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INCREASE OF COMPACTNESS OF HYDROABRASIVE JET AND RELIABILITY OF CUTTING PROCESS WHILE USING FUNCTIONAL COATINGS ON JET ELEMENTS

ПОВЫШЕНИЕ КОМПАКТНОСТИ ГИДРОАБРАЗИВНОЙ СТРУИ И НАДЕЖНОСТИ ПРОЦЕССА РЕЗАНИЯ ПРИ ИСПОЛЬЗОВАНИИ ФУНКЦИОНАЛЬНЫХ ПОКРЫТИЙ НА СТРУЙНЫХ ЭЛЕМЕНТАХ

Salenko, O.*

Kremenchuk Mykhailo Ostrohradskyi National University, Kremenchuk, Ukraine

Schetynin, V., Khorolska, M.
Kremenchuk Mykhailo Ostrohradskyi National University, Kremenchuk, Ukraine

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Аннотация

В работе рассмотрены вопросы качества и надежности гидроабразивной обработки на основе повышения компактности гидроабразивной режущей струи за счет применения функциональных покрытий на струеформирующих елементах гидрорезной системы. Доказано повышение их работоспособности.

Ключевые слова: гидроабразивная обработка, режущая струя, функциональные покрытия, струеформирующие элементы

INTRODUCTION

Hydroabrasive machining is a modern highly productive process of shock-dynamic influence on the workpiece, resulting of which is phenomena of abrasive wear on surface, softening and microcutting with forming of destruction crater.

The cutting tool – a thin stream of liquid saturated with abrasive particles – formed by hydraulic cutter head, resulting a stream becomes a geometric form and supply of kinetic energy. Design features of jet head (interposition of parts, the nature of their connections and hermetization, cameras size and walk-through holes), affecting on the hydrodynamic characteristics and compactness of molded jet, determine the quality and reliability of the cutting process in general. The majority of functional failures in the implementation of hydroabrasive cutting is a result of sudden changes in geometry of jet-forming elements – nozzles and gauge tube, their sudden damage. Progressive failure – increasing of passage holes, changing forms of the channel, lead to parametric failures, i.e. before the emergence of wider cuts, partial cutting of sheet, ramification inhomogeneous workpiece and others.

Despite the significant developments in the field of reliability of complex technical systems, the question of further increasing the reliability and efficiency of hydroabrasive equipment is currently topical and urgent.

Basic techniques for reliability ensuring of complex technical systems more fully disclosed in the works of N. Pronikov, A. Salenko, A.Harchenko and others. Reliability and stability of hydraulic cutting tools are explored in the works of A. Antonenko, V. Dudyuk, O. Fomovska.

Obtained data [1] indicate that the most problematic (in terms of reliability) are such elements of hydrocutting system as calibration tube, nozzle, means of abrasive submission. The period of stability of the calibration tubes is 20-30 h, the nozzle – 10-40 hours, and sudden failures associated with stop of the abrasive flow, followed at intervals of 1 time per 10-15 hours. That is why the issue of increasing the stability and reliability of the jet-forming elements become especially important as search of new directions of improvement of jet opens new perspectives reducing costs and improving the quality of treatment.

STATEMENT OF MATERIAL

Modern tendencies in searching of method to improve the stability of nozzle devices are aimed, primarily, at improving the design of the devices or the use of new, super hard and wear-resistant materials such as boron carbide, tungsten carbide, silicon carbide. These materials can slightly improve the performance of the nozzle, which continues the durability of its work. It should be noted that the use of effective wear-resistant materials significantly affects the cost of treatment.

In [2] to improve the stability of nozzle devices is suggested to use porous nozzle surrounded by a reservoir containing a lubricating liquid of high viscosity. The fluid is under the same pressure as the jet in nozzle. Pressure drop through the porous medium formed by fast-flow through the nozzle, forcing the lubricating fluid to pass through it and form a lubricating film on the walls of the nozzle, which will protect them from abrasive wear particles of jet stream. Porous nozzle is manufactured on electroerosive machine tools and tested in the scanning electron microscope. Control device is determined by the

*Тел. (+380536)74-12-67, e-mail: salenko2006@ukr.net

presence of the oil film, the degree of wear of the nozzle. According to the authors [2], the wear of the walls of the nozzle is 111% of the diameter with the absence of lubricant, and 4% with the lubrication fluid with a viscosity of 1800 mm^2s^{-1}. Wear increases with reducing the velocity and viscosity of the lubricating fluid. The presence of lubricating fluid also improves the compactness of the jet.

In [3] is suggested to use a nozzle containing choke with spherical ends and axial fluid submission channel, holder mounted on the choke, flush mounted in the holder liner covered by the sleeve made of soft material and which is adjacent to its spherical end face to end choke, placed with a gap relative to the inverse end insert it. The inner liner profile is designed as a body rotation with variable radius section (Figure 1).

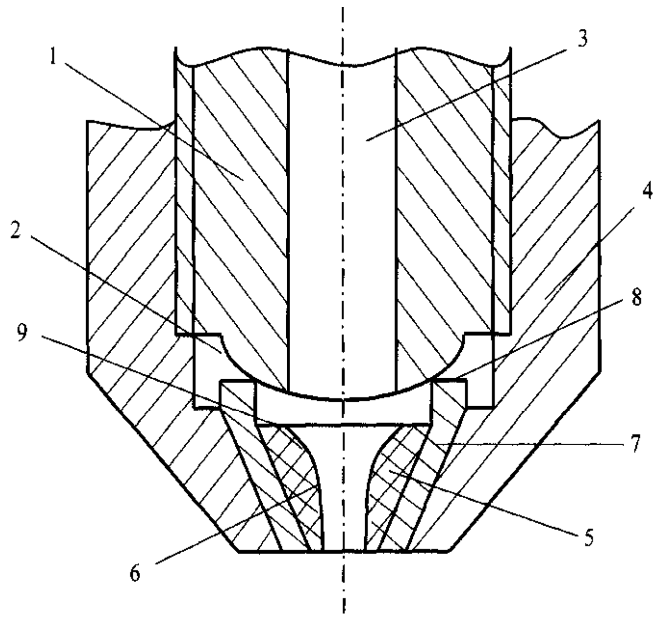


Figure 1. Nozzle for getting cutting liquid jet [2]:
1 – choke, 2 – spherical end 3 – axial fluid submission channel,
4 – holder, 5 – insert, 6 – section of variable radius,
7 – bushing, 8 – bushing 7 end,
9 – end insert 5

Nozzle for getting liquid jet cutting works as follows. The insert 5 which is made of wear-resistant material, such as diamond, elbor, quartz or solid alloy, insert to brass bushing 7. Brass bushing 7 with insert 5 is settled in the holder 4 by cone surface, which is also equal 40°. The top end of brass bushing 7 is pressed against the spherical end of choke 1 and conical surface of the holder 4.

Supersonic flow of liquid is fed through the axial channel 3 of choke 1, passes through a smooth bore liner 5 like a body rotation with variable cross-section radius, thus achieved the minimum thickness of the boundary layer, reducing the potential of separation of the boundary layer jets, reducing cavitation.

Featured nozzle for getting cutting fluid jet allows to increase cutting properties of the jet by reducing the hydraulic resistance and turbulent perturbations near the walls of inner profile, executed in the insert, taking into account the changes in characteristics of supersonic fluid flow (kinematic viscosity, the thickness of the boundary layer, etc.), reduces cavitation.

The authors of [4] propose to perform the nozzle with following structure for realization of technical problem of increasing the stability of nozzle for waterjet surface treatment (Figure 2).

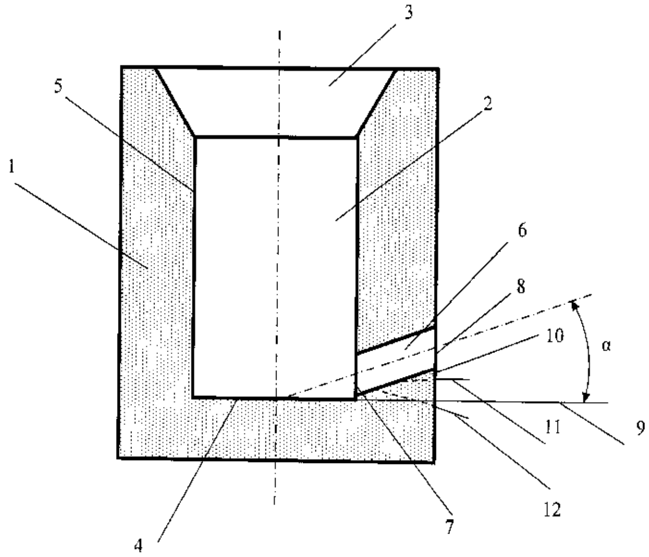


Figure 2. Wear-resistant nozzle [3]

The nozzle comprises a housing 1, designed as cup, the inner cavity of which forms a dead center channel 2 with inlet 3. Central channel is limited with bottom part 4 and side wall 5. In the side wall 3 of cup is made side channel 6. Side channel has an inlet 7, which is connected with the central channel, and the outlet 8 on the outer surface of the nozzle body for producing abrasive jet. Side channel is inclined in relation to the normal 9 to the axis of the central channel. The angle is 1-5 °. Direction of inclination of lateral channel is selected away from the bottom of the center channel 2 to input of its hole. When processing the details it is pre-prepared waterjet mixture under high pressure enters the central channel 4 of nozzle, from which through a side channel 6 is released in the form of high-energy jets on a processed surface. When exiting of abrasive jet from the outlet 8 from lateral channel the side section of housing wall of nozzle 10 is subjected to intensive abrasive influence with abrasive jet, takes place the wear of this part of housing wall, that is why a channel at first have initially normal way to the axis of the central canal 11, with a further abrasive wear the channel deviates down to the bottom of the center channel, getting the direction 12 in the direction opposite to the initial inclination. In dismissing of lateral canal down to 1-5 ° angle nozzle service life can be increased up to 2 times.

The angle of inclination 1-5 ° of lateral channel nozzle in relation to the normal for axis of center channel ensures stable work when processing small nozzle surfaces, inaccessible areas, etc., i.e. those surfaces details to process of which it should be focused spot. Increasing the angle will lead to expansion of coverage with abrasive jet of the treated surface, bringing the design of the nozzle to the corner performance, reducing the angle of lateral canal - to reduce the effect. However, it is obvious that for the process of cutting using of such technical solutions is impossible.

To reduce the wear of nozzle neck in [4], the authors decided to change its construction from a solid design to the component. Featured nozzle consists of three main parts: broad conical entrance, porous cylindrical tube insertion, a long narrow cone output (Figure 3).

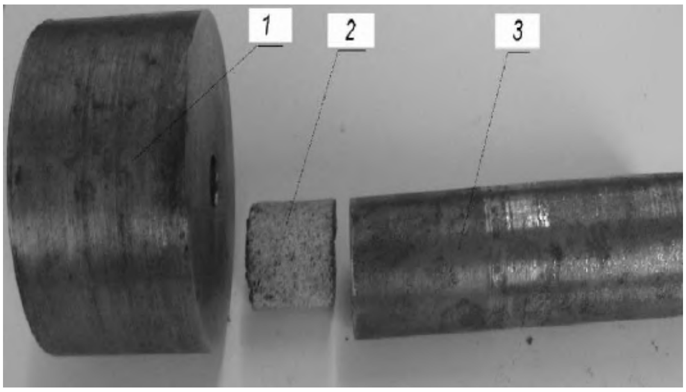


Figure 3. Nozzle parts: 1 – broad conical entrance, 2 – porous cylindrical tube insertion, 3 - long narrow cone output

Porous cylindrical tubular insert is made of a metal powder based on titanium alloy with the size fraction +0,3 ... – 0,4 using axial dry pressing. However it has not yet got real results to improve the sustainability of this type of nozzle.

The purpose of this work – to improve the reliability of the process of waterjet cutting using functional coatings on jet elements, in particular the calibration tube, which provide a more stable wear of gauge channel taking into account the dynamics of the flow.

MATERIAL OF RESEARCH

At movement of two-phase flow "liquid - solids" in the gauge tube it takes place chaotic action on the walls of the tube of certain abrasive particles at different angles of attack and with different force of impact.

However, in [5] shows that the jet of fluid is in contact with the inner surface of the elements of jet-forming system only with its own periphery, since getting of the particles on the surface will be determined with the paraboloid that in the first approximation can be imagined like inclined cylinder, the slope angle of which correspond to the angle of flow of fluid (9-14°). Leakage of abrasive particles on the surface will occur at different angles, but from the evidence of work these angles can be considered almost the same and those that are equal to the angle of flow. This assumption can only be in a first approximation, since on the workpieces is observed significant difference of angles of motion of abrasive particles. At the same time, these angles are small.

It is characteristic for cavitation and jet disruption is dependent of rate of destruction from flowing time. The process of destruction of the nozzle devices can be divided into four stages: plastic deformation without fracture, early destruction of the surface layer, the maximum destruction with separation of small particles, fall the rate of destruction and increasing of influence of hydrodynamic processes. Further study of the process allowed to set that more solid materials exposed more frequently to cavitation destruction than plastic and elastic due to relaxation properties of materials.

The depth of introduction of a particle and its tangential displacement during the introduction associated with the mechanical properties of the abrasive and material of the wearing surface, particle sizes, the deformation of the metal.

At small angles of attack, due to the predominance of tangential components of the velocity of impact, the main process of destruction of the surface layer is tangential displacement of microvolumes of metal towards implementation, i.e. microcutting. The distribution of abrasive particles for jet crossing is uneven.

The action of abrasive particles on the inner surface of the channel nozzle and gauge tube causes the wear of the latter. In [6] the authors note several axial and cross-sectional models of wear gauge tube. Wear cross-section can be uniformly regular or irregular. Irregularity in cross section related to three factors: eccentricity, angular displacement and disparity in the distribution of abrasive particles by cross section. Eccentricity leads to consistent wear from top to bottom. Angular displacement of leads to random radial wearing. However, the most important factor is the impact of distortions in the nozzle that affect the wear of the channel. Uniform circular wear model observed in the case of the most compact jet, flowing coaxially to the gauge tube.

Axial wearing models can be divided into divergent wearing, wearing with converges, wavy wearing and wearing by pulling. Below is a brief description of these models:

1. Divergent wearing will occur if abrasive material is much stronger than the material of the nozzle, for example, if the nozzle material – silicon carbide, tungsten carbide, ceramic or Roctec®. After a period of time, the shape of the cross section will resemble the shape of the jet expansion.

2. When wear with converges, nozzle wearing and wearing of gauge tube is faster at the top than at the bottom. This type of wear is typical for the case where the tensile strength of the material jetforming elements is less than the tensile strength of the abrasive. This type of wear of is most commonly seen when used as an abrasive garnet (or less hard abrasive) with nozzles made of tungsten carbide and Roctec ®.

3. Wavy wearing. First found in the X-ray study of gauge tubes. This wearing is more pronounced when the ratio of distance between the cut of the gauge tube and the workpiece to the diameter of the calibration tube is relatively small. This may be due to strong fluctuations in the jet (resonant character), resulting from side impacts in the event appeared and endangered steps of cutting. This model is insufficiently explored.

4. Wearing by pulling (Fig. 4). Sometimes there is that calibration is destroyed as a result of pulling. This is mainly due to significant disturbance of geometry or defects in material of tube.

Figure 4. Wearing by pulling

The phenomena of heavy wear of items in jet-forming device and dosing of abrasive particles lead to changes in shape, sizes and condition (including microgeometrical) of surface layers, which leads to changes in characteristics of the jet: changing the thickness of the embossed layer, varies compactness of jet and its energy, determined including coefficient of costs, in some cases, can significantly decrease the length of the core (cutting tools). Therefore nozzle wear and wear of gauge tubes, uneven in supply of abrasive grains, due to their sticky or congestion on the way, and cause different parametric failures associated with getting of defects and decreasing the expected performance of the process.

In [1], the authors proposed a model of the probability of failure-free operation:

$$P(t) = P_{n_1}(t)\cdot P_{в_1}(t)\cdot P_{в_2}(t)\cdot P_{n_3}(t)\cdot P_{в_3}(t), \qquad (1)$$

where the variables are probability of faultless work, respectively: $P_{n1}(t)$ – at gradual wear of gauge tube; $P_{b1}(t)$ – at sudden failure associated with a break of gauge tube; $P_{b2}(t)$ – at sudden failure associated with violation of the camera (when congestion supply abrasive) of mixer; $P_{n3}(t)$ – a gradual deterioration of a nozzle; $P_{b3}(t)$ – at sudden failure associated with shearing or clogging of hole with dirt particles.

However, given the fact that the manifestation of progressive failure is the result of processes of wear and the probability is defined as:

$$P_1(t) = 0{,}5 + \Phi\left(\frac{X_{\max 1} - a_{01} - \gamma_{cp1}t}{\sqrt{\sigma_{a1}^2 + \sigma_{\gamma 1}^2 t^2}}\right)$$

and the occurrence of random failures, based on physical laws, obeys the exponential law $P_p(t) = e^{-\lambda t}$, in [7] the author proposes an equation for the reliability evaluation of process, taking into account the reliability of supply abrasive:

$$P(t) = \left[0{,}5 + \Phi\left(\frac{d_{c\max} - \bar{d}_c - \gamma_c t}{\sqrt{\sigma_{dc}^2 + \sigma_{\gamma c}^2 t^2}}\right)\right] \times \qquad (2)$$

$$\times\left\{1 - \left[0{,}5 - \Phi\left(\frac{D_{k\max} - \bar{D}_k - \gamma_{Dk}t}{\sqrt{\sigma_{Dk}^2 + \sigma_{\gamma Dk}^2 t^2}}\right)\right]\left[1 - e^{-\lambda_D t}\right]\right\} e^{-\lambda_d t} P^z(t)$$

As constructed model does not consider the peculiarities of the jet and the features of wear effects of the channel to achieve this goal it was built calculation model of two-phase jet flow in the inner channel of the gauge tube (Fig. 5). In this note it were adopted the following assumptions:

1) all particles that fall into the camera, get into the mixing tube;

2) liquid abrasive jet consists of a shell (aerosol-rescission flow) and the nucleus;

3) the sizes of the nucleus correspond to present concepts and particles can get only in a shell; wave processes of encountering particles and water droplets are neglected;

4) depending on the point of falling into a shell, particles are being accelerated by one or another direction.

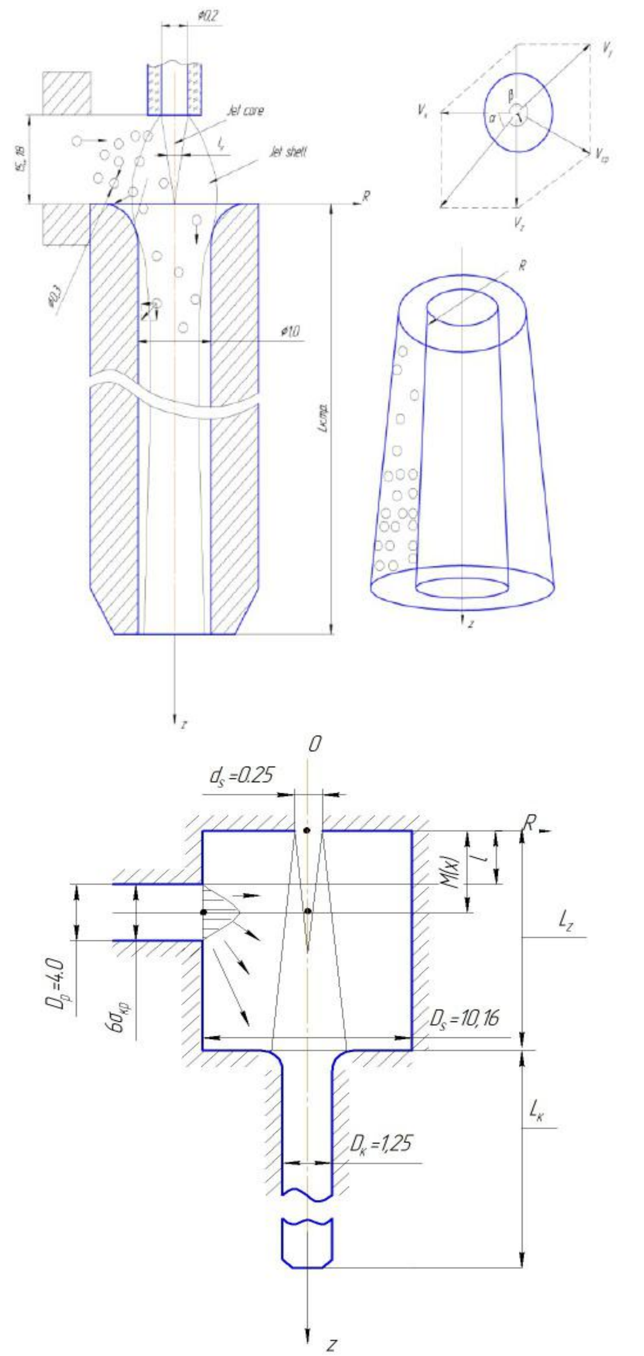


Figure 5. Calculation model of two-phase jet flow in the inner channel of the gauge tube: $R_o=f(z)$, $R_я=f(z)$, l_v - length of the ring, in which particles can get

For study of peculiarities of the multi-phase flow are devoted a significant amount of works, particularly made by O. Provolotskiy, O. Salenko, Z. Stotsko, T. Stefanovych, O. Fomovska et al. Based on Mendeleev-Clapeyron equation it was established that consumption of abrasive particles depends on the relationship of orifice volumes of giving of compressed air and the mixing chamber subject to isothermal process $p_k = \frac{p_j W_j}{W_k}$ where p_j – pressure in the orifice. In this regard, flow of liquid abrasive mixture as a function of geometric parameters of jet-forming hydrocutting machine can be defined:

$$Q_m = \frac{5}{2}\mu\pi d_c^{\,2}\sqrt{\frac{2p_j d_j^2 l_j \rho_a \rho_r}{\left[x_a\rho_r + \rho_a(100 - x_a)\right]d_k^2 l_k}}, \qquad (3)$$

where d_c, d_j, d_k – diameter of outlet, outlet of orifice and mixing chamber, respectively; μ – coefficient of expenses of outlet; ρ_a, ρ_r – density of abrasive particles and liquid, respectively; l_j, l_k – length of orifice and mixing chamber, respectively; x – mass concentration of abrasive in a liquid,%.

At the same time, taking into account that the particles introduced into the flow at a certain interval l = 15-18 mm, and taking into account that in the immediate vicinity of the nozzle they have the greatest momentum of movement in the radial direction, while moving along the *OZ* direction the vector of movement is changed and became very close to the direction of axis z, the motion of particles after collision with some drops of liquid flow will be determined by the conditions of the particles entering in the periphery of the stream. Simulations were performed in the environment Flow Vision. At the same been evaluated probability of different directions of particle motion after its immersion in jet shell, expanding movement during the axes *OZ* and *Or*.

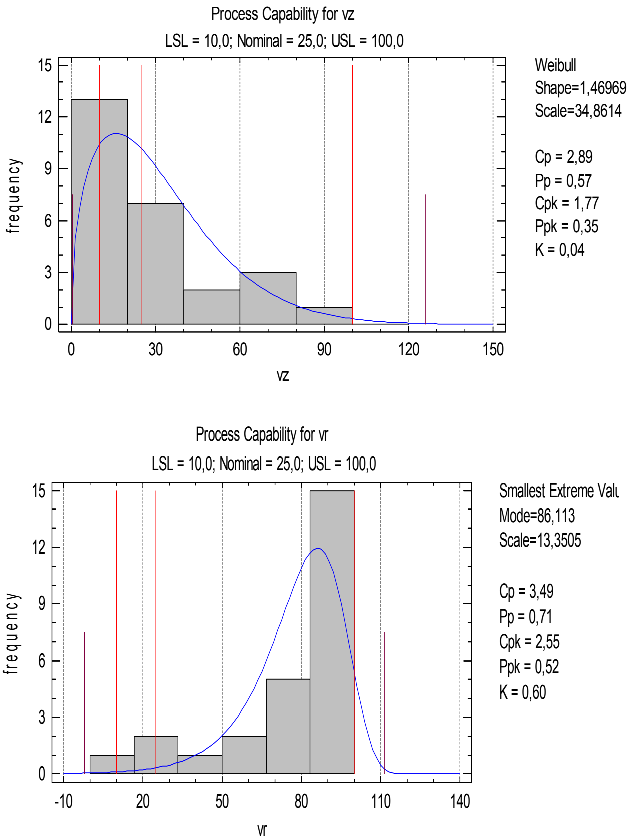


Figure 6. Histogram of frequencies and directions of movement of abrasive particles according to the coordinates z (along the gauge tube)

The authors of [10], [11] showed that the uniform distribution of particles by crossing does not occur. Description of the distribution of mass flow is more likely described by Gauss law. That is why at the first stage it was performed the sampling of coordinates of particles centers by crossing of summing channel, that is corresponding to the Gauss law with parameters *M* and σ_{kp}. At the same it was thought that $6\sigma_{kp}=D_p$=4,0 mm, and M defines the middle of the hole of supply channel.As a result of modeling to determine the direction of movement of the abrasive particles it was constructed histogram of the distribution relative frequency of particles on the surface of the gauge tube in a radial or axial (near-axial) directions (Fig. 6). At the same proceeded from the thresholds directions of particles movement: in the radial direction to angles $90^0{}_{-15}{}^0$ and in the axial – $0^{0\ +25}$. These limits are due to the fact that the mechanism of destruction of surface of the tube in them practically does not change, according to [9].Histogram allows to select three characteristic zones along the gauge tube: 1 – an area in which there is a high probability of the presence of radial motion vectors of accelerated abrasive particles: high-intensity shock loading of the gauge tube walls with particles that move at angles close to normal takes place here; 2 – zone where you can expect the motion of particles at angles close to 45^0: area, where will appear the phenomenon of shock destruction; 3 – zone in which moves almost straightened particles: it should be expected here only sliding destruction – microcutting of surface with particles.

From the presented results it is evident that the maximum wear of tube is possible in areas 1 and 2, and in the third area – the destruction is only possible if there are some defects on the surface of solids. To test this assumption it was experimentally investigated extremely worn gauge tube of domestic and foreign production and it was built profile of wear (Fig. 7). For this purpose tube was cut along the axis with electrical erosion machine. Simulation results and real profiles of wear are satisfactorily agreed.

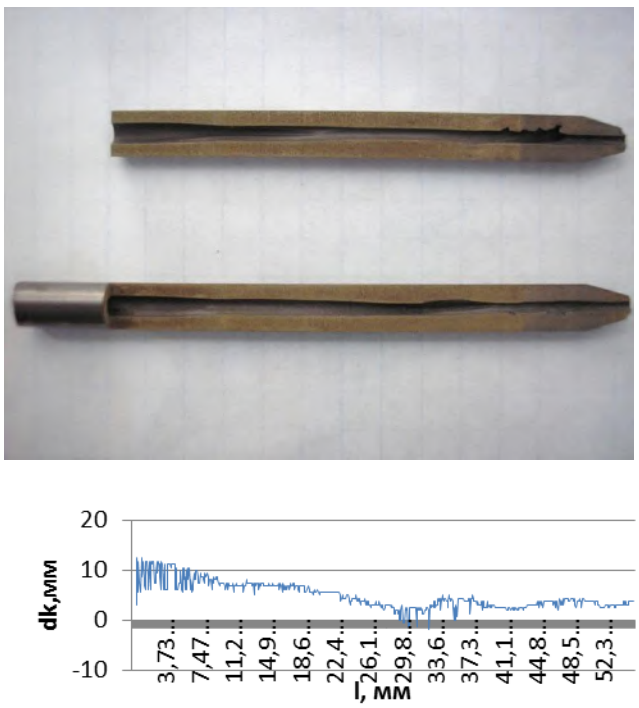


Figure 7. Extremely worn gauge tube (a) and constructed profiles of wear (b)

Thus, it becomes possible the apparent increase in reliability and stability of hydraulic cutting process by using special wear-resistant coatings deposited on the surface of the channel of the gauge tube. It is known, wear of channel of the gauge tube ΔT increases the diameter D_k, above of which clearly leads to defects. At a certain rate of damage γ_M, the expected time of the failure allows you to set period of probable resistance of tube. For serial tubes this time is 10-12 hours. However, apart from gradual failure caused by wearing phenomena in a tube there are sudden failures [11], see Fig. 8, which are random in nature.

Used nozzles and gauge tubes made of quasibrittle materials may be destroyed as a result of critical stresses. This causes the appearance of microcracks that are growing rapidly.

According to the provisions of the linear fracture mechanics, energy release rate through the crack banks is determined as $G = \frac{1-\nu^2}{E} A(V)k^2$, where $k = \sigma\sqrt{\pi a}$ – stress intensity factor, for this class of materials velocity V of shores of crack growth is due to the difference $(G - R)$, where R – resistance to cracking, can reach V=500…600 m/s, i.e. destruction of body with size 3,5 mm happens during 3...5 microseconds – almost instantly. Thus, the gradual wear and brittle destruction take place as independent events, then the uptime will be: $P_c(t) = P_n^c(t) \cdot P_p^c(t)$.

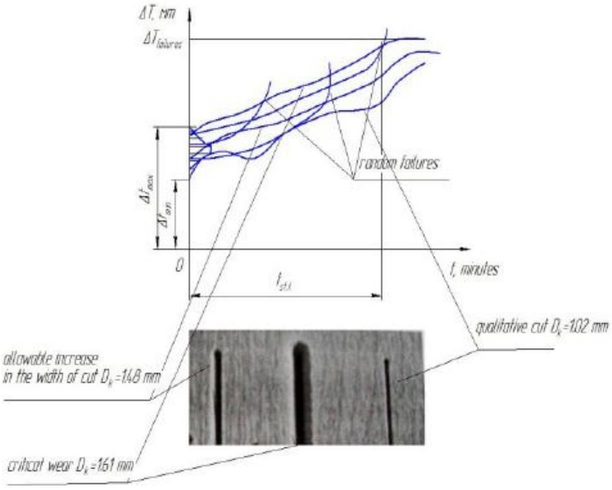


Figure 8. Occurrence of failures of jet-forming system based on gradual and sudden failure jet-forming items

After setting of the values of initial scattering in parameters and limits changes in D_k and d_c, it was conducted modeling of reliability process, resulting of which it was found that the time distribution for onset of failure as a random variable can be approximated by a Gauss law with mathematical expectation of failure time set by the average parameters of jet system, for example, if primary failure of the nozzle $T_{st.t.1} = \frac{d_c^{\max} - \bar{d}_c}{\gamma_c}$ minutes, or by Veybul-Gnedenko law provided that a resistance is defined as $T_{st.t.1} = \frac{d_c^{\max} - (\bar{d}_c + 3\sigma_d)}{\gamma_c + 3\sigma_\gamma}$ [13]. Under these conditions for the probability P=0,99 of failsafe process time is $T_{st.t.1} = 5{,}6$ h, which is sometimes unacceptable due to the large processing time (for example, when doing difficult critical profile cutting products, cell processing, etc.).

In view of the analyzed phenomenon of wear of the gauge tube and their influence on the parameters of waterjet machining the profile of tube channel must provide the following flow conditions:

1) the minimum thickness of the boundary layer of flow inside the tube, turbulent layer of the free jet output, which reduces the thickness and reducing interaction of the jet with the environment;

2) reduce the possibility of separation of the boundary layer of jet, helping reduce the excitation of central flow;

3) reduce the possibility of cavitation, which provides an exception of formation low pressures inside the tube to avoid the following formation of bubbles associations and destruction of tube;

4) the shape of the profile should remain constant as a longer time, thereby following by the development of progressive damage of the canal.

In our opinion, the decrease in the intensity of damage and increase the term of stability of tube by eliminating the occurrence of random failures is possible with the use of special wear-resistant coatings, as noted in [13]. Thus, the use of special wear-resistant coatings can significantly improve the stability time of materials in aggressive environments, improve the stability of the process due to less intense dynamics of changes in initial geometric parameters of the channel. Now, however, there are no clear recommendations for the type of coating that can be used in this practice and rational application of technologies of such coatings on the inner surface of the channel. Taking as a basis the production technology of gauge tubes from two symmetrical parts, connected together by bandage, examined the possibility of using certain types of coatings on the surface of the channel.

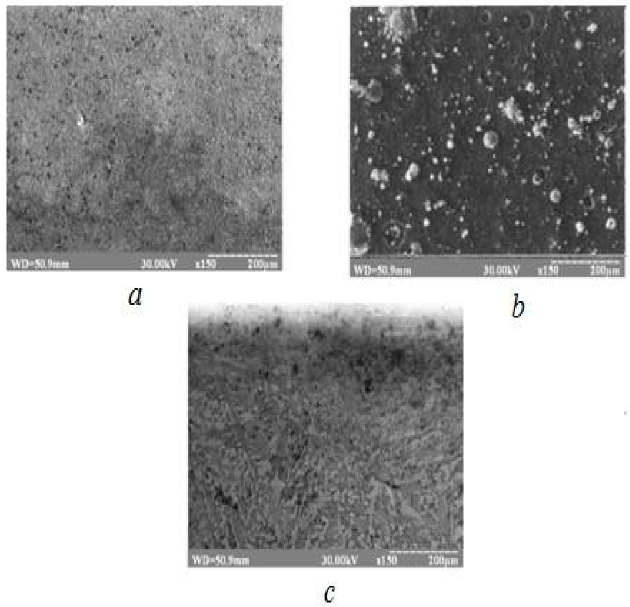


Figure 9. Microelectronic researches of alloy VK8: a – without coating; b – with coating TiN; c – with the nitrided surface layer

To address the question of whether the use of certain surface coatings on hydroabrasive resistance the samples with size 40x10x5 mm from titanium alloy VK8 were tested, which is instrumental material of elements of hydroabrasive processing, as no cover, so with a vacuum-plasma coating TiN, with the nitride layer and the combined coverage of the nitride layer and TiN (Fig. 9, 10). To microelectronic studies of these, coating were deposited considering functional-oriented approach to flat plates, which were established for research under certain angles to leakage jet.

Functionally-oriented approach involves the production of calibration tube by special technology, which is based on strict topologically oriented implementation of the required set of algorithms of technological performance of processing in required micro and macro zones and parts of the product that meet the functional requirements of their operation in each of its zone.

For the purpose of following microelectronic researches of coatings were applied on the basis of functional-oriented approach to the flat plate, which were established for research under certain angles to leakage jet.

For comparative analysis all experimental studies were made with the same process parameters that have been adopted: leakage pressure – 280 MPa, the volumetric concentration of abrasive in suspension – 0,6 kg/min, processing time – 10,5 minutes.

The influence of the angle of attack on the wear resistance of samples were carried out using as an abrasive in suspension of garnet sand with grain size 30 mesh. The distance between the starting section of the ejecting attachment of jet apparatus and the sample was taken equal to 80 mm.

Found that the dynamics of damaging of protective coatings is fundamentally different: TiN coating wear more dynamically and within 3 minutes the damage peaked. After that, the damage rate slowed, and the samples began to occur with zones with almost complete removal. Further began active destruction of substrate material. Samples, which were combined coated are more resistant to liquid-abrasion and cavitation wear (almost in 3 times). Wearing is uniformly without forming detached regions.

Samples from heat-resistant steel without coating wore out more dynamically and within 10 seconds wear reached the maximum until cutting the full sample. Samples coated with PGS1 wear less intensive and damaging peaked within 32 s. After that rate of damage also slowed, and at the samples began to experience zones of coverage detachment. Later there was an active destruction of substrate material. Samples coated with FMY 2 were more resistant to liquid - abrasion and cavitation wear (wear rate was observed after 41 s). Wearing was uniformly without forming detachment regions [17]. Comparison of stability of coated and uncoated samples proves that the coating provides a two-zone growth dynamics of outlet of the gauge tube: until the operation time of coverage and when working tube has worn surface.

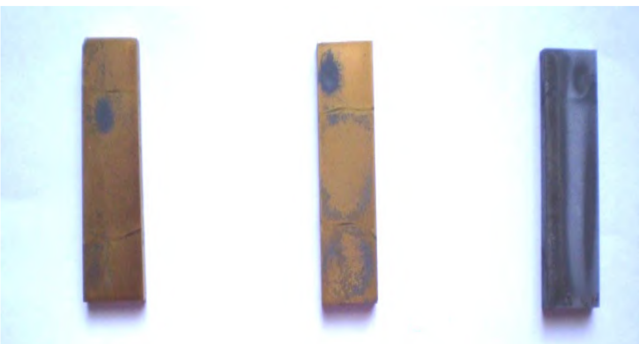
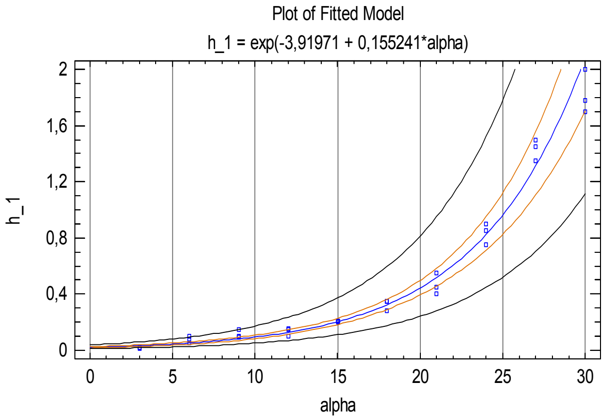


Figure 10. Samples after testing

Thus, the comparative experimental tests have shown that, depending on modes of technological processing, samples with a combined cover of nitrided layer and TiN wear less intense than the samples without coating and with coatings FMY 2 and PGS 1 when exposed with waterjet stream.



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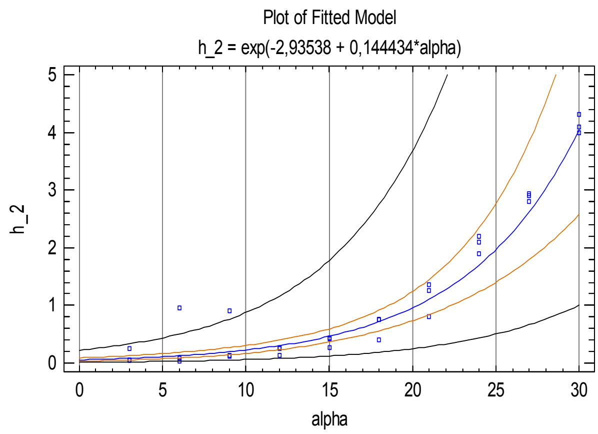

b

Figure 11. Dependence of wear coating TiN (a) and combined coating on the corner of accumulating (b)

Favorites coating was applied to the surfaces of channels of 10 gauge tubes that have been tested in the inkjet head LSK-400-5. According to the results of tests it was built curve of damage shown in Fig. 9. Based on these data it is evident that a stability time $T_{st.t.}'$ of coated gauge tubes is greater than a stability time $T_{st.t.}$ of conventional tubes in average 1,8…2,2 times and averages 17,2 hours. Characteristic is the elimination of the appearance of sudden failures.

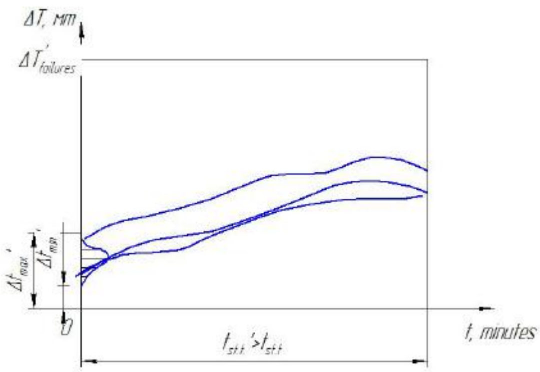

Figure 9. Occurrence of failures of jet-forming elements of hydro cutting systems with functional coatings

CONCLUSIONS

Thus, the stability of system components of hydrocutting equipment can be enhanced by the application of protective coatings that are relevant in hydrocutting of critical details.

These functional dependencies of wear of the gauge tube with coatings according to the criteria of hydroabrasive stability complement the overall methodological information base and certainly contribute to the development of the management principle of the properties of the surface layer.

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