文章编号: 1001－2060(2004)04－0408－03

异型高温热管翅的实验研究

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摘　要: 对一结构特殊、长为 6 cm 的异型高温热管翅在不同的工况下进行实验研究。通过改变蒸发段长度、绝热段长度、冷凝段长度、散热条件及其放置位置, 观察其壁面温度分布情况, 掌握其最佳工作状况。结果表明, 当热管翅水平放置且在自然环境下散热时, 不凝性气体的影响使热管翅冷凝段末端温度偏低; 当蒸发段长度太长时, 热管翅蒸发段会出现过热点, 而冷凝段出现温度回升现象; 若使热管翅的冷凝段在有限空间散热, 则温度回升现象消失; 当热管翅倾斜放置时, 热管翅工作性能处于最佳状态。

关　键　词: 热管翅; 异型高温热管翅

中图分类号: TK172　　文献标识码: A

1　引　言

热管是一种导热性能好的元件, 如果将其作为一种导热材料应用于扩展表面上传热, 其翅化系数及翅效率均可以达到相当高的值, 这在工程中具有广阔的应用前景。文献[1] 提出将热管作为一种新型的翅片引入到空间表面进行强化换热, 从而形成一种全新形式的翅片——热管翅。文献[2～4] 都对热管翅进行了初步的研究与探讨。为进一步分析热管翅的影响因素, 掌握其最佳工作性能, 本文在上述文献研究基础上, 对异型高温热管翅在不同的工况下进行实验研究, 分析其蒸发段或冷凝段长度变化、散热条件变化以及放置位置变化对热管翅的影响, 目的是为进一步的开发研究工作奠定基础。

2　实验装置与测试系统

实验所用的高温热管翅为异型热管翅, 如图 1 所示, 该热管翅总长度为 6 cm, 管内径为 1.2 cm, 管内有吸液芯, 充有液态金属钠。管外结构为异型, 中间部分为圆柱型, 长度为 1.5 cm。两端截面积形状如图 A－A 剖面, 一端长度为 3 cm, 一端长度为 1.5 cm。异型高温热管翅测试的实验装置见图 2。该系统主要由加热、冷却和测量系统组成。加热系统为电加热炉, 绝热系统由保温材料组成以防止热量散失, 冷却系统分两种情况测试, 一种是将热管翅完全暴露于自然环境中, 以自然对流与辐射方式进行冷却; 另一种是将热管翅外面罩上直径较大的保温筒, 使其在有限的空间散热。热管翅的壁面温度采用 φ 0.02 cm 的镍铬—镍硅热电偶点焊在管壁上测量。图 3 给出高温热管翅壁温测试时的 6 个热电偶的布置形式。实验是在 6 种不同工况下进行(见表 1), 通过改变蒸发段长度、绝热段长度、冷凝段长度、散热条件及其放置位置的变化, 观察其壁面温度分布情况, 掌握热管翅的最佳工作性能, 了解其最佳工作状况。

表 1　高温热管翅的工作状况

	总长/cm	蒸发段长度/cm	绝热段长度/cm	冷凝段长度/cm	散热条件	放置位置
工况 1	6	3.0	1.5	1.5	自然环境	水平放置
工况 2	6	4.5	0	1.5	自然环境	水平放置
工况 3	6	4.5	0	1.5	有限空间	水平放置
工况 4	6	4.5	0	1.5	有限空间	倾斜 30°
工况 5	6	3.0	1.5	1.5	有限空间	倾斜 30°
工况 6	6	3.0	1.5	1.5	自然环境	倾斜 30°

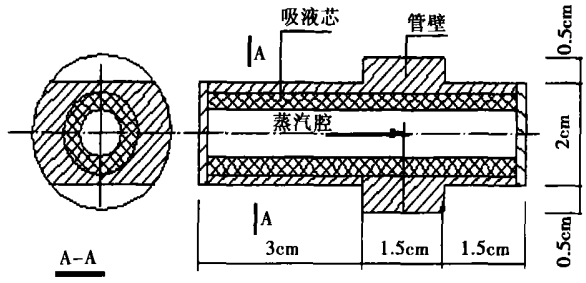

图 1　异型高温热管翅结构

收稿日期: 2003－09－23
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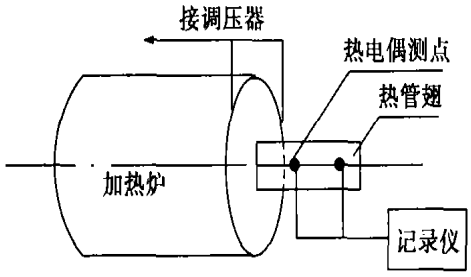

图 2　实验装置图

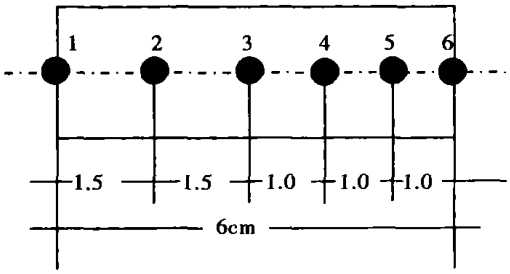

图 3　热电偶的布置形式

3　实验结果讨论与分析

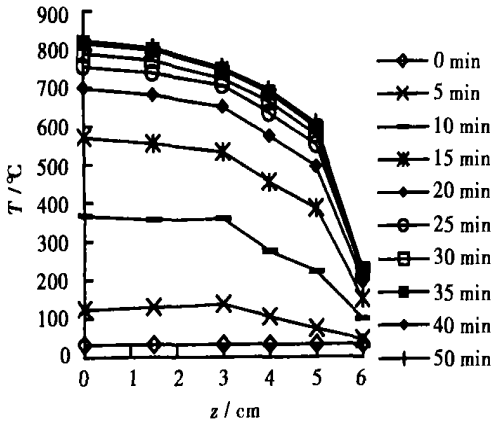

图 4　热管翅在工况 1 下的温度分布

图 4 ~ 图 6 给出热管翅水平放置时的壁面温度分布。图 4 为热管翅在工况 1 下的壁面温度分布, 由图中看出热管翅受热之后, 大约在 25 min 时蒸发段热电偶 1 的温度就达到 760 ℃, 然后随着时间的增加, 温度增加幅度不再明显增大, 表明热管翅基本上达到稳定状态。此时蒸发段的等温性很好, 但冷凝段的末端由于不凝性气体的存在, 温度始终偏低。图 5 表征的是工况 2 的工作情况, 与工况 1 相比, 工况 2 的热管翅蒸发段长度变长, 而绝热段长度为零, 冷凝段长度不变, 即受热面积增大。由图 5 中可以看出热管翅壁面温度受热初始时出现明显过热点, 但随着时间增加过热现象减弱, 大约在 30 min, 蒸发段热电偶 1 大约为 750 ℃时, 热管翅达到稳定状态。工况 2 的冷凝段末端热电偶 6 还出现温度回升现象, 且比工况 1 的热电偶 6 的温度有所提高, 但热电偶 5 的温度比工况 1 的偏低。实验时还发现另外一种现象, 如果将冷凝段外罩上直径较大的保温筒, 使其在有限空间散热, 则热管翅的冷凝段末端热电偶 6 的温度回升现象消失(如图 6 中工况 3 壁面温度分布)。

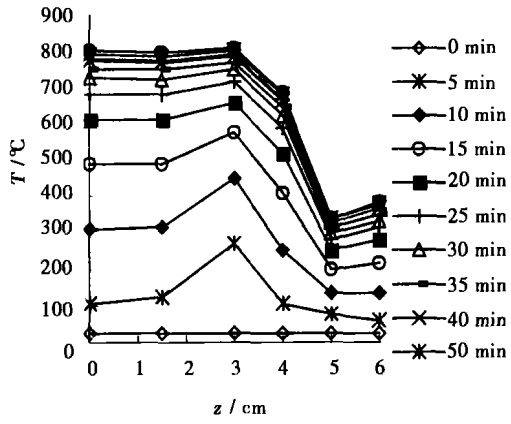

图 5　热管翅在工况 2 下的温度分布

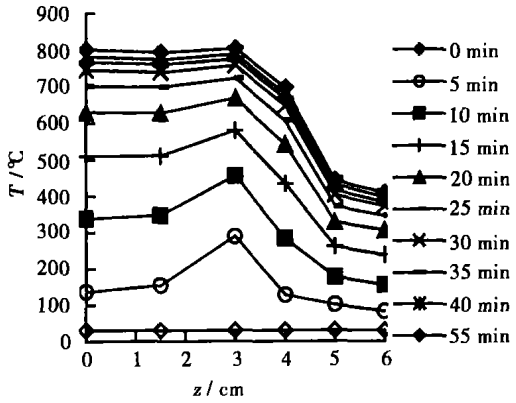

图 6　热管翅在工况 3 下的温度分布

进一步分析高温热管翅的壁面温度分布, 将热管翅倾斜放置进行测试。图 7 ~ 图 9 给出热管翅倾斜放置时的壁面温度分布。图 7 的工况 4 与图 6 的工况 3 相比较, 倾斜放置后热管翅蒸发段受热初始时过热现象降低, 热电偶 5 的温度明显提高。若受

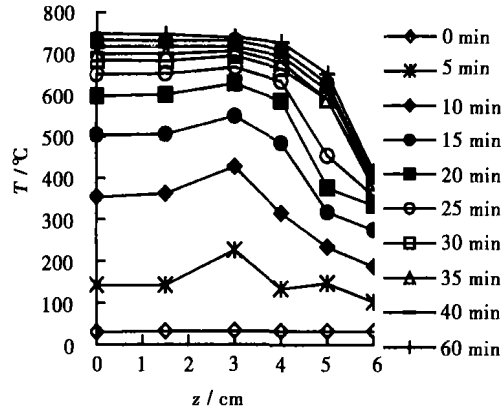

图 7 热管翅在工况 4 下的温度分布

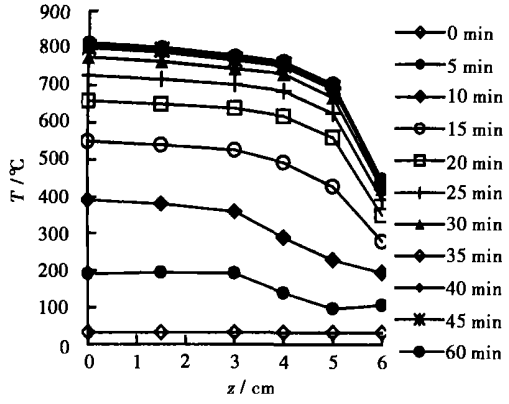

图 8 热管翅在工况 5 下的温度分布

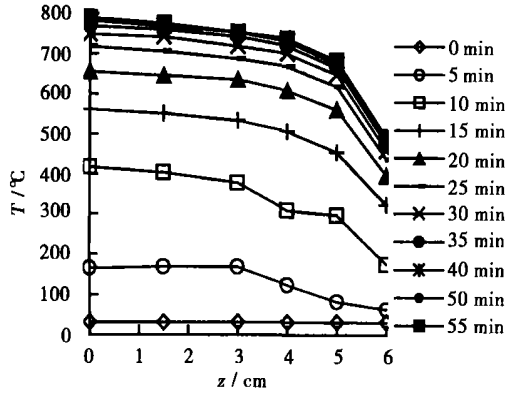

图 9 热管翅在工况 6 下的温度分布

热面积再减少，冷凝段散热条件再变化，使其分别在工况 5、6 下工作，结果发现热管翅的工作性能进一步有所改善，工况 6 得到最好的工作状况，即当蒸发段长度为 3 cm，绝热段长度为 1.5 cm，冷凝段为 1.5 cm 且倾斜放置时，热管翅的工作性能最好。根据传热原理，由传热公式 $K=\frac{Q/A}{\Delta T}$ 可以计算传热系数，A 为热管翅的有效横截面积，ΔT 为热管翅蒸发段平均温度与冷凝段的平均温度之差。若将 Q 按其输入功率计算，A 采用有效内截面积，则可以算出该种情况下异型高温热管翅的传热系数约为 8 846 W/(m^2·K)。

4 结 论

(1) 异型热管翅在不同工况下工作时，大约运行 25 ~ 30 min 就完全达到稳定状态，热管翅的蒸发段表面温度能达到近 760 ℃。

(2) 当热管翅水平放置时，热管翅冷凝段末端温度偏低；当增大受热面积时，热管翅蒸发段有明显的过热点，会出现温度回升现象；但当减少散热量时，使其在有限空间散热，温度回升现象消失。

(3) 当热管翅倾斜放置，且蒸发段长度为 3 cm，绝热段长度为 1.5 cm，冷凝段为 1.5 cm，在自然环境散热时，异型热管翅的温差最小，工作性能为最佳。

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半焦氧化过程中反应活化能的变迁= **The Transition of the Activation Energy of Semi-coke During Its Oxidation Process** [刊, 汉] / ZHANG Shou-yu, LU Jun-fu, YUE Guang-xi (Thermal Engineering Department, Tsinghua University, Beijing, China, Post Code: 100084), WANG Yang (Institute of Coal Chemistry under the Chinese Academy of Sciences, Taiyuan, China, Post Code: 030001) // Journal of Engineering for Thermal Energy & Power. — 2004, 19 (4). — 398 ~ 401.

The activation energy of five kinds of semi-coke during its eigen oxidation in air was investigated by using a thermogravimetric balance. These semi-cokes were prepared from Datong coal, Shenmu coal, Yuxian coal, Jianjiang coal and Taiwan petroleum coke by pyrolysis for 7 minutes at a temperature of 900 ℃. A distributed activation energy model (DAEM) was employed to describe the transition of activation energy of semi-cokes during an oxidation process. Initially, the activation energy of Datong coal semi-coke assumes a minimum value. With an increase in carbon loss rate the activation energy will increase (the increase at initial period of reaction is relatively rapid), and decrease on reaching a peak value at a later period of reaction. The activation energy of Jianjiang coal semi-coke is very high at the initial period of reaction (as high as 250 kJ/mol). It decreases rather rapidly at first, but tends to decrease slowly when the carbon loss is assessed at 20%. As for the semi-coke of the other three kinds of coal their activation energy will experience respectively two peaks at the initial and later period of reaction with a relatively mild change between the two peaks. The different transition mechanisms of the activation energy specific to various kinds of semi-coke reflect their different internal qualities. As compared with coal cokes, the semi-coke of petroleum coke exhibits a relatively uniform internal structure. **Key words**: semi-coke, oxidation, activation energy, distributed activation energy model.

空煤比对煤气化过程中痕量元素迁移规律的影响= **The Influence of Air-coal Ratio on the Migration Mechanism of Trace Elements During a Gasification Process** [刊, 汉] / HUANG Ya-ji, JIN Bao-sheng, ZHONG Zhao-ping, et al (Education Ministry Key Laboratory of Clean Coal Combustion Technology and Power Generation under the Southeastern University, Nanjing, China, Post Code: 210096) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 402 ~ 407.

By the combined use of a hydrogenate generator and atomic fluorescence spectrum method as well as an inductance-coupled plasma emission spectrum method measurements were taken of the content of 14 trace elements in gasification products of a constant-pressure fluidized bed. These trace elements are: As, Cd, Co, Cr, Cu, Mn, Mg, Ni, Hg, Pb, V, Se, Sr, Zn. An analysis was conducted of the influence of air/coal ratio on the migration mechanism of trace elements in the gasification products. It has been found that in the high-temperature coke from a cyclone, Cd and Ni have been enriched, and As Co, Cu V, Se and Hg dissipated. Air/coal ratio does not have any significant influence on Mn, Sr, Hg, Se and As. With an increase in the air/coal ratio the relative enrichment factor of Pb, Zn, Cu and Ni will slightly increase, while that of Cd and Mg will decrease. Under a low air/coal ratio V and Cr will have a comparatively high relative enrichment factor. In the low-temperature coke from a cloth bag, Cd, As, Cu, Cr Ni Pb and Zn will be enriched while Co, V Se, and Hg dissipated. With an increase in the air/coal ratio the relative enrichment factor of Pb, Cu and Ni will increase, while that of Cd, As Cr and Se decrease. Relative to high and low-temperature coke the Mn and Sr in the bottom slag will be slightly enriched. An increase in the air/coal ratio will lead to a higher content of Cu and Zn in the gas, and a lower content of Cr, Co, As and Hg in the gas. **Key words**: trace element, migration law, air/coal ratio, fluidized bed, gasification furnace, relative enrichment factor.

异型高温热管翅的实验研究= **Experimental Study of Shaped High-temperature Heat-pipe Fins** [刊, 汉] / ZHAO Wei-lin, ZHUANG Jun, ZHANG Hong (College of Mechanical & Power Engineering under the Nanjing Polytechnical University, Nanjing, China, Post Code: 210009) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 408 ~ 410.

Shaped high-temperature heat-pipe fins with a length of 6 cm and a special configuration underwent an experimental study under various operating conditions. To identify an optimum operating condition, the temperature distribution on a fin wall surface was observed during a change of the following items: evaporating section length, thermal insulation section

length, condensing section length, heat dissipation conditions and their layout location. It was found that when the heat-pipe fins are horizontally placed and allowed to dissipate heat in a natural environment, then due to the influence of a non-condensing gas, there could appear an excessively low temperature at the end portion of the heat-pipe fin condensing section. If the evaporating section is excessively long, there will emerge overheating points with a simultaneous occurrence of temperature rise. If the condensing section of the heat-pipe fin is allowed to dissipate heat in a finite space, the temperature rise phenomenon will disappear. If placed in an inclined position, the heat-pipe fins will attain an optimum performance. **Key words**: heat pipe, heat-pipe fin, shaped high-temperature heat-pipe fin.

脉动热管运行可视化及传热与流动特性的实验研究＝**Experimental Investigation of the Visualization of Pulsating Heat-pipe Operation as well as Heat Transfer and Flow Characteristics** [刊, 汉] / CAO Xiao-lin, XI Zhan-li (Institute of energy and Power Engineering under the Zhongnan University, Changsha, China, Post Code: 410083), ZHOU Jin, YAN Gang (Department of Refrigeration and Cryogenics Engineering, Xi' an Jiaotong University, Xi' an, China, Post Code: 710049) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 411 ~ 415.

A visualization experiment is conducted with respect to the operation of pulsating heat pipes. Under different conditions of filling rate, inclination angles, section shape and heating rate, tests are conducted on the operation of the pulsating heat pipes. The results of the tests indicate that the pulsating heat pipes represent a kind of very effective heat dissipation technology. There exists a heat transfer limit for the pulsating heat pipes. During operations at an optimum filling rate (50%) and an optimum inclination angle (50°), the pulsating heat pipes have a maximum heat transfer limit with a minimum heat transfer resistance under a high heat flux density. In the case of a relatively small heat flux density the pulsating heat pipe with a triangular channel will be superior to that with a square-shaped channel. However, when the heat flux density is relatively great, the shape of the channel will not have any significant influence on heat resistance and unit section heat-transfer limit. The size of the channel exercises a very small influence on the thermal performance of the heat pipes. **Key words**: pulsating heat pipe, visualization, operation mechanism.

基于多参数的电站风机监测技术的试验研究＝**Experimental Investigation of Multiple Parameter-based Monitoring Technology for a Power Plant Air Blower** [刊, 汉] / WANG Shong-ling, HOU Jun-hu, AN Lian-suo (Power Engineering Department, North China Electric Power University, Baoding, China, Post Code: 071003) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 416 ~ 420.

By using a experimental study method an investigation was conducted of a multiple parameter-based monitoring technology involving the performance, non-steady state flow and mechanical vibrations of a power station air blower. On the basis of the stable and good mapping mechanism existing among the performance parameters as reflected by non-dimensional performance curves, a RBF (Radial Basis Function) network featuring excellent approximation characteristics was employed to approximate the non-dimensional performance curves of the air blower. As a result, a parameter mapping-based flow-monitoring model was derived, thereby realizing the on-line monitoring of the air blower performance. Through a study of the rotating stall at the 4-73 air blower suction and pressure side and the frequency characteristics of inlet vortex flow and an analysis of three kinds of non-steady flow specific features given are combined eigen parameters capable of accurately describing three kinds of non-steady state flows. Mechanical vibration characteristics of the air blower are divided into harmonic, energy and singularity characteristics. By using frequency-division section technology and a binary small-wave transformation method derived are harmonic monitoring indexes, energy and singularity indexes. **Key words**: air blower, parameter monitoring, RBF network, small wave transformation, experimental study.

900 MW 锅炉水冷壁鳍片超宽问题分析及处理＝**Analysis and Treatment of the Problem Relating to Excessive Width of Water Wall Fins in a 900 MW Boiler** [刊, 汉] / FENG Wei-zhong (Shanghai Waigaoqiao No. 2 Power Generation Co. Ltd., Shanghai, China, Post Code: 200137) // Journal of Engineering for Thermal Energy & Power. — 2004, 19(4). — 421 ~ 423.

Described is the problem relating to the excessive fin width in some parts of the boiler water wall used in a Shanghai