文章编号: 1001- 2060(1999) 05- 0385- 02

风机转子的振动与临界转速计算分析

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摘 要: 某电厂锅炉送风机,多次发生叶片断裂事故,严重影响了电厂生产的正常运行。本文针对风机转子进行了固有频率振型和临界转速计算。根据对计算结果的对比分析,排除了转子结构不合理是造成事故直接原因的假设,避免了电厂对转子结构进行不必要的改造。

关 键 词: 风机; 转子; 振动; 临界转速; 计算

中图分类号: TK223. 26

1 计算原始资料

1. 1 风机转子的有关参数

叶轮直径 (m)	2. 07
轮毂直径 (m)	0. 9
风机转子重量 (kg)	1071
送风机转速 (r/min)	1490

1. 2 材料特性数据

名称	材料牌号	弹性模量 (MPa)	泊松比	密度 (kg/m^3)
轮毂	16Mn	2. 0× 10^5	0. 3	7. 8× 10^3
主轴	45# 钢	2. 0× 10^5	0. 3	7. 8× 10^3

2 转子振动计算分析

2. 1 力学模型的建立及边界条件

转子为悬臂支承结构,转子质心在左轴承外侧。左侧轴承为 N322MB滚珠轴承,右侧轴承为 6322M滚珠轴承与 7322BCM止推轴承的组合,轴承安装在轴承座上,轴承座位于固定的轴承支承装置上。在边界条件处理时,取左侧轴承的支点为转子的可滑动支点,即仅约束 *Y*和 *Z*向坐标的运动,放开 *X*向的位移,对右侧轴承的支点,做固定约束,即限制 *X*、*Y*、*Z*向的运动。由于轮毂中心具有空腔体,叶片根部也有空孔,所以进行力学模型的模拟,就应求接近实际情况,有限元节点及单元化分较多。

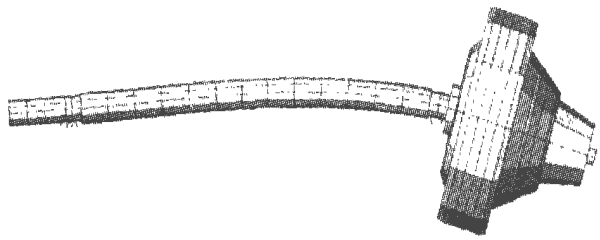
因液压调节驱动装置是与轮毂相接的,而其顶部又无固定支承,其重量就直接作用在转子轴承左侧,对转子强度、振动分析结果影响较大,所以我们在分析转子的同时,是连同液压调节驱动装置一同进行分析的。转子的有限元模型,共化分为 3754个节点, 2664个单元。

2. 2 转子的振动计算结果

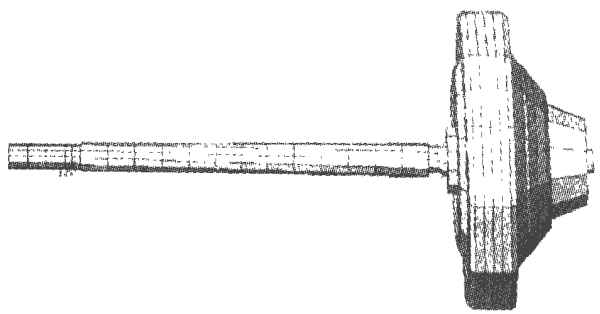
转子的前三阶振动固有频率和振型列于表 1中,转子的振型图片见图 1。

表 1 转子的前三阶振动固有频率和振型

振动阶数和振型	振动固有频率
一阶弯曲振动	30. 2 Hz
二阶扭转振动	45. 2 Hz
三阶弯曲振动	118. 3 Hz



(a) 一阶振型图 (弯曲)



(b) 二阶振型图 (扭转)

收稿日期: 1998- 09- 10; 修订日期: 1999- 02- 10

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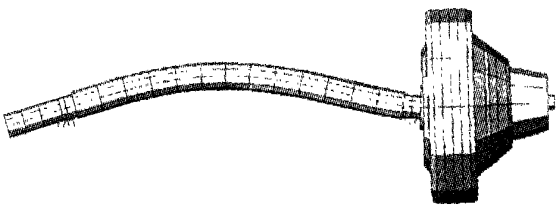

(c)三阶振型图(弯曲)

图 1 转子振型图

2.3 转子振动计算结果分析

转子的工作转速为 1490 r/min,其工作频率值 f = 24.83 Hz,计算结果表明,转子的前三阶固有频率均高于其工作频率,计算出的第一阶弯曲频率为 30.2 Hz 则 $(f_1 - f_g)/f_g \times 100\% = 21.6\%$,满足工程上避开 15%的要求,此外转子的其它各阶固有频率都已避开了激振源频率,且无倍频关系存在,所以从振动角度来看,转子不会产生共振,转子结构是安全可靠的.

3 转子临界转速计算分析

3.1 计算方法简述

转子临界转速计算的初参数法,具有通用性与较简易性相结合的特点. 对于一个多跨度变截面的轴来说,要直接求解振动分方程是很困难的. 初参数法是把实际转子简化成具有若干集中质量的有限自由度系统,质点间用无质量等截面弹性轴段联接,质量分布的间距应选择与真实转子相近. 同样,联接质点间弹性轴的柔度取值也与真实转子相应.

3.2 简化假设

计算中作如下简化和假设:

· 前、后支承轴承视为铰支.

· 整个转子简化成有 18个集中质量的有限个自由度系统,质点间是用无质量有弹性的等截面轴联接,沿轴没有考虑温度的影响.

· 轮毂、叶片、可转动叶机构等简化成集中质量,分计入和不计入陀螺力矩影响的两种情况计算.

· 转子上的负荷(横向力、轴向力、扭矩等)对临界转速的影响未考虑.

· 由于没有确切的支承刚度数据,计算中参照类同风机设定两种支承方案进行计算:

a. 支承为刚性.

b. 支承刚度为 10^4 kN/cm.

3.3 计算结果与讨论

· 支承为刚性时:

未计入陀螺力矩影响时一阶临界转速

N^I_{kp} = 1845 r/min

计入陀螺力矩影响时一阶临界转速

N^I_{kp} = 2276 r/min

· 支承刚度为 10^4 kN/cm 时:

未计入陀螺力矩影响时一阶临界转速

N^I_{kp} = 1733 r/min

计入陀螺力矩影响时一阶临界转速

N^I_{kp} = 2249 r/min

实际的支承并不是绝对刚性,而是弹性支承. 但电厂未提供支承刚度数据. 根据经验取偏低的支承刚度值 10^4 kN/cm,一般结构将大于 10^4 kN/cm. 转子的临界转速将高于支承刚度为 10^4 kN/cm 的临界转速. 随支承刚度提高而提高临界转速的结论从本计算中支承为刚性与支承刚度为 10^4 kN/cm 的计算值中也已表明.

从计算结果看到,考虑陀螺力矩影响,将增大轴系刚度提高临界转速值. 且提高幅度约为 30%,这主要是轮毂叶片直径大,质量集中的原因. 从计算结果看到:转子为刚性轴系,工作转速在第一阶临界转速以下工作,最小安全裕量为 50.9%以上,不会产生临界转速下的共振.

4 结论

通过以上转子的振动与临界转速计算分析,发现当不考虑陀螺力矩的影响时,其临界转速的频率与转子一阶振频非常接近,从而也证实了两种计算方法的正确性,也提高了结论的可靠程度. 在此基础上,可确定转子结构是合理的,因此我们没有改变转子的结构,而是采用了其它方法,避免了事故的再次发生,减少了不应有的损失.

参考文献

〔1〕 陆颂元. 汽轮发电机组大不平衡非线性振动与轴系事故. 动力工程, 1994(6).

(何静芳 编辑)

itability. The foregoing can be conducive to an enhancement of the failure diagnosis automation level. **Key words** symptom acquisition, vibration, fault diagnosis

风机转子的振动与临界转速计算分析= **Calculation and Analysis of Fan Rotor Vibrations and Critical Speeds**〔刊,中〕/Gao Chunshan, et al (Harbin No. 703 Research Institute) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 385~ 386

The forced draft fans of a certain power station suffered repeated failures because of blade ruptures, seriously disrupting the normal operation of the power station. Calculations were conducted of the fan rotor natural frequency, vibration modes and critical speeds. On the basis of a contrast analysis of the calculation results, the assumption that an irrational rotor construction caused the failure has been ruled out. This made it possible to avoid the unnecessary work relating to the modification of the fan rotor structure. **Key words** fan rotor, vibration, critical speed, calculation

电厂旋风分离器计算机仿真与优化= **Computer-based Simulation and Optimization of a Power Plant Cyclone Separator**〔刊,中〕/Yang Weihong, Xiao Zeqiang (South China Industrial University) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 387~ 389

With the help of a computational fluid mechanics CFX4.2 software a three-dimensional numerical simulation was performed of the gas-solid two-phase flow of a power plant cyclone separator for pulverized-coal following its modification. The rotational flow of its gas-phase flow field was calculated by the use of a differential Reynolds stress model with the particle movement being computed in Lagrangian coordinates. To attain an optimized solution, employed is a multi-block grid with appropriate-shaped meshes. Discrete equations were solved by a SIMPLE algorithm. The velocity distribution at various sections and particle trajectory within the modified cyclone separator were presented. It is demonstrated that the modified cyclone separator enjoys a higher efficiency as compared with conventional cyclone separators. **Key words** cyclone separator, numerical calculation, rotational flow

基于知识与模糊神经网络的故障诊断技术= **Knowledge and Fuzzy Neural Network-Based Fault Diagnostic Techniques**〔刊,中〕/Qiu Zhongyu, et al, (Zhejiang University) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 390~ 392

Discussed in this paper are the theory and method of constructing a rule-based fuzzy neural network (FNN). With respect to a large-sized rotating machine the authors have come up with a fault diagnostic technique, which employs a multi-layer rule base and intelligent reasoning approach. With the rule-type fuzzy association memory device serving as a classification and synthesis algorithm of the diagnostic system the knowledge-based symbol processing method is organically integrated with the FNN. Discussed are the issues of FNN input and output vectors. This paper has provided a new approach for setting up a fault-diagnosis expert system suitable for power plant turbogenerators. **Key words** rotating machinery, fault diagnosis, fuzzy neural network, expert system

承担冷负荷的热水网水力工况模拟计算及应用= **Simulated Calculation on an Hourly Basis of Hydraulic Operating Conditions for a District Heating and Cooling water Network and its Applications**〔刊,中〕/Fu Lin, Jiang Yi (Qinghua University) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 393~ 396

The basic principles are described of a simulated calculation on an hourly basis of the hydraulic operating conditions for a district heating and cooling (DHC) water network. The method for determining heat loads of this kind of network is given and specific examples of calculating pump working points and energy consumption in the DHC project are provided to explain the above-mentioned principles. **Key words** DHC network, hydraulic operating conditions, heat load, pump, simulated calculation

供热机组特性分析的循环函数法= **Cycle Function Method for the Analysis of Heat Supply Unit Character-**