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Experimental Research of Parameters of the Device Operational Contactless Diagnostics Forms of Large-size Parts with an Unfixed Axis of Rotation

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Abstract: Determination form large parts rotating in two roll sets by using the apparatus operational noncontact diagnostics, which comprises a laser device, the video receiver and a personal computer. A laser device projects light through a nozzle grid and video device reads the curved surface of the detail reflected geometric shape. By distorting forms of the projected figure and its parameters are determined by the geometrical parameters of the matrix parts of video device. Produced research on factors affecting the thickness of the projection lines during non-contact laser-operative diagnosis: distance, angle and power projection light grid.

Key words: Non-contact · Diagnosis · Large parts with non-stationary rotation axis stand for experimental studies · The device operational contact diagnostics · Rational parameters of the projection in determining the shape of the part

INTRODUCTION

To ensure the efficiency of rotating process units required operative diagnostics of the roll surface of large parts with non-stationary axis of rotation, a part of them [1, 2]. Diagnosis of such details contactless fashion. Currently, commonly used laser trackers, total stations for determining the distance to the object, working on the basis of triangulation method [3, 4]. It is well known that in studies of processes in mechanical engineering, as well as the functioning of various unique units, having in its composition large parts and assemblies, there are difficulties associated with obtaining data on the characteristics of the object [5]. In such cases recourse to the use of mathematical modeling or simulation, the results of which are checked on physical models of objects smaller dimensions than designs, particularly if related to the study of complex processes, such as the active sizing [6] and an error of shape of parts during their operation.

A new type of operational contactless diagnostics of outdoor skating surfaces of large parts rotating on two roll sets, based on the results of video - projection image of a geometric figure, read from the outer curved surface of the part [7]. The purpose of the pilot study is to determine the parameters of rational projection operational contactless device that provides the required accuracy of measurements of parameters of large parts. Geometrical parameters of items determined during its rotation process based on the distortion of the figures projected by the laser device through the diffraction grating to the outer curved surface of large items [8]. To solve the problems of experimental research in the field of regenerative processing base of supports rotary cement kilns proposed to use a specially designed stand [8], which allows you to perform experiments to measure the shape and size of the working parts, based on the roller.

Methods: Was developed 3D-model of the stand (Figure 1) with the use of solid modeling, defining the basic parameters of the experimental device.

Stand (Fig. 1) consists of: 1 base, the support roller 2, 3 band model, the drive roller 4, the model processing device 5. All elements of the plant are collected on the basis of one (Fig. 2a). The axis of the drive roller 4 is connected with a drive consisting of motor and gear

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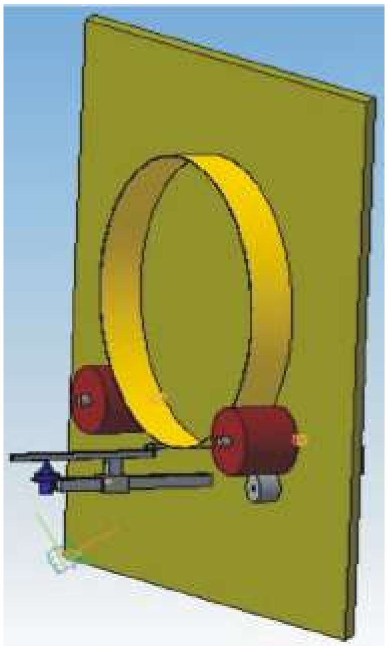


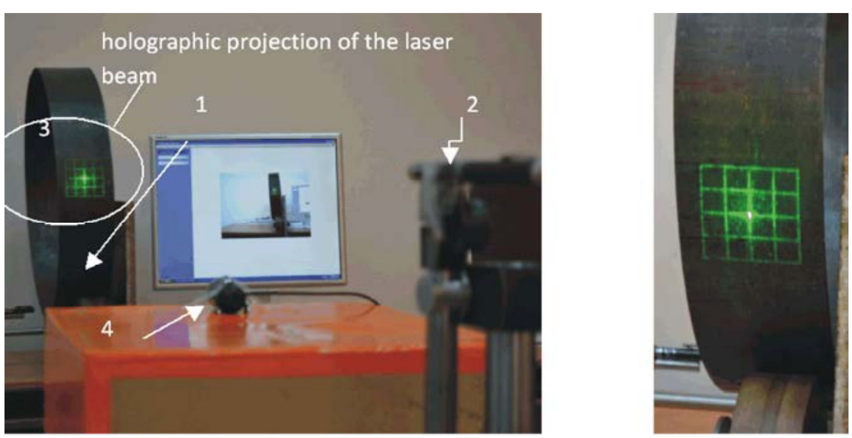
Fig. 1: Model stand for experimental studies

transmitting torque. The shaft of the drive roller 4 is mounted the support roller 2, a motion-transmitting shroud 3 by friction. Dimensions model supports, which are mounted on rollers and are reduced strap 10 times with respect to support industrial kiln 5 x 185 sq. Model shroud may be made of any material installed on the two rollers and has no additional fasteners. The outer surface pattern in contact with the outer band surfaces of the two support rollers.Determination of parameters of the form and the outer surface of the errors made by the measuring device, consisting of a laser unit 2 (Fig. 2a), projecting a Figure 3 through the grating in the form of a rectangle on the outer cylindrical surface of the ski brace and video receiver 4, the recorded image projected figure (Fig. 2b). According to the accepted video receiver reflected image shapes defined by the matrix video device geometric parameters of the light grid and transmitted to the processing of the personal computer.

The rotation of the drive roller 4 (Fig. 1) is an electric DC motor MH-145B (Fig. 3). The engine provides the power supply to 27V, the maximum output speed - 145 r / min., Power - 2.45 watts. And to ensure the movement of the model processing unit 5 (Fig. 1) using a stepper motor. Their control is a special module, which is a set of devices managed by the software, connected to a PC through LPT-port.

To ensure noncontact diagnostics part shape at its outer surface projected through the laser light grid apparatus. Used a laser device is characterized by the following values: wavelength 532 ± 10 nm, the maximum output power of 5 mW, power density does not exceed 2.5 mW / cm 2, the class CLASS IIIa, meets CFR 21 (Part 11 of the Code of Federal Regulations, adopted in the United States concerning the description of the devices of electronic documents and electronic signatures), is powered by 2 batteries of 1.5 V. Before the laser emitter mounted nozzle, which is located in the center of the diffraction grating. A beam of light passing through it takes the form of regular geometric shapes - a square with axial center lines (Fig. 2b). Reflex Figure read video device and transmitted to the personal computer.

Projecting device and a video camera mounted at a distance from the part that allows you to make a "seizure" of the projection directly on the details, combined with the axis of the laser devices and video cameras. When misalignment of the axes and the wrong choice of distance is distorted parameters of the figure (Fig. 4), such as:



a) b)

Fig. 2: Stand assembly (a) and view the projected figure (b) on the surface of the shroud model

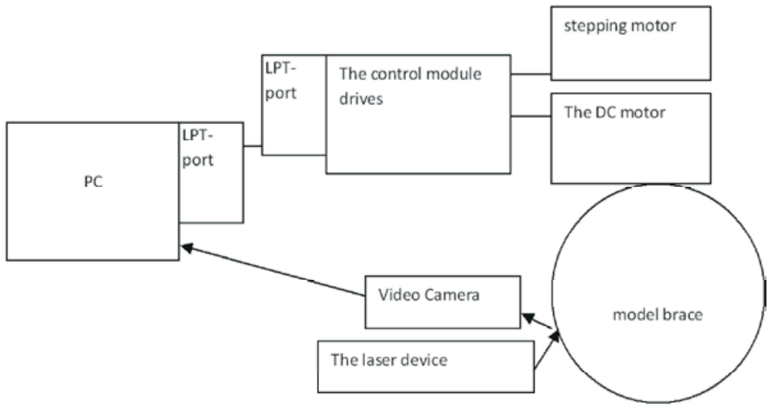


Fig. 3: The scheme of connecting devices to a personal computer

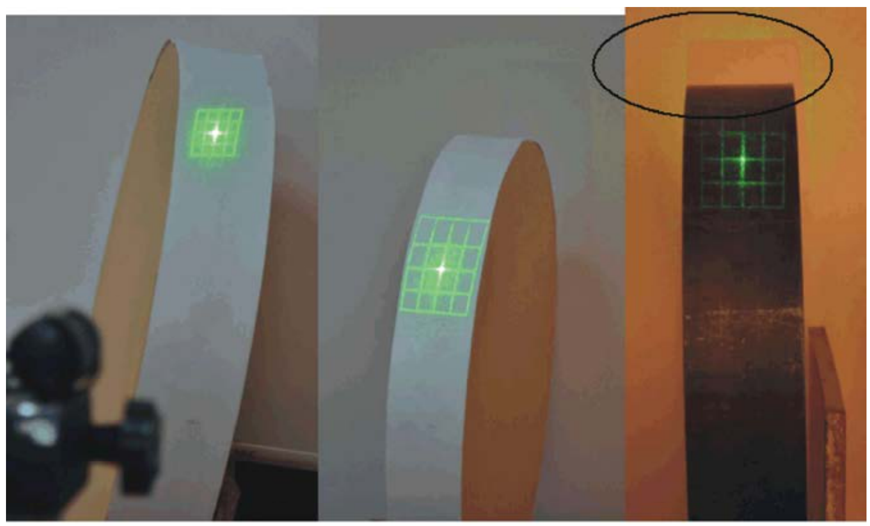


Fig. 4: The distortion of the projection parameters of the figure:
a) the displacement of the vertical axis of the parts and b) when the angle of the deviation from the normal and c) in contact with the projection of the part model abroad

offset part of the vertical axis, the angle of the deviation from the normal, entering overseas projection model details.

Projected figure of a video device is perceived as a set of pixels in the lines that form it. To achieve accurate results, you should first have a thickness equal to the projection lines to one pixel. A special software module processes the read image with calculates the number of pixels in forming lines of projection and selects the line where the maximum concentration value of pixels. The thickness of the line is calculated by the formula:

$$b = \Delta \cdot n;$$

where b - line thickness, mm

Δ - pixel size, mm (depending on the resolution of the matrix the higher the resolution of the matrix, the greater the thickness of the line in pixels), for example, the matrix used for video cameras 640h430 - Δ = 7,4 um;

n - the number of pixels.

The process of measurement and shape of the shroud experimental stand in a continuous rotation of its components is controlled and managed by a software module and the parameters are determined by the projected figures geometric parameters of the model band.

Thus, the developed model allows us to perform a bench study the functioning of the technological capabilities of the system using a non-contact laser-operative diagnosis of the geometric parameters of the part shape.

The Main Part: The formation of the light grid when reading images from the surface of the part affected by a number of factors:

$$b = f(L, a, P, p, C); \quad (1)$$

where L - the projection distance, mm,

[alpha] - angle of projection, rad,
P - source power projection, mW,
p - light, lux,
S - dust, mg/m^3 .

Making measurements must take into account the illumination. When the video camera sensitivity of 0.01 lux illumination of the object should be in the range of from 5000 lux to 20 [9]. Dust level should not exceed 20 mg/m^3 and the size of dust particles 60 microns and more negatively affect the operation of video cameras [10].

The main influence on the quality of the laser grid projected on the surface of the part, have radiated power projection angle and projection distance.

Based on the analysis of literary sources and the search was determined that:

- The distance between the source and the surface must be not less than 0.8 m and not more than 1.6 m, because the parameters of the projection light will be small or increased, respectively, which leads to the accumulation of errors of measurement (Fig. 4);
- It is advisable to change the projection angle in the range from 0.08 rad to 0.62 rad, otherwise the value of the size of the projection does not allow to determine the accuracy of the part shape. The angle of projection is quite varied from 0.15 rad to 0.35 rad glad, because for determining the radius of the inscribed circle brace cement kiln enough to make measurements at 36 points [11, 12];
- Rated power laser facility ranges from 2.2 mW to 5.8 mW, which is due to passport data of the laser device.

To compile the regression equation, which describes the influence of the main factors on the quality of the projection lines readable projection used rototabelnoe uniforms planning 2nd order and held full factorial experiment 23 (Table 1). As the thickness of the desired function appears projection lines b, which affects the accuracy of the shape of the measured part.

In coded form the main factors are represented by formulas:

$$x_1 = \frac{L \pm \Delta_L}{L_n}, x_2 = \frac{\alpha \pm \Delta_\alpha}{\alpha_n}, x_3 = \frac{P \pm \Delta_P}{P_n} \quad (3)$$

wherein L, [alpha], P - varying factors;

Ln, [alpha] n, Pn - the average level;
[delta] L, [delta] [alpha], [delta] P - interval varying main factors (respectively).

The calculations were the regression equation in coded form:

$$y = 3{,}4\text{-}0{,}12x_1 + 0{,}37x_2 + 0{,}78x_3\text{-}x_1x_2 + 0{,}5x_1x_3 + 0{,}5x_2x_3 + 0{,}05x_1^2 + 0{,}05x_2^2 + 0{,}2x_3^2. \quad (4)$$

The resulting 3-dimensional graphic depicting the structure in which values of the main factors we can get a line width of 1 pixel projection (Fig. 5a), 3 pixel (Fig. 5b), 5 pixels (Fig. 5c) 9 pixels (Fig. 5d). Each point lying on a particular graphical structure shows for which values of the main factors is possible to get some value projection line thickness in pixels.

Table 1: Surveyed factors and levels of variation full factorial experiment 2^3

	Projection distance, L, m	The angle of projection, α, rad	Power laser, P, mW
Coded designator	x1	x2	x3
Average level	1,200	0,25	4
Variation interval	0,200	0,1	1
Top level	1,400	0,35	5
Lower level	1,000	0,15	3
"Star" level (top level) -1.68	0,86	0,08	2,3
"Star" level (lower level) +1,68	1,54	0,42	5,7

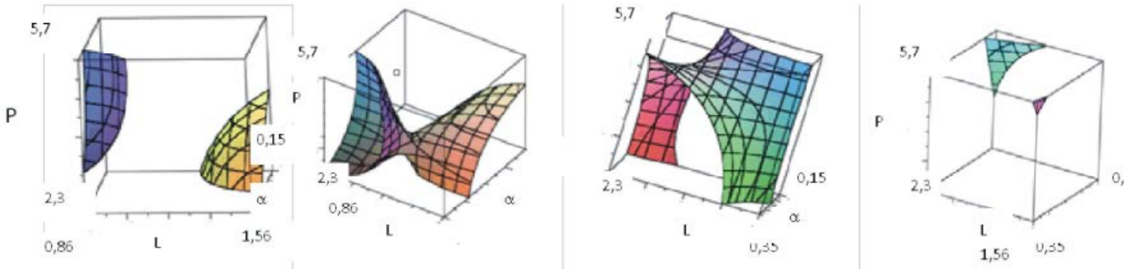


Fig. 5: Graphic structure reflecting the technological parameters for projection lines thickness: a)1-pixel b) 3 pixels, c) 5 pixels, d) 9 pixels

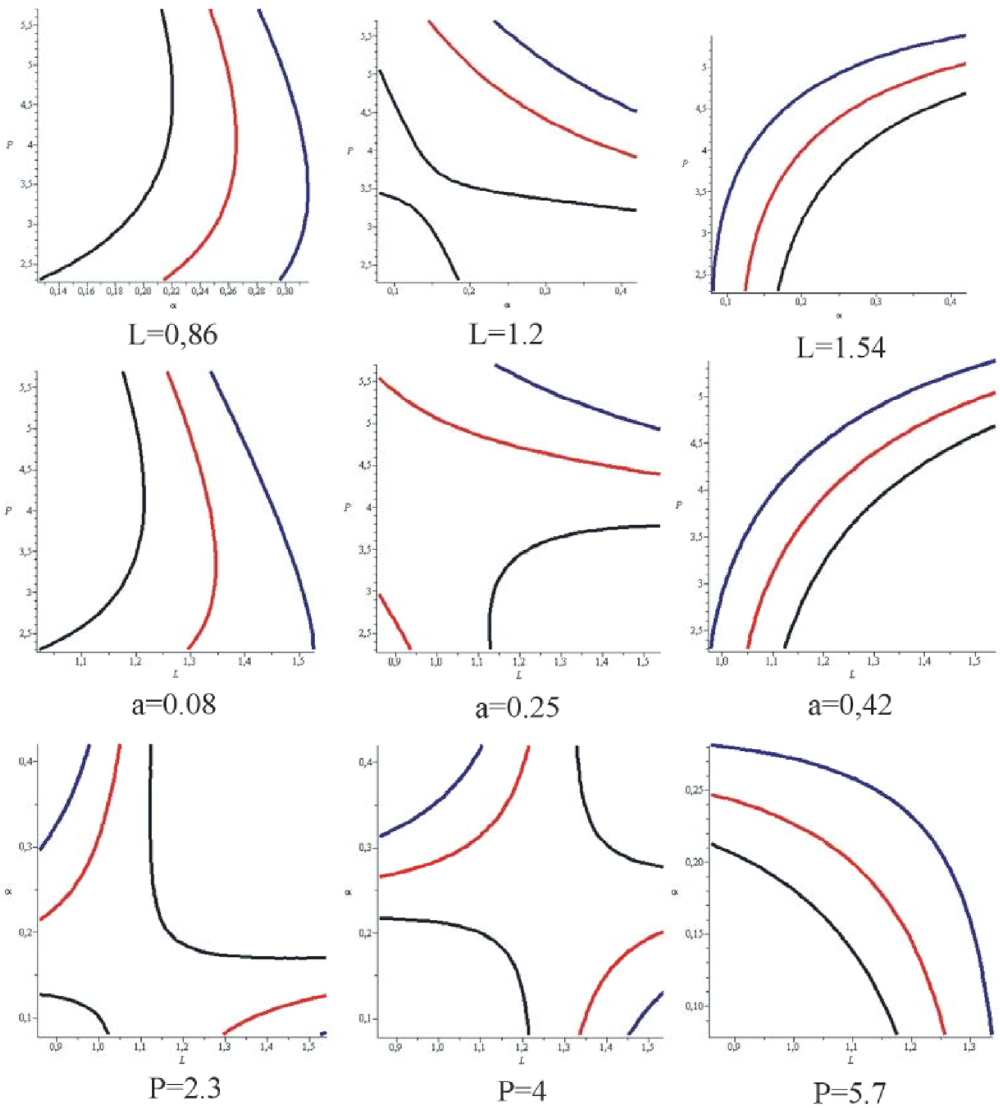


Fig. 6: Nomogram influence of the main factors on the thickness of the lines of projection: a) the dependence of the projection angle and power at fixed distances projection, b) the dependence of projection distance and power at fixed angles of projection, c) the dependence of projection distance and projection angle for a fixed capacity; black lines - projection thickness b = 3 pixels, the red lines - projection thickness b = 4 pixels, the blue lines - projection thickness b = 5 pixels

The thickness of the line projection of one pixel (Fig. 5a) is the best option when determining accurate geometry of the object, but for large objects such accuracy is not required. The most appropriate in terms of the ratio "price - quality" projection line width of 3-5 pixels. Therefore, it was made to build additional graphic structures to more accurately determine the intervals of the main factors of variation (Figure 6).

Decode regression equation using equations (3):

$$b = 7,39 - 1,1L + 41,2\alpha - 5,1P - 50L\alpha + 0,25LP$$
$$+5\alpha P + 1,3L^2 + 5\alpha^2 + 0,2P^2 \qquad (5)$$

Since the three factors vary, for nomograms that can determine the shooting modes for lines of 3, 4, 5 pixels fix the value of the parameter - is the value of star points and zero (Fig. 6).

Consider the case where the parameters are fixed reference point on the example of the parameter to 5 pixels (blue line) with L = 1,2 m such a value can be obtained with P = 4,5 mW... 5,5 mW and α in the range of 0.22 rad - to 0.4 rad at [alpha] = 0,25 rad, P = 5.5 mW 4.9 mW, L = 1,15 and above, with a fixed value of power, equal to 4 mW, the response function equal to 5 pixels can be obtained with two different modes:

- At the minimum and maximum values of [alpha] L;
- At the minimum and maximum L [alpha], which is consistent with theory.

The experimental results show the range of factors that influence the required line thickness projection figures projected on a curved surface, depending on the required accuracy of measurement.

The most acceptable settings required for projecting the projection accuracy, the thickness of the lines which are selected from 3 pixels to 5 pixels are in the ranges:

For the projection lines with a thickness of 3 pixels:

- The projection distance - from 0.86 mm to 1.54 mm;
- The projection angle - from 0.12 rad to 0.21 rad;
- Emission power - from 2.3 mW to 5.5 mW.

For the projection lines with a thickness of 4 pixels:

- The projection distance - from 0.86 mm to 1.54 mm;
- The projection angle - from 0.18 rad to 0.27 rad;
- Emission power - from 2.25 mW to 5.5 mW.

For the projection lines with a thickness of 5 pixels:

- The projection distance - from 0.86 mm to 1.54 mm;
- The projection angle - from 0.25 rad to 0.38 rad;
- Emission power - from 4.2 mW to 5.5 mW.

Conclusion: To determine the shape of large parts rotating in two roll sets was proposed a new type of contactless operative diagnosis, which comprises a laser device, the video receiver and a personal computer. The laser device through a nozzle mounted directly in front of him, forming a light on the details of the model grid. Video device reads the curved surface of the part reflected a geometric shape, the parameters of which and its distortions of special software module determines the geometric parameters of the details. Produced research on factors affecting the thickness of the projection lines during non-contact laser- operative diagnosis: distance, angle and power projection. Justified on the basis of which the rational parameters to project a light grid on the curved outer surface of the part, using non-contact laser device operative diagnosis.

CONCLUSIONS

To solve the problems of experimental research in the field of regenerative processing base of supports rotary cement kilns proposed to use a specially designed stand that allows you to perform experiments to measure the shape and size of the working parts, based on the roller.

Based on the analysis of literary sources and the search was determined that: the distance between the source and the surface must be not less than 0.8 m and not more than 1.6 m, because the parameters of the projection light will be small or increased, respectively, which leads to the accumulation of measurement error, it is advisable to change the projection angle in the range of 0.15 rad to 0.35 rad rated power laser facility ranges from 2.2 mW to 5.8 mW.

Obtained 3- dimensional graphics structure and nomograms each dot lines which shows a fixed value main factors for determining the thicknesses of the projection lines in three, four and five pixels.

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