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PRACTICAL APPLICATION OF THETECHNOLOGY OF ULTRASONIC STABILIZATION OF ACCUMULATED DEFORMATION OF CIRCULAR PLATES

Abstract

The most important task of precision mechanical engineering at the present stage is development of more efficient technological processes of manufacturing parts, providing not only achieving high accuracy at the lowest cost, but also the preservation of the initial indicators of accuracy for the life of the product. The authors consider the method of stabilizing the accumulated deformation of parts based on the application of ultrasonic energy.

***Keywords**: The elastic sensing element, circular plate, stabilization, relaxation of stresses, accumulated deformation.*

The performed studies on the applicability of ultrasound to stabilize the accumulated deformation allow solving the problem of reducing the error of devices, in which round metal plates are used as a sensitive sensor, by developing an effective technology for stabilizing the geometric parameters of round metal plates. Since one of the main factors affecting the residual deformation of the plate is the number of load cycles, this factor should also be used to solve the task. In practice, many enterprises carry out so-called instrument training for this purpose. Training consists in the fact that the instruments, before final calibration, work for a long time in the training mode on a special stand, where the plate is loaded with a working medium-liquid or gas, simulating the operation of the device during operation. But such training is ineffective, as it takes a very long time and at the same time consumes a lot of energy. Sometimes, in parallel with the training, a thermal stabilizing treatment of the parts of the device is carried out.[1]

In our opinion, the effectiveness of training devices that have a circular metal plate as a sensitive element can be significantly increased if an ultrasonic method of stabilizing the plate is used, which ensures a high frequency of oscillation of the plate, and, consequently, a reduction in training time, in which the required number of loading cycles $i = f \cdot t$ is provided, where t - processing time, s.

The technological operation of stabilizing the residual stresses of the circular plate is based on the method of relaxation of residual stresses by the action of oscillatory movements of the ultrasonic frequency.

This technological operation provides the ability to avoid distortion of the geometric parameters of parts, under the influence of load, and improve the quality of processing [1], [2], [3]

Stabilization of geometric parameters of circular plates is achieved by the fact that in a method involving fixing a part on a support and installing a source of ultrasonic vibrations with the possibility of deformation of a part, the piece in the form of a circular plate is fixed along its edge, the source of ultrasonic vibrations is fed to the center of the plate and the plate is deformed by an amount equal to:

$$\delta \leq \frac{P}{\pi \cdot \sigma_t}(1+\mu)\cdot\left(\frac{d_o^2}{d^2} - 4\ln\left(\frac{d_o}{d}\right)\right),$$

where d is the outer diameter of the plate, mm;

d_o - diameter of the tip of the ultrasonic instrument, mm:

δ - plate thickness, mm;

μ - Poisson's ratio of plate material;

σ_t - yield point of the plate material, MPa.

Since the deformation of the part is limited by the occurrence in the plate of stresses not exceeding the yield strength, this prevents distortion of the geometric shape of the part during machining. In this way, a plate of any shape, including round, can be processed, which extends the technological capabilities of the method. [4]

The scheme of the technological operation for stabilizing the geometrical parameters of the circular plates is shown in Figure 1.

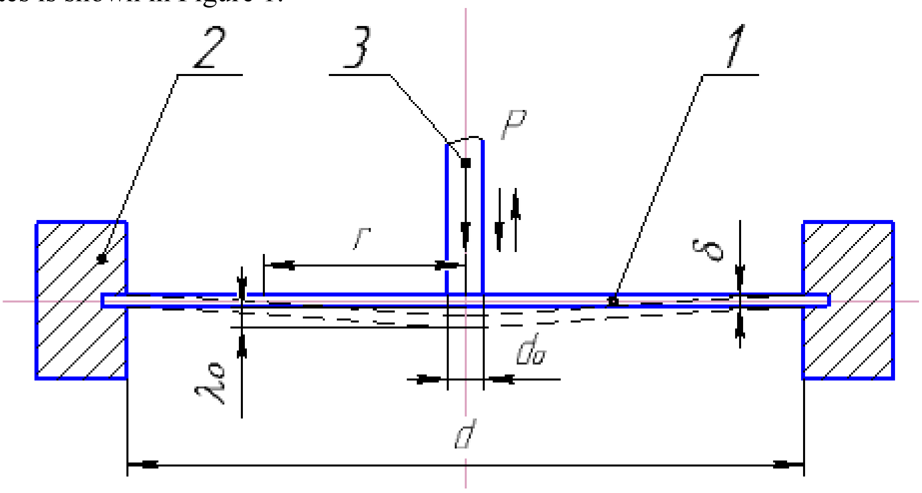

Figure 1 – Scheme of technological operation of stabilization of geometrical parameters of round plates (1 - round plate, 1 - contour rigidly pinching a circular plate, 3 - tip of an ultrasonic tool)

On the circular plate 1, which is an elastic sensitive element (membrane) of thickness δ and diameter d rigidly clamped along the contour in the housing 1, the tool 3 is operated by oscillations of the ultrasonic frequency. The tool tip 3 having a diameterd_0 is set perpendicularly to the surface of the circular plate 1 and is acted upon by a static force *P*, informing oscillatory movements of the ultrasonic frequency within 18-11 kHz. Using a static force *P*, the part is deformed by a value.

With this deformation, the bending stresses in part 1 do not exceed the yield strength of the material, which eliminates the loss of the initial geometric shape.The technical and economic efficiency of the proposed method of stabilizing the geometric parameters of parts is determined by: providing high processing capacity, with high quality of processing, this method guarantees the absence of residual deformation of the part, damage to its outer surface and maximum utilization of ultrasonic vibration energy to ensure the stabilization of geometric parameters, as well as lower production costs parts. [4], [5]

As is known, for the indicated working conditions of a plate its deformation with $0 \le r \le 0.5d_o$ is equal to:

$$\lambda(r) = \frac{30 \cdot P \cdot d^2}{64\pi \cdot \eta \cdot \delta^3}\left(4 - 3\frac{d_o^2}{d^2} + 4\frac{d_o^2}{d^2}\ln\frac{d_o}{d} - 8\frac{r^2 d_o^2}{d^4} + 32\frac{r^2}{d^2}\ln\frac{d_o}{d} + 16\frac{r^4}{d_o^2 d^2}\right), (1.1)$$

where d_o - diameter of the tip of the ultrasonic instrument, mm;

$P = P_o + P_a$,

P_o - static load on the plate, N;

P_a - the load arising from the bending of the plate by the amplitude of the oscillations *A*, N.

The intensity of the radial bending moment per unit length of the cylindrical section of the plate, N·mm / mm

$$M_r(r) = \frac{P}{16\pi}\left[-4 + (1-\mu)\frac{d_o^2}{4r^2} + (1+\mu)\left(\frac{d_o^2}{d^2} - 4\ln\frac{2r}{d}\right)\right] \quad (1.2)$$

The intensity of the circumferential bending moment per unit length of the cylindrical section of the plate,

$$M_\theta(r) = \frac{P}{16\pi}\left[-4\mu + (1-\mu)\frac{d_o^2}{2r^2} + (1+\mu)\left(\frac{d_o^2}{d^2} - 4\ln\frac{2r}{d}\right)\right] \quad (1.3)$$

The intensity of the radial shear force per unit length of the cylindrical section of the plate:

$$Q(r) = \frac{P}{2\pi \cdot r}, \text{ N / m.} \quad (1.4)$$

deformation of an elementary Substituting expressions (1.2), (1.3), and (1.4) into equation 1.2, we obtain the specific energy of elastic annular portion of radius*r*:

$$dU(r) = \frac{3\cdot r\cdot P^2}{64E\cdot\delta^3\pi}\left(\begin{array}{l}\left(-4 + (1-\mu)\frac{d_o^2}{4r^2} + (1+\mu)\left(\frac{d_o^2}{d^2} - 4\ln\frac{2r}{d}\right)\right)^2 + \\ + \left(-4\mu + (1-\mu)\frac{b_o^2}{r^2} + (1+\mu)\left(\frac{d_o^2}{d^2} - 4\ln\frac{2r}{d}\right)\right)^2 - \\ 2\mu\cdot\left(-4 + (1-\mu)\frac{d_o^2}{4r^2} + (1+\mu)\left(\frac{d_o^2}{d^2} - 4\ln\frac{2r}{d}\right)\right)\times \\ \times\left(-4\mu + (1-\mu)\frac{b_o^2}{r^2} + (1+\mu)\left(\frac{d_o^2}{d^2} - 4\ln\frac{2r}{d}\right)\right)\end{array}\right) + \frac{(1+\mu)P^2}{8\pi E\delta\cdot r}. \quad (1.5)$$

Integrating (1.5) with respect to the variable*r*, we find the total potential energy of the elastic deformation of the plate *U (J)* under the action of a concentrated force *P* acting on the central pad with a diameter d_o. With $d_o \le 0{,}1d$ an error of less than 1%, we get:

$$U = \frac{3\cdot P^2 d^2}{8E\cdot\delta^3\pi}(1-\mu^2) + \frac{(1+\mu)P^2}{16\pi E\delta}\ln\frac{d}{d_o} \quad (1.6)$$

Equation (1.6) represents the potential deformation energy of the internal forces of the plate, which, after removing the external load, can return the plate to its original state. The potential energy of internal forces should be equal to the kinetic energy of deformation of external forces. Let us find this energy. [6]

Since the external load acts on the center of the plate, then on the annular portion of the plate with radius $r \le d_o / 2$ the deformation energy in the deformation of the plate in the direction of the load P_o is:

$$Wn = \int_0^A P(\lambda)d\lambda = \int_0^A \left(P_o + P_a\frac{\lambda}{A}\right)d\lambda = A\left(P_o + \frac{1}{2}P_a\right), \quad (1.7)$$

where W_n is the energy of deformation of the plate when it moves in the direction of the action of the external load, *MPa*;

P_o - external load, N;

P_a - the load arising under the action of deformation of the plate by the value of *A*, N;

A - amplitude of oscillations of the tool, *mm*.

Similarly, with the reverse motion of the plate, the energy expended will be:

$$W_v = A\left(P_o - \frac{1}{2}P_a\right), \qquad (1.8)$$

where W_n is the strain energy of the plate when it moves in the opposite direction of the external load, MPa. [6], [7]

Using equality (1.1), we express the strain energy of the plate by the amount of deformation:

$$W_n = A^2 \cdot \frac{64\pi \cdot \eta \cdot \delta^3}{30 \cdot d^2 \cdot \left(4 - 3\frac{d_o^2}{d^2} + 4\frac{d_o^2}{d^2}\ln\frac{d_o}{d}\right)}\left(\frac{\lambda_o}{A} + \frac{1}{2}\right); \qquad (1.9)$$

$$W_v = A^2 \cdot \frac{64\pi \cdot \eta \cdot \delta^3}{30 \cdot d^2 \cdot \left(4 - 3\frac{d_o^2}{d^2} + 4\frac{d_o^2}{d^2}\ln\frac{d_o}{d}\right)}\left(\frac{\lambda_o}{A} + \frac{1}{2}\right).$$

Denote by:

$$K_W = \frac{64\pi \cdot \eta \cdot \delta^3}{30 \cdot d^2\left(4 - 3\frac{d_o^2}{d^2} + 4\frac{d_o^2}{d^2}\ln\frac{d_o}{d}\right)}. \qquad (1.10)$$

Then the equalities (1.9) take the form:

$$W_n = A^2 \cdot K_W\left(\frac{\lambda_o}{A} + \frac{1}{2}\right); \qquad (1.11)$$

$$W_v = A^2 \cdot K_w\left(\frac{\lambda_o}{A} + \frac{1}{2}\right).$$

After the first deformation of the plate in the direction of the external load, part of the deformation energy is absorbed by the defects of the material and there remains in it a potential energy determined by the equation:

$$U_{on} = U_o\left(1 - \frac{W_n}{U_p}\right). \qquad (1.12)$$

After the plate is deformed in the opposite direction, a part of the deformation energy is also absorbed in it and the residual internal potential energy of deformation of the plate will be equal to:

$$U_{o1} = U_{on}\left(1 - \frac{W_v}{U_p}\right) = U_o\left(1 - \frac{W_n}{U_p}\right)\left(1 - \frac{W_v}{U_p}\right). \qquad (1.13)$$

After the i -deformation, the residual potential energy of the workpiece material is:

$$U_{oi} = U_o\left(1 - \frac{W_n}{U_p}\right)^i\left(1 - \frac{W_v}{U_p}\right)^i. \qquad (1.14)$$

Using equalities (1.9) and (1.14), we determine the residual stresses in the plate after the i - cycles of oscillations:

$$u_i = u_0 \cdot \left(1 - \frac{W_n}{U_p}\right)^{\frac{i}{2}}\left(1 - \frac{W_v}{U_p}\right)^{\frac{i}{2}}. \qquad (1.15)$$

Since the internal potential strain energy is proportional to the residual stresses, then, as follows from equality (1.15), as the number of loading cycles increases, the residual stresses in the plate material decrease [6], [7], [8].

After the first half-cycle of oscillations, the residual deformation of the plate in accordance with (1.15) will be:

$$\Delta\lambda_{1n} = A\frac{U_o}{U_p}.\quad(1.16)$$

At the end of the first cycle of oscillations, the residual deformation will be equal to the residual strain difference in the first and second half-periods:

$$\Delta\lambda_1 = \Delta\lambda_{1n} - \Delta\lambda_{1v} = A\frac{U_o}{U_p} - A\frac{U_{on}}{U_p} = A\frac{U_o \cdot W_n}{U_p^2}.\quad(1.17)$$

Similarly, we find the residual deformation after the i-th cycle of oscillations:

$$\Delta\lambda_i = A\frac{U_o \cdot W_n}{U_p}\left(1-\frac{W_n}{U_p}\right)^{i-1}\left(1-\frac{W_v}{U_p}\right)^{i-1}.\quad(1.18)$$

Summing the residual deformation along the oscillation cycles, we get:

$$\Delta\lambda_i = A\frac{U_o \cdot W_n}{U_p}\sum_{i=1}^{n}\left(1-\frac{W_n}{U_p}\right)^{i-1}\left(1-\frac{W_v}{U_p}\right)^{i-1}.\quad(1.19)$$

The sum on the right-hand side of (1.19) is the sum of the geometric progression. There fore:

$$\Delta\lambda_n = A\frac{U_o \cdot W_n}{U_p^2}\frac{1-\left(1-\frac{W_n}{U_p}\right)^{n-1}\left(1-\frac{W_v}{U_p}\right)^{n-1}}{1-\left(1-\frac{W_n}{U_p}\right)\left(1-\frac{W_v}{U_p}\right)}.\quad(1.20)$$

In the limit with $n \to \infty$

$$\Delta\lambda = A\frac{U_o \cdot W_n}{U_p}\frac{1}{1-\left(1-\frac{W_n}{U_p}\right)\left(1-\frac{W_v}{U_p}\right)}\quad(1.21)$$

It is seen from the expression (1.21) that the accumulated residual deformation is difficult to depend on the influencing factors. Therefore, in order to analyze the dependence obtained, it is necessary to develop a computer model of the stabilization process for the plate parameters on the basis of the dependences obtained [8], [9].

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РЕЗЮМЕ

Важнейшей задачей прецизионного машиностроения на современном этапе является разработка более эффективных технологических процессов изготовления деталей, обеспечивающих не только достижение высокой точности при минимуме затрат, но и сохранение первоначальных показателей точности в течение всего срока службы изделия. В статье авторами рассматривается метод стабилизации накопленной деформации деталей, основанной на применении ультразвуковой энергии.

ТҮЙІН

Қазіргі кезеңде прецизиондық машина жасаудың маңызды талабы болып бөлшектердің өндіру процессінің ең тиімді әдістерін әзірлеуде тек ең төменгі шығындармен дәлдікке қол жеткізуді қамтамасыз ету ғана емес, және де өнімнің барлық қызмет көрсету кезеңінде алғашқы дәл көрсеткішті сақтау. Автордың мақаласында ультрадыбыстық энергияда қолданылатын бөлшектердің жинақталған деформациясын тұрақтандыру әдісі қарастырылады.

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ПРИМЕНЕНИЕ ЦЕНТРОБЕЖНЫХ ФИЛЬТРОВ ДЛЯ ОЧИСТКИ МАСЛА В ДВС

Аннотация

В данной статье рассматриваются теоретические данные и математическая модель центробежных фильтров по очистке масла. Определена необходимость повышения точности диагностирования технического состояния центробежных фильтров.

Ключевые слова: *Масляная центрифуга, центробежный фильтр, двигатель, масло, давление, центробежный маслоочиститель математическая модель, момент инерции, крутящий момент, фильтр тонкой очистки, механическая примесь, очистка масла, момент сопротивления.*

За последнее время в автомобильных двигателях для очистки масла получают все большее применение очистители центробежного типа. Центробежные очистители (центрифуги), в которых очистка жидкостей от твердых частиц осуществляется под действием центробежного поля. Как в отстойниках, так и в центрифугах жидкость очищается только от тех частиц, плотность которых больше плотности самой жидкости. На автомобилях и тракторах применяют центрифуги, имеющие частоту вращения от 5000 до 8000 мин$^{-1}$. Скорость осаждения твердых частиц загрязнения в центробежном поле таких центрифуг от 1000 до 2000 раз выше, чем в гравитационном поле отстойников. В зависимости от характера привода центробежные очистители подразделяют на центрифуги с гидравлическим, механическим, электрическим, а также газовым (от отработавших газов) и пневматическим приводами [1]. Особенно большое распространение получили центрифуги с гидравлическим приводом.