逆流喷雾式饱和器内湿化过程的实验研究

王玉璋, 李 一兴, 翁 史烈, 王永泓

（上海交通大学 动力机械及工程国家教育部重点实验室，上海 200030）

：对逆流喷雾式饱和器内部空气的湿化过程进行实验研究，实验中不仅测量了饱和器进出口湿空气的相对湿度、温度和水的温度，而且也测量了饱和器内部几 个高度截面上湿空气的相对湿度和气相、液相的温度。根据实验测量的湿空气的相对湿度和温度，计算出了饱和器内湿空气的含湿量和测量高度间湿空气的加湿量。由实验结果可见，随水气质量比的增大，饱和器出口湿空气的温度和温升也相应增大。湿空气的含湿量和水的蒸发量、出口 温度随进口 水温升高、水气质量比增大而增大。在所有实验工况下，饱和器出口湿空气接近或达到饱和。随空气速度增大 水滴逃逸量增大。总体上饱和器内部下部主要是加湿进口 空气，上部是加湿和加热空气。

:   ;   ;   ;

: TK123   : A

1

(Humid Air Turbine, HAT)   ,

1985

[1~2]

,

,   HAT

[3]

。   HAT

2

[4]

2 150 mm,   1 580 mm

PDA   [5]

WIKA   —

—19. 9~+400 ℃,

±1.0℃,   100 ℃   0.1 ℃。

T   —

[6]

（VAISALA ）   HMD70U

±2％。

3

1

图 1　相对湿度测量装置

0.5 mm，　16

1。

2

1.0 MPa，
1.6 MPa。

: (1)
; (2)

; (3)
(
),

; (4)
(
),　　　　　　　　　(
),

表 1

	/kg·s⁻¹	/℃		/kg·s⁻¹	/MPa	/℃
1	0.027	21.88	33.96	0.004 58	1.0	61.40
2	0.040	22.20	34.66	0.004 58	1.0	60.80
3	0.027	20.88	34.18	0.005 83	1.6	60.32
4	0.040	21.98	34.52	0.005 83	1.6	61.18
5	0.027	22.16	51.92	0.004 58	1.0	61.20
6	0.040	22.68	50.26	0.004 58	1.0	61.68
7	0.027	21.76	51.86	0.005 83	1.6	60.20
8	0.040	22.60	52.60	0.005 83	1.6	61.30
9	0.025	22.40	35.16	0.004 58	1.0	75.92
10	0.040	22.84	35.98	0.004 58	1.0	76.46
11	0.025	22.46	35.94	0.005 83	1.6	76.06
12	0.040	22.84	36.20	0.005 83	1.6	76.18
13	0.027	22.26	49.70	0.00458	1.0	76.16
14	0.040	22.28	51.16	0.00458	1.0	75.16
15	0.027	21.42	51.56	0.00583	1.6	75.16
16	0.040	21.80	51.38	0.00583	1.6	75.62

3
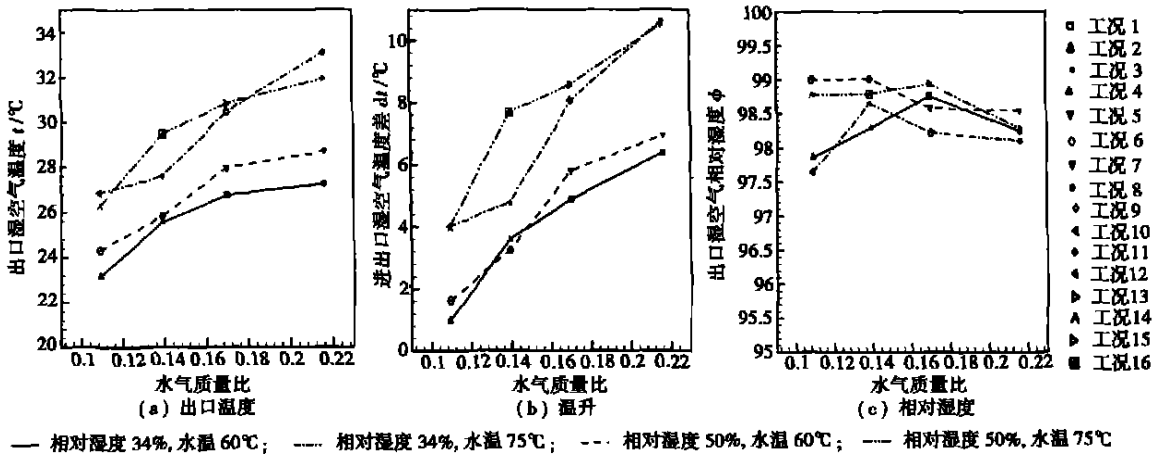
图 2　饱和器出口湿空气的温度、温升的相对湿度的分布
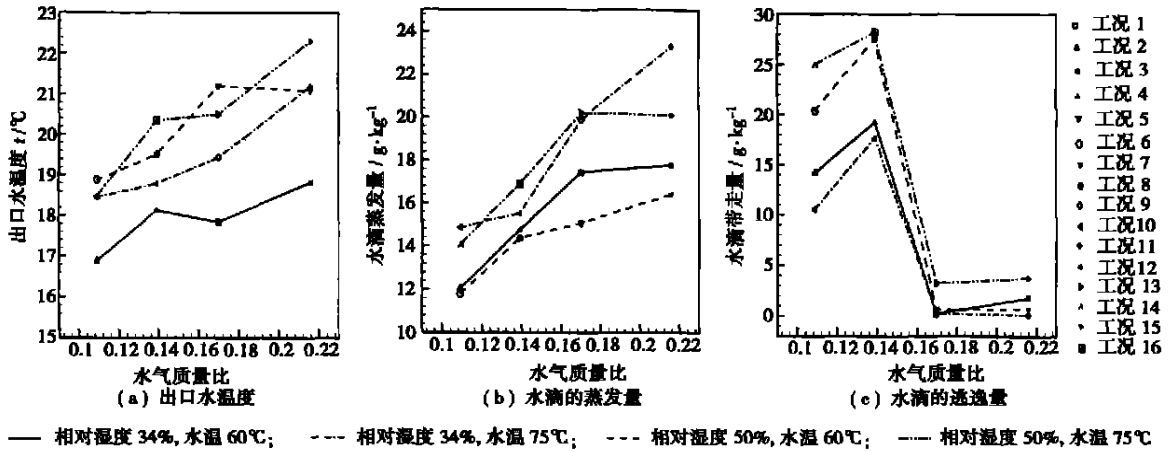
图 3　饱和器出口水温度、饱和内水滴蒸发量和水滴逃逸量的分布

HAT

(g/kg　　)。

HAT

(g/kg　　)。

4

6

6

30 mm。　4　　　　　　　　　　1. 0 MPa　4

H , 。 $H=0$ $X=0$,

,

。X

(a) 进口水温 60 ℃ (b) 进口水温 75 ℃

图 4 饱和器内部湿空气相对湿度的分布

(a) 进口水温 60 ℃时温度分布（℃）

(b) 进口水温 75 ℃时温度分布（℃）

图 5 饱和器内气相和水滴温度分布

, (6 14），

50%, ,

。 4（a） , (5 13) ,

（*H*

，， 。

=－505）， ，

， ，

， ，

， ，

。 。

， 4 ，

， ， ，

15 mm,

， ， ， 50％。 5

， ， 。

， ， ，

。 ，

。

4 （a）（b） ， ， ，

，

图 6 饱和器内湿空气的含湿量和加湿量

5 （a）（b） ， 0.027 kg/s

， ， ，

。 ， 4 ℃ ，

0.040 kg/s ， ，

4　　　　　　　5　　　　　　　（2）

4

　　　　　　　6 。　6（a）

（　　　　）

　　　　　　　　　　　　　　　　　　　　　（3）

　　　　　　　6（b）

$H = -400 \sim -505$ mm

　　　10 g/kg,

　　　　　　　　　　　　　　　　　　　　　：

　　　　$H = -160 \sim -265$ mm

[1]　　　　　，　.　　　　　HAT　　　　　[J].　　　　　　，
　　　1993, 6(2)：1—6.
[2]　　　　，　　　　.　　　　　（HAT）
　　　[J].　　　　　　，1998, 13(78)：387—391.
[3]　PARENTE JOAO O S, TRAVERSO ALBERTO, MASSARDO ARIS-
　　　TIDE F. Saturator analysis for an evaporative gas turbine cycle[J]. Ap-
　　　plied Thermal Engineering, 2003, 23：1275—1293.
[4]　　　　　，　　　　，　.
　　　[J].　　　　　，2004, 17(2)：41—45.
[5]　　　　　，　　　　.
　　　[J].　　　　，2003, 23(1)：2210—2214.
[6]　　　　，　　　，　　　，　.
　　　[J].　　　　　　，2004, 24(7)：152—156.

5

　　　　　　　　　　　　：

（1）

Taurus 65

据《Diesel & Gas Turbine Worldwide》2005 年 1~2 月号报道,美国 Solar Turbine 公司推出其最新研制的 Taurus 65 工业燃气轮机发电机组。该机组被设计成满足电力生产市场对于 6 MW 功率等级机组更高效率和更高排气温度的要求。

高的热效率结合高的排气温度和低的排放使 Taurus 65 成为对于热电联产应用很有吸引力的一个产品。

Taurus 65 具有 13 级轴流压气机,压比为 15∶1,空气质量流量为 19.4 kg/s。三级动力涡轮包括有带冠的第三级涡轮叶片,以便提高部件效率。环形燃烧室装有 10 个燃料喷嘴,它结合了 Solar 的干式贫预混 Solo NO_x 燃烧系统,以便减少 NO_x 和 CO 排放,在没有燃烧后处理装置的情况下保证 NO_x 排放不超过 15 mg/kg。

Taurus 65 燃气轮机的热耗率为 10 943 kJ/kWh,热效率为 33%,排气质量流量为 70 614 kg/h,排气温度为 547 ℃。打算把该机组作为热源,用于许多余热回收应用,包括生产蒸汽、吸收制冷或各种直接和间接的供热活动。

计划 2005 年 8 月交付使用第一台生产型 Tauras 65 燃气轮机发电机组。

　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　　（　　　　　）

= A Closed Cycle Helium Gas Turbine Plant Used for a High-temperature Gas Cooled Reactor-based Electric Power Generation Unit [,] / WANG Hui (Harbin No. 703 Research Institute, Harbin, China, Post Code: 150036), WANG Chong (Heilongjiang University, Harbin, China, Post Code: 150080) // Journal of Engineering for Thermal Energy & Power. — 2005, 20(4). — 337~341

A brief account is given of the helium gas turbine plant installed in a HTGR-GT electric power generation unit. After a description of its cycle, working medium and key factors having an impact on its cycle efficiency analyzed are the current and near-term parameters of the HTGR-GT power generation unit-based Brayton cycle system. Regarding the helium gas turbine plant the design and construction features of its major components are discussed. They include the turbine, air compressor, heat exchangers, rotors, bearings and hot helium gas piping, etc. Materials used for the helium gas turbine are also briefly described. In conclusion, two key technical issues demanding close attention during the development of HTGR-GT power generation equipment are pointed out. They are: 1. the development of safe and reliable magnetic bearings to be used for a large-sized unit, 2. the elimination of radioactive pollution to ensure a safe operation and the realization of effective maintenance. **Key words:** power generation unit, helium gas turbine, heat exchanger, material, design

PSR = Thermal Strength Analysis of the Corrugated Plates of Primary Surface Recuperators (PSR) [,] / LIU Zhen-yu, CHEN Hui-er (Mechanical & Power Engineering Institute under the Shanghai Jiaotong University, Shanghai, China, Post Code: 200030) // Journal of Engineering for Thermal Energy & Power. — 2005, 20(4). — 342~345

Proposed is the strength design technology for an innovative compact recuperator, the so-called primary surface recuperator (PSR). In conjunction with the development of a PSR for an intercooled recuperator-based marine gas turbine with a 3.7 MW gas turbine serving as a background unit a physico-mathematical model is set up for analyzing the thermal strength of PSR plates on the basis of thermo-elastic mechanics and heat transfer theory. A contrast calculation was conducted for the thermal stresses being subjected to by three kinds of commonly seen corrugated heat-transfer plates. They feature elliptical, sine wave and parabola curves. An analysis is performed of the impact of plate thickness, pressure difference at two sides, plate temperature and shape on the thermal strength of the plates. The minimum design thickness of the plate based on von Mise equipotent stress limiting value is presented along with a study of the elastic deformation situation under the typical operating condition of the corrugated plates. The work conducted by the authors is of major reference value for the construction design of PSR. **Key words:** primary surface recuperator, corrugated plate, thermal stress

PG6581B = Performance Analysis of a PG6581B Gas Turbine-based Coal-fired Combined Cycle System [,] / WANG Li-wei, XU Xiang-dong (Key Laboratory of Electrical Power System & Power Generation Equipment Control and Simulation of the Thermal Energy Engineering Department under Tsinghua University, Beijing, China, Post Code: 100084) // Journal of Engineering for Thermal Energy & Power. — 2005, 20(4). — 346~349

The construction and features of a PG6581B gas turbine-based coke-carrying thermal partial-gasification coal-fired combined cycle system are described along with a calculation and analysis of the performance of the PG6581B gas turbine when firing coal gas of medium and low calorific value. The results of the calculation indicate that the output power and efficiency of the PG6581B will somewhat be reduced when firing the above-mentioned coal gas, but the reduction is within an acceptable range. A further analysis has revealed that by lowering the content of non-combustible constituents in coal gas, such as CO_2 and N_2 and by increasing the H_2 content in the combustibles it is possible to enhance gas turbine performance. A preliminary calculation of the combined cycle system shows that the thermal efficiency of the PG6581B gas turbine-based coke-carrying thermal partial-gasification coal-fired combined cycle system can exceed 42%. **Key words:** coal-fired combined cycle, coke-carrying thermal partial-gasification, PG6581B, performance analysis

= Experimental Study of a Humidifying Process in a Counter-flow Spray Saturator [,] / WANG Yu-zhang, LI Yi-xing, WENG Shi-lie, et al (Education Ministry Key Laboratory for

An experimental study was conducted of the humidifying process of air in a counter-flow spray saturator. During the study measurements were taken not only of the relative humidity and temperature of the humid air and water temperature at the saturator inlet and outlet, but also of the humid-air relative humidity and the temperature of gas and liquid phase of the sections at several levels of height within the saturator. On the basis of experimentally measured humid air relative humidity and temperature calculated was the humidity content of the humid air within the saturator and the added humidity of humid air between the levels of height being measured. From the experimental results it can be seen that with an increase in water-gas mass ratio, there will be a corresponding increase in humid air temperature and temperature rise at the outlet of the saturator. The humidity content of the humid air and the evaporation rate of water and outlet temperature will increase with an increase in inlet water temperature and water-gas mass ratio. Under all experimental conditions the humid air at the saturator outlet approaches or has attained saturation. With an increase in air speed there will be an increase in escaped quantity of water droplets. Viewed as a whole, within the saturator humidified inlet air predominates at the lower portion with the upper portion being occupied by humidified and heated air. **Key words**: saturator, humidifying process, relative humidity, gas-liquid two phase flow

＝Numerical Simulation Calculation of the Flow Rate and Lifting Force Characteristics of a Marine Steam Turbine Short-seat Valve[,] / LIU Zi-gen (Harbin No. 703 Research Institute, Harbin, China, Post Code: 150036), LI Yan, MEI Xue-yan, et al (Harbin Steam Turbine Works, Harbin, China, Post Code: 150046) //Journal of Engineering for Thermal Energy &Power. －2005, 20(4). －356～360

Owing to the restriction of inner space in a marine steam turbine and its multi-regime operation requirements short-seat valves are employed in some marine steam turbines. Due to a considerable reduction of diffusion section length a relatively great change will take place in the aerodynamic performance and strength/vibration characteristics of the short-seat valve. This, in turn, can affect to a fairly great extent the general performance of the steam turbine. Based on the experimental study of a short-seat valve the authors have performed a numerical calculation and analysis. Through aerodynamic tests a group of curves was obtained for the flow rate and lifting force coefficients of a marine steam turbine short-seat valve. On the basis of a compressible N-S equation and by using a S-A turbulent flow model, a finite integral method and the non-structural network of a four-faced body a numerical simulation calculation was carried out for the above-mentioned valve. The numerical calculation of the valve has revealed that the calculated results at various relative degrees of valve opening and various pressure ratios agree quite well with the test results. In addition, a calculation method generally applicable for various kinds of short-seat valves was obtained, hus providing an important basis for the design and performance analysis of marine regulating valves and bypass valves. **Key words**: short-seat valve, S-A turbulent flow model, flow rate factor, lifting force factor

W ＝ **Experimental Investigation of the Combustion Process Detection in a W-shaped Furnace**[,] / FANG Qing-yan, YAO Bin, JIANG Rui-bao, et al (National Key Laboratory for Coal Combustion under the Huazhong University of Science &Technology, Wuhan, China, Post Code: 430074) //Journal of Engineering for Thermal Energy &Power. －2005, 20(4). －361～364

A whole set of equipment was designed for conducting temperature measurements, flue gas analysis, and particulate sampling research, etc in a large-sized coal-fired boiler. It comprises water-cooled gun suction thermocouples, fly-ash constant speed sampling device and flue gas multi-function measurement analyzer. With the help of the above devices comprehensive measurements and tests were conducted on a 300 MW W-shaped boiler, including temperature measurements, etc along with the measurement of the carbon content and particulate diameter distribution of the sampled particulates. The results of the measurements and tests indicate that in-furnace temperature and pulverized coal fineness are major factors having a great impact on the burn-out rate of the pulverized coal. When the boiler load exceeds 260 MW, the pulverized coal fineness will become a predominant factor. Because of the insufficient reserve margin of the coal pulverizer capacity, in case of low coal quality, the pulverized coal fineness will drastically deteriorate under a higher boiler load, resulting in an increase in me-