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供热机组特性分析的循环函数法及其应用

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摘 要: 介绍了蒸汽动力循环的局部定量分析方法—— 电厂蒸汽循环的函数与方程 (以下简称循环函数法),并将之用于供热机组运行特性的分析,编制了通用的分析软件包。对国内外典型供热机组的分析计算表明,该软件包计算准确、使用方便,极大地方便了对供热机组特性的分析工作。

关 键 词: 供热机组; 循环函数; 特性分析

中图分类号: TK262

1 循环函数与方程式

对图 1所示系统,根据反平衡原理

循环吸热量 $Q_0 = 1 \cdot (h_0 - h_{fw})$ (1)

循环放热量 $Q_k = T_k (h_k - h_{wk})$ (2)

循环做功量 $W_k = Q_0 - Q_k$ (3)

循环效率 $Z_t = W_k / Q_0 = 1 - Q_k / Q_0$

$= 1 - [T_k (h_k - h_{wk})] / (h_0 - h_{fw})$ (4)

式 (3) 和 (4) 不仅简化了循环功的计算,而且指明: 在循环初终参数 (h_0、h_{fw}、h_k、h_{wk}) 一定的条件下,减少 T_k,可减少 Q_k,增加 W_k,为提高循环效率明确了目标,这一结论与热力学第二定律关于减少循环的不可逆性可以提高循环效率的结论是一致的[1]。

单位工质动力循环的排汽率 T_k 是由回热系统的结构与抽汽参数 (机组运行工况) 决定的,确定 T_k 及其它特性参数 (如循环功、汽耗率、凝汽率等) 与回热系统结构、抽汽参数间的函数关系,是循环函数法解决的基本问题之一。

供热机组以电、热两种能量产品供应用户,其循环较凝汽机组复杂。利用循环复合迭加的方法,经严格的理论推导,获得供热循环各项特性系数的计算函数与方程式是该方法需解决的另一基本问题。

由于供热机组循环的复杂性,传统的热平衡方法对其进行分析相当繁琐,使用循环函数方法后,极大地简化了供热机组的特性分析工作。

2 供热机组的特性系数及其相互关系

根据循环函数法,对任何单抽供热循环 (如图 2所示) 可视为纯凝循环 (k循环) 与采暖抽汽循环 (T循环) 的复合 (对于双抽机组还有生产抽汽循环)。以下就单抽供热机组的循环分别进行讨论。

2.1 单项特性系数

循环函数法定义了以下特性系数:

T_k— 凝汽系数,指单位进汽条件下,凝汽循环的排汽份额, $T_k = 1 - \sum_{i=1}^{n} T_i$;

w_{0k}— 单位进汽的凝汽循环内功, kJ/kg进汽;

n_{0k}— 单位进汽的凝汽循环电功, $n_{0k} = w_{0k} Z_m Z_g / 3600$ kWh/kg进汽;

d_k— 单位电功的进汽率, $d_k = 1 / n_{0k}$ (kg/kWh);

为了分析问题的方便,上述指标亦可表达为单位排汽条件下的指标。

T_k— 单位排汽时的进汽份额, $T_k = 1 / T_k$;

w_k— 单位排汽时的凝汽循环内功, $w_k = T_k \cdot w_{0k}$;

n_k— 单位排汽时的凝汽循环电功, $n_k = T_k \cdot n_{0k}$;

k— 单位电功率下的排汽份额, $k = 1 / n_k = T_k \cdot d_{0k}$;

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类似于凝汽循环,供热循环亦有以下特性系数:

对于进汽 1 kg,排汽为 τ_T kg的 T循环:

w_{0T}— 单位进汽 T循环内功;

n_{0T}— 单位进汽 T循环电功;

d_T— 单位电功的 T循环汽耗率;

对于排汽 1 kg,进汽为 τ_T kg的 T循环:

w_T— 单位排汽 T循环内功;

n_T— 单位排汽 T循环电功;

T— 单位电功的 T循环排汽率。

根据上述单项特性系数有

$$D_0 = D_{0k} + D_{0T} = \tau_k D_k + \tau_T D_T \quad (5)$$

$$P = P_k + P_T = n_k D_k + n_T D_T \quad (6)$$

式中 D_0、D_k、D_T、P分别表示过汽量、凝汽量、T循环抽汽量、电功率。

上面(5)、(6)是相互独立的。

2.2 综合特性系数与动力特性方程

由式(6) $D_k = (P - n_T D_T)/n_k$

代入式(5) $D_0 = d_k P + (\tau_T - n_T d_k) D_T$

$= d_k P + \tau_{TK} D_T$

τ_{TK}— T级抽汽引起的进汽多耗系数

同样,由式(5) $D_k = (D_0 - \tau_T D_T)/\tau_k$

代入式(6) $P = n_{0k} D_0 - (\tau_T n_{0k} - n_T) D_T =$

$n_{0k} D_0 - n_{Tk} D_T$

n_{Tk}— T级抽汽引起的做功减少系数。

由式(6)还可表达为: $D_k = (P - n_T D_T)/\tau_k n_{0k}$

$= \tau_k d_k P - \tau_k d_k n_T D_T = k P - k_T D_T$

k_T— T级抽汽引起的凝汽减少系数。

这样供热机组的动力方程为:

$$D_0 = d_k P + \tau_{Tk} D_T \quad (7)$$

$$D_k = k P - k_T D_T \quad (8)$$

$$P = n_{0k} D_0 - n_{Tk} D_T \quad (9)$$

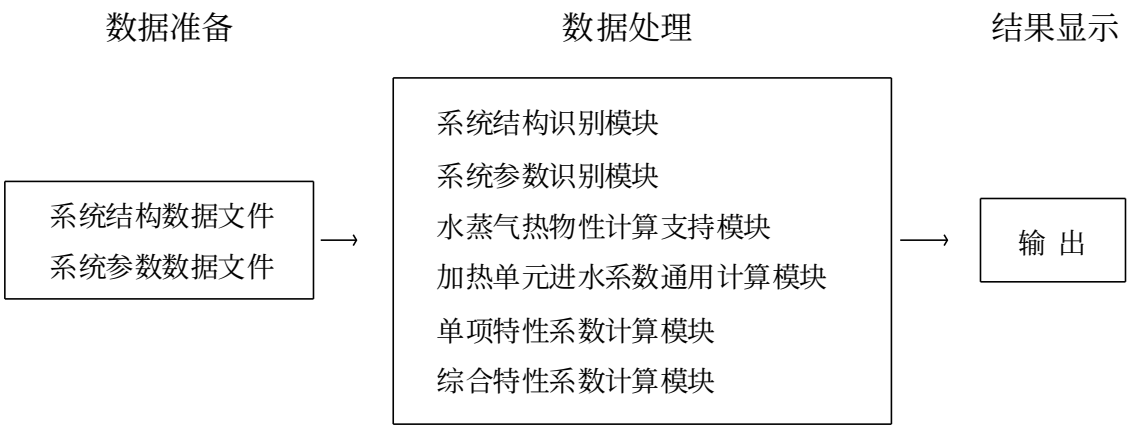
τ_{Tk}、n_{Tk}、k_T为 T级抽汽的综合特性系数。

单项和综合特性系数是了解供热机组性能的重要指标。(7)、(8)、(9)就是单抽供热机组的运行特性方程。

3 通用分析软件的编制

我国运行的供热机组的型式和参数是多种多样的,有国产的、也有进口的,实现供热机组的通用分析有十分重大的实用意义,因此,根据循环函数法的基本原则,编制通用分析软件包。

框图如下:



4　计算示例及分析

名　　称	符号	单位	C50－90/1.2	C50－90/13	CC50－90/42/15	CC50－90/13/1.2	引T 50－2*
凝汽循环排汽率	τ_k	kg/kg进汽	0.687	0.702	0.713	0.674	0.691
凝汽循环进汽率	τ_k	kg/kg排汽	1.456	1.425	1.402	1.484	1.447
单位进汽凝汽流做内功	w_{0k}	kJ/kg进汽	941.235	965.921	973.172	808.758	989.147
单位排汽凝汽流做内功	w_k	kJ/kg排汽	1370.402	1376.91	1364.38	1200.59	1431.24
单位电功凝汽流汽耗率	d_{0k}	kg排汽/(kWh)	3.825	3.848	4.021	4.637	3.752
单位电功凝汽流排汽率	k	kg排汽/(kWh)	2.627	2.7	3.868	3.123	2.593
单位生产抽汽进汽率	τ_p	kg/kgP抽汽	~	1.378	1.424	1.451	1.483
单位生产抽汽做内功	w_p	kJ/kgP抽汽	~	654.05	428.767	660.856	767.872
单位生产抽汽进汽多耗系数	τ_{pk}	kg/kgP抽汽	~	0.701	0.983	0.634	0.707
单位生产抽汽凝汽减少系数	k_p	kg/kgP抽汽	~	0.475	0.3142	0.55	0.537
单位采暖抽汽进汽率	τ_t	kg/kgT抽汽	1.327	~	1.424	1.297	1.271
单位采暖抽汽做内功	w_t	kJ/kgT抽汽	1036.051	~	632.245	934.625	971.877
单位采暖抽汽进汽多耗系数	τ_{tk}	kg/kgT抽汽	0.227	~	0.774	0.141	0.289
单位采暖抽汽凝汽减少系数	k_t	kg/kgT抽汽	0.756	~	0.463	0.778	0.679

* 引T 50－2为双抽供热机组，工业抽汽压力为 1.3 MPa，采暖抽汽压力为 0.12 MPa。

由于不同供热机组的热力系统结构和参数的差别，供热机组的特性存在差异，相应地，不同机组在热电中节煤效果也不相同。

4.1　分析上表进汽多耗系数的变化可见，抽汽压力愈高，该供热抽汽引起的进汽多耗系数就愈大，相应地，联产供热的热耗量就愈高，折算节煤量就愈小。

4.2　分析上表凝汽减少系数的变化可见，抽汽压力愈高，该供热抽汽引起的凝汽减少系数就愈低，意味着相应地冷源损失就愈大，热电联产的经济效果就愈差。

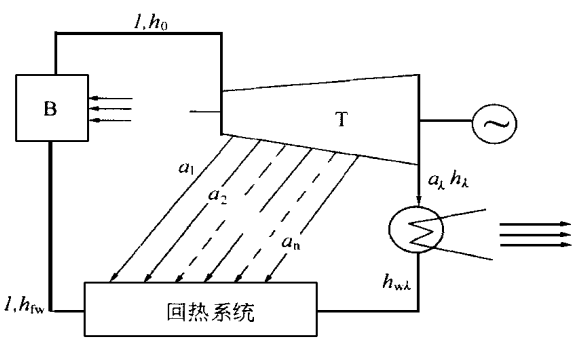


图 1　凝汽机组

可以从不同的侧面了解供热机组的运行经济效果，还可以直接得到机组运行的特性方程，为确定合理的运行方式提供依据。

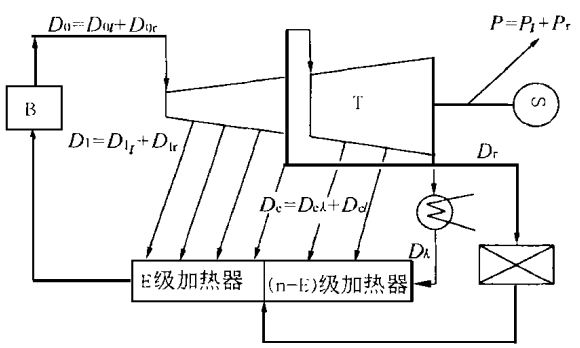


图 2　单抽供热机组

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利用循环函数法分析得到的综合特性系数，不仅

(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-**

istics and its Applications〔刊,中〕/Wang Peihong, et al (Southeastern University) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 397~ 399

Described in this paper is a local quantitative analytical method for a steam power cycle, the so called power plant steam cycle function and equation method. It has been employed for the analysis of heat supply unit operating characteristics. In this connection the authors have prepared an universally applicable analytical software package. The analytical computation of typical heat supply units both at home and abroad has shown that the above-cited software package features ease of use and precision in calculation, contributing to an exceptionally high convenience for analyzing heat supply unit characteristics. **Key words** heat supply unit, cycle function, characteristics analysis

热电厂计算机监控与综合管理系统的研制= **Research and Development of a Computer-based Monitoring and Comprehensive Management System for Heat-and-Power Cogeneration Plants**〔刊,中〕/Le Jing (Huazhong University of Science & Technology) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 400~ 402

This paper presents a plant-wide comprehensive information and monitoring network system for cogeneration plants. It integrates the cogeneration plant production real-time monitoring, and remote and real-time monitoring of heat network end-users with the production real-time management and enterprise comprehensive management. Through the comprehensive utilization of a computer and its network technology the system under discussion has succeeded in realizing information sharing within the network, real-time monitoring of production and end-users as well as the enterprise comprehensive management. As a result, the safe and economic operation of the cogeneration plant is fully ensured along with a considerable enhancement of plant broad-based management level. **Key words** cogeneration plant, computer-based monitoring, computer-based comprehensive management

完全气体一维无粘可压振荡流动的一个解析解= **Analytical Solution of an Ideal Gas One-dimensional Non-viscous Compressible Oscillation Flow**〔刊,中〕/Huang Diangui (National Research Center of Thermal Power Plants under the Southeastern University) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 403~ 405

Presented in this paper is an algebraic and explicit analytical solution of ideal gas one-dimensional non-viscous compressible oscillation flow. In addition to its theoretical significance this solution can also serve as a standard method for verifying various kinds of numerical solutions. Moreover, it enjoys promising prospects in widespread engineering applications. **Key words** flow, oscillation

正确选择进油位置= **Maximization of the Effectiveness of an Oil Cleaning Device by Correctly Siting Its Oil Inlet**〔刊,中〕/Wang Jinming (Huaibei Municipal Thermal Power Plant) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 406

轴承工作温度探讨= **An Exploratory Investigation of Bearing Operating Temperatures**〔刊,中〕/Wang Jinming_ (Huaibei Municipal Thermal Power Plant) //Journal of Engineering for Thermal Energy & Power. – 1999, 14(5). – 407