Investigation on Thermo-physical Properties of Graphitized Carbon Materials

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Abstract: A transient experimental system was designed to determine the thermo-physical properties of the graphitized carbon material for aluminum reduction industry by employing modern electrical facilities and data acquisition apparatus. The periodic heat flow was recognized by the two thermocouples as a sinus temperature variation with decreasing amplitude and increasing phase lag when the heat wave propagated through the specimen. The thermal diffusivity can be calculated directly by processing experimental data, and then the thermal conductivity can be obtained with relation to thermal diffusivity if the specific heat and the density are known. The measuring system and the instrument are applicable in the temperature 20～300℃. The method will pave a way to obtain the available thermo-physical properties data.

Key words: periodic heat flow method; thermal conductivity; thermal diffusivity; graphitized cathode; aluminum reduction cell
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At present, cathode carbon material for Aluminum reduction cell is mainly semi-graphitic carbon which uses anthracite coal and graphite fragment as raw material in China. Compared with graphitized carbon, the resistivities of heat shock and sodium corrosion/penetration of semi-graphitic carbon block are worse, the thermal conductivity is lower and the electric resistivity is higher. The aluminum electrolytic technology has difficulty in further developing because of those inferior lining materials in China[1-2]. The application of graphitized cathode carbon material is presently unprecedented in China. A transient thermo-physical properties measurement method, called as periodic heat flow method has been developed in this research. The conductivity and the diffusivity of several kinds of graphitized cathode block and semi-graphitic cathode block samples for industrial test have been determined and calculated. Compared with the apparatus using a laser as a periodic heat source, this experimental test facility is cheap and feasible[3]. Its convenient operating system and reliable determining results give a possibility to establish a national data bank of thermo-physical properties of carbon material for aluminum reduction cell.

1 Experimental

Based upon the assumption of this experiment that the specimen could be considered as a semi-infinite cylinder and the heat conduction process in it is of one axial dimension, the thermal diffusivity of the specimen can be formulated by measuring the decreasing amplitude or the increasing phase lag between the two different positions as the heat wave propagated through the specimen in its axial direction[4]. When the one end of the specimen is exposed to a periodic sinus heat flow and the other end is kept the constant temperature, the thermal diffusivity can be calculated by using the theoretical formula of periodic heat flow method[5]. The thermal conductivity can be got with relation to thermal diffusivity if the specific heat and the density are known[6-7]. The two methods, the amplitude decay and the phase lag, are combined to improve the classical method in this research.

The specimen is mounted in the concentric position of a vertical tubular furnace where the temperature is kept at the given value initially. As an independent temperature controller to meet the boundary condition at the top, the cooling system, connected with the top of

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the specimen. The bottom of the specimen connects with a small electrical chip heater. Additionally, an electric tube furnace is applied to reduce the radical heat dissipation as an auxiliary side heater.

2 Results and Discussion

According to the principle of least squares procedure, the results of determination are optimized and treated by using single-variable searching method[8]. Figure 1 and Figure 2 respectively showed the relationships between temperature and thermal diffusivity/thermal conductivity in the temperature 20～300℃.

The thermal diffusivity and the thermal conductivity decrease with increasing of the temperature. The thermal diffusivity of the graphitic carbon materials increases when the graphite percentage is higher in the same condition. The thermal conductivities of the graphitized carbon materials fluctuate slightly in the temperature 20～300℃. Table 1 listed the calculated results and the corresponding reference values from the literatures[9－11].

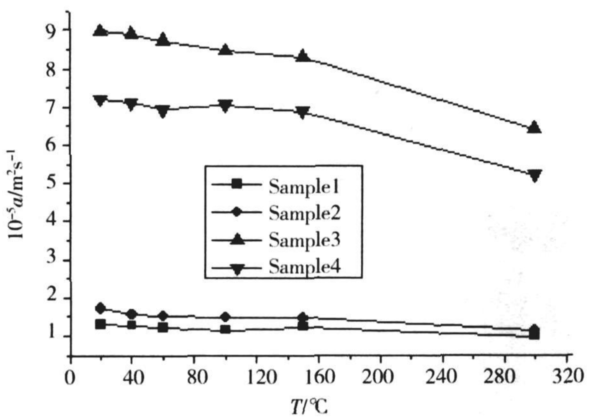

Fig.1　Temperature/thermal diffusivity graph of specimens

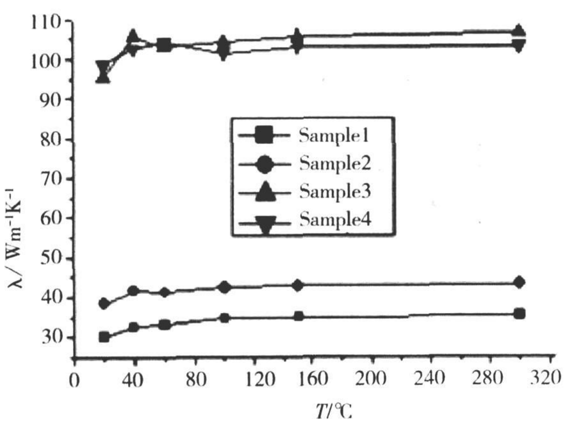

Fig.2　Temperature/thermal conductivity graph of sample

Tab.1　The result of determination

subject	Experimental value /($Wm^{-1}℃^{-1}$)	Reference value /($Wm^{-1}℃^{-1}$)	Relative error/%
Sample1	29.6～34.5	30～38	－9.2
Sample2	32.8～44.2	35～45	－6.3
Sample3	96.4～108.6	100～120	－9.5
Sample4	94.2～105.4	100～120	－12.2

The average relative error between the calculating values and the reference values is 9.5%, which is mainly resulted by the radical heat dissipation and the temperature fluctuation on the top surface.

3 Conclusions

The corrections to the two classical solutions of periodic heat flow method are approved to be rational, which make the theoretical analysis bias error. Several types of samples including graphitizing and graphitic carbon materials are determined. The average absolute relative error is no more than 9.5% in the temperature range of 20～300℃. The method for determining thermal diffusivity and thermal conductivity of graphitizing carbon materials is feasible and practical.

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石墨化阴极炭材料热物性测试研究

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摘 要：对经典的周期热流法测试原理进行深入分析，根据实验模型和石墨化阴极炭块材料性能的特点，设计开发了一套铝电解槽用阴极碳素材料瞬态热物性测试系统。采用两路热电偶来检测通过试样的正弦温度信号，根据信号在试样内传播时产生的振幅衰减和相位滞后，可以直接计算出导温系数，在已知密度和比热参数的情况下可以计算出导热系数。在 20～300℃的范围内，测定装置操作方便，数据可靠。对计算方法和测试系统的研究，为获得可靠的热物性数据提供了有效的途径。

关键词：周期热流法；导温系数；导热系数；石墨化阴极；铝电解槽
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