FORMATION OF THE SURFACE LAYER DURING HYDROABRASIVE SEPARATION OF METALS

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ABSTRACT

The range of physicomechanical properties and structure of materials processed by the method of hydroabrasive cutting is considered. Technological capabilities of hydroabrasive separation of metals by a high-pressure jet are given and its comparison with such progressive methods, such as laser, plasma, and erosion.

Keywords: *transport engineering, machine parts, hydroabrasive separation of metals, comparison of separation methods, quality of the separation surface.*

Background. *One of the main directions in the production of machine parts is the increase of reliability, labor productivity, excluding significant cash costs. Such parts, as a rule, are made from hard-to-treat, complex-alloyed, high-strength, heat-resistant, corrosion-resistant materials and high demands are placed on their working surfaces for the accuracy, height of unevenness of surface roughness, hardness, and corrosion resistance.*

The dominant position is occupied by technologies which, almost instantaneously, for a very limited period of time, produce complex, shaped spatial forms of various parts [1, 2]. At the same time, quality indicators of the surface layer (roughness, microhardness, phase and structural composition of the surface layer, etc.) are linked by customers with the factors of technical and economic feasibility of using one or another method, technological reception that provides the required productivity, reliability, labor intensity, minimization of costs for preparation of production in comparison with a number of competing methods, etc.

Objective. *The objective of the authors is to consider the process of hybroabrasive separation of metals.*

Methods. *The authors use general scientific and engineering methods, experimental studies, analytical approach.*

Results. *A group of technological methods, including laser, plasma, erosion, hydroabrasive processing methods, meet all the requirements set forth [3]. The liquidity of these technologies is one of the highest in the world. Such methods allow dynamically to master new products of aerospace industry and are characterized by the following advantages in comparison with traditional mechanical methods of shaping [4]:*

– Reduction of the terms of mastering the preparation of the production of new products from 6 to 10 times;

– Increase in the utilization factor of the material 3–5 times;

– Reduction of labor intensity in the manufacture of parts by such technologies due to the use of the mode drawing – computer – finished part;

– Providing in the surface layer of moldable parts the required distribution of quality parameters – such as roughness, geometric accuracy, depth of the surface layer, phase chemical composition of the work material;

– Modular structure of the equipment set for the implementation of technologies.

Among the technologies considered, the hydroabrasive one is distinguished by its advantages [5, 6]:

– part (material to be cut) is not subjected to thermal impact from heat generated during processing (cold cutting actually takes place);

– absence of dust and gases (the flow of water jet carries with it the processing products);

– low tangential cutting force per part (in some cases, even clamping of the cut material is not required);

–small width of the cut (which affects the reduction of material losses and the improvement in cutting efficiency);

– high cutting speed of any materials (including dielectrics);

– possibility of obtaining by separating material complex contours, including transition areas with a radius of rounding less than one millimeter.

The method of hydroabrasive separation of materials is increasingly used and allows to use the kinetic energy of a jet of liquid supplied at a supersonic speed (400–1000 m / s) under a pressure of 100–400 MPa to be used from a hole 0,1–0,4 mm in diameter [7]. The force of impact of such a jet on the material is capable of causing its destruction with the detachment of microparticles. Consequently, during processing, the kinetic energy of the jet is converted into a mechanical cutting operation, and the jet itself is a cutting tool. The jet of liquid in its technical capabilities is close to an ideal point tool, which allows processing a complex profile with different radius of fillet. Since the width of the cut can be in the range of 0,1–3 mm, the material waste in the chips is much less than in traditional methods of processing. It is possible to start the cutting at any point of the workpiece without first having to make a hole. Small forces (1–100 N) and insignificant temperature (60–90°C) in the cutting zone exclude deformation of the workpiece, as well as melting and burning of the material in the area adjacent to this zone, which contributes to the improvement of processing quality and makes it possible to process combustible and explosive materials [8, 9]. The jet of liquid does not change the physicomechanical properties of the material being processed.

Application of hydroabrasive processing allows:

– if necessary, to fully automate the process of material separation [10];

– to exclude from the technological cycle the traditional cutting tool, the working edges of which are continuously worn out;

– to release personnel and equipment that produce and regrind the instrument;

– to improve productivity and quality of processing;

– to reduce material waste into chips;

– to reduce the noise level;

– to completely eliminate the dustiness of the workplace.

One of the most demanded users of the technology of hydroabrasive separation is aircraft construction and instrumentation, where cutting of laminated composite materials is widely used.

The range of physicomechanical properties and structure of materials processed by hydroabrasive cutting is quite wide. These include paper, cardboard, textiles, leather, rubber, wood, polymeric materials (vinylplast, fluoroplastic, organic glass, getinax, textolite, fiberglass), foil and metallized plastic, metals and alloys, including hard-to-work (hard and magnetic alloys, titanium, corrosion-resistant and heat-resistant steels, composite materials, ceramics), etc.

A water jet can cut almost any material with a thickness of up to 30 mm, but the greatest effect is achieved when cutting objects with a thickness of 2–6 mm [11]. In this case, the jet competes successfully with the laser beam. For the treatment of metals and ceramics, a water-abrasive mixture is used, since the kinetic energy of a jet of clean water is not sufficient for cutting solid materials [12].

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When comparing the method of hydroabrasive cutting with the existing technologies of material processing, in particular laser, plasma, electroerosive, gas cutting, milling, its essential advantages of hydroabrasive cutting can be noted [13]:

– there is no need for an instrument and its replacement;

– significant material savings due to the possibility of optimal cutting and a much smaller width of the cut;

– ease and speed of programming.

Despite all its advantages, hydroabrasive cutting has some drawbacks due to the fact that the jet used at the exit from the material lags behind the entry point, which can lead to processing errors in the following cases:

– when moving along the radius, the inertia of the jet can cause the deviation of the dimensions of the part from the specified ones;

– when cutting internal angles, the lag of the jet can also affect the correctness of the processing, and when changing the cutting direction it is able to make an overcut in the part.

However, these shortcomings can be eliminated by reducing the processing speed in problem areas.

Another significant disadvantage of hydroabrasive processing is conicity of the edges of the resulting parts. The angle of the cone depends on a number of parameters: the distance from the cutting head to the workpiece, the material of the part, the processing speed, the type of abrasive used. To reduce the conicity, the processing speed is reduced, and the gap between the cutting head and the part is minimized [14]. A combination of physical effects serves as an effective means of increasing the accuracy of the geometry of the groove walls at the place of material separation and eliminating the impregnation [15, 16].

Conclusion. *Thus, the method of hydroabrasive cutting is one of the promising for the separation of most materials in industrial production. Currently, over 7000 machines for various purposes using the method, work abroad. In Russia and CIS countries, no more than 70 units of such equipment are known.*

REFERENCES

1. Usov, S. V., Vyacheslavova, O. F., Sviridenko, D. S., *et al.* Nontraditional methods of processing machine parts, created on the basis of information technology [*Netradicionnye metody obrabotki detalej mashin, sozdannye na osnove informacionnyh tehnologij*]. Podolsk, Slavjanskaja shkola publ., 2010, 150 p.

2. Electrophysical and electrochemical methods of processing materials [*Elektrofizicheskie i elektrohimicheskie metody obrabotki materialov*]. Educational guide (in 2 volumes). Processing of materials with the use of tools [*Ucheb. posobie (v 2-h tomah). Obrabotka materialov s primeneniem instrumenta*]. Ed. by V. P. Smolentsev. Vol. 2. Moscow, Vysshaja shkola publ., 1983.– 208 p.

3. Popov, A. P., Popova, T. A., Komarov, Yu. Yu. Methods for increasing reliability [*Metody povyshenija nadezhnosti*]. *Vestnik Moskovskogo gosudarstvennogo otkrytogo universiteta. Serija «Tehnika i tehnologija»*, 2013, Iss. 4, p. 32.

4. Usov, S. V., Sviridenko, D. S., Boldyrev, A. A., Kovalev, S. V., Mandrykin, A. V. Estimation of efficiency at introduction of high science-intensive technologies [*Ocenka effektivnosti pri vnedrenii vysokih naukoemkih tehnologij*]. *Vestnik Voronezhskogo gosudarstvennogo tehnicheskogo universiteta*, Vol. 8, 2012, Iss. 7–1, pp. 87–91.

5. Usov, S. V., Sviridenko, D. S., Goncharov, E. V., Kodentsev, S. N. Structural and technological capabilities of hydroabrasive machining of machine parts as a factor of scientific and technical progress [*Konstruktivno-tehnologicheskie vozmozhnosti gidroabrazivnoj obrabotki detalej mashin kak faktora nauchno-tehnicheskogo progressa*]. *Fundamental'nye i prikladnye problemy tehniki i tehnologii*, 2013, Iss. 2, pp. 95–99.

6. Usov, S. V., Nazarov, Yu. F., Sviridenko, D. S. Fundamentals of hydroabrasive processing technology for machine parts [*Osnovy tehnologii vodoabrazivnoj obrabotki detalej mashin*]. Podolsk, Slavjanskaja shkola publ., 2010, 148 p.

7. Smolentsev, V. P., Goncharov, E. V. Hydroabrasive separation of metals with the imposition of an electric field [*Gidroabrazivnoe razdelenie metallov s nalozheniem elektricheskogo polja*]. Interuniversity collection of scientific works, Iss. 6. Voronezh, VSTU publ., 2011, pp. 102–108.

8. Kuzovkin, A. V., Smolentsev, V. P. Dimensional shaping of complex profile parts with the use of solid current-carrying filler [*Razmernoe formoobrazovanie slozhnoprofil'nyh detalej s primeneniem tverdogo tokoprovodjashhego napolnitelja*]. Voronezh, VSTU, 2000, 176 p.

9. Smolentsev, V. P., Goncharov, E. V. Increase in accuracy of hydroabrasive processing and quality of the surface layer in the zone of separation of viscous materials [*Povyshenie tochnosti gidroabrazivnoj obrabotki i kachestva poverhnostnogo sloja v zone razdelenija vjazkih materialov*]. *Uprochnjajushhie tehnologii i pokrytija*, 2012, Iss. 4, pp. 45–48.

10. Popov, A. P. Integrated Production Systems [*Integrirovannye proizvodstvennye sistemy*]. Vestnik mashinostroenija, 2014, Iss. 3, pp. 80–82.

11. Barsukov, G. V., Mikheev, A. V. Determining the productivity of hydroabrasive cutting taking into account the characteristics of abrasive grain [*Opredelenie proizvoditel'nosti gidroabrazivnogo rezanija s uchetom harakteristik abrazivnogo zerna*]. *Inzhenernyj zhurnal*, 2008, Iss. 1, pp. 9–14.

12. Smolentsev, V. P., Boldyrev, A. A. Application of magnetic-rheological fluids in metalworking [*Primenenie magnitno-reologicheskih zhidkostej v metalloobrabotke*]. *Netradicionnye metody obrabotki: mezhvuz. sb. nauch. Trudov*, Iss. 9, Part 3. Moscow, Mashinostroenie publ., 2010, pp. 120–129.

13. Popov, A. P. Modeling of control systems for machine-building production [*Modelirovanie sistem upravlenija mashinostroitel'nym proizvodstvom*]. *Izvestija MGTU «MAMI»*, 2013, Iss. 2, pp. 273–276.

14. Ivanov, G. M., Sveshnikov, B. I., Cherpakov, B. I. Equipment for water jet cutting [*Oborudovanie dlja vodostrujnogo rezanija*]. *STIN*, 2000, Iss. 25, pp. 34–39.

15. Usov, S. V., Sviridenko, D. S. Scientific bases of creation of progressive methods of processing of machine parts on the basis of information technologies [*Nauchnye osnovy sozdanija progressivnyh metodov obrabotki detalej mashin na baze informacionnyh tehnologij*]. Podolsk, Slavjanskaja shkola publ., 2011, 208 p.

16. Popov, A. P., Popova, T. A. Optimization of Technological Processes. *World of Transport and Transportation*, Vol. 13, 2015, Iss. 5, pp. 16–25.

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