Preservation of material quality with the use of combined treatment

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Abstract. This research is devoted to some techniques of combined treatment including anodic attack and mechanical impact. The salutary effect of these methods permits one to get the requisite accuracy and quality of work surface. The article contains final results of theoretical and experimental study of metal working for inner apparent surfaces.

1. Introduction

The research of new technologies theory in combined treatment for achievement of the best results was conducted in Voronezh State Technical University and Bryansk State Technical University. The results of it are previously unknown processes that the authors called electromechanical treatment and treatment by unbound particles in neutral salt medium. These processes were successfully used in military industry and are now being used in the production of compressors, pumps, transport facilities. The above mentioned method permits to produce complex parts without finishing operations and with considerable saving.

2. Results and Discussion

It is known that every method of treatment changes material surface coating and affects its mechanical properties, especially the endurance strength of alloys. If the final processing operation is yielding, its influence on surface quality greatly depends on the method and conditions of the previous treatment, that is, such conditions as machine direction stresses, the importance of cutting tool and strain hardening. The only method for removal of previous operations residual factors without new changes of surface coating is electromechanical treatment in electrolyte (aqueous solutions of neutral salts are used as electrolytes).

However it is necessary to achieve the relevant surface strength to guarantee a high quality of mechanical properties of machine parts. For this purpose we need calculated working tolerance of the nominal dimension with a minimum number of mistakes. Therefore in this case it is necessary to have the exact passage form before surface yielding. A separate passage formed by electromechanical precision treatment and plastoelastic strain can guarantee stable results only with total strain hardening of material as long as the passage accuracy changes of electromechanical treatment reach the ISO 9-10 echelon accuracy, but the expected echelon accuracy is ISO 7-8.
Figure 1. Influence of the surface layer hardening on the endurance limit; 
a – 40XHMA steel; b – BT3-1 titanium alloy.

The endurance strength of alloys \( \sigma_i \) changes at multicycle tension in accordance with the level of hard-facing \( U \) is shown in Figure 1.

The general endurance strength of structural steel 40XHMA (Figure 1,a) in the initial state equals 590 MPa and after achievement of full load is 610 MPa. The maximum strength increases up to 650 MPa when hardening level \( U = 16 \% \). A similar linear connection is considered in titanium alloy BT3-1 (Figure 1,b). Thus some methods of mechanical treatment that are widely used in mechanical engineering industry such as, for example, vibro-strengthening and shot-blast cleaning permit one to achieve the increase of endurance strength in only one part and the reduction of specific quantity of metal in manufactured goods.

We offer the method calculated for achievement of the high passage accuracy with desired strengthening. Figure 2 shows the model of this method.

The control strategies that form the basis of this method are:
- metal removal before the change of a dimension element in proportion to an allowance value along the entire perimeter;
- mechanical properties of material become permanent throughout the depth and they do not affect the force shift of dimensional tool.

Figure 2. Method of combined treatment:
1 – cathode instrument; 2 – calibrating element; 3 – guide member; 4 – outlets for electrolyte; 5 – dielectric socket; 6 – bar with current lead.
We managed to formulate the method that conducts this process by keeping the calculated force shift of a combined instrument constant.

Cathode instrument 1 (Figure 2) is hold by dielectric rails provided with parallel pits or connected with axes of a tool in the electrolyte pump. Dimensional tool 4 has an external unit holding the contour surface of the passage. It is connected through a dielectric interlayer with a cathode instrument. Expected force $F$ is calculated with the use of the allowance value that is given for optimal strengthening of the obtainable surface. Force $F$ is kept constant regardless of change in the initial passage size. When the allowance exceeds the calculated value, combined instrument stops and does not move until its allowance value reduces, and traces left by the previous treatment are removed by the anodic attack on the cathode. At the time when allowance reaches the calculated value, the feed of the combined instrument is renewed. When the allowance value is unequal throughout the passage perimeter, it is necessary to achieve speeded dissolving in the unit with a thick layer that removes metal. In this case the process of metal removal is intensified by local strengthening.

The design of the combined instrument (Figure 2) helps with this. There is elastic element 5 that is compressed when combined instrument stops in front of the unit with high allowance. It turns off the feeder for some time and bar 6 moves backwards, then forward again, and dimensional element is removed throughout the extended area of the passage. As a result we obtain local strengthening, which permits to intensify the metal dissolution efficiency up to 60 % and quickly equalizes the total allowance.

Feed force is

$$F = \pi \cdot p \cdot z \cdot d \cdot \left(1 + \frac{f}{\log \alpha}\right),$$

where $p$ - regular contact pressure;
$z$ - allowance;
$d$ - dimensional instrument diameter;
$f$ - index of friction;
$\alpha$ - angle of a taper lead in the grade unit.

When $F=const$, random errors of the passage cross section after treatment by the combined instrument include errors caused by nonuniformity of the dimensional unit allowance and a rigidity change. The first group of mistakes is not so important as mistakes caused by the nonuniformity of rough tolerance. The overall error of the passage cross section with the diameter of more than 20 mm at treatment of the parts from structural steel corresponds to a tolerance range with 7 ISO accuracy degree, but in case of treatment of the passages with the diameter of more than 50 mm the achieved accuracy degree is 6 ISO.

We made calculations that permitted the identification of operation conditions for machine-tools with CNC with the combined tool intended for treatment of cylindrical pipes of 37 mm in diameter made from structural steel 40XHMA. Inaccuracy of strain hardening for the rated size was less than 1 %.

The research of a surface quality after combined treatment showed that yielding caused by the dimensional unit improves the quality of surface coating. After finishing the surface is almost free of anodic and pitting attack traces that were typical for previous electrochemical treatment because of defect influence (healing). Moreover the structure of layers united with the surface undergoes the above-mentioned changes. These changes are small distortion in structure formation and a considerable increase of grains. The structure of surface coatings approximates to the structure of amorphous metallic materials.

The measurement of undulation showed the possibility of reaching stability: $Ra = 0.16-0.08$ mym – for steels; $Ra = 0.32-0.16$ mym – for aluminium alloys.
The limit of endurance after combined treatment exceeds the limit of cutting, after which strengthening for most materials followed (Fig.3).

**Figure 3.** Limit of endurance (MPa) after different treatments: MP – mechanical processing; MP+VH – mechanical processing with vibrohardening; CT – combined treatment.

Thus we recommend the worked out method instead of unrolling, grinding, polishing, etcetera in order to increase the stress state of the surface that is preferable with regard to wearability.

For the complex surfaces formation we suggest a combined technique of electrochemical treatment with the use of a solid current-conducting filler. The basic principle of this method is that spherical filler grains (\(d = 2-7\) mm) are fed to the place of treatment by the electrolyte flow. Figure 4 presents the treatment pattern. The suggested method can be used for treatment of outer and inner surface at a distance of up to 100 mm from the outlet of the nozzle passage.

A hydrodynamic flow regime of the process of the fluid and electromagnetic field distribution in gaps between electrodes is the main factor of a treatment process. Shaping of the workpiece surface coating directly depends on the presence of filler grains in gaps between electrodes. Watching the movement of separate grains and collision with a workpiece it is possible to expect the following consequence of surface coating yielding:
- first of all yielding and microinhomogeneities take place, then the anodic attack starts along tips;
- contact surfaces appear after dissolving and distortion of inhomogeneous cross sections;
- distortion and the anodic attack proceeds in the microprofile basis of the workpiece.

**Figure 4.** Treatment pattern: 1 – jet; 2 – grains; 3 – doser; 4 – electrolyte; 5 – workpiece.
For qualitative adjectives of surface coating it is necessary to control the speed of filler grain feed supplied to the place of treatment.

A selection of the grain feed speed depends on 2 conditions:
- time of grains movement to a machined surface must be less than time of grain storage;
- speed of grain movement supports the necessary hydrodynamic flow pressure which depends on the surface coating quality of the workpiece.

The linear connection of hydrodynamic pressure with speed can be presented by the following expression:

\[ p = \gamma \cdot v^2, \]  

where \( \gamma \) - density of processing medium;
\( v \) - speed of grain movement.

The application of this method in treatment of the pump impeller surface decreased its undulation from 5 m\( \mu \)m to 0.4-1.2 m\( \mu \)m and eliminated the following 3 operations of workpiece treatment that took up to 6 hours.

3. Conclusion
This research presents some engineering opportunities of treatment by combined techniques that are worked out and are being used at some Russian plants with great success. The development of new combined process techniques gives scientists and engineers an opportunity to create new alternative processing techniques ensuring competitiveness of manufactured goods.

References
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