# COMPLETE AUTOMATION OF ASSEMBLY PROCESS FOR CYLINDRICAL PARTS WITH USING VIBRATIONS

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**Abstract.** In given article the method of assembly on the rotor assembly machines that ensures the mutual search of the connected parts is examined. At this method parts are arranged on two rotors and brought to an assembly position with unequal linear speeds. One of the parts is imparted oscillatory movements in a cross-section direction – in the plane of rotation of rotors, but the effort of assembly is attached to the parts perpendicularly to this plane. In article the optimal value of displacement of the parts and assembly conditions for assembly on rotors with an external contact of pitch circles is determined.

**Keywords:** assembly process, automation, vibrations, rotor, external contact.

## Introduction

Assembly is a very complex process and consists of different kinds of performed operations, which are various by character and duration. Low level of assembling process automation in machine and instrumentation engineering can be explained by this. But in spite of this, the assembling process is on the leader position in modern automated manufacturing.

Typical process of automatic assembly consists of many steps, such as loading of components, their feeding, orientation, fitting, control, transportation etc. But the most difficult and responsible step in the all-assembling processes is to make sure of interaction between the components relative to each other on the assembling position with demanded accuracy, because the possibility of assembly depends on accuracy of this step.

There are few methods allowing to increase accuracy of relative interaction in assembly: application on the parts chamfers and force for connection; reporting one of the parts rotational movement; the method of relative misalignment of the connecting parts axes; shaking of the part, which is coming on; orientation with using ultrasound devices etc.

But the method with application of vibrations is the most reliable to achieve this goal [1]. For this purpose a vibratory device is included in the assembly machine, but for drive of the movable part electromagnetic vibrators are usually used. On the position of assembly the vibrating device displaces one or both assembling parts by a certain trajectory in the plane, which is perpendicular to the direction of the connection of the parts. In the result in certain areas the "search" of mated surfaces of parts takes place and the assembly process is provided [2]. The existing vibratory devices perform the search in a direction of two axes and provide reliable assembly of parts such as a shaft - bush with the initial alignment error $\Delta\Sigma$ of the axes, 7-8 times greater than the tolerance.

## Different ways of assembly on the rotors by applying vibrations

In given article the vibration assembly on the rotary machines in which parts are arranged on two rotors and are brought to an assembly position with unequal linear speeds is examined. One of the parts is imparted the oscillatory movements in a cross-section direction – in the plane of rotation of the rotors, but the effort of assembly is attached to the parts perpendicularly to this plane [3]. This method of assembly does not require a precise orientation of the parts relative to each other.

Rotors 1, 2 can be arranged with an external (Figure 1) or internal (Figure 2) contact of pitch circles. In the first case, the trajectories of the parts overlap each other on a smaller length than in the second case. Centers of the parts are arranged on circles with radii $R_1$ and $R_2$ that are different from the radii of the pitch circles Rp1 and Rp2.

$$R_1 = R_{p1} + \varepsilon \ ; \ R_2 = R_{p2} - \varepsilon \ , \tag{1}$$

where $\varepsilon$ – value of displacement of power heads and assembly devices relatively to the pitch circles of the rotors.

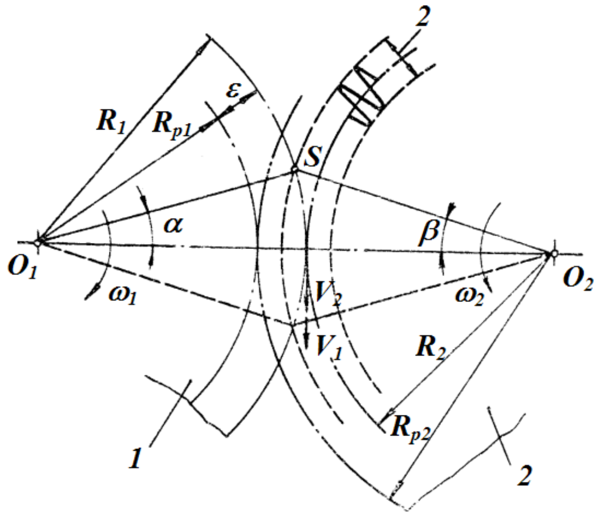


Fig. 1. **Assembly on the rotors with external contact of pitch circles**

This allows to get different speeds for the centers of the parts while maintaining constant ratio of the mechanism of drive

$$i_{21} = \frac{\omega_2}{\omega_1} = \frac{R_{p1}}{R_{p2}}, \tag{2}$$

where $\omega_1$ and $\omega_2$ – angular velocity of the 1st and 2nd rotor.

To cancel the error of the relative orientation of the parts one of them is reported vibrations in the plane of rotation of the rotors, for example, in the radial (Fig. 2), tangential or intermediate directions [4-6].

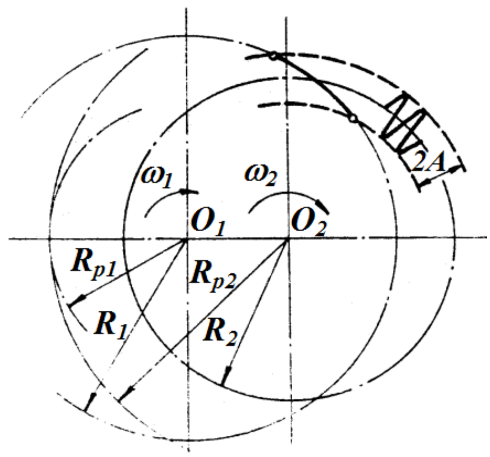


Fig. 2. **Assembly on the rotors with internal contact of pitch circles**

Each scheme of assembly has some specifics, but the method of calculation of vibration conditions is common for all of them. The purpose of this article is to research the definition of optimum conditions during the assembly on the rotors with external contact of pitch circles.

## External contact of pitch circles

In the examined scheme of assembly with external contact of pitch circles (Figure 1) the parts are oscillated with the amplitude $\pm A$ and the trajectories of movements of the parts' axes can cross each other only during the first rotor takes the turn at the angle $\pm\alpha$ or $2\alpha$ and, accordingly, when the second rotor takes the turn at the angle $2\beta$.

Let us define the optimal value of displacement of the parts on the rotors.

Obviously that the assembly conditions will be optimal only in the case, when during the turn of the first rotor on the angle 2α the difference of the paths of the parts will equal to the value $2\Delta\Sigma y$, that is the path of the parts covers the zone of possible deviations of the parts from the calculated position. $\Delta\Sigma y$ – is an error of relative orientation of the parts in the tangential direction. This demand is carried out only if

$$R_1\alpha - R_2\beta = \Delta_{\Sigma y}. \tag{3}$$

For the mechanism of drive the next equation is true:

$$\beta = \frac{R_{p1}}{R_{p2}} \cdot \alpha = i_{21}\alpha, \tag{4}$$

where $i_{21}$ – is a drive ratio of the rotors.

After putting in equation (3) the values $R_1$, $R_2$ (1) and $\beta$ (4) we will get the next formula:

$$\alpha\left(R_{p1} + \varepsilon\right) - i_{21}\alpha\left(R_{p2} - \varepsilon\right) = \Delta_{\Sigma y}. \tag{5}$$

And in the result:

$$\alpha = \frac{\Delta_{\Sigma y}}{\varepsilon\left(i_{21} + 1\right)}. \tag{6}$$

In equation (6) the values $\varepsilon$ and $\alpha$ are unknown. The value $\alpha$ is dependent on the amplitude of oscillation $A$ and is chosen according to the optimal value of displacement $\varepsilon$. The results of calculating of the values $\alpha$ at the different values ε in the dependence on the amplitude of oscillation $A$ are shown in Figure 3, where the rotors are with equal radii of pitch circles.

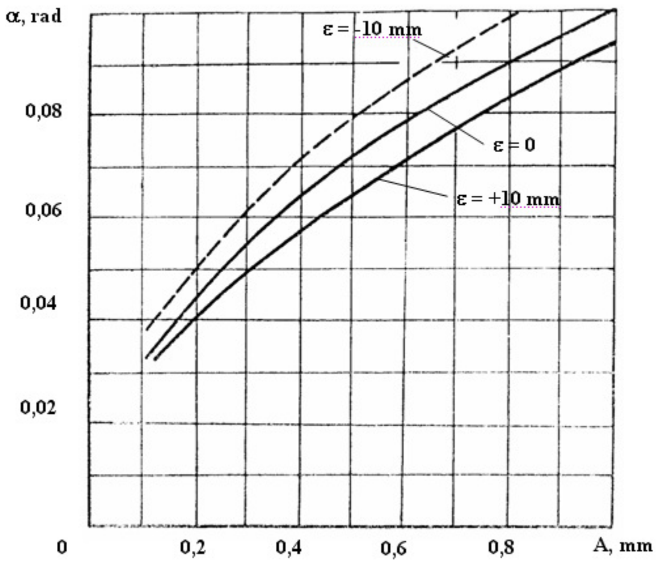


Fig. 3. **Diagrams of dependence $\alpha = f(A)$**

For determination the value of optimal displacement ε let us examine the *t*riangle $O_1SO_2$ (Figure 1). During changing the value of displacement ε, that is at changing of radii $R_1$ and $R_2$, the point S moves along the ellipse (Figure 5), where the distance between focuses is a spacing on the centers of the rotors

$$O_1O_2 = R_{p1} + R_{p2} = a, \tag{7}$$

but the semi-major axis $c$ and semi-minor axis $b$ are

$$c = \frac{1}{2}\left(a + A\right),\ b = \frac{1}{2}\sqrt{A\left(2a + A\right)}. \tag{8}$$

The desired quantity $\varepsilon$ can be found from the combined equations

$$\left.\begin{array}{l} \alpha = \dfrac{\Delta_{\Sigma y}}{\varepsilon\left(i_{21} + 1\right)}; \\ \dfrac{x^2}{c^2} + \dfrac{y^2}{b^2} = 1; \\ \alpha \approx tg\alpha = \dfrac{y}{R_1} \\ x = R_{p2} - \dfrac{a}{2} - \varepsilon; \end{array}\right\}. \tag{9}$$

In the combined equations (9) the first equation is equation (6), the second – the equation of ellipse, the third and fourth equations are received from the geometrical constructions on the ellipse. The $x$ and $y$ are current coordinates of the ellipse (Figure 4).

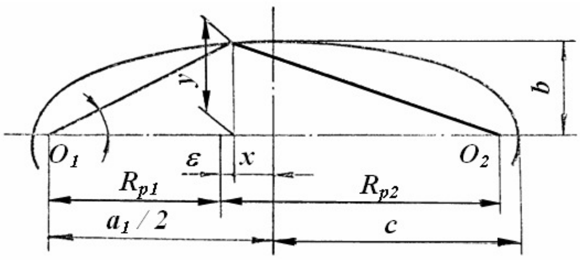


Fig. 4. **Scheme for determination of the value of optimal displacement $\varepsilon$**

Calculation of the combined equations gives the quartic equation and to receive the formula for ε is hard. Therefore, let us include the next correlation

$$y = k\,b, \tag{10}$$

where $k$ – a coefficient, which takes into account the difference of the values y and b at the drive ratio of the rotors $i_{21} \neq 1$ (if $i_{21} = 1$, $k = 1$).

In this case the third equation can be written, as

$$\alpha = \frac{k\,b}{R_1}. \tag{11}$$

In the result equation (9) will take the next view

$$\left.\begin{array}{l} \alpha = \dfrac{\Delta_{\Sigma y}}{\varepsilon\left(i_{21} + 1\right)} = \dfrac{\Delta_{\Sigma y}}{\left(R_1 - R_{p1}\right)\left(i_{21} + 1\right)}; \\ \alpha = \dfrac{kb}{R_1}; \end{array}\right\}. \tag{12}$$

Solving the combined equations for $R_1$ we will get the following formula

$$R_1 = \frac{Rp1}{1 - \frac{\Delta_{\Sigma y}}{k\,b\,(i_{21} + 1)}}. \tag{13}$$

When the $R_1$ is known, we can find all other values. Formula for calculating the optimal value of displacement can be written as:

$$\varepsilon_{opt.} = R_1 - R_{p1} = R_{p1}\left(\frac{1}{1 - \frac{\Delta_{\Sigma y}}{2b\sqrt{i_{21}}}}\right). \tag{14}$$

Radii, on which the axes of assembly devices should be placed, can be determined as:

$$\begin{aligned} R_1 &= Rp1 + \varepsilon_{opt} \\ R_2 &= Rp2 - \varepsilon_{opt} \end{aligned}. \tag{15}$$

## Conclusions

Application of vibrations at automatic assembly on the rotors increases the area of their use. The method of assembly, which is based on the difference of linear speeds of movement of rotors, gives the possibility to minimize the demands for the accuracy of relative orientation of the connected surfaces of the assembled parts. Ensuring movement with different speeds on the rotors is connected only with selection of the optimal value of displacement of the parts in the assembly devices.

In given article the optimal value of displacement of assembly devices on the rotors and the radii, on which the axes of the assembly devices should be placed, are determined.

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