电厂热力系统工质流量分配计算方法

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[摘要] 文中提出了一组热力系统工质流量分配因子的计算公式,这组公式可以简化电厂热力性能的计算方法,这种计算是运用热力学第二定律分析电厂热力系统的基础。

关键词 循环函数法 加热单元 流量系数
中图分类法 TK212

1 引言

电厂热力系统的优化设计对节能有着重要的意义。近年来,许多学者对电厂热力系统的计算和优化方法进行了广泛深入的研究[1-4]。热力系统的计算方法,有传统的求解代数方程组计算法、等效焓降法、循环函数法等。这些方法是以热力学第一定律为基础的。随着电厂节能工作的深入开展,人们不仅要求知道热力系统总的不可逆损失的大小,而且需要知道不可逆损失在热力系统中的分布。这样,以热力学第一定律为基础的分析方法已逐渐不能适应节能工作的需要,进行以热力学第二定律为基础的精确定量分析方法的研究势在必行。在运用热力学第二定律进行热力系统分析时,求解热力系统的真实流量分配是关键。热力系统的工质流量,依据其变化方式可分为调节抽汽(疏水)和非调节抽汽两种形式。调节抽汽(疏水)的流量以及所携带的能量品质是由热力系统的调节设备(或工艺过程)决定的,对于热力系统流量计算而言是已知量;非调节抽汽量则取决于回热系统加热器的热平衡,是热力系统流量计算的待求量。由此可见,热力系统流量计算的核心就是求取回热系统的非调节抽汽量。

文中通过对目前的循环函数法的改进,提出了一组简便、通用的计算电厂热力系统流量分配的公式,非常适用于编制计算机程序进行电厂热力系统精确定量分析。

2 回热系统简化原理

在回热系统中将汇集疏水的加热器连同向其排放疏水的表面式加热器看作一个整体,称为一个加热单元。典型的加热单元的型式如图 1所示。

图中,h_i、h_{Ti}、$\bar{t}_i$、$\bar{t}_{Fi}$,分别为第 i号加热器的非调节抽汽焓、调节抽汽焓、出口主凝结水焓、疏水焓。d_i、d_{Fi}、d_{Ti} 分别为第 i号加热器的单元抽汽系数、单元疏水系数、单元调节抽汽系数。$\bar{t}_{Gn}$、d_{Gn} 分别为单元主凝结水进口焓、单元进水系数。r_i、r_{Fi} 为主凝结水、疏水在第 i号加热器中的焓变化;q_i、q_{Ti} 为非调节抽汽、调节抽汽在第 i号加热器中的焓变化。对于表面式加热器,$r_i = \bar{t}_i - \bar{t}_{i+1}$,$r_{Fi} = \bar{t}_{Fi-1} - \bar{t}_{Fi}$,$q_i = h_i - \bar{t}_{Fi}$,$q_{Ti} = h_{Ti} - \bar{t}_{Fi}$。对于汇集式加热器,选取进入该加热单元的主凝结水焓 $\bar{t}_{Gn}$ 作为汇集式加热器的计算能量的起点(这与传统的循环函数法不同),$r_n = \bar{t}_n - \bar{t}_{Gn}$,$r_{Fn} = \bar{t}_{Fn-1} - \bar{t}_{Gn}$,$q_n = h_n - \bar{t}_{Gn}$,$q_{Ti} = h_{Ti} - \bar{t}_{Gn}$

加热单元的单元抽汽系数、单元疏水系数以汇集式加热器汇集非调节疏水之后的流量 1kg为基准(这与传统的循环函数法不同),根据表面式加热器的能量平衡和物质平衡可得如

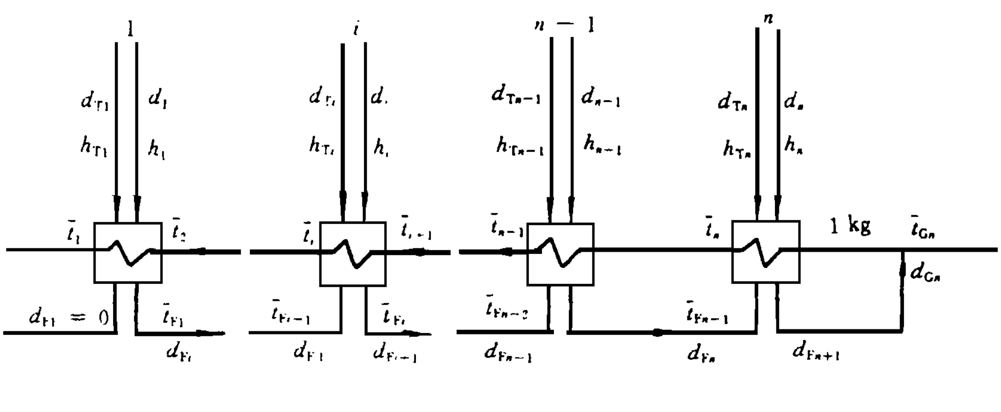

图 1 典型加热单元

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下计算式:

$$d_{Fi+1} = d_{Fi} + d_i + d_{Ti} \quad (1)$$

$$r_i/\eta = d_{Fi}\times r_{Fi} + d_i\times q_i + d_{Ti}\times q_{Ti} \quad (2)$$

其中 η 为加热器的热效率。

经整理得:

$$d_{Fi+1} = d_{Fi} + d_{Ti} + r_i/(\eta\times q_i) - d_{Fi}/q_i - d_{Ti}\times q_{Ti}/q_i \quad (3)$$

其中, $d_{Fi} = 0, i = 1, 2, \cdots, n$

加热单元的进水系数为:

$$d_{Gn} = 1 - d_{Fn+1} \quad (4)$$

当有来自第 n号加热器的热量使主凝结水在离开第 n号加热器之后又升高了 Δr,第 n号加热器需增加的抽汽量为:

$$d_n^{**} = \Delta r/q_n \quad (5)$$

Δr将排挤第 n－1号加热器的抽汽,使第 n－1号加热器的抽汽量减少量为:

$$d_{n-1}^{*} = \Delta r/q_{n-1} \quad (6)$$

第 n－1号加热器的抽汽量的减少,使疏水在第 n号加热器的放热量减少,为了维持第 n号加热器的出口主凝结水焓 $\bar{t}_n$ 不变,第 n号加热器应增加的抽汽量为,

$$d_n^{*} = d_{n-1}^{*}\times r_{Fn}/q_n \quad (7)$$

因此,第 n－1号加热器和第 n号加热器的疏水系数应作如下修正:

$$d_{Fn} - d'_{Fn} = d_{n-1}^{*} \quad (8)$$

$$d'_{Fn+1} - d_{Fn+1} = d_n^{*} + d_n^{**} - d_{n-1}^{*} \quad (9)$$

引入单元系数 U: $U = \Delta r/d'_{Fn+1}$

将式(5)、(6)、(7)和 U代入式(8)、(9),经过整理得,

$$d'_{Fn} = d_{Fn} - k_2 \quad (10)$$

$$d'_{Fn+1} = d_{Fn+1}/k_1 \quad (11)$$

其中, $k_1 = 1 - U/q_{n-1}\times [q_{n-1}/q_n + r_{Fn}/q_n - 1] \quad (12)$

$$k_2 = U\times d'_{Fn+1}/q_{n-1} \quad (13)$$

单元进水系数为,

$$d_{Gn} = 1 - d'_{Fn+1} \quad (14)$$

加热器的单元抽汽系数为,

$$d_i = d_{Fi+1} - d_{Fi} - d_{Ti}$$

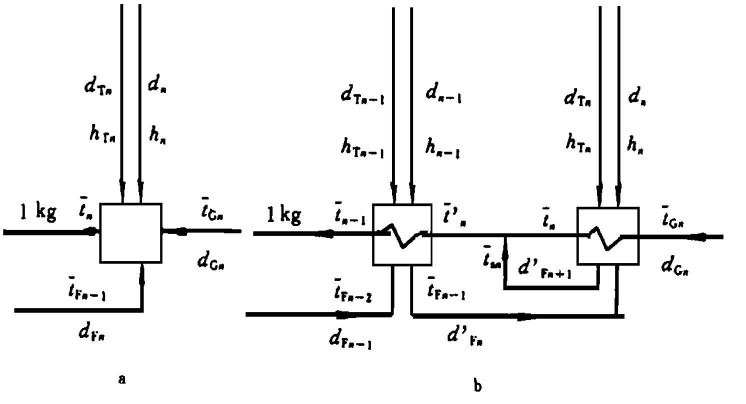

图 2　a混合式加热器

b疏水被泵入加热器出口的汇集式加热器

$$(i = 1, .. n-2, 且\ n \geqslant 3) \quad (15)$$

$$d'_{n-1} = d'_{Fn} - d_{Fn-1} - d_{Tn-1} \quad (n \geqslant 2) \quad (16)$$

$$d'_n = d'_{Fn+1} - d'_{Fn} - d_{Tn} \quad (17)$$

3　讨论

3.1　当加热单元只有一个加热器时,为了使上述公式仍能使用,需要合理地选择递推关系式的初值。为此目的,重新改写式(3):

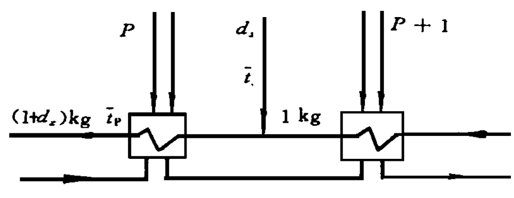

图 3　调节疏水被泵入第 p号加热器主凝结水进口管道

$$d_{Fi} = d_{Fi-1} + d_{Ti-1} + r_{i-1}/(\eta\times q_{i-1}) - d_{Fi-1}\times r_{Fi-1}/q_{i-1} - d_{Ti-1}\times q_{Ti-1}/q_{i-1} \quad (3a)$$

其中, $i = 1, 2, ..., n, n+1$

初值选择为: $d_{F0} = 0$; $d_{T0} = 0$; $q_0 = q_1$;

$r_0 = 0$; $r_{F0} = 0$; $r_{F0} = q_1$。

式(3a)、(10)～(17)可以适用所有型式的加热单元。这组初值适用于所有类型的加热单元。

3.2　U的取值:对于如图 2b当加热单元,$\Delta r = d'_{Fn+1}\times(\bar{t}_{Sn} - \bar{t}_n)$,$\bar{t}_{Sn}$为第 n号加热器抽汽压力下所对应的饱和水焓。所以,$U = \bar{t}_{Sn} - \bar{t}_n$;对于如图 1、图 2a所示的加热单元,$\Delta r = 0$,所以 $U = 0$。这样,式

(3a)、(10)~ (17)可以适用所有型式的加热单元。

3.3　当加热单元的第 p号加热器的入口主凝结水管道上有焓值为 $\bar{t}_x$ 的调节疏水 $d_x(kg)$ 进入主凝结水时(如图 3所示),则主凝结水在第 p号加热器的焓变化为

$$r'_p = r_p + d_x \times (\bar{t}_p - \bar{t}_x) \quad (1 \leqslant p < n) \quad (18)$$

主凝结水在第 1号到第 p-1号加热器的焓变化为,

$$r'_i = r_i + d_x \times r_i \quad (n \geqslant 3) \quad (19)$$

其中,i= 1,...,p-1。

用 r'_i 代替式(3a)中的 r_i(i= 1,...,p),而从第 p+1号到第 n号加热器的主凝结水焓变化仍为 r_i,可用式(3a)、(10)~ (17)计算该加热单元的流量系数。这时,流出该加热单元的主凝结水流量为(1+ d_x)(kg)。若要求出相对于 1(kg)流出该单元主凝结水流量,只需在上述计算的基础之上乘以修正系数 [1/(1+ d_x)]即可。

3.4　当有纯热量 q_x(kJ/kg)被进入该加热单元第 p号加热器的主凝结水吸收(以该单元非调节疏水汇入主凝结水管道之后 1(kg)主凝结水为基准),则主凝结水在第 p号加热器中的焓变化将减少 q_x。主凝结水第 p号加热器中的焓变化为,

$$r'_p = r_p - q_x \quad (1 \leqslant p < n) \quad (20)$$

这时,用 r'_p 代替式(3a)中的 r_p,仍可用式(3a)、(10)~ (17)计算该加热单元的流量系数。

4　应用举例

对本文导出的公式(3a)、(10)~ (17)通过具体例子进行了验证,结果见图 4,显然计算结果是正确的。

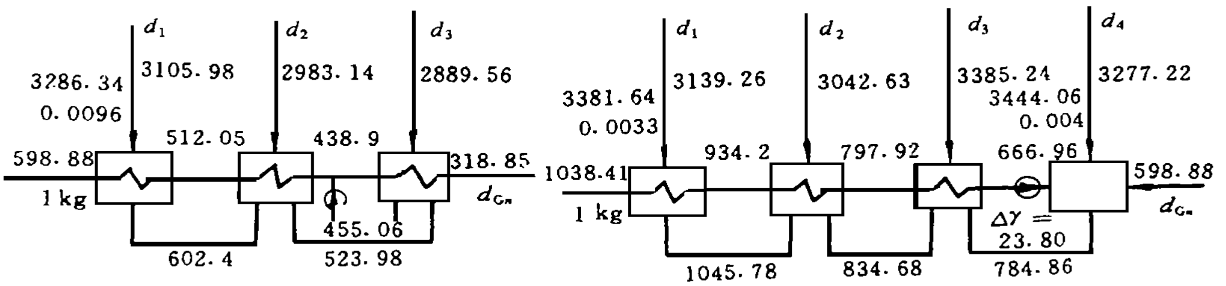

图 4　加热单元应用举例

加热器效率: 0.98
计算结果: d_{Gn} = 0.8935
d_1 = 0.0251; d_2 = 0.0285
d_3 = 0.0433

加热器效率: 0.98
计算结果: 单元进水系数 d_{Gn} = 0.8361;
d_1 = 0.0471; d_2 = 0.0582;
d_3 = 0.0400; d_4 = 0.0114

5　结论

本文给出了一组电厂热力系统工质流量的简便、通用计算公式。在这组公式中可以方便的考虑热力系统连结方式变化或局部参数变化对热力系统的整体流量分配的影响。可以作为对热力系统进行热力学第二定律分析的基础。

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某三元流长叶片振动特性的计算与分析 = **Calculation and Analysis of Three-dimensional Long Blade Vibration Characteristics**[刊, 中]/Gao Chunshan, Li Guiying, Liu Yujie, Zou Jiguo//Journal of Engineering for Thermal Energy & Power. - 1998, 13(5). - 348~350

By using a finite element method a calculation and analysis is conducted of three-dimensional long blade vibration characteristics, especially with an in-depth exploratory study of constraint form of the three-dimensional long blade root portion. The relationship between the blade vibration frequency and the root portion constraint form was obtained, thus providing a basis for further analyzing the causes leading to the rupture of three-dimensional flow long blades. **Key words** three-dimensional flow blade, finite element method, vibration

低肋横槽管单管外降膜吸收的传热传质模型及计算 = **Heat and Mass Transfer Model of a Single-tube Falling film Absorption Outside a Low Rib Horizontal Channel Tube and its Calculation** [刊, 中]/Liu Cunfang, (Shandong Industrial University)//Journal of Engineering for Thermal Energy & Power). - 1998, 13(5). - 351~353

Presented in this paper is a new mathematical model for calculating the single-tube falling film absorption outside a low rib tube. The liquid outside a horizontal channel tube with a rib assuming the shape of an equilateral triangle and having a height less than 0.5 mm is regarded as consisting of an inner and external layer. Through a theoretical analysis obtained is an analytical solution of the speed, temperature and concentration distribution inside the inner layer liquid film. The external layer is solved by the use of a numerical calculation method. A second order coupling method is adopted for the liquid between the inner and the external layer so that there will be a smooth transition between the inner and the external layer. The speed, temperature and concentration distribution inside the external tube liquid film of this kind of heat transfer tube has been studied by using the above-mentioned mathematicl model. **Key words** low rib horizontal channel tube, falling film absorption, heat and mass transfer, mathematical model

电站锅炉通用热力计算程序的编制 = **The preparation of a General Thermodynamic Calculation Program for a Utility Boiler**[刊, 中]/Liu Yangfeng, Lu Yukun, Wang Jun(North China Electrical Power Engineering University)//Journal of Engineering for Thermal Energy & Power. - 1998, 13(5). - 354~356.

A general thermodynamic calculation program suitable for medium pressure up to super-high pressure coal-fired boilers has been developed by utilizing VB and Fortran language mixed programming. The present paper gives a brief description of the structure of this general program and the approach for solving some key technical problems. The thermodynamic calculation of three boilers of different capacities was also conducted by using the above-cited general program. **Key words** boiler, thermodynamic calculation, program

电厂热力系统工质流量分配计算方法 = **A Study of the Method for Calculating the Working Medium Flow Distribution of a Power Plant Thermodynamic System**[刊, 中]/Yan Shuibao (North China Institute of Water Resources and Hydropower)//Journal of Engineering for Thermal Energy & Power. - 1998, 13(5). - 357~359

A group of formulas for calculating the working medium flow distribution factor of a thermodynamic system is described in this paper. With the help of this group of formulas it is possible to simplify the method for calculating a power plant thermodynamic performance. Such a calculation constitutes a basis for the analysis of a power plant thermodynamic system by the use of the second law of thermodynamics. **Key words** cycle function method, heating unit, flow rate factor

喷水减温器内部过程的数值模拟 = **Numerical Simulation of the Internal Process of a Spray Water Desuperheater**[刊, 中]/Lou Gang, Zhang Mingchuan (Shanghai Jiaotong University)//Journal of Engineering for Thermal Energy & Power. - 1998, 13(5). - 360~363

Proceeding from the basic principle of liquid breakage the authors have proposed a physical model describing the formation of initial liquid drop following the spray of desuperheating water from a nozzle into a steam flow, secondary breakage and a vaporization following this. On the basis of the above a proper assumption is introduced and a numerical simulation conducted with respect to the interaction of the steam and desuperheating water as well as its flow process. As a result, a quantitative description is obtained of the vaporization length. **Key words** desuperheating water, vaporization length, numerical simulation

DMC-502锅炉微机控制系统 = **A Microcomputer-based Control System for a DMC-502 Boiler** [刊, 中]/Song Hongtao (Harbin No. 2 Pharmaceutical Factory), Li Biao (Harbin Bank Electronics Co. Ltd.)//Journal of Engineering for Thermal Energy & Power. - 1998, 13(5). - 364~366

应用极性相关技术在线测量高温烟气流动速度 = **On-line Measurement of High-temperature Gas Flow Speed through the Use of Polarity Correlation Techniques**[刊, 中]/Zhou Jie, Yuan Zhenfu, Pu Xingguo, et al (Zhejiang University)//Journal of Engineering for Thermal Energy & Power. - 1998, 13(5). - 367~369

By the use of a measurement system based on a single-chip microcomputer MCS 51 series and self-developed expansion system (including software) conducted is a successful on-line measurement of high-temperature gas flow speed in a piping. With the help of a novel zero-cross time sampling method and zero-cross time algorithm the above-cited system underwent a polarity correlation treatment of the gas flow noise signal. A rapid search of a timede-lay value corresponding to a peak value was conducted and on this basis a measurement speed obtained. The tests show that the measurement technique features high precision, short measurement time and high reliability, thus making it suitable for industrial site on-line measurement. **Key words** polarity correlation, flow speed, on-line measurement, high-temperature gas