

# 焦化装置富气压缩机干气密封系统的应用及维护

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**摘 要:**文章根据干气密封的工作原理、基本结构、应用特点及操作条件, 分析了焦化富气压缩机干气密封系统在运行过程中出现的故障, 并针对故障的原因采取了相应的措施进行维修保养, 保证了干气密封系统连续稳定运转 34 个月以上, 保障了机组的安全、稳定、长期、满负荷的优质运行。

**关键词:**富气; 压缩机; 干气密封; 应用及维护

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中国石油天然气股份有限公司克拉玛依石化分公司的 1 500 kt/a 延迟焦化装置, 2004 年 12 月底建成投产, 其中焦化装置富气压缩机为全厂近半数加热炉提供燃料气, 属于全厂的关键设备, 而受工艺的影响, 焦化装置富气中含有少量的焦粉颗粒, 对压缩机的密封产生影响。在设计时, 结合工艺介质危险程度高, 介质中含有焦粉颗粒等诸多因素, 公司选用了天津新技术产业园区约翰克兰鼎名密封(天津)有限公司的干气密封系统, 压缩机为沈阳透平机械股份有限公司设计的 2MCL458 富气压缩机组, 汽轮机驱动。经过 2006 年 5 月检修时的拆检维修和调整之后, 一直连续运行, 密封性能稳定可靠, 确保了机组长周期平稳运行, 取得了良好的经济效益和社会效益。

## 1 机组概况

K-2201 型号为 2MCL458-6, 介质为焦化装置富气, 最大流量 19 400  $\text{Nm}^3/\text{h}$ , 进口压力 0.14 MPa, 出口压力 1.46 MPa, 一阶临界转速 4 040 r/min, 二阶临界转速 14 669 r/min, 跳闸转速 13 674 r/min, 调速范围 8 287 ~ 12 431 r/min, 进口介质温度 40  $^{\circ}\text{C}$ , 出口介质温度 125  $^{\circ}\text{C}$ , 额定功率 2 584 kW, 缸内装的叶轮级数为 8 级, 首级叶轮名义直径为 450 mm, 压缩机及其辅助设备使用寿命至少为 20 年, 不间断地运行时间至少为三年, 机组采用汽轮机驱动, 由杭州汽轮机厂生产。

## 2 干气密封结构及其控制系统

### 2.1 干气密封主要结构

焦化装置富气压缩机的干气密封系统为约翰

克兰鼎名密封(天津)有限公司生产的螺旋槽端面密封, 其中双端面干气密封由静环、动环组件(旋转环)、副密封“O”形圈、精密封、弹簧和弹簧座(腔体)等组成<sup>[1]</sup>。弹簧在密封无负荷状态下使静环与固定在轴上的动环组件配合。干气密封的密封面较宽, 动环采用单向双列螺旋槽, 如图 1 所示。

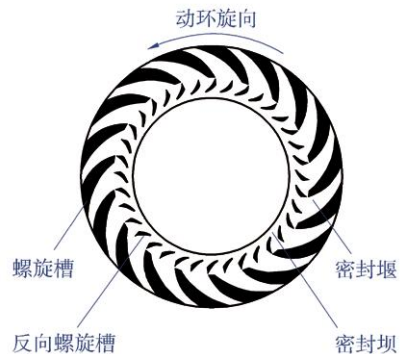


图 1 螺旋槽密封面

### 2.2 干气密封控制系统

该密封设计有专门的监测控制系统(见图 2), 可保证干气密封长期可靠地在最佳状态运行。

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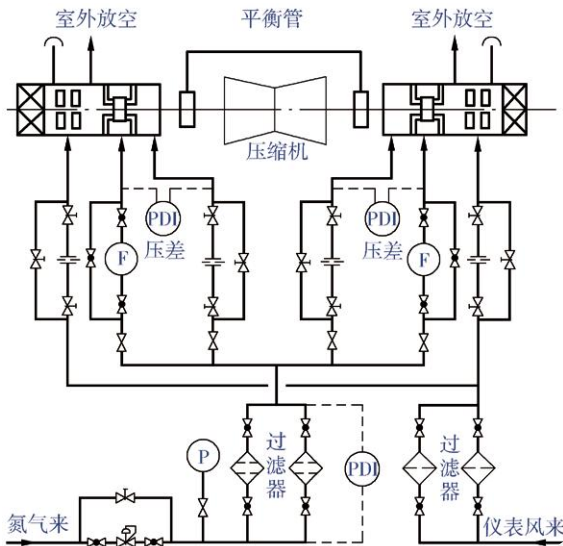


图 2 干气密封控制系统

如图 2 所示,氮气气源自系统来,经过减压阀和过滤器后分为两路,一路作为缓冲气,经限流孔板,进入密封的前端(介质端),其压力稍高出平衡管处的工艺气压力  $0.1 \sim 0.2 \text{ MPa}$ ,可阻挡含有焦粉杂质的工艺气进入密封端面;另一路作为主密封气进入干气密封的腔体,起阻塞气体的作用,通过系统的自立式压力调节阀,控制其进口压力高于前端的缓冲气压力  $0.2 \sim 0.3 \text{ MPa}$ 。由于主密封气进入密封腔后只能通过密封端面分别向介质端和大气端泄漏,故其流量即为两端密封的泄漏量,在  $0.6 \sim 0.9 \text{ Nm}^3/\text{h}$  之内。其中的一部分通过介质侧的密封端面漏入工艺气内,另一部分则通过大气侧的密封端面漏入外置的迷宫密封腔内。再引一部分氮气作为隔离气,进入迷宫密封中的密封腔,控制其进口压力稍高于轴承箱油压(通常为大气压)  $20 \text{ kPa}$ ,形成一个可靠的阻塞密封,可保证轴承箱中的润滑油不进入干气密封。由于密封气全部为氮气,对环境无害,可直接排空,所以一部分进入轴承箱,另一部分从干气密封大气侧密封端面排出<sup>[2]</sup>。

判断密封是否正常工作,主要是通过监测主密封气流量来进行的。正常情况下,主密封气入口端显示的流量即为两端泄漏量之和,其值由金属转子流量计测量,并远传至控制室,该值稳定且较小。如任何一端的干气密封出现失效时,会导致流量的急剧增大,若达到设定值时控制室即发出声光报警<sup>[2]</sup>。

干气密封系统的测量仪表在现场检测的同

时,将重要测量点采集的信号输出至中控室 ESD 系统,并设置高低限位报警及连锁。使操作人员能及时了解密封件的运行情况,确保该系统的可靠运行。具体设置如下:

- (1) 设置主密封气的氮气流量(即密封的泄漏量)报警,  $Q > 3 \text{ Nm}^3/\text{h}$  时,高报警;
- (2) 设置主密封气与缓冲气的压差报警, PDI  $100 \text{ kPa}$  时,低报警; PDI  $50 \text{ kPa}$  时,连锁停车;
- (3) 设置主密封气过滤器的压差报警,设定为 PDI  $60 \text{ kPa}$  时,高报警;
- (4) 设置密封气入口压力报警,设定为 PDI  $0.4 \text{ MPa}$  时,低报警,此时氮气瓶气源启动;

密封系统的测量仪表、接线盒、过滤器、阀门,均安装在现场的干气密封仪表盘上。压力、流量、差压变送器输出  $4 \sim 20 \text{ mA}$  模拟信号,经隔离转换模块送入 PLC,信号超限时,PLC 输出报警信号进行声光报警。达到连锁停车值时,及时停车<sup>[2]</sup>。

### 3 双端面干气密封的使用情况

干气密封系统于 2004 年 12 月底一次试车成功,达到了良好的密封效果。在之后的运行过程中,压缩机机组经历了多次紧急开停车(其他工艺原因引起)的考验,结果表明机组在低转速  $2000 \text{ r/min}$  以下运转时,主密封气流量计显示两端密封泄漏量为 0。随着转速的升高密封气量增加,升速至  $9000 \text{ r/min}$ ,密封泄漏量显示为  $0.85 \text{ Nm}^3/\text{h}$ ,上下波动为  $0.1 \text{ Nm}^3/\text{h}$  左右,表现基本稳定。机组运行逐渐进入稳定状态,密封腔温度亦逐渐升高,两端密封泄漏量随温度上升而逐步下降,最终稳定在  $0.7 \sim 0.8 \text{ Nm}^3/\text{h}$ 。

2004 年 12 月到 2006 年 5 月压缩机在运转过程中,发生过两次一侧密封泄漏量出现瞬间报警的情况,但随即恢复正常值。经分析是由于机组工艺参数的波动和个别流量计的质量问题引起。与此同时,压缩机干气密封系统还经历了多次低转速运转和喘振的考验,经过调整后运转情况仍然非常理想,表明该干气密封设计合理,具有极强的抗干扰能力,达到了预期的使用效果,完全能保证长周期运行<sup>[2]</sup>。

尽管压缩机干气密封系统整体情况运行良好,但密封气泄露量还是在使用的过程中有所增加,这表明密封系统动静环的接触面出现了一定

的损伤。2006 年 5 月全厂大检修时,针对焦化装置富气压缩机干气密封系统主密封气量增加和振动增大的现象,将压缩机解体进行检查,发现焦粉在压缩机部件上粘结严重,压缩机叶轮大面积结焦,厚度在 1.5 ~ 2.0 mm 之间,分布不均。压缩机后端盖上积有一层焦粉,端盖和叶轮间的轴向间隙、吸入隔板和叶轮间的间隙等,因积集粉料而使间隙变小,密封面产生了一定的磨损。经过维修后,压缩机组一直使用至今,干气密封系统连续平稳运行超过 34 个月,目前其主要参数如表 1 所示。

表 1 目前干气密封主要参数

项 目	实测值
高压端密封气流量/ $\text{Nm}^3 \cdot \text{h}^{-1}$	0.801
低压端密封气流量/ $\text{Nm}^3 \cdot \text{h}^{-1}$	0.738
高压端主密封气与缓冲气压差/kPa	423
低压端主密封气与缓冲气压差/kPa	320
主密封气过滤器压差/kPa	39.13
密封气入口压力/MPa	0.83

## · 技术信息 ·

### 长输管线压缩机模型级攻关获突破

长输管线压缩机模型级关键技术研究项目于 2010 年 1 月初,在沈阳鼓风机集团有限公司获得重大突破。这项新技术打破了国外对我国长输管线压缩机模型级技术的封锁,为西气东输提供了重大技术支撑,从而加速我国长输管线压缩机国产化步伐,提升国内大型长输管线工程压缩机制造能力。

在天然气等长输管线工程中,压缩机是一个极其关键的设备,而模型级系统是压缩机内离心叶轮系统制造的一个特定系数,不仅决定着叶轮系统流量的大小,以及流速、压比、摩擦流损等关键技术指标,而且决定着压缩机的体积和成本、机械性能,此前,只有极少数国家拥有此项技术。因国内没有掌握模型级系统,导致压缩机体积大、耗能高、消耗材料多,压缩机小了又达不到功能要求。而有了模型级系统,无论制造什么规格的压缩机都可以达标。

为攻克这项技术,沈阳鼓风机集团有限公司科技人员经过不懈努力,首先攻克了模型级基本级系数,自主开发了 7 个长输管线压缩机模型级基本级。在此基础上,他们采用准相似切割计算、性能分析、反复修正等技术措

## 4 结语

(1) 由于密封气流量相对于工艺气量微不足道,不会影响工艺气的质量,所以对于工艺气不允许泄漏到大气中,但允许密封气进入机内的工况时,宜采用双端面干气密封。

(2) 焦化装置富气压缩机其工艺气中含有少量焦粉杂质,应严格控制干气密封系统,保证密封面的清洁,降低焦粉对干气密封系统的影响,保证压缩机长、稳、优的运转。

(3) 2006 年 5 月大检修对干气密封系统进行修复和调整,焦化装置富气压缩机运行比较平稳,至今已经连续平稳运转了 34 个月,证明干气密封系统技术先进,安全可靠。

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施,优化模型级系列化设计方案,完成了大量性能试验,获得了大量可靠数据,完成了长输管线压缩机模型级技术攻关。

沈阳鼓风机集团有限公司研发的模型级技术先进,其长输管线压缩机 PCL 系列包含 11 个模型级,流量系数范围为 0.090 ~ 0.038,可满足近期长输管线压缩机新产品开发的需要。其系列模型级的效率,无论是无叶扩压器还是叶片扩压器级都达到了当前世界先进水平。他们研发的级能头系数设计合理,可满足管线压缩机的特殊要求。

压缩机广泛应用于石油、化工、天然气输送、冶金、空气分离等国民经济的各个领域,是国家基础工业和重大工程成套装置的核心设备。压缩机在长输管线装置中具有特殊的作用,目前正在向大型化、系列化、运行高效化、结构小型化、低噪声化方向发展,而这些均取决于压缩机制造技术的核心 - 模型级系数。确定模型级系数不仅是压缩机设计的关键技术,也是衡量一个国家压缩机发展水平与能力的重要标志。

(上海擎督金秋石化科技传播工作室 钱伯章供稿)

and quality control measures of anchor flange used in the Sichuan-to-East Gas Transmission Pipe Line Project. The improved CF62 steel was selected as the raw and processed material of anchor flange. A batch of domestic large diameter anchor flanges has been manufactured by punching technique with free forging and rotary swaging. And these anchor flanges have met the national major project demands.

**Keywords** anchor flange; manufacturing technology; quality control

**CONVERSION OF THE BASIC WIND SPEED PARAMETERS BETWEEN CHINESE STANDARD JB/T 4710 AND AMERICAN UBC-97**

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**Abstract** This paper expounds the definitions of the basic wind speed and wind pressure in both Chinese standard JB/T4710 and American UBC-97. It analyzes the difference of the parameters in these two standard systems. The authors put forward a converting method. After the conversion, the basic wind speed and wind pressure value in domestic system can adopt the calculation method of UBC-97 standard more reasonably to seek solutions to wind bending moment of towers used in domestic projects.

**Keywords** basic wind speed; basic wind pressure; JB/T 4710; UBC-97

**FINITE ELEMENT ANALYSIS OF LOCAL STRESSES DUE TO EXTERNAL LOAD**

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**Abstract** In the area of connecting nozzle with shell, the most common methods applied to calculate the local stresses due to external load are WRC 107, WRC 297 and EN 13445. When the thickness of the shell and nozzle is too thin to meet the demands of the above-mentioned methods, the finite element method can be used to take the reinforcement effect of the strengthening element into consideration so as to solve the problems properly.

**Keywords** local stresses; stiffening rib; reinforcing ring; finite element method

**APPLICATION OF ENHANCED HEAT TRANSFER TECHNOLOGY IN THE CAPACITY EXPANSION OF CHEMICAL PLANT**

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**Abstract** The capacity expansion of chemical plant expands with the production capacity. Simple magnifying of heat exchanger is the often used design. And along with such design, problems such as low heat transfer efficiency and heavy devices pop out. Good results have been obtained by designing heat exchanger through integrated application of the technology with the theoretical basis of enhanced heat transfer and specific media environment. This paper introduces the application of enhanced heat transfer technology in certain capacity expansion of chemical plant. And examples of industrial application of heat transfer equipment have been listed in this paper.

**Keywords** enhanced heat transfer technology; heat transfer coefficient; condensation; evaporation; structure; medium; application

**FAILURE ANALYSIS AND COUNTER-MEASURES OF THE CRACKING OF HIGH TEMPERATURE HEAT EXCHANGER IN STYRENE UNIT**

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**Abstract** In this paper, the cracking head of high temperature heat exchanger in styrene unit is studied by micro-macro analysis, metallographic analysis, mechanical properties analysis, finite element analysis and other methods of the failure samples. The results show that the quality of the material deteriorates after a long time high temperature service with repeated increase or decrease in temperature and the performance of the material also drops. Thermal stress and other stresses lead to cracking failure. And this paper proposes some measures to resolve this problem.

**Keywords** styrene; high temperature; cracking; countermeasures

**APPLICATION AND MAINTENANCE OF DRY GAS SEAL SYSTEM FOR RICH GAS COMPRESSOR IN COKER**

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**Abstract** The failures of dry gas seal in the operating process of rich gas compressor in delayed coker is analyzed on the basis of working principle, fundamental structure, application characteristics and operation of the compressor. Some corresponding maintenance is executed according to

the reasons for such failures, which assures the continuous operation of the dry gas seal system with good stability for more than 34 months and guarantees the safe, stable, long-term and full-load operation of the unit.

**Keywords** rich gas; compressor; dry gas seal; application and maintenance

**APPLICATION OF FREQUENCY CONVERSION IN CENTRIFUGAL PUMP**

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**Abstract** As important power equipment, centrifugal pump is widely used in many fields. According to incomplete statistics, the annual power consumption by centrifugal pumps is about 700 billion kilowatt-hour, which accounts for nearly 20% of our country's total generating capacity. Therefore, as such a big user of power, it is highly necessary to find methods to save energy. Based on the actual situation of the process equipment and the performance characteristics and process features of the centrifugal pumps, this paper puts forward application methods and precautions of frequency conversion in centrifugal pumps, first taking the components of power consumption into consideration.

**Keywords** centrifugal pump; frequency conversion; energy saving

**FAILURE ANALYSIS AND HANDLING OF S1802 BALERS**

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**Abstract** Since the HS1802 balers have been installed and put into use, the expected goal has never been reached and many failures occur frequently. There have been serious leaks and loss of the main pressure and pre-pressure in particular. Through the research and analysis of the technical staff and manufacturers, it is believed that the problems lie in HS1802 baler hydraulic system. After the improvement and replacement of the main pressure, pre-pressure tanks and increase of the pressure packages, the equipment can be operated smoothly and efficiently.

**Keywords** balers; hydraulic system; failure; transformation

**BRIEF DISCUSSION ON THE CAUSES AND COUNTERMEASURES OF SCALE DEPOSIT IN STEAM TURBINE**

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**Abstract** This paper introduces the problems

appeared in the operation of turbo-set and the impact that these problems bring to production. In order to solve these problems, scale deposit of steam turbine can be estimated through turbine operating parameters and boiler water quality analysis. Based on the mechanism of scale deposit and analysis of the chemical composition, the real causes of scale deposit in steam turbine can be identified. According to the analysis of the causes of scale deposit in steam turbine, measures to solve the problems are put forward and online cleaning is put into practice. The cleaning effect has achieved the expected goal. The paper also introduces experience and precautions in the process of online cleaning.

**Keywords** steam turbine; scale deposit; reason analysis; countermeasures

**THE TECHNICAL KEY POINTS OF THE PERFORMANCE TEST OF LARGE RECYCLE HYDROGEN COMPRESSORS**

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**Abstract** Along with rapid development of large centrifugal compressors used in petrochemical project PX unit, the technical performance of new model are more and more concerned, so, the performance test of centrifugal compressors will be also much more concerned by engineering company and customers. Taking the performance test of recycle hydrogen compressor used in Sinopec Fujian project PX unit as example, the technical key points of centrifugal compressor performance test were introduced in detail and the results of test were also be detailed narrated and analyzed.

**Keywords** PX unit; Large centrifugal compressor; Performance test; Witness test

**RESEARCH AND APPLICATION OF BUILDING LOW-TEMPERATURE PROPYLENE SPHERICAL TANK WITH DOMESTIC-MADE STEEL PLATE**

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**Abstract** The propylene spherical tank with a capacity of 2000m<sup>3</sup> in Huizhou refining project is designed and built under the condition of designed temperature -48 °C and designed pressure 2.177 MPa. It adopts B610CF-L2 high strength steel sheet made of low welding crack-sensitive steel, which was newly developed by Bao Steel Group. It chooses the 08MnNiCrMoVD forgings and jointing materials and holds the whole set of technique to design, fabricate and install the large low-temperature propylene spherical tank,