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过热器管束断裂分析

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摘　要: 用有限元法对余热锅炉过热器管束与外管网系统进行了热应力计算分析, 指出启动时为过热器管束受力最恶劣状态, 外管网的布置刚度影响着过热器管束的寿命及安全运行。

关　键　词: 过热器; 热应力; 外管网; 刚度

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1　引言

联合循环机组中的余热锅炉过热器管束在运行的几个月内多次发生断裂事故, 断裂部位为管束与集箱连接的焊缝及热影响区(见图 1), 且均发生在与外管网相连接的出口集箱弯管管束处, 影响了生产的正常运行。在寻找管束断裂原因时, 我们用有限元方法(管单元和弹簧单元)对过热器及其外管网热应力进行了重新校核计算和分析, 从计算结果上找到了管束断裂原因, 也为排除事故提供了依据。

图 1　管束断裂

燃－蒸联合循环机组余热锅炉烟气侧为燃气轮机排放的 537 ℃尾气。电厂联合循环机组为调峰机组, 因此余热锅炉也随之频繁启停, 平均每天启停一次以上。

余热锅炉启动瞬间, 还没有产生过热蒸汽, 因此过热器管束基本处于干烧状态, 其壁温接近烟气温度 537 ℃, 而外管网则还处于冷态。即使在正常运行过程中, 由于同过热器连接处外管网的布置在 Z 方向(垂直方向)长度与过热器管束长度不一致, 过热器管束与外管网热膨胀量不同, 外管网仍会对过热器管束产生过大的约束力, 为此我们作了如下的计算分析。

2　模型的建立

余热锅炉过热器取与外管网相接的上、下集箱和三组管子组成的过热器管组(简称过热器管束, 下同), 外管网取与过热器相连接处至外管网的第一个固定支架止。

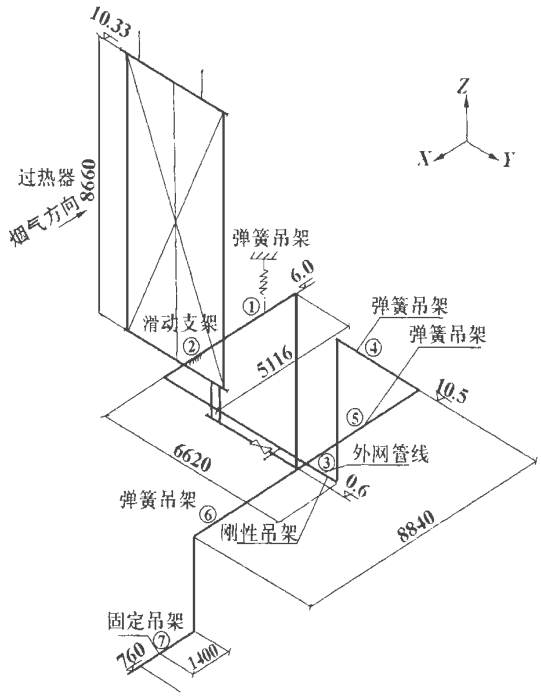

图 2　模型 b、c 示意图

针对有代表性的状态建立三种模型进行热应力计算分析。

模型 a: 过热器管束本身

此模型是过热器没有与外管网连接完全处于自由状态, 目的是了解过热器管束自身的热应力状况, 此时取过热器干烧状态(即最恶劣的外部条件)。

模型 b: 过热器管束与外管网相连接, 锅炉启动状态

此时过热器管束壁温取 537 ℃, 外管网壁温取 0 ℃。

模型 c: 过热器管束与外管网相连接, 锅炉正常运行

过热器管束壁温取 470 ℃, 外管网取 450 ℃。

3　原始数据和性能参数

过热器管束材料为 12Cr1M_0V, 外管网材料为 20

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号钢。

表 1　材料参数

项　目	温度/ ℃	20 号钢		12Cr1MoV	
		0	450	470	537
弹性模量 E/ 10^5MPa		1. 92	1. 58	1. 70	1. 56
热膨胀系数 α/ 10^{-6}1/ ℃		10. 8	13. 93	14. 05	14. 3

表 2　外管网弹簧支吊架参数

支吊架编号	弹簧刚度 N/ mm^{-1}	安装压缩量/ mm
①	12. 13	23
④	18. 67	60
⑤	88. 88	37
⑥	88. 88	35

蒸汽压力 P= 3. 82 MPa

12Cr1M$_0$V 材料:

屈服极限　σ_s= 255 MPa

许用应力　$[\sigma]_{470℃}$= 125 MPa

$[\sigma]_{537℃}$= 79. 7 MPa

4　计算结果

查图 3 应力集系数 K = 3. 6

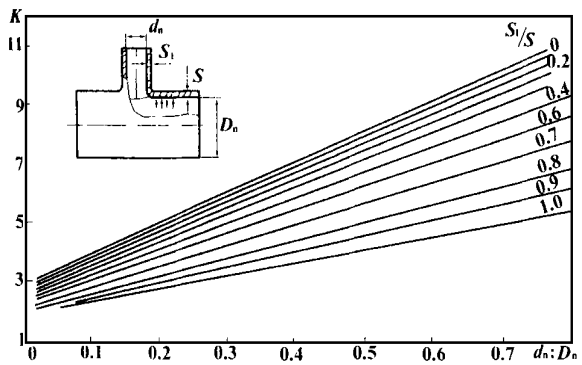

图 3　筒壳上径向开孔的最大应力集中系数

热应力按下式计算: $\sigma = \dfrac{KP_i}{F} \pm \dfrac{K\sqrt{M_j^2 + M_z^2}}{J}$

式中: F、J 为管束的横截面积和截面系数;

P_i、M_j、M_z 为有限元法得到的力与力矩。

仅列出发生最大热应力的与上下集箱相接处弯管部份计算值。

表 3　与上集箱连接弯管各单元热应力

(单位: MPa)

热应力	111	112	113	114	115	579	580	581	582	583
σ^a	23	23	27	35	50	25	25	28	37	52
σ^b	−239	−258	−275	−287	−294	266	257	247	242	244
σ^c	−63	−61	−57	−53	−48	138	142	148	155	162

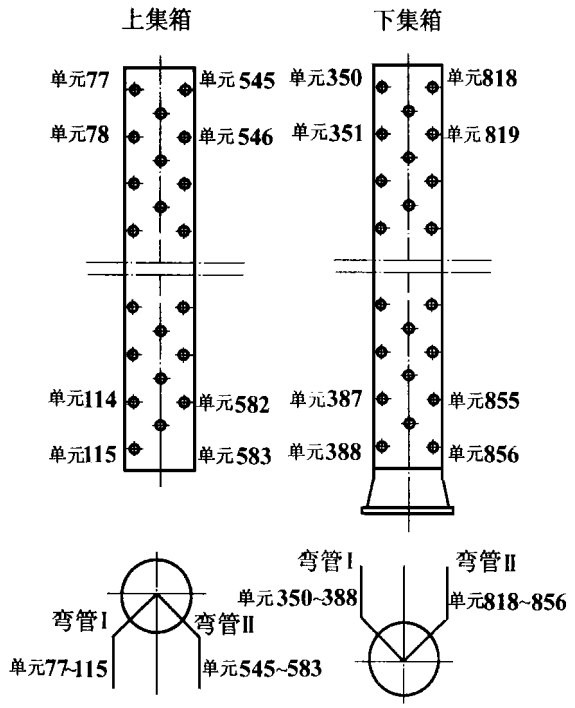

图 4　与集箱相接的弯管单元示意图

表 4　与下集箱连接弯管各单元热应力

(单位: MPa)

热应力	384	385	386	387	388	852	853	854	855	856
σ^a	−0. 7	−0. 4	5. 5	15	30	2	3	7	17	33
σ^b	−231	−257	−279	−292	−298	212	210	204	199	199
σ^c	−96	−96	−94	−90	−85	125	135	145	153	162

从表 3、表 4 看到最大热应力:

$\sigma^a_{max} < [\sigma]_{537℃}$, $\sigma^b_{max} > \sigma_s$, $\sigma^c_{max} > [\sigma]_{470℃}$

5　结论

余热锅炉启动状态是过热器管束受力最恶劣状态, 在外管网约束下, 过热器管束在锅炉启动瞬间热应力已超过材料的屈服极限, 因此外管网对过热器管束过大的约束力, 加之频繁启动的疲劳应力是过热器管束发生断裂的主要因素。外管网的布置形成了与余热锅炉连接处的管网刚度, 影响着过热器管束的寿命和安全运行, 可通过对外管网的改进设计以求解决过热器管束断裂问题。

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(渠　源　编辑)

ent will be beneficial for decreasing transverse flow losses. The analysis of vorticity isolines shows that the horseshoe vortex and passage vortex measure and strength in the positively-curved blades have been found to be smaller than those in the straight blades. Furthermore, from the distribution picture of energy loss factors one can see that the use of positively-curved blades can bring about a decrease in energy loss of a cascade inner-flow field. **Key words**: positively-curved blade, energy loss, secondary flow

基于过程系统工程理论的热力系统性能模拟=**Thermal System Performance Simulation Based on a Process System Engineering Theory** [刊, 汉] /Ding Yanjun, Wang Peihong, Lu Zhengzhong, et al (Southeastern University) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —153 ~155

Based on the introduction of a process system engineering (PSE) theory this paper sets up a process unitary model and a system model for a power plant steam turbine thermodynamic system through the use of a sequential-module method of the PSE theory. A performance simulation has been conducted using a loop fracture and convergence algorithm, and the accuracy of the above-cited model verified. Finally, analyzed and discussed is the feasibility and importance of applying PSE theory for the power plant performance simulation, analysis, optimization and diagnosis. **Key words**: process system engineering, sequential-module method, thermodynamic system, performance simulation

浅析《统一建筑法规》地震荷载的计算与应用=**A Preliminary Analysis of Seismic Load Calculation on the Basis of "Uniform Building Code of** 1997" **and its Practical Use** [刊, 汉] /Wang Jianhua, Yue Xue, Zhou Chengli (Harbin Boiler Co. Ltd.) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —156 ~159

This paper describes a seismic load calculation method as set forth in "Uniform Building Code of 1997". The selection of various factors in the seismic load calculation is discussed and practical engineering-calculation examples given. **Key words**: seismic-proof design, basic seismic design, sole shear

过热器管束断裂分析=**Superheater Tube-Bank Fracture Analysis** [刊, 汉] Li Ming, Wang Yanbin (Harbin No.703 Research Institute) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —160 ~161

With the help of a finite-element method a thermal stress calculation and analysis was performed of a heat recovery boiler superheater tube-bank and an outer tube network system. It is noted that during a boiler start-up the superheater tube-bank is subjected to a most unfavorable load-bearing condition. Moreover, the layout rigidity of the outer tube network can influence the service life and safe operation of the superheater tube bank. **Key words**: superheater, thermal stress, outer tube network, rigidity

锅炉一次风通过节流孔板时的数值模拟=**Numerical Simulation of a Boiler Primary-Air Flow through a Throttle Orifice-plate** [刊, 汉] /Pan Weiguo, Shen Feng, Zheng Puyan, et al (Shanghai Electric Power Institute) //Journal of Engineering for Thermal Energy & Power. —2000, 15(2). —162 ~164

A numerical simulation was conducted of the air and pulverized-coal multi-phase flow pattern after an adjustable throttle orifice-plate was installed in the pulverized-coal horizontal feed-pipe of a boiler combustion system. It has been found through the above-mentioned simulation that an effective numerical simulation method consists in the following: a gas-phase turbulent flow model is first described by the use of a K-ε dual-equation model and with the help of SIMPLE algorithm the gas-phase speed field can be calculated. Then, a FSRT model and Lagrange method are employed to calculate the particle field characteristics. **Key words**: gas-solid multiple-phase flow, numerical simulation

利用一维热膜探针对旋流燃烧器出口冷态旋流流场的测量=**Measurements of Cold-state Rotating Flow**