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Application of two-component technological media for surface processing with a high degree of curvature

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Abstract. The final dimensional combined treatment with the application of an electric field by a tool in the form of unbound metal pellets of complex profile components used in aviation, rocket and space technology and in the oil and gas industry is considered. Such parts include impellers and the flowing component of the turbo-pump units, augers, impellers, where there are sections of variable curvature with limited access of the tool to the processing area. It is shown that the combination in a combined process of two-component technological media from current-carrying granules and an electrically conductive liquid medium supplied at high speed to the treatment zone allows to provide the required technological and operational processing parameters; the action of an electric field from a source with an increased voltage makes it possible to remotely perform a final dimensional processing of the pieces of metal parts with the creation of the required cold-hardening against the impacts of solid granules; a combination of mechanical, chemical and magnetic impacts ensures obtaining a given profile accuracy, surface roughness. As a result, it is possible to increase the action and durability of important units of aerospace engineering and oil and gas equipment, and also to expand the area of technological use of the combined treatment method with unbound granules to component parts that are not accessible for processing by an integral tool. In the method under consideration, a universal granule tool is used which does not have a constant geometric shape and is capable of being delivered to the treatment zone through openings into parts whose dimensions are commensurable with the cross-section of the granules.

1 Introduction

Method [1; 2] is for the stream of components using an unshaped universal tool which is carried out under the influence of an electric field of increased Voltage with a mechanical impact of the streamin a two-component process medium representing a suspension of unbound metal pellets and liquid of conductive fluid. Method [3] allows the performance of finishing dimensionalprocesses on the parts of metal components to obtain a predetermined work-hardening, profile accuracy, surface roughness and the possibility of increasing the

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action and durability of highly loaded products, including the flowing part of impellers and turbo-pump aggregates, augers, impellers for aerospace machinery, oil and gas equipment, the profile of channels in which contain sections of variable curvature with limited access of the tool to the processing area. The use of the combined processing method [3] with the anodic removal of the allowance in two-component technological media makes it possible to extend the field of technological use to semi-enclosed cavities with a small cross-section of the tool access opening.

The operation of the combined treatment process using solid conductive filler includes changes aimed at calculating the hydrodynamic parameters [4; 5], processing modes [6; 7], providing quality indicators [8], designing [9] or selecting [3] tools, technological processes [10; 11].

2 Technological capabilities of the method

A new method of electrochemical-mechanical treatment has been developed [1; 3], (Fig. 1) using solid conductive filler, equipment and technological equipment for its implementation.

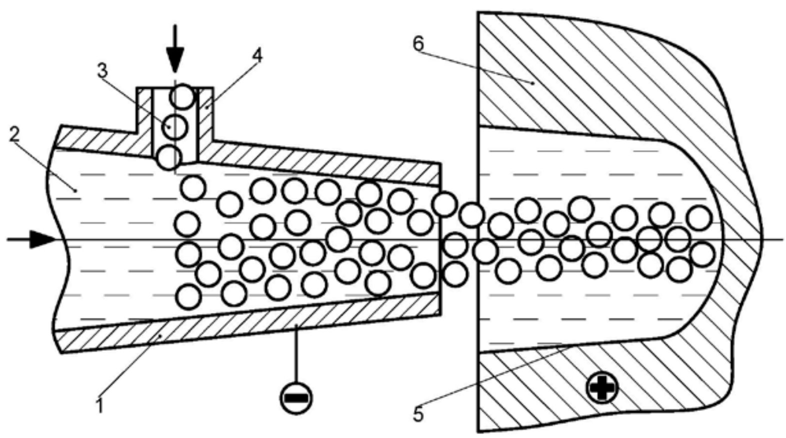

Fig. 1. Diagram of electrochemical-mechanical treatment: 1 - nozzle; 2 - technological environment; 3 - current-carrying granules; 4 - a branch pipe; 5 - processing surface; 6 - component.

Method (Fig. 1) provides dimensional processing of arduous surface areas for traditional tools, far from the cut of the nozzle 1, at considerable distances from the surface to be treated 5. The process takes place in a two-component process medium including the liquid process medium 2 and conductive granules 3 fed into the nozzle through the branch pipe 4. Nozzle 1 and part 6 are connected to an overvoltage current source, which ensures high-quality processing of the closed areas obtaining the required hardening of the surface layer. Dimensional shaping in this way increases the resource and durability of liable units of aviation equipments and oil and gas facilities, expands the field of its use for parts used in modern consumer goods.

3 Flow patterns of manufacturing process

The process of dimensional removal of the allowance and the formation of the specified characteristics of the work piece surface layer represents the synthesis of the effects on the surface to be treated in a two-component anodic dissolution process medium and mechanical hardening. Such a mechanism represents the synthesis of successive and parallel processes: hydrodynamic and anodic local dissolution, determining the mass extrusion and the rate of allowance removal; formation of roughness and cold work hardening of the surface layer ensuring minimum hydraulic resistance to the flow of liquid and gas media components and also obtaining a given durability under multi-cycle loading. For zone treatment with a stream of a two-component technological medium, the main technological parameter is the processing time of the local part of the work piece surface, $t_{loc,}$ at which the required properties of the surface layerthat determine the performance characteristics of the product are formed:

$$t_{local} = f(U_n, h_n, R_a, \Delta_{\det}), \quad (1)$$

where U_n, h_n, $R_{a,}$ Δ_{det} are the characteristics of the quality of the surface layer: the hardening value U_n, the thickness of the reinforced layer h_n, the roughness R_a and the component profile error Δ_{det}.

The following initial assumptions were used in constructing the model:

- granules with mechanical action on the surface of the work piece create a cold-hardening in the surface layer, which does not differ in uniformity, since in most known applications of the process, the filler dimensions are several orders of magnitude greater than the cavities dimensions of the irregularities in the original surface, and repeated entry of the pellet into the previously formed hole having highly low possibility;

- Anodic dissolution of the work piece surface of the partequals the degree of hardening of the surface layer due to the increased rate of removal of theallowance in the hardening places, but slightly reduces its value, since these two processes (hardening and anodic dissolution) occur simultaneously;

- mechanical and anodic impact on the surface of the work piece occurs simultaneously, but their mutual components can vary over a wide range and to obtain optimal values of quality and performance that ensure the maximum fatigue strength of the part, it is necessary to determine the optimal levels of exposure of all factors.

The task of creating a model of the dimensional shaping process consists in obtaining the basic mathematical dependencies applicable from the positions of real technology that provide the dimensional processing ensuring the obtaining of a given roughness parameter of the work piece surface at which the endurance limit of the material Ϭ-1 stabilizes and is maximum at the optimally stable hardening value .

Time, as a generalized criterion for managing the dimensional processing of complex profile parts, essentially depends on the applied processing scheme and the goals that are pursued in its use. If during the processing it is necessary to ensure not only the removal of the local allowance for processing, but also to achieve the required parameters of roughness and surface accuracy, the size and depth of the hardened layer and the surface finish of the part (all other processing schemes are special cases and in their use, the calculation of processing time is only simplified) the total time T of the work piece can be determined by the expression:

$$T = t_{\text{local}} \cdot N, \quad (2)$$

where N is the number of local sections to which the surface under consideration is divided, pcs.

The processing time of the local section $\boldsymbol{t_{local}}$ consists of the time $\boldsymbol{t_{ld}}$ of removal of the allowance for processing due to anodic dissolution of the work piece material and the time

$\boldsymbol{t_n}$ necessary for the formation of surface quality characteristics due to anodic dissolution and plastic deformation:

$$t_{\text{local}} = t_{ld} + t_n \tag{3}$$

The removal time of the allowance depends on the rate of anode dissolution of the allowance:

$$t_{ld} = \frac{Z_{la} \cdot \rho_{pb} \cdot L}{\alpha \cdot \eta \cdot K_n \cdot U\left[\gamma_{el} + \beta\left(\gamma_{gr} - \gamma_{el}\right)\right]}, \tag{4}$$

where Z_{la} - the size of allowance for anodic dissolution at the local section, mm; ρ_{pb} - density of the work piece material, kg / m3; L - the gap between the electrodes, mm; α - the electrochemical equivalent of the work piece material, kg / (A.s); η - current output; K_n - coefficient characterizing the increase in the rate of anodic dissolution, due to the formation of hard work in the subsurface layer, K_n = 1,2 - 1,5; U - working voltage, V; β- concentration of filler granules, β = 20 - 25%; γ_{el}, γ_{gr} - specific conductivity of electrolyte and material of granules, $(\text{Ohm} \cdot \text{m})^{-1}$.

Expression (4) establishes a relationship between the characteristics of solid granules (physical and mechanical properties and concentration in the flow) and the time of removal of the allowance from the local surface area.

The procedure for finding the time t_n, necessary to achieve the required parameters of the surface layer (roughness R_a, the hardening value U_n and thickness h_n of the hardened layer), includes an estimate of the formation time of each of these indices at the site of the stream of a two-component medium, i.e. on the i-th area of the treated surface. Then the most effective value is chosen and for it $\boldsymbol{t_{ni}} = \boldsymbol{t_n}$ is assumed. The time of the formation of indicators depends on the properties of the surface layer of the part and the hereditary roughness, processing conditions, the material of the granules, the nozzle design, the angle of the stream flow to the surface of the part (angle of attack). For the case of the formation of a set value for hard work in the surface layer, the time $\boldsymbol{t_n}$ is determined by the expression:

$$t_н = \frac{\ln\left|\left(\sqrt{\frac{V_{gr} \cdot \beta}{2R \cdot \tau}\sqrt{\frac{K_m \cdot \delta}{2c \cdot \sigma_g}}\left(1 + \frac{1}{K_\mu}\right)^{0,5}} - 1\right)\right|}{tg\beta_{pb}}, \tag{5}$$

where V_{gr} is the speed of the filler granules, m / s (5-10 m / s); R is the radius of the granules, m; τ is the ratio of the curvature radius of the treated surface to the radius of the granule curvature, K_m is the complex coefficient that takes into account the mass of granules and the compliance of the component material, kg, the method of its determination is given in [3]; δ is a coefficient that takes into account the influence of the surface roughness on the change in the pressure diagram in the contact zone, δ <1, c is the coefficient of constraint of the component material, 1 / m; σ_g is the dynamic yield strength of the component material, Pa; K_μ is the strain hardening coefficient, the method of its determination is presented in [3], β_{pb} is the contact angle of the two-component stream with the surface being treated, deg.

Then the total processing time of the work piece T_{pb} is:

$$T_{pb} = (t_{ld} + t_n) \cdot N = \frac{(t_{ld} + t_n) \cdot S_{pb}}{S_{eff}}, \qquad (6)$$

where S_{pb}, and S_{eff} –areas of the processing work piece surface and the "effective" stream action spot, m^2.

Expression (6) is the law of the dimensional formation of qualitative and operational characteristics of the product, expressed in the form of the time necessary for processing the interfaced local "effective" areas. If the allowance is removed by anodic dissolution of the work piece material with simultaneous hardening of the surface (two processes proceed simultaneously), expression (6) can be transformed to the following form:

$$T = k_{all} \cdot k_i \cdot k_{cur} \frac{S_{pb}}{S_{eff}} t_{ld}, \qquad (7)$$

where k_{all} is the coefficient characterizing the anodic removal of the allowance for processing (depending on the component material, for aluminum k_{all} = 1.1, for steel k_{all} = 1.15, for copper k_{all} = 1.25); k_i is a coefficient that takes into account the uniformity of the stream movement of the multiphase working medium along the treated area (for standard processing conditions k_i = 1.2 due to overlapping of adjacent areas); k_{cur} is a coefficient that takes into account the surface curvature being treated (for the case when the curvature radius of the surface being processed exceeds the radius of the granules, then k_{cur} = 1).

These dependencies are used to calculate the technological modes of processing closed channels in the impellers of pumps (Fig. 2).

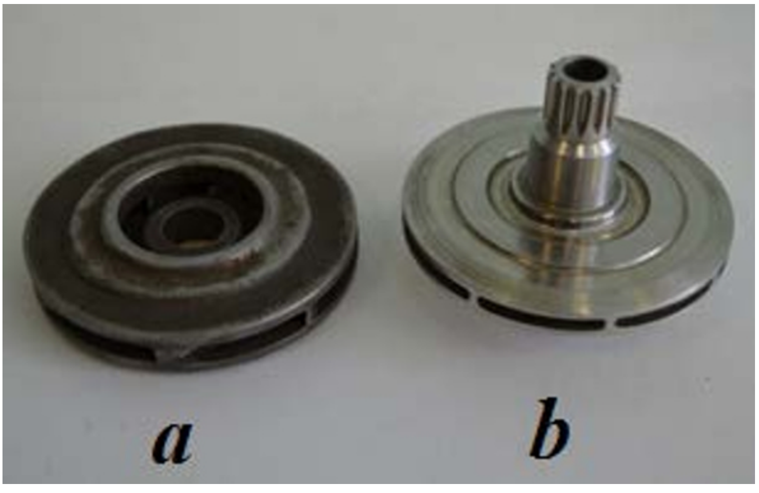

Fig. 2. Impellers of pumps: a - cast wheel of gray cast iron; b - steel component

Fig. 2.a shows the wheel in which it was required to reduce the roughness of the flowing part to R_a = 3.2 μm. A technological medium was used - granules of graphite with a diameter of 2-4 mm in industrial water and the following technological regimes: voltage 90 V, rotation speed of the component - 1440 rot/min, processing time 4.5 minutes.

The steel part (Fig. 2.b) was processed in the same modes after the channel flashing, but the processing time was 7.5 minutes to achieve a roughness of the flow part R_a = 1.6 μm.

4 Conclusion

A new method for combined dimensional shaping of complex profile surfaces with a non-profiled tool in a two-phase process medium containing solid conductive granules has been developed.

The mechanism of the formation of component parts, removed from current supply point is disclosed, which allowed to develop a methodology for designing technological regimes and to implement the process for finishing channels.

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