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Experimental Study of Thermal Conductivity of Multilayer Cylindrical Walls

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Abstract

Thermal conductivity is an important physical parameter in thermal equipment, in the blast furnace, rotary kiln and other equipment, multi-layer cylindrical wall is extremely important in industrial production of a thermal conductivity model, its thermal conductivity coefficient determines the ability of the cylindrical wall, which results in the existence of a large number of multi-layer cylinder thermal conductivity problems of the pitfalls. This paper focuses on the establishment of a mathematical model of the multi-layer cylinder thermal conductivity problem, by applying different voltages to the multi-layer cylinder wall, study the temperature distribution of the multi-layer cylinder wall under the conditions of natural convection and forced convection, and draw the line graphs under the conditions of natural convection and forced convection by Origin software, and finally conclude that: under the same conditions, the forced convection is significantly stronger than the natural convection; under the conditions of different voltages, the multi-layer cylinder wall under the conditions of steady state convection, the forced convection is much stronger than natural convection. Under different voltage conditions, the temperature of the multilayer cylinder wall under steady state conditions increases with the increase of voltage, which provides a strong support for the related research.

Keywords: *Multilayer cylindrical walls; Thermal conductivity; Temperature; Experiments*

1 Introduction

In thermal equipment, heat transfer is realized through the wall of the tube, so the thermal conductivity is one of the important thermal and physical parameters of the material, characterizing the ability of material heat conduction. Its thermal conductivity determines the ability of the cylinder wall, which results in the existence of a large number of multi-layer cylinder thermal conductivity problems of hidden trouble. Such as when the internal flame temperature is too high, the refractory material will occur ablation, shedding phenomenon, serious cases of red kiln, red furnace and other malicious accidents [1]. Only understand his temperature distribution, timely grasp of the distribution of temperature overheating, so as to avoid the vicious accidents caused by excessive temperature. Through experiments and software simulation to study the temperature distribution law, through experimental simulation can not only study the distribution law of the temperature curve of thermal conductivity [2]. It can also be very intuitive to see the distribution of the temperature field inside the device, which is of great significance in solving the problem of not being able to detect the damage caused by high temperature inside the cylinder wall in time.

Blast furnace is an important equipment in steel production, providing raw materials for the production of other steel products. The cost of pig iron is 50% of the production cost of the whole iron and steel combine, so reducing the cost of pig iron is an urgent task, to achieve the reduction of the cost of pig iron, it is necessary to reduce the investment in fixed capital, and one of the measures is to build a long-life blast furnace [3]. The study of multi-layer cylindrical walls has received wide attention both at home and abroad, especially in the engineering field. This structure is widely used in various industrial equipment and installations due to its special physical and mechanical properties.

Multilayer cylindrical wall structures play an important role in various types of engineering due to their unique heat transfer, thermal resistance and structural strength properties [5]. The study of the properties of multilayer cylindrical walls can help to

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improve the operational efficiency of equipment, extend the service life, and reduce the maintenance cost. At the same time, the research results can also provide theoretical basis and technical support for engineering design and manufacturing, and promote the progress and development of engineering practice; with the increasingly serious global energy shortage and environmental pollution problems, energy saving and emission reduction has become the focus of today's society [6]. The study of multilayer cylindrical wall helps to promote the innovation of energy saving and emission reduction technology. By optimizing the structure and materials of the cylinder wall, energy consumption and pollution emissions can be reduced, promoting green and sustainable development.

2 Test

2.1 Experimental setup

(1) Overall device: the multi-layer cylinder wall is divided into three layers, from the inside out is the pipe, cement pipe (high alumina cement and particle size of 3 ～ 6mm volcanic stone in accordance with the 1:1.5 evenly mixed), thermal insulation cotton (aluminum silicate ceramic fiber paper), cast as a whole;

(2) Control device: use the regulator knob to adjust the voltage value under different gears to carry out heating of the multi-layer cylinder wall at different temperatures.

(3) Measuring device: Measuring device includes multi-layer cylinder wall, two K-type thermocouples, three linear thermocouples, DM6902 temperature digital display, one-way contact regulator, smoke tube, finned single-ended single-ended heating tube (220V, 400W) and so on.

2.2 Experimental principle

According to the thermal conductivity differential equation:

$$\frac{d}{dr}\left(r\frac{dt}{dr}\right)=0 \tag{1}$$

If it is known that the radius of the inner wall is r_1 and the temperature t_1, and the radius of the outer wall is $r_2$and the temperature is t_2, the boundary conditions corresponding to Eq. (1) are $r=r_1,t=t_1;r=r_2,t=t_2$, which yields a temperature distribution of:

$$t=t_1+\frac{t_2-t_1}{ln(r_2/r_1)}ln(r/r_1) \tag{2}$$

The derivation of Eq. (2) is taken into Fourier's law and obtained as:

$$q=-\lambda\frac{\mathrm{dt}}{\mathrm{dr}}=\frac{\lambda}{r}\frac{t_1-t_2}{ln(r_2/r_1)} \tag{3}$$

The heat flow through the entire cylinder wall $\phi$is

$$\phi=2\pi r_1=\frac{2\pi\mathrm{l}\lambda(t_1-t_2)}{\ln(r_2/r_1)} \tag{4}$$

The thermal resistance of thermal conductivity through the entire cylinder wall is:

$$R=\frac{\triangle t}{\phi}=\frac{ln(r_2/r_1)}{2\pi\lambda l} \tag{5}$$

As with analyzing multilayer walls, applying the principle of superposition of series thermal resistance, the thermally conductive heat flux through a multilayer cylindrical wall can be obtained as (assuming good interlayer contact):

$$\phi=\frac{2\pi\mathrm{l}(t_1-t_4)}{ln(r_2/r_1)/\lambda_1+ln(r_3/r_2)/\lambda_2+ln(r_4/r_3)/\lambda_3} \tag{6}$$

The temperature between the layers of the wall can be obtained by thermocouple measurements, or can be calculated using theoretical formulas under the condition that the internal and external wall temperatures are known, for the nth layer of the cylindrical wall there are:

$$t_n=t_1-\frac{\phi}{2\pi l}\left(\frac{1}{\lambda_1}ln\frac{r_2}{r_1}+\frac{1}{\lambda_2}ln\frac{r_3}{r_2}+\ldots\ldots+\frac{1}{\lambda_n}ln\frac{r_n}{r_{n=1}}\right) \tag{7}$$

3Experimental Procedure

3.1Experimental operation process

(1) Multi-layer cylindrical wall temperature measurement device before work, first check whether the connection is good, plug in the power supply, slowly adjust the one-way contact regulator, so that it is adjusted to a certain value.

(2) Open the temperature digital display, observe the changes in the number of signs, when the temperature digital display readings in a minute without a significant jump in the case, identified as this time the multi-layer cylindrical wall temperature measurement device has reached thermal equilibrium.

(3) In order to record the center of the furnace chamber temperature t_0, the temperature of the inner wall of the furnace chamber t_1, the temperature of the inner wall of the cement pipe t_2, the temperature of the inner wall of the insulation cotton t_3 iron, the circle of the temperature of the inner wall of the t_4, in order to data accurately, you can carry out a number of measurements.

(4) After the end of the measurement, first of all, slowly adjust the one-way contact regulator, so that it is adjusted to zero, turn off the power switch as well as the temperature digital display meter.

3.2 Experimental data

(1) Record parameters such as ambient temperature and humidity for the day;

(2) Close doors and windows to reduce the impact of external convection on the experiment;

(3) Check the power cord equipment and plug in the power supply;

(4) Slowly adjust the voltage regulator to 50V for natural convection experiments;

(5) Record a set of data at intervals of one hour until it reaches steady state;

(6) After reaching steady state, turn on the forced

convection and measure the wind speed value of 4.2m/s;

(7) Every ten minutes, record a set of data until it reaches steady state;

(8) Sequentially adjust the regulator to 75V, 100V repeat the above operation, the experiment;

(9) Record data.

Table 1 Temperature data at **50**V

	t_0	t_1	t_2	t_3	t_4	time		t_0	t_1	t_2	t_3	t_4	time
Natural Convection	21	21	21	21	21	7:45	Forced Convection	45	38	37	24	23	17:55
	30	26	26	24	23	8:45		44	36	37	24	23	18:05
	36	30	30	26	26	9:45		42	36	36	24	23	18:15
	40	34	33	28	27	10:45		42	35	35	24	23	18:25
	42	36	35	30	28	11:45		42	34	35	24	23	18:35
	44	37	37	31	29	12:45		42	34	34	24	23	18:45
	45	38	37	32	30	13:45		41	34	34	24	23	18:55
	45	39	38	32	30	14:45		40	32	33	24	23	19:05
	46	40	39	32	30	15:45		40	32	33	24	23	19:15
	46	40	39	32	30	16:45		39	32	32	24	23	19:25
	46	40	39	32	30	17:45							

Table 2 Temperature data at **75**V

	t_0	t_1	t_2	t_3	t_4	time		t_0	t_1	t_2	t_3	t_4	time
Natural Convection	21	21	22	22	20	8:10	Forced Convection	74	59	57	35	26	18:30
	45	31	31	27	26	9:10		72	58	56	29	26	18:40
	60	42	42	34	31	10:10		70	56	54	28	25	18:50
	68	51	50	39	35	11:10		70	56	53	27	24	19:00
	71	55	54	41	36	12:10		70	55	53	25	24	19:10
	74	58	58	44	38	13:10		69	55	53	24	24	19:20
	76	63	59	45	39	14:10		69	55	53	24	23	19:30
	77	64	61	46	40	15:10		68	54	52	24	23	19:40
	78	64	62	48	40	16:10		68	54	52	24	23	19:50
	78	64	62	48	40	17:10		68	54	52	24	23	19:00
	78	64	62	48	40	18:10							

Table 3 Temperature data at **100**V

	t_0	t_1	t_2	t_3	t_4	time		t_0	t_1	t_2	t_3	t_4	time
Natural Convection	21	21	21	21	21	8:55	Forced Convection	110	86	82	35	29	19:05
	67	48	41	33	30	9:55		107	84	79	34	28	19:15
	68	64	58	43	39	10:55		105	81	77	34	28	19:25
	99	72	71	51	44	11:55		101	79	75	34	28	19:35
	106	84	78	55	47	12:55		100	77	73	33	28	19:45
	111	90	83	58	49	13:55		98	74	72	32	27	15:55
	113	93	86	61	51	14:55		96	73	70	32	27	20:05
	112	94	87	61	51	15:55		95	71	68	31	27	20:15
	112	94	88	61	51	16:55		94	71	66	31	27	20:25
	113	94	88	61	51	17:55		94	71	66	31	27	20:35
	113	94	88	61	51	18:55							

3.2 Results of the experiment

The temperatures at which 50V, 75V and 100V reached steady state were plotted as line graphs using origin and the results are shown in Figures 1～3.

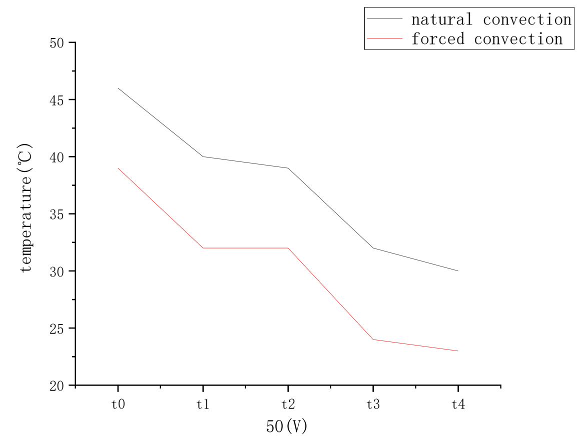

Figure 1 50V steady state values

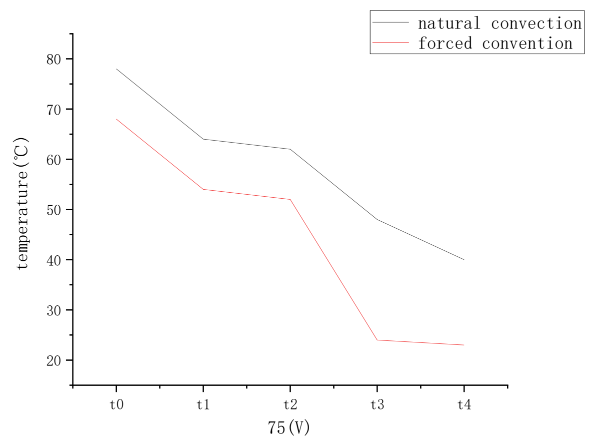

Figure 2 75V steady state values

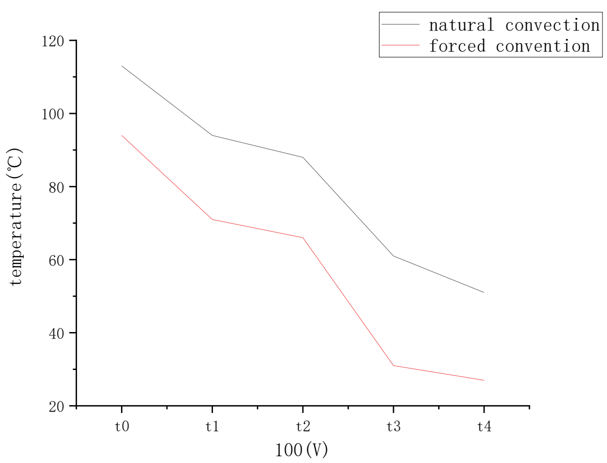

Figure 3 100V steady state values

3 Conclusion

Through the experimental results, it is found that natural convection and forced convection have similarity in temperature distribution and heat flow density in the walls of multilayer cylinders. Due to the different materials, the thermal conductivity is different. Specifically, it is shown as follows: under the same working condition, the temperature change between t_1 and t_2 in the experiment is small, and the thermal conductivity phenomenon is not obvious, and the temperature change between t_2 and t_3 is large, and the thermal conductivity phenomenon is obvious; under the same condition, the forced convection is obviously stronger than the natural convection; under the condition of different voltages, the higher the voltage is, the higher the temperature under the steady state condition is also the higher one.

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