Information technology of ultrasonic assembly and pressing of joints

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Abstract. The paper considers the issues of increasing the efficiency of forming press connections by using additional ultrasonic vibrations introduced during the pressing process. A distinctive feature of the proposed approach is the use of ultrasonic vibrations simultaneously both for technological purposes to improve the efficiency of Assembly of press connections, and for indirect non-selective diagnostics of formed connections by analyzing vibrations directly in the Assembly process. The developed algorithm and device for ultrasonic pressing of teeth of a roller bit with an assessment of the quality of pressing on diagnostic indicators is presented.

Press connections are widely used in mechanical engineering and instrumentation due to their good functional characteristics, simplicity of Assembly equipment and lack of additional fasteners [1].

The ability of press joints to withstand significant loads depends on the amount of tension, which when landing is usually determined by the nominal size of the covered and spanning parts without taking into account the microgeometry of the surface. At the same time, the unavoidable micro-roughness during any processing, crumpling under the influence of pressures on the mating surfaces, reduces the amount of tension [2].

The operating modes of modern machines and mechanisms are characterized by high loads and speeds, which puts forward increased requirements for the dynamic characteristics of connections, determined to a large extent by the dynamic connections of the contacting surfaces formed during the Assembly process. However, traditional Assembly methods are focused on achieving the specified geometric (dimensional) relationships and do not take into account the dynamism of modes and the nature of the contact interaction of parts, which leads to an unacceptable deviation of functional characteristics, reducing reliability and durability, which is especially negative when using high-tech products characterized by increased requirements for quality indicators [3]. A distinctive feature of press connections is the inaccessibility of the zone of contact interaction of parts for direct observation, control and management, but it is in the process of force contact interaction of surfaces that the main functional characteristics of connections are formed, operational reliability and durability of products are laid.

One of the features of the modern stage of development of mechanical engineering technology is the application of a systematic approach that combines the use of modern information technologies and computer technology to design, manufacture, Assembly, control and operation of machines and in the synthesis of new technological methods of processing and Assembly, allowing to provide the necessary performance properties of machine parts.
Recently the increasing distribution in the Assembly to receive ultrasonic technology, the main features which determine their technological prospects, are high concentration of vibrational energy introduced into the area of contacting parts, which provides local exposure, with significantly lower energy consumption, the low inertia of the process, resulting from direct conversion of electric energy into ultrasonic technological impact, and the possibility of using induced during ultrasonic Assembly vibrations, as in the process, so for diagnostic purposes. The basis of the technological application of ultrasonic effects is the well-known acoustoplastic effect [4], consisting in increasing the plasticity of materials under the action of ultrasound, experimentally detected at ultrasonic frequencies by Blach and Langeneker and representing a jump-like reduction in the stress of unidirectional deformation of the crystal when alternating deformations are applied to it. The effect of ultrasound on the plastic deformation of metals is determined both by an increase in the number of dislocations under the influence of alternating changes in loading, which leads to hardening of the material, and by the effect of increasing the mobility of dislocations that cause the material to soften. At the same time, the effect of reducing friction between surfaces moving relative to each other when ultrasonic vibrations of one of them occur. The acoustoplastic effect is technically realized with simultaneous exposure to ultrasound and static loading and represents the result of summing static stresses and dynamic stresses of the ultrasonic wave [4].

The use of high-frequency vibrations of small amplitude makes it possible to intensify the Assembly process, which is due to a number of specific features of the ultrasonic effect, which include a significant reduction in the resistance forces during Assembly, self-centering of parts, improving the performance of connections by direct action on the formed characteristics of the contacting surfaces, as well as the possibility of mechanization and automation of the technological process. The determining parameters for ultrasonic Assembly are the static force, speed and time of Assembly, as well as the amplitude, frequency and scheme of introduction of ultrasonic vibrations.

The paper proposes an approach in which the dynamic quality indicators are evaluated directly during the formation of the connection, and the ultrasonic vibrations excited during the Assembly process are used for both technological and diagnostic purposes in the form of a test resonant effect on the mechanical system. The principal difference between the proposed approach and the currently used technologies for Assembly and testing of products is the presence of indirect non-selective vibration diagnostics, carried out in conjunction with ultrasonic Assembly, and an assessment of the actual technical condition of the product based on the characteristics of the mechanical dynamic processes occurring in it. In this case, the connection is considered as an object of vibration diagnostics, and in the process of forming a mechanical connection, there is a relative movement and force contact interaction of the surfaces of the connected elements, which generates vibroacoustic processes that carry information about the state of the connection and are used for its diagnosis. Obtaining information about the dynamic characteristics of a compound directly in the process of compression reduces the uncertainty in the formation of indicators of quality of compounds, provides warning about trends in changes in characteristics, makes it possible to actively counteract negative changes in the process of compression and reduce the dispersion of indicators of accuracy of compounds [5].

One solution to the problem of ensuring the required quality press connections is the development of methods and means of control current the information contained in the fluctuations accompanying a process of ultrasonic pressing, for the purposes of adaptive control of technological process Based on operational parameters of the connection, determine the numerical value of the required dynamic characteristics and the nature of their changes coordinate the movement of parts.

The developed algorithm is implemented as follows. A constant static pressure is applied to one of the parts and ultrasonic elastic vibrations are excited in the connected parts. By changing the frequency of disturbing forces, resonance is achieved and the amplitude of the vibration signal is measured, which determines the q-factor of the oscillatory mechanical system, which characterizes the dynamic quality of the formed connection. Comparing the informative parameters of the resulting compound with the reference values, the quality of the compression is judged [6].
Experimental studies were conducted for such high-tech products as drilling roller bits. One of the main problems that reduce the drilling efficiency is a large variation in the strength characteristics of the pressed teeth, which leads to the loss of teeth during drilling and reduced productivity, and increased tension leads to the formation of microcracks and accidents. Taking into account the above-mentioned features of the impact of ultrasonic vibrations during Assembly, a scheme for building an information and measuring complex based on a personal computer was developed (Fig. 1) and a stand was made for ultrasonic pressing of the teeth of roller bits [7, 8].

![Information and measurement complex for controlling the pressing of teeth of roller bits](image)

**Figure 1.** Information and measurement complex for controlling the pressing of teeth of roller bits

The information and measuring complex contains a force – measuring resistive type 1 sensor, connecting parts of the tooth 2 and the ball 3, an oscillatory energy concentrator 4, a piezoceramic vibration exciter 5 with a counterweight 6, a hydraulic cylinder rod 7; vibration sensors of the KV-10 type 8 and 9; an electric oscillator of the GZ 109 type, a resistive type 10 displacement sensor, analog-to-digital converters ADC1,...ADC4, which are part of the interface device with a computer of the LA2USB type, personal computer PC.

In the conducted experimental studies, flat disks made of 14KHNZMA steel (bit steel) were used as imitations of the balls, which were subjected to mechanical and chemical-thermal treatment, similar to the serial technology of processing the balls of drilling bits at JSC "Volgaburmash". We used serial
factory hard-alloy teeth made of VK10 alloy, with a diameter of 7.8 mm. In each disk, 20 through holes were made, which allowed first pressing the teeth into the holes from top to bottom, and then pressing them from bottom to top to assess the strength of the formed joints. Experimental studies on ultrasonic pressing were carried out on a specially designed stand, in which the static force was created by a hydraulic press and was about 3000 N, and vibrations were excited by a package of 6 piezoceramic washers of the CTS-19 type with a diameter of 46 mm and a thickness of 9 mm. The vibration amplitude after amplification by the vibration concentrator was 10-15 microns [9].

The connecting parts 2 and 3 are installed in the Assembly position. With the help of the hydraulic cylinder rod 7 through the vibrational energy concentrator 4, an Assembly force is applied to the connected parts and at the same time, elastic vibrations are excited in the Assembly parts using the G3-109 generator and the piezoceramic exciter 5.

During the pressing process, information about the Assembly force and relative axial movement of the assembled parts is continuously transmitted to the PC using the force measuring sensor 1 and the displacement sensor 10 via ADC1 and ADC2. Simultaneously, during the entire Assembly process, using vibration sensors 8 and 9, information about the frequency characteristics of the formed connection is transmitted to the PC via ADC3 and ADC4. With the help of special PC programs, the q-factor value of the formed connection is continuously calculated and controlled.

Analysis of the data obtained during the experiment showed that for pressing joints using resonant ultrasonic vibrations, the average reduction in the pressing force was from 11% to 42%, with a simultaneous increase in strength to 12%. The q-factor of the mechanical oscillatory system varied from 6 to 80 relative units at resonance frequencies from 12 to 21 kHz [10].

Thus, the proposed method based on the received operational information about the parameters of the pressing process allows you to ensure the guaranteed quality of each connection without tightening the manufacturing and Assembly technology of parts.

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