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I. G. Arslanov

Branch of Ufa State Petroleum Technological University ,Russian Federation

I. G. Galeev

Branch of Ufa State Petroleum Technological University ,Russian Federation

R. N. Suleymanov

Branch of Ufa State Petroleum Technological University ,Russian Federation

O. V. Filimonov

Branch of Ufa State Petroleum Technological University ,Russian Federation

K. T. Tincherov

Branch of Ufa State Petroleum Technological University ,Russian Federation ,

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Optical assembly for laser alignment of shafts

I.G. Arslanov, I.G. Galeev,
R.N. Suleymanov*, O.V. Filimonov, K.T. Tincherov

Branch of Ufa State Petroleum Technological University,
Oktyabrsky, Republic of Bashkortostan, Russian Federation

* e-mail: rsulem@mail.ru

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The article presents a new method of increasing laser radiation power of the receiving device while performing alignment for reducing excessive pump vibration. The optical arrangement and device design are presented. The possibility of application of glass system with definite refraction index of laser beam system sweeping in a line direction is theoretically justified. The paper presents that the beam sweeping in immediate proximity to a receiving device allows to increase the "beam force/disturbance force ratio" without increasing the laser power. The results of the experimental comparative testing are described. The experiment was conducted in plant conditions of Formation Pressure Maintenance Department OGPD Tuimazaneft, group modular pumping station BKNS-20C using CNS 63-1400 (sectional centrifugal pump) in cooperation with specialists of Oktyabrsky URONO LLC "OZNA".

Keywords: pump efficiency, hydraulic efficiency, vibration, alignment, misalignment, laser beam units.

Introduction

It is known that excessive vibration of rotary equipment leads to the failure of support system (bearing assembly) as well as to the reduction of hydraulic efficiency and in general to the reduction of energy-efficiency process of injection [1-7]. One of the major defects leading to the increase of equipment vibration is misalignment of the shafts [8-16].

Alignment devices

Currently the market of alignment devices for units of the "engine-machine" type of various coupling (rotary, belt-driven) has a variety of construction solutions [1]. They can be divided into two large classes - using radial and axial measurement and using only radial measurement (the so-called reverse dial indication method), see Figures 1, 2. In the latter, radial motion of an indicator rod that can be read visually serves as an information-bearing parameter.

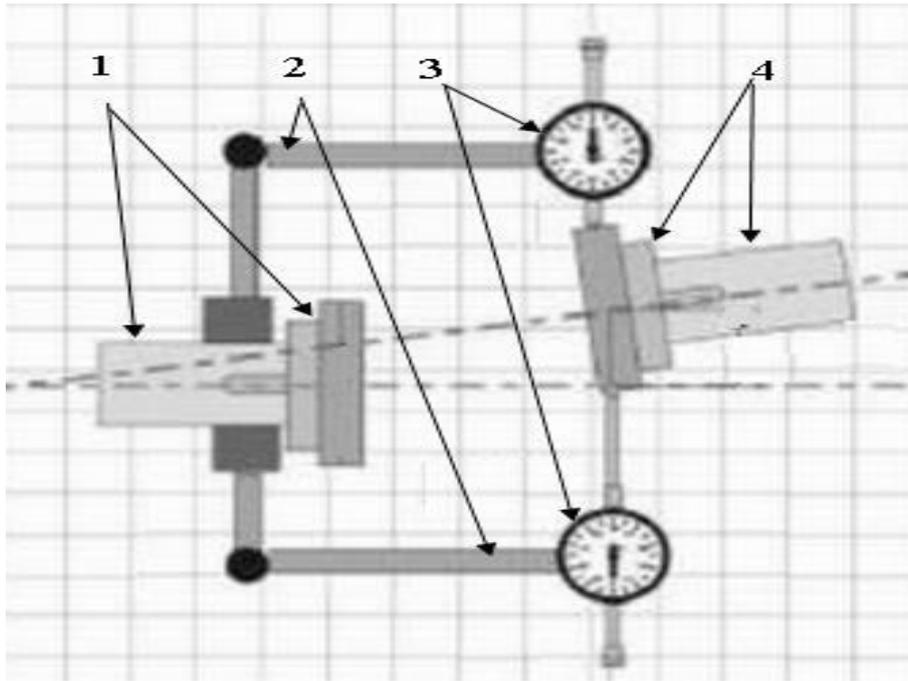


Figure 1. Arrangement of dial gauges: 1 - shaft and coupling of pump, 2 - rods, dial indicator, shaft and coupling of engine.

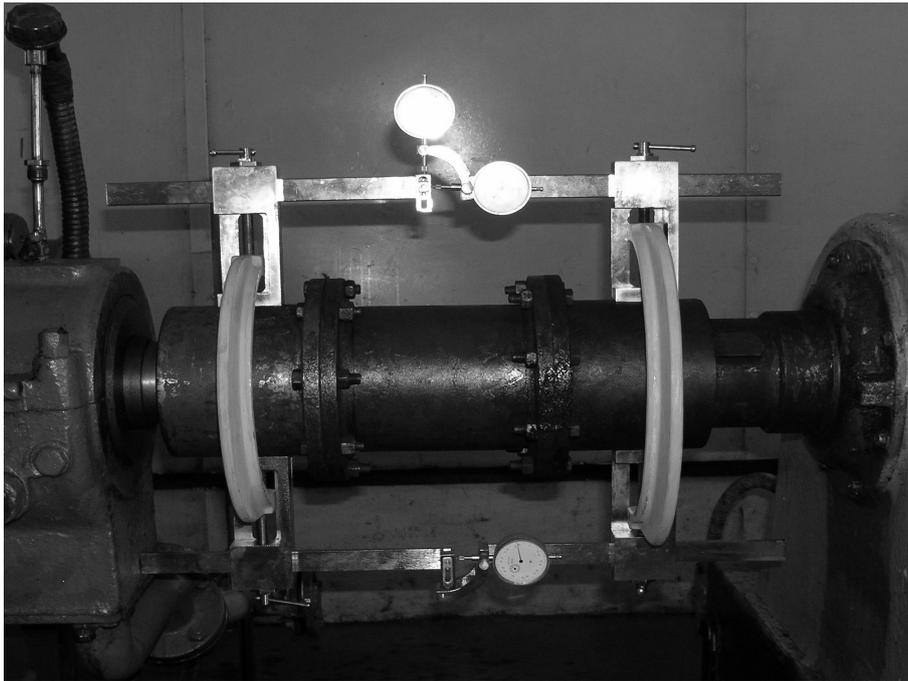


Figure 2. Alignment device PC-4 on coupling of pump CNS 180-1422 (reverse dial indication method [3]).

The length of the matrix is obviously higher than the change of the laser line position even under the biggest possible misalignments. The disadvantage of this method is that the light flux is "spreading" across the full length of the line that leads to a deterioration of the ratio of "the beam force/disturbance force" ratio (from other light sources), and consequently, to the necessity of increasing the initial power of the laser (Figure 3).

The last condition is undesirable as consequently current consumption of batteries increases which accordingly reduces the operational life of the device in an



Figure 3. Wireless alignment system "PC-Lazer-V".

autonomous mode, the presence of the laser beam sweeping system complicates the laser construction that leads to a risk of eye injury as a result of laser radiation.

However, for measurements on large bases (L1 1 m. or more), the geometrical dimensions of the matrix must be large enough for the spot of laser beam must stay inside the matrix - this is especially acute if the misalignment is large (for example, immediately after installation of the unit)".

The highly focused beam produced in the laser source falls on the optical system sweeping it in a line, perpendicular to the axis of light sensitive one-dimensional matrix (see Figure 4).

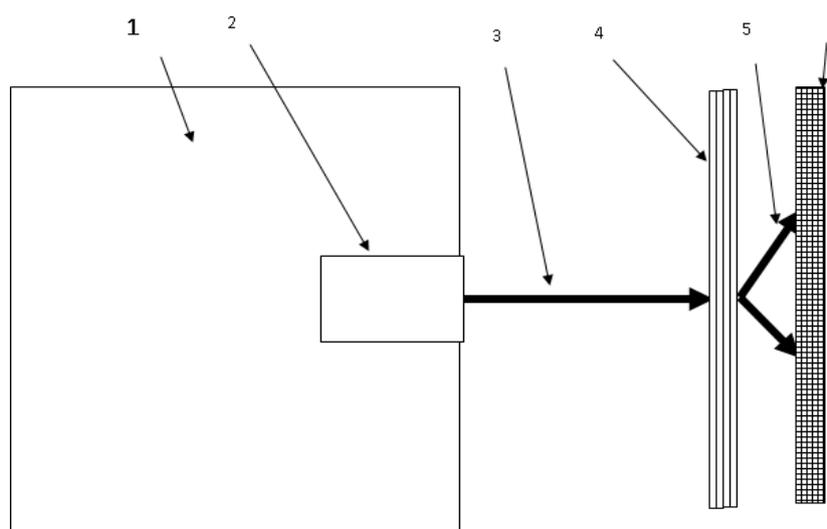


Figure 4. Arrangement of sweep system: 1 - laser module, 2 - collimator, 3 - narrowly focused beam, 4 - optical scheme, 5 - beam swept in a line direction, 6 - light sensitive matrix.

Due to the location of optical system in immediate proximity to light sensitive matrix, the light flux on matrix spreads on considerably less area and illumination (power per unit area) of matrix is enough to compete with light sources.

Moreover the beams of light from external sources of light falling at angles α (see Figure 5) bigger than 70° turn to be strongly weak [4], since the reflexion index k increases sharply (see Figure 6), compared with reflexion index k for angles 0 to 50° :

$$k = (n - n_0) / (n + n_0), \quad (1)$$

where n, n_0 - refraction indices of glass (cylinder) and air ($n_0=1,000292$ under ordinary conditions).

In the latter it is possible to apply laser gages consisting of a source of monochrome highly focused particle beam and a receiving matrix with an accuracy of $1 \mu\text{m}$ instead of widely spread dial gauges (accuracy $10 \mu\text{m}$). This allows not only to improve the accuracy of misalignment measurement, but also to make the measurement automatically. However, for measurements on large bases (L1 1 m. or more), the geometrical dimensions of the matrix must be large enough for the spot of laser beam must stay inside the matrix - this is especially acute if the misalignment is large (for example, immediately after installation of the unit).

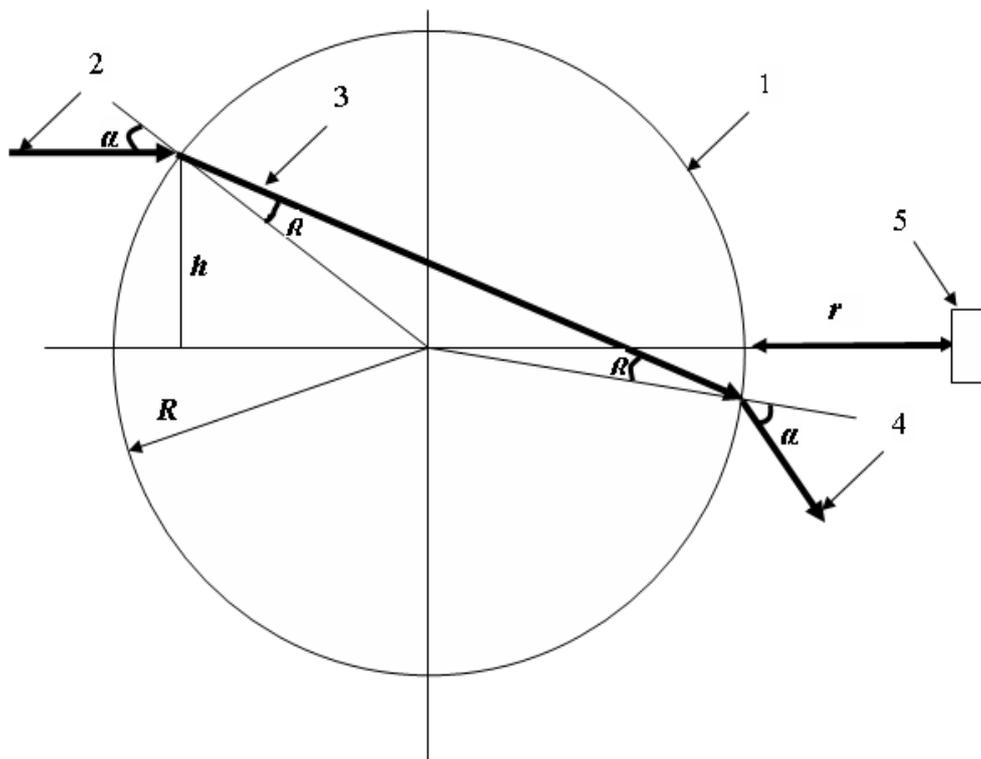


Figure 5. Beam path falling on cylindrical lens: 1 - optically transparent with refraction index n ; 2 - beam of light falling at an angle α on the cylinder surface, $\sin(\alpha) = h/R$; 3 - beam refracted in glass (cylinder) at an angle β to the cylinder surface; $\sin(\beta) = \sin(\alpha)/n$; 4 - beam, that passed through lens; 5 - light sensitive receiving matrix; R - cylinder radius of optical scheme, r - distance from optical scheme to light sensitive matrix; α, β - angles of incidence and angle of refraction (the principle of reversibility is applied).

Statement of the problem

As a solution to this problem, the developers proposed using a linear array instead of a circular receiving matrix, while the length of the matrix exceeds the

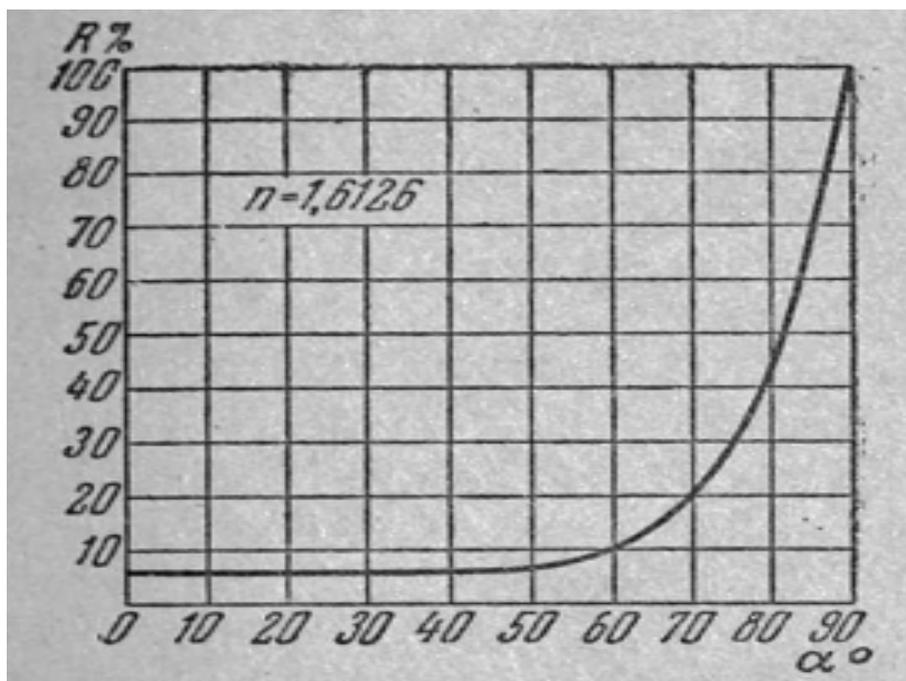


Figure 6. Dependency of reflexion index k on angle of incidence α .

changes in the position of the laser line, even at the largest possible misalignments. Then for measurements of position (only in one plane) a ray developed in line [2] is applied, see Figure 3.

Moreover, to increase the signal-to-noise ratio, the beam is swept into the line not at the output of the beam from the laser, but in the immediate vicinity of the matrix by means of an optical system.

This optical system is included in the assembly of the receiving device (one-dimensional matrix). The system consists of a number of optically transparent cylinders adjacent to each other (see the beam path in Figure 5).

Theory

The aim is to increase the reliability of laser spot position detection by one-dimensional matrix without increasing the power of laser radiation and expanding the area of beam sweeping in a line direction.

Besides, to increase the illumination (power per unit area) of matrix with the use of radiation distance between the optical system r and light sensitive matrix satisfies the following condition (see Figure 3):

$$r \leq 10 * R, \quad (2)$$

where R - radius of optical system cylinder.

Results Of Experiments

The experimental comparative testing of shaft alignment devices "PC-Lazer-B" with the optical arrangement described above (LLC Specialnye technologii [5]) and Fixstur-Lazer (Sweden [6]) was conducted. The testing was conducted in plant conditions of Formation Pressure Maintenance Department OGPD Tu-imazaneft, BKNS-20C using CNS 63-1400 (sectional centrifugal pump) in cooperation with specialists of Oktyabrsky URONO LLC "OZNA". See Table 1 below.

Table 1.
Results of field experiments.

Type of device	Type of misalignment	Of misalignment, mm		Alignment\correction, mm			
				<u>horizontal</u>		<u>vertical</u>	
		horizontal	vertical	front	back	front	back
PC-Lazer - V	Radial	0.56	0.20	0.49	0.06	-0.37	-1.27
	Angular	0.04	0.05				
Fixtur-Lazer	Radial	0.57	0.20	0.5	0.08	-0.35	-1.26
	Angular	0.03	0.04				

Conclusion

The comparison of results show:

- rapid installation of magnetic based sensors "PC-Lazer-B" (1 min) in comparison with Fixtur-Lazer with chain brackets (8 min);
- rapid (1 min) and ergonomic setting of "PC-Lazer-B" (swept line for one-dimensional matrix with length 30 mm) in comparison with Fixtur-Lazer - 6 min (circular point on matrix of 10 mm);
- precision of results for angular alignment in the range of 0.01 mm/100 mm, for radial alignment in the range of 0.01 mm;
- calculation of adjusting plates thickness also shows that its practical coincidence: for horizontal correction in the range of 0.03 mm, vertical - 0.09 mm.

Thus the conducted laboratory and in-situ scale testing showed that the employment of the described optical system greatly increases "the laser light/light from external luminous sources" ratio for systems with sweeping light in a line direction.

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