UDC 528.48

THE EFFECT OF TEMPERATURE ON THE POSITION OF THE AXIS OF ROTATION OF THE ROTARY KILN

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Key words: rotary kiln, axis of rotation, temperature, thermal imager.

Problem definition

The problem of control over the large-sized equipment, in particular rotary kilns, has become considerably aggravated so far. This is due to the fact that almost all cement plants are privately-owned. All cement and alumina, being raw materials for aluminum smelting and production of lime and mineral fertilizers, go through the rotary kilns, being the equipment of continuous action. That is why an unplanned downtime of the rotary kiln leads to the huge losses, for example, one hour of downtime of the kiln 5 x 185 m in size means the loss of 80 tons of cement. The importance of control over the large-sized processing equipment in the process of its installation and operation becomes obvious. Assigned tasks may be solved only by means of engineering geodesy. Efficiency of the large-sized equipment, in particular rotary kilns, depends heavily on the accuracy of their installation. It has been proved that about third part of all breakdowns happens due to the straightness error of the axis of rotation of the kiln, which is determined only by means of engineering geodesy.

Analysis of the latest research and publications concerning the solution to this problem

The effect of temperature on the position of the axis of rotation of the rotary kiln in the course of control through the transition from static to dynamic condition has been considered only in the recommended sources [1,2,7]. In modern publications it is pointed out that temperature on the kilns is measured by thermal imagers [3,10,11,12], though the question of accounting of temperature correction into the vertical position of the axis is not considered.

Task definition

The aim of the research is to prove that due to uneven heating of details of supporting nodes and bandages, vertical position of the axis of rotation of the kiln may vary even up to 10 mm, while permissible deviation is ±3 mm. Thus, it is necessary to take into consideration miscellaneous temperature variations when passing from cold to hot kiln.

Presentation of the basic material

Control and correction of the axis of rotation of the kiln is performed according to procedures [5,6,7,8,9] when it is cold. If during the operational period all units and parts heated up evenly, the position of the axis of rotation in a vertical plane would have constant (one and the same) variation value due to the unit expansion under the influence of temperature, and the axis would stay straight after repair. However, after bringing the kiln into operation, temperature variation of the kiln shell in the inlet and outlet ends is non-linear. Centershift of banding sections of shells also varies disproportionately, towards the increase of the distance to the cold edge of the kiln. Because of the specified factors, there may be the curvature of the axis of rotation of the kiln in the course of its operation, which was set rectilinearly during repairs.

Figure 1 [2] depicts all parts of the cold rotary kiln by means of full lines, and all parts of the hot rotary kiln by means of dashed lines.

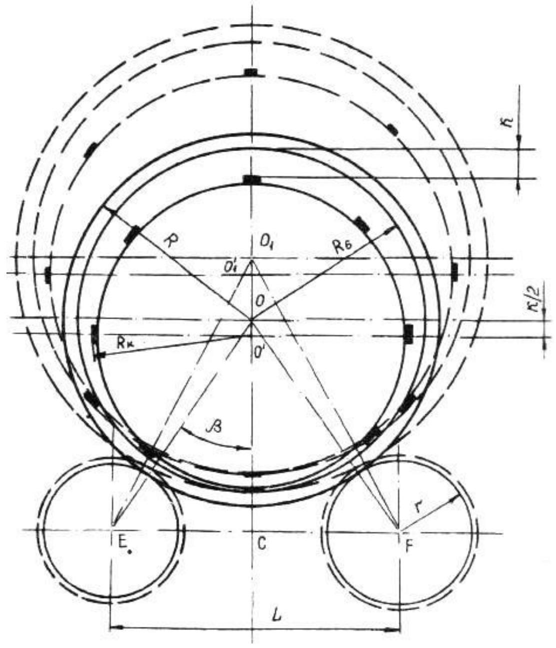


Fig. 1. Scheme for the determination of cross-section centershift of banding shell, associated with heating of the kiln

The range of change of the position of the banding axis of rotation of the kiln OO_1 (Fig.1) in the vertical plane in the course of heating of the kiln may be determined as follows:

$$OO_1 = O_1C - OC, \qquad (1)$$

$$O_1C = \sqrt{\{[(R+r)+\propto[R(t_1 - t_{n1} + r(t_2 - t_{n2})]\}^2 - (\frac{L}{2})^2} \qquad (2)$$

$$OC = \sqrt{(R+r)^2 - (\frac{L}{2})^2}. \qquad (3)$$

Then

$$OO_1 = \sqrt{\{[(R+r)+\propto[R(t_1 - t_{n1} + r(t_2 - t_{n2})]\}^2 - (\frac{L}{2})^2} - \sqrt{(R+r)^2 - (\frac{L}{2})^2}. \qquad (4)$$

The value of the change of the shell axis position in the vertical plane is determined as follows:

$$O'O_1' = OO_1 + \alpha[R_k(t_3 - t_{n3}) - R_в(t_1 - t_{n1})]. \qquad (5)$$

Then

$$O'O_1' = \sqrt{\{[(R+r)+\propto[R(t_1 - t_{n1} + r(t_2 - t_{n2})]\}^2 - (\frac{L}{2})^2} - \sqrt{(R+r)^2 - (\frac{L}{2})^2} + \alpha[R_k(t_3 - t_{n3}) - R_в(t_1 - t_{n1})], \qquad (6)$$

where R, r, radii of bandage, rollers and shell correspondingly, measured in the course of the cold kiln check; t_1, t_2, t_3 – average temperatures of the corresponding kiln units in dynamics; $t_{п1}$, $t_{п2}$, $t_{п3}$ – average temperatures of the corresponding kiln units in cold condition;inner radius of the banding in the course of check in statics; L – center-to-center distance between rollers; α – coefficient of linear expansion, constant (α=11,5 10^{-6}).

Value K of banding clearance hasn't been applied in formulas intentionally because the kiln under investigation has welded-in kiln tyres.

Because of difficulties associated with measurement and awkwardness of calculation of the value [1,2,7], manufacturers neglected the degree of impact of uneven heating of the kiln on the vertical position of the axis of rotation after static check, though it is insignificant. At present, it is not a problem thanks to the large number of programs for calculation.

Recommended procedures [7] apply high-pressure air devices and angle gauge AIZ-50. High-pressure air device measures diameters of rollers and bandings both in static and dynamic state of the kiln, and angle gauge measures an angle β between the centerline of bandage and rollers in the vertical plane (Fig.1). If we know angle β and neglect temperature expansion of rollers and diametric gap (the kiln under investigation with welded-in kiln tyres), then it is easier to determine the value :

$$O'O_1' = \Delta R \cos\beta, \qquad (7)$$

where . – radius of the bandage in hot condition of the kiln, - radius of the bandage in cold condition of the kiln.

If such devices are not available then it is necessary to take into account the effect of uneven thermal increase of bandage diameters on the straightness of the axis of rotation, measuring the temperature of bandages, shell, measurements of their radii and diametric gaps. Temperature of parts is measured by magnetic thermometers as the speed of the kiln is low or by device. Complexity and drawbacks of measurements are evident in the above-mentioned recommended procedures. Modern geodetic instruments, in particular total stations and thermal imagers, ensure quick, convenient and accurate measurements.

An experiment using five-bearing rotary kiln was conducted. Geometric parameters of the kiln were measured by electronic total station Leica TDRA6000 with precision 0,2 mm (Table 1). Temperatures of all parts were measured by thermal imager NEC TH 9100 WRI8.5 (Fig. 2, 3). Data were processed using Spatial Analizer software.

Table 1

Geometric and temperature parameters of the rotary kiln

№ of bearing	Bandage		Rollers				Shell		center-to-center distance between rollers,L,mm	Average air temp.
	Radius, mm	Average temp.,	Radius of the left, mm	Average temp.,	Radius of the right, mm	Average temp,	Radius, $R_{k,}$ mm	Average temp.,		
1	2417	105	700	80	699	75	1900	166	3109	25
2	2419	137	707	105	737	95	1900	202	3066	25
3	2419	140	751	145	753	133	1900	254	3157	25
4	2423	155	740	165	742	125	1900	303	3100	25
5	2420	182	712	140	716	135	1900	328	3128	25

Numbering of bearings is indicated along the kiln charge.

In order to determine the change of position of the bandage axis of rotation OO_1 and axis of the shell (Fig.1) in the vertical plane due to unevenness of heating of various parts of the rotary kiln, we should measure diameters of bandages, rollers and shell, center-to-center distance between bearing rollers using electronic total station. These measurements may be taken in two ways: using the procedure developed by the author[1] [4] with respect to certain sections, or according to another author[2], who suggests processing by means of Spatial Analizer software. All diameter measurements are linear and they are taken by electronic total station Leica TDRA6000 with precision 0,2 mm with the use of reflectors. Temperature of all necessary parts was taken by thermal imager (Fig.2). Based on the measurement results thermograms were made on each bearing,. There is an example of one of them for the fifth bearing in Fig. 3.

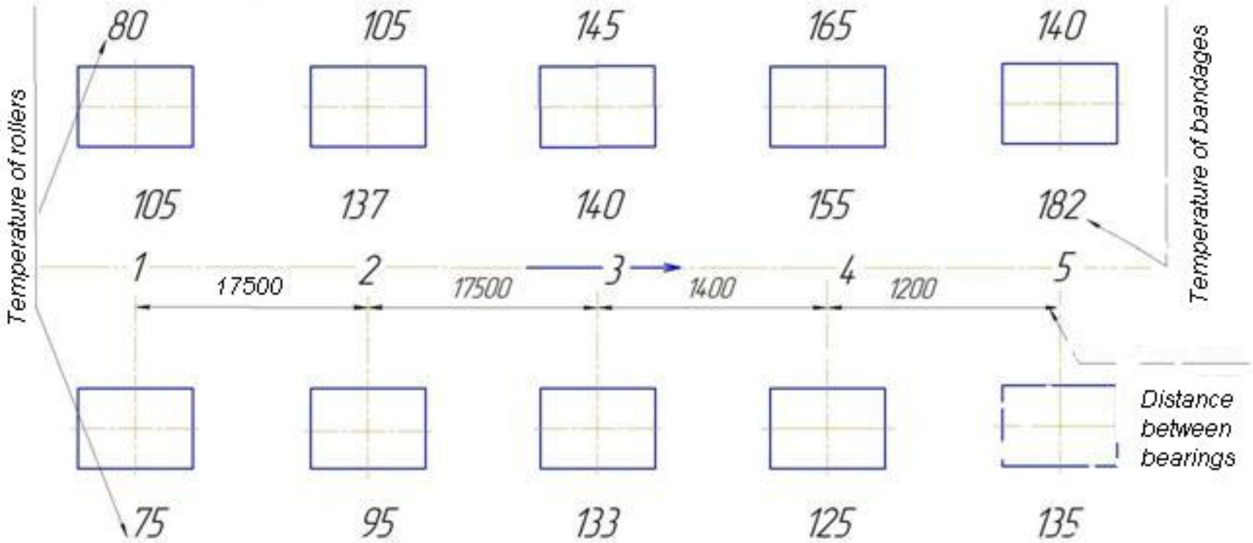
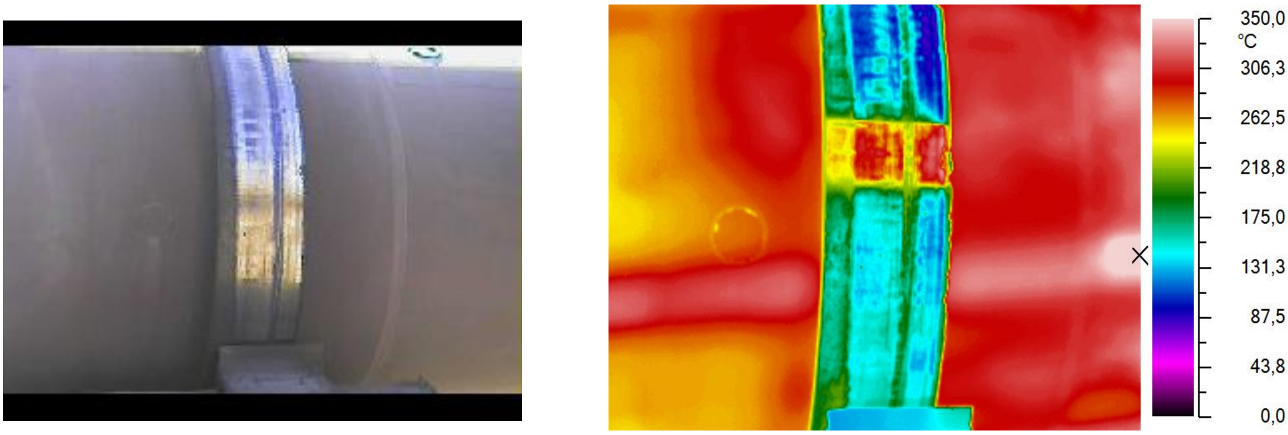
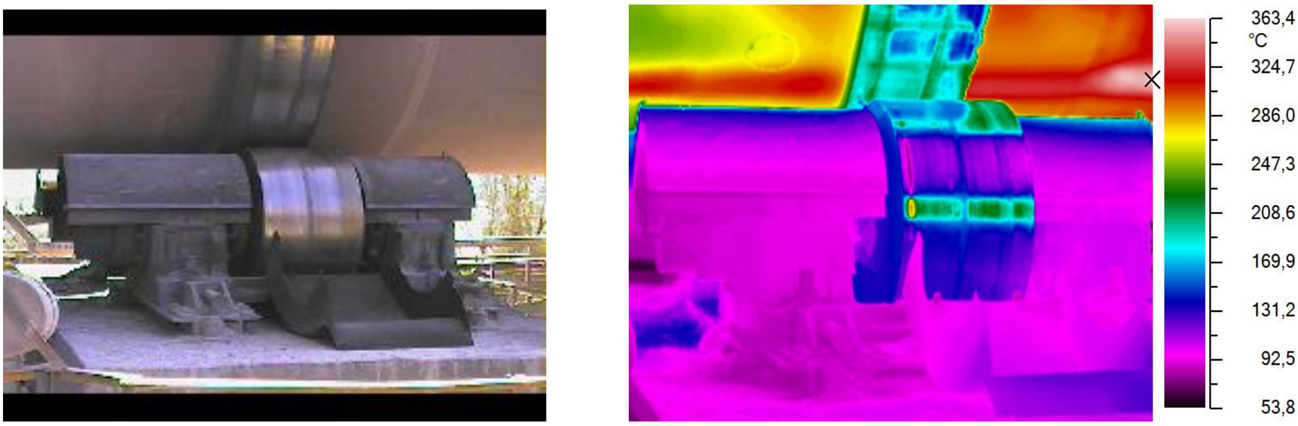


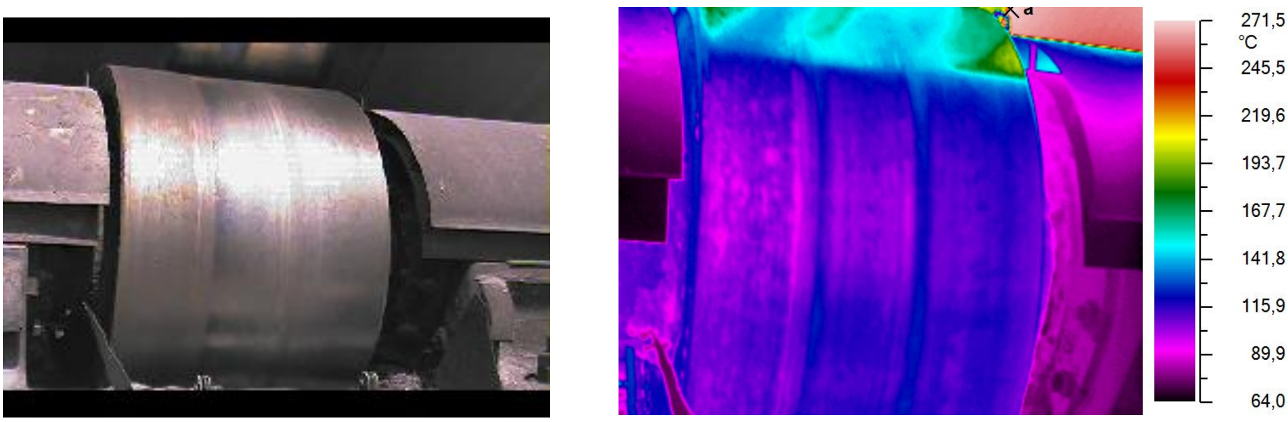
Fig.2.Scheme of the temperatures taken on the bearings



Bearing № 5- bandage



Bearing №5 – left roller

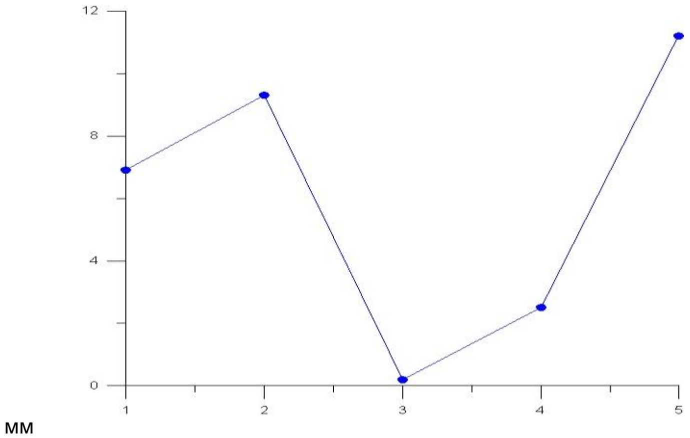


Bearing № 5- right roller

Fig.3. Thermograms for the fifth bearing

The usage of thermal imager, apart from simplicity, convenience and accuracy of measurement of high temperatures of the large-sized equipment parts, allows us to define whether there is lining in the rotary kiln shell, depending on the colour. The advantage is that there is no need to stop the kiln and view the shell from within. An area without lining would have different colour as compared to the most part of the kiln, and, what is the most important, an elevated temperature. Thus, it would be necessary to restore it there.

Using Spatial Analizer software, we processed all data (Table 1) and determined values of the change of position of the bandage axis of rotation OO_1 and axis of the shell in the vertical plane due to unevenness of heating of various parts of the rotary kiln on five bearings. Following the calculation results, we constructed the graph of the change of position of the rotary kiln axis of rotation regarding straightness, due to the difference of temperature of the parts (Fig. 4). Spatial Analizer allows to take an angle β between centerline of bandage and rollers in the vertical plane graphically and calculate (7) using much simpler formula.



Numbers of bandages

Fig.4.The graph of the change of position of the rotary kiln axis of rotation regarding straightness, due to the difference of temperature of the parts

This graph, constructed in accordance with formula (6) calculations, shows that the effect of unevenness of heating of the kiln shell on the straightness of its axis of rotation is considerable – the largest deflection is on the fifth bandage and makes 11,2 mm, while straightness deflection tolerance of the axis of rotation is ±3 mm.

Conclusion

It has been proved that axis of rotation of the kiln changes its position and deviates from straightness after starting the kiln because of the effect of unevenness of the kiln shell heating. It has been demonstrated that deviations are significant (max=11,2 mm, while deflection tolerance makes ±3 mm), that is why the necessity of their consideration is evident. For this purpose in the course of the cold kiln check one should take into account position changes of the axis of rotation on each bearing due to the heating and its unevenness, and subtract these values from the position of centers of the middle cross-sections of the banding shells on each bearing. Thus, in the dynamic state the axis of rotation would increase by the accounted values and take the correct position.

Modern electronic total stations and thermal imagers as well as the newest software make the measurements quick, accurate and convenient, and make calculations easier

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The effect of temperature on the position of the axis of rotation of the rotary kiln

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It has been proved that it is important to consider different temperature changes during the transition from cold to hot kiln condition, as it has significant influence on the position of the axis of rotation of the kiln.