MATEC Web of Conferences **226**, 01021 (2018) https://doi.org/10.1051/matecconf/201822601021
DTS-2018

Achievement of required surface roughnesses in complex profile channels by dynamic combined processing

Alexander I. Boldyrev*, *Gennady A.* Sukhochev, *Alexander A.* Boldyrev, *Denis V.* Silaev, and *Vasily N.* Sokolnikov

Voronezh State Technical University, 394026 Voronezh Moscow ave. 14, Russia

Abstract. At present for processing of complex geometrical channels of workpieces electrochemical dimensional processing, vibro-impact machining and vibro-extruding are widely used. However combined electrochemical mechanical processing, that unites anodic dissolution and plastic flow of material in space and time, provides the required characteristics of surface layer. Local action anodic dissolution changes cold work amount and accelerates dissolution of micro- and macro-cusps, this causes annealing of physical and mechanical parameters in processed segments and accross the whole surface profile the required strengthening degree is attained.

The authors examine annealing model for microsurface by grain displacement in channel where extrusion forcing is dictated by grains size and profile of narrow blade channel and also by actual processing conditions. Operating conditions that are recommended for implementation of combined electrochemical mechanical processing of impeller and turbine type workpieces are found by experiments.

In consequence of field research they determined availability of standard microgeometry across the whole surface profile by combined processing with vibrations hashing with up to 2030 Hz frequency and low voltage current (in operation range from 1,2 till 1,8 V). Therein technological cycle decreases up to two fold, this reduces inadmissible jumping of blade edges and dimensional allowance.

1 Introduction

In the examined workpieces of impeller and turbine types (Fig. 1) with different initial surface engineering we process complex profile channels “closed” by external shroud in which access of abrasive or cutting tool is limited or excluded, it is difficult to feed tool electrode. Efforts in assembly electrodes and non rigid tools application partially solved this task [1], but high costs for similar tool forbade its use in low batch items [2].

* Corresponding author: alexboldyrev@yandex.ru

Fig. 1. Turbine with “Closed” Blade Channels.

We have data on blade channel processing by conventional vibro-impact method and extrusion of granular processing medium [3, 4]. The vibro-extruding method that consists in periodical reciprocating extrusion of granular operating environment through blade edges of workpiece under low-frequency vibration shows promising results. This advance is fulfilled under dynamic pressure produced in operating environment alternately in input and output of blade channel according to directions of its vibro-extruding. But recent researches show that these methods keep from achievement high cold work uniformity and stable increase in surface finish in narrow (less than 5 millimeter) curved channels with channel aperture angle of less than 45°. For solution of assigned tasks it is necessary to use combined methods where alongside with plastic deformation we apply local action anodic dissolution of material.

In this case:

- mechanical impact on the surface changes conditions of anodic dissolution, mechanism of microsurface formation, and physicomechanical properties of surface layer;

- anodic dissolution changes surface layer heredity and permits stabilization of process parameters in mechanical contact action. Force variation appearing due to variable workpiece cross-section can be compensated by redistribution of residual stresses under the influence of external electric field;

- workpiece initial surface must be examined as quantified at the level of micro- and macro-geometry. These parameters depend on profile, cold work degree, and grain energy at different processing stages;

- grain energy necessary for production of specified cold work depends for concerned workpieces on impingement angles, determined by geometry of channel borders, state of initial surface and load energy.

So, local action anodic dissolution can change cold work amount and accelerate dissolution of micro- and macro-cusps, this causes annealing of physical and mechanical parameters in processed segments and across the whole surface profile the required strengthening degree is attained.

2 Experimental studies

Figure 2 shows annealing model for microsurface by grain displacement in channel where effort P will depend on size of grains (in this case of spherical shape) and also on profile of narrow blade channel. In case of anodic dissolution effort will decrease due to liquid and oxide films between workpiece and grain and also due to anodic dissolution of asperity tips in places of contact with grain, that decreases friction resistance.

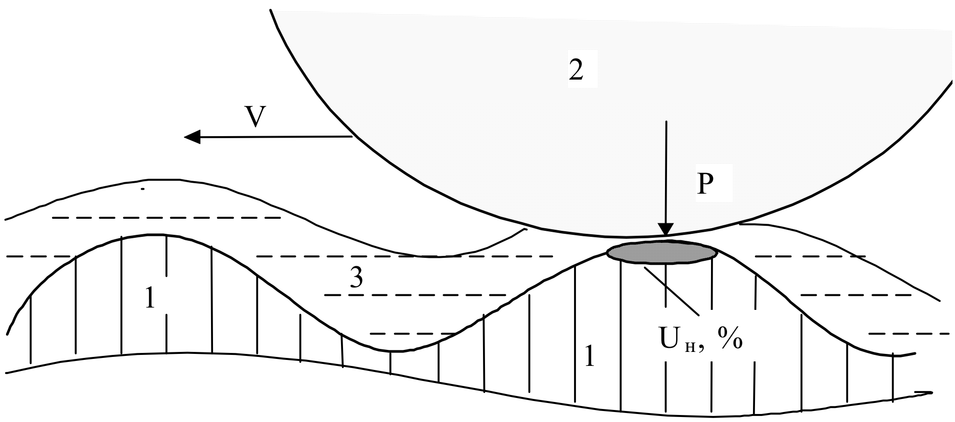

Fig. 2. Microsurface Annealing during Combined Processing: 1 – strain-hardening ranges of workpiece surface; 2 – grain; 3 – oxide film.

At combined processing

$$P = k_k P_0, \quad (1)$$

where k_k – coefficient that takes into account decrease of grain extrusion effort at current application;
P_0 – grain extrusion forcing without current application

Speed of anodic dissolution increases with cold work rise. Herewith marginal growth in metal removal rate can achieve 60-70 % against initial surface. However according to [3] high amounts of cold work cause decrease in endurance limit at alternating-sign thermodynamic loadings. At optimum cold work increase in anodic dissolution speed does not exceed 45%. For heat-resistant alloys according to known data the optimum cold work equals 35%, for titanium alloys – 15-18 %, for structural materials – 10-22 %.

During mechanical strengthening cold work can not exceed the above-mentioned limits. If the strengthening process is combined than cold work can achieve some permitted values upon condition of anodic dissolution removal of surface layer spots with overflow cold work.

The amount of processing allowance depends on surface microgeometry. For calculation of pimples it is necessary to find the gap width between grain and workpiece. We accept film width as constant, having average value. Than due to current it is possible to find its density j. We measured film thickness δ_f due to fixed value of voltage U. Than with defined grain diameter and film density ρ_f.

$$\delta_f = U / (\rho_f j). \quad (2)$$

For different materials and processing methods film thickness is different as it is shown in Figure 3 for titanium alloys. It is evident that film thickness depend on many factors that we have not considered, that is why the found values should be regarded as averaged, although their application in technological calculations of processing modes has good reason. The works of E.V. Vorontsov and his school contain data on thickness of oxide film for titanium (0,1-0,3 micron), it proves our research.

When choosing voltage you should be guided by experimental data (Fig. 3), they show that if voltage is less than 1 V current does not flow (pro forma it looks like infinitely thick layer of film and is not shown in Fig. 3). At voltage from 1 V till 2 V process runs stably, hereafter punctures and mode disturbance appear (dash line in Fig. 3). Therefore in operative range we use voltage from 1,2 V till 1,8 V. Total processing allowance Z can be calculated by method, but it requires experimental verification. Such data are presented in Table 1. The allowance was found by direct measuring of channels sizes during processing with application of current as compared with initial size.

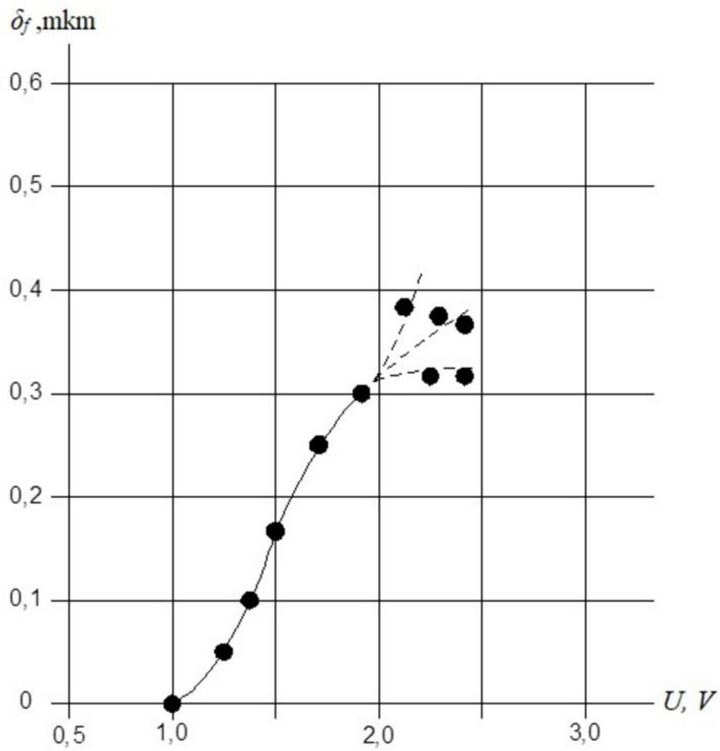

Fig. 3. Change of Film Thickness δ_f Depending on Voltage *U*.

3 Results and discussion

Comparative study of different methods for finishing and strengthening channels with changing profile of blade workpieces showed availability of stable microgeometry across the whole surface profile of combined processing with application of 2030 Hz frequency vibrations and low voltage current (in operation rage from 1,2 V till 1,8 V). For calculation of pimples it is necessary to find amount of processing allowance. Minimum allowance for processing was found by calculations and experimentally verified by direct measuring of channels sizes during processing with application of current as compared with initial size. Table 1 shows that allowance amount for combined processing of cast surface is approximately twice as high as compared to previous electrochemical processing.

Table 1. Minimum Allowance for Combined Processing.

Initial surface	**Minimum allowance for alloys, millimeter**	
	titanium	**heat-resistant**
cast	0,05	0,02
after electroerosion processing	0,06	0,05
after electrochemical processing	0,02	0,01

At the same time it is stated that surface finish in the place of channel minimal cross-section decreases and accesses conservative value after 60-90 minutes of vibro-extruding machining in special devices or after 25-30 minutes of combined processing (Table 2). So technological cycle shortens approximately twice, this reduces inadmissible jumping of blade edges and allowance for following processing.

Table 2. Change of Surface Finish according to Channel Depth.

Depth	**Roughnesses R_a, micron**	
	vibro-impact machining	**vibro-extruding machining**
at the channel inlet	10-12	8-11
at minimal cross-section	7-8	5-6
at the output part	8-10	7-8

4 Conclusions

Table 2 shows that surface roughnesses problem has positive solution with all processing methods, although anodic dissolution allows annealing of surface roughness characteristics to measurement accuracy and lowering of pimples to theoretically desired level from the perspective of achieving the greatest endurance for the workpiece, operating in extreme service conditions.

For further technological advancement of controlled processes in combined machining with current application in technologically hard-to-reach places it is necessary to develop new equipment that allows quantified selective dissolution of material in complex profile workpieces during combined processing.

References

1. V.P. Smolentsev, A.I. Boldyrev, E.V. Smolentsev, A.A. Boldyrev and V.L. Mozgalin, IOP Conf. Ser.: Mater. Sci. Eng., **327**, 042015, (2018) doi:10.1088/1757-899X/327/4/042015
2. A.S. Vereshchaka, S.N. Grigor’ev, V.A. Kim, B.Ya. Mokritskii and A.V. Kirichek, Russian Engineering Research, **34**, 8 (2014) doi:10.3103/S1068798X14080152.
3. A.A. Boldyrev, A.I. Boldyrev, E.V. Smolentsev and V.M. Skantsev, IOP Conf. Ser.: Mater. Sci. Eng., **124**, 012152 (2016) doi:10.1088/1757-899X/124/1/012152.
4. A.V. Kirichek, S.V. Barinov, Applied Mechanics and Materials, **7** (2014)