汽蚀的机理与离心泵完全一样。离心泵发生汽蚀的条件:当入口处压力低于叶轮内蒸汽压力时,即有效汽蚀余量($NPSHa$ 和必需汽蚀余量 $NPSHr$ 相等时,开始发生汽蚀^[1]。下面从易引起泵汽蚀的因素(吸入装置特性、液体物理性质、工艺流程设计等方面)进行分析。

4.1.1 吸入装置特性

由于设备已经安装就位,管路特性已经固定,通过对泵的安装高度进行核算,看其是否满足要求。根据伯努利方程得出如下公式^[2]:

$$h_g = (p_A - p_v) / \rho g - NPSHa - \Sigma h_c \quad (1)$$

式中: ρ ——液体密度, kg/m^3 ;

g ——重力加速度, $g=9.8\text{m}/\text{s}^2$;

h_g ——安装高度, m ;

p_A ——吸入液面压力, Pa ;

p_v ——液体抽送温度下的饱和蒸汽压力, Pa ;

$NPSHa$ ——有效汽蚀余量, m ;

Σh_c ——泵吸入口管系阻力降, m 。

查得当苯的操作温度为 93°C 时:

$$\rho = 971.8\text{kg}/\text{m}^3;$$

$$p_v(\text{绝}) = 1.3 \times 1.013 \times 10^5\text{Pa};$$

$$p_A(\text{绝}) = 1.6 \times 1.013 \times 10^5\text{Pa};$$

$$\text{取 } NPSHa = NPSHr = 1.1\text{m}; \Sigma h_c = 1\text{m}。$$

代入式(1),求得:

$$\begin{aligned} h_g &= (1.3 - 1.6) \times 1.013 \times 10^5 / \\ &\quad (971.8 \times 9.8) - 1.1 - 1 \\ &= -5.3\text{m} \end{aligned}$$

装置 C-401 塔的实际安装高度为 -6.5m ,完全满足泵的安装要求,不会因吸入高度达不到要求造成汽蚀。

4.1.2 介质物理性质

泵汽蚀的发生与泵送介质的物理性质有很大关系,介质的温度越高,液体的挥发性就越大,则液体的饱和蒸汽压就越高,从式(1)可以看出, p_v

根据计算,苯在 P-401A/B(见图 1)入口处的压力为 0.16MPa ,查得该压力下苯的沸点为 96°C ,非常接近苯的工作温度,操作稍有波动就会引起介质汽化,极易造成汽蚀。

4.1.3 苯干燥塔 C-401 的工艺流程

从 C-401 工艺流程来看,由于 P-401A/B 直接从塔底抽出物料,介质温度高达 93°C ,这正好处于苯汽化的临界温度,为泵产生汽蚀创造了先决条件。

4.2 屏蔽电机结构对汽蚀的影响

屏蔽电机结构有转子屏蔽套和定子屏蔽套,流体必须经过两屏蔽套的间隙,为电机绕组提供冷却,为轴承提供润滑。该泵的循环方式为内循环,即在叶轮出口处引出部分高压流体,先后经过前轴承、屏蔽套间隙、后轴承,送入电机尾部带走热量,经泵轴内返回到泵的入口处,完成一个循环,其循环方式见图 2。

由于屏蔽泵的特殊结构,电机绕组作功所产生的热量与轴承摩擦损失所产生的热量汇合在一起,有很大一部分传给了电机冷却液,致使冷却液温度上升。在该泵运转时通过红外测温仪可对泵的入口、出口、电机外壳的温度进行测量,数据见表 1。

表 1 泵运转时温度测量 $^\circ\text{C}$

时间	入口温度	出口温度	外壳温度
08-28	93.3	103.3	126.5
08-29	92.6	102.8	126.1

由表 1 可以看出,屏蔽电机外壳温度很高,使循环冷却液的温度有较大的上升,从而导致冷却液产生汽化,使电机自身循环冷却液中断,从而导致轴承表面温度急剧上升,膨胀变形造成轴承破裂,产生轴抱死的现象。这一点从检修时,发现轴承摩擦面发蓝,表面有沟槽可得到验证。

同时从冷却液的循环方式来看,由于循环冷却液从泵的叶轮出口处引出,吸收电机和轴承的热量后温度升高,在经过循环回到泵入口处时,由于压力突然降低,而发生部分汽化,这也是造成泵汽蚀的主要原因。

5 对策

量,直接影响到屏蔽泵的正常运行,同时介质的温度接近其沸点温度也是造成泵汽蚀的一个重要原因。因此要采取措施,尽量降低介质的吸入温度或采用外循环方式带走电机绕组与轴承摩擦损失产生的热量。

5.1 采用外循环方式

外循环方式:将屏蔽电机冷却液引出至泵体外部。先通过换热设备降温后再流经轴承、屏蔽套间隙,可及时带走电机内部的热量,保证屏蔽电机的正常运转。

由于采用外循环方式,必需对泵的结构做较大的调整,或者是重新选用带外冷却器的泵,结构如图 3 所示,由于此项投资太大,所以选择了降低介质吸入温度的方式。

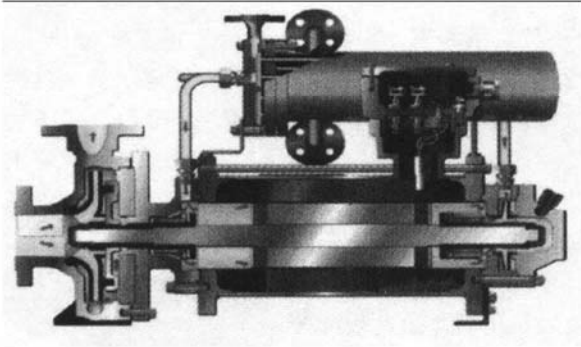


图 3 外循环方式

5.2 降低介质的吸入温度

根据装置的实际运行情况,在不影响 C-401 塔操作条件的前提下,为降低泵 P-401A/B 的吸入温度,对 C-401 塔底苯的出料流程进行了改造,将高温苯先进入换热器 E-402 换热降温后,再进入泵 P-401A/B,具体流程见图 4。

流程改变后,在该泵运转时曾通过红外测温仪对泵的入口、出口、电机外壳温度进行了测量,数据见表 2。

由表 2 可以看出,流程改变后,泵的入口、出口、电机外壳温度有了大幅度的降低,冷却液的温

度远远的低于其沸点温度,确保了电机转子和轴承的润滑和冷却。新工艺投运后 P-401A/B 运转正常,装置达到满负荷的生产,维修费用也得到了大幅度降低。

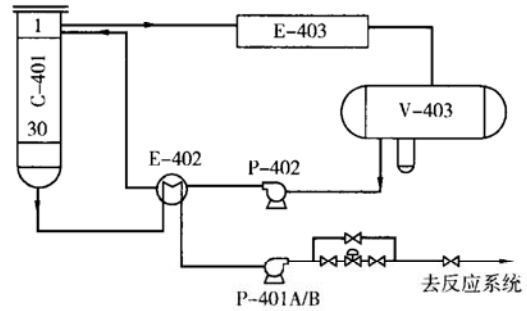


图 4 C-401 塔改造后工艺流程

表 2 流程改变后泵运转时温度测量 $^{\circ}\text{C}$

时间	入口温度	出口温度	外壳温度
10-10	40.2	51.2	71.6
10-15	40.8	52.0	72.3

6 结论

(1)由于屏蔽泵的叶轮与电机同轴,结构上不需要轴封装置,在输送有毒、易燃、易爆介质时,完全可以做到无泄漏,利于环保;

(2)屏蔽电机的结构是屏蔽泵产生汽蚀的重要原因;

(3)屏蔽泵选型时,一定要结合介质的物理性质、工艺操作条件等方面综合考虑,对于工作温度与沸点温度相接近的介质,要尽量选用外循环方式的屏蔽泵。

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· 更正 ·

《石油化工设备技术》2004 年第 1 期第 27 页右栏下数第 21 行“处理量(标准状态)大于或等于 $40\text{m}^3/\text{min}$ ”,应更正为“处理量(标准状态)小于或等于 $40\text{m}^3/\text{min}$ ”。

TURE ETHYLENE SPHERICAL TANK

Xu Yan, et al. Mao Ming institute mechanical engineering department, P. C 525000

Abstract In accordance with the situation existed in the repair of local overproofed defect for low temperature ethylene spherical tank, the analyses and discussions on the aspects of material, structure, welding procedure etc. were conducted. The problems been well worth using in reference in the processing of local repair for low temperature spherical tank made of WES3003LT409 steel were proposed.

Keywords Spherical tank, Low temperature steel, Defect, Repair

ANOTHER METHOD OF SELF—REINFORCEMENT OPTIMAZATION OF THICK WALL CYLINDER

Cui Jing, et al. Hebei Industry university chemical engineering institute, P. C 300130

Abstract The methods of thick wall cylinder (tube) strength design and self—reinforcement optimization analysis given by literature were in progress step by step, that was; at first the K (ratio of thick wall cylinder and radius) was determined by relative strength design code, then the optimum elasticity—plastic interface radius r_{opt} was determined. So not only the calculation speed was slow, but also the accuracy was low. Accordingly a self—reinforcement optimization analysis method with "double variable" was given. Select K and r_{opt} as the design variables, strength and geometric limit as the constraints, minimum comprehensive stress as the objective function. By the use of corresponding calculation program compiled by TurboC language, and the given suitable values of K and r_{opt} , the calculation example of high strength steel (4333M4) was given. A simple and easy description of double linear stress—strain curve was proposed, and was very convenient for use.

Keywords Optimization analysis, Self—reinforcement, Optimum interface radius

APPLICABLE CONDITION OF SPIRAL BAF-FLE TUBULAR HEAT EXCHANGER

Song Xiaoping, et al. Da Lian Hai Te heat transfer technology Co. Ltd., P. C 116600

Keywords Spiral baffle tubular heat exchanger, Performance feature, Applicable condition

ANALYSIS AND IMPROVEMENT ON SHUT DOWN FAILURE IN 2003 FOR CATALYTIC CRACKING UNIT FLUE GAS TURBINE—EXPANDER

Wang Jianjun. SINOPEC refine undertaking department, P. C 100029

Abstract The situations shut down for 51 times in 2003 of energy recovery flue gas turbine—expander sets in catalytic cracking units for SINOPEC were analyzed. The reasons were found out. The improved suggestions and measures for increasing operation level of flue gas turbine—expander from now on were proposed.

Keywords Catalytic cracking, Flue gas turbine—expander, Failure, Analysis, Measure

ANALYSIS ON EFFECT FACTOR OF LONG PERIOD OPERATION FOR RECYCLE HYDROGEN COMPRESSOR

Tong Xiaodong. Yangzhi petrochemical company, refinery, P. C 210048

Abstract By means of analysis on the effect factor of interlock shut down for recycle hydrogen compressor, the corresponding measures were adopted, the operation, maintenance and repair of equipment and instrument were strengthened, the long period operation of compressor set was realized.

Keywords Recycle hydrogen compressor, Interlock, Long period operation

APPLICATION OF VARIABLE FREQUENCY SPEED REREGULATION TECHNOLOGY ON RECYCLE HYDROGEN COMPRESSOR OF REFORMER

Feng Heping, et al. Yanan refinery, Industry and commerce group company, P. C 727406

Abstract The basic principle of variable frequency speed regulation technology was recommended. The specific application situation of variable frequency speed regulation technology on recycle hydrogen compressor of reformer was mentioned simultaneously. The economy of variable frequency speed regulation was analyzed in the main point briefly. The conclusion showed that; the application of variable frequency speed regulation technology on recycle hydrogen compressor of reformer was successful and was worth popularizing.

Keywords Variable frequency speed regulation, Recycle hydrogen compressor, Application

ANALYSIS ON CAVITATION EROSION OF SCREENING PUMP AND ITS COUNTERMEASURE

Chen Gang. Jinling petrochemical company, alkylbenzene works, P. C 210033

Abstract In combination with structure feature of screening pump, the reasons of cavitation erosion of screening

pump were analyzed from tow fields of pump body and screening motor. The corresponding countermeasure was proposed.

Keywords Screening pump, Cavitation erosion, Reason analysis, Countermeasure

TRANSFORMATION OF BITUMEN SHAPER SYSTEM

Ma Weiqi, SINOPEC Jinling petrochemical branch company, P. C 210033

Abstract A series of transformations on power system, mechanical drive system, instrument control material drain system and flue gas draft and effluent system of bitumen shaper in oxidizing bitumen unit that have operated for many years were conducted. After transformation the operation of bitumen shaper was stable, the safety was raised, the failure rate was dropped, the operation was simple, and the labour intensity of operator was decreased.

Keywords Shaper, Structure, Material drain system, Technical transformation

ANALYSES ON 110 PROBLEMS OF COMPRESSOR AND PUMP

Dong Changshan, SINOPEC engineering incorporation, P. C 100011

Abstract In accordance with problems occurred in domestic rotation type compressor and pump in the recent years, and by means of summary and classification, the occurred reason and adopting measure were illustrated.

Keywords Compressor, Pump, Problem classification, Measure

LOW TEMPERATURE STEEL AND ITS APPLICATION

Qiu Zhenghua, et al. SINOPEC engineering management department, P. C 100029

Abstract The feature and its application range of low temperature steel were recommended mainly. The domestic low temperature steel, the categories of low temperature steel in ASME, JIS standards and the applicable situations were recommended.

Keywords Low temperature steel, Performance feature, Application

CONSTRUCTION OF 2000m³ LPG SPHERICAL TANK MADE BY 15MnNbR STEEL

Fang Wunong, et al. Hefei universal machine research institute, P. C 230031

Abstract 15MnNbR steel was a new type steel used for pressure vessel, and was applied on Jiu Jiang petrochemical company 2000m³ LPG spherical tank for the first time.

By means of experimental study and open tank inspection denoted that: 15MnNbR steel used for large scale LPG spherical tank had excellent comprehensive performance, and was substituted for imported SPV355 steel plate. The cost of 2000m³ spherical tank made by 15MnNbR steel was decreased 5% than the cost of tank made by 16MnR steel.

Keywords 15MnNbR steel, Large-scale LPG spherical tank, Construction

ANALYSIS ON PERFORATION FAILURE OF HIGH PRESSURE AIR COOLER BUNDLE FOR HYDROGENATED CRACKING UNIT

Han Jianyu, et al. SINOPEC Maoming Branch Company, P. C 525000

Abstract The corrosion problem of air cooler in hydrogenated cracking unit for Mao Ming branch company was discussed thoroughly. The corrosion phenomenon, corrosion production and collected data in site were analyzed thoroughly. By the means of discussion on injecting water capacity, injecting water flow sheet, flow rate and the raw oil scale inhibitor of hydrogenated cracking air cooler, the possible reasons occurred problem was pointed out, and the solvent was proposed.

Keywords Hydrogenated cracking air cooler, Corrosion, Prevenon measure

APPLICATION AND RESEARCH OF INFRARED HEAT IMAGE DIAGNOSIS SOFTWARE ON ELECTRICAL EQUIPMENT

Zhang Hong, et al. CNPC Jin Zhou petrochemical company equipment research institute, P. C 121001

Abstract The analysis and handling on infrared image of electrical equipment were conducted by the use of infrared heat image diagnosis software. The change tendency of operation situation for electrical equipment was grasped. The safe diagnosis of failure for electrical equipment was realized.

Keywords Electrical equipment, Infrared software, Application, Research

DEVELOPMENT AND APPLICATION OF BOTTOM PLATE LEAKAGE MAGNET DETECTION TECHNOLOGY FOR STORAGE TANK

Li Chunshu, et al. Tianjin petrochemical company mechanical research institute, P. C 430082

Abstract The important meaning of development and application of bottom plat leakage magnet detection technology for storage tank were recommended. The comparison of technical feature between common non-destructive in-