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# The influence of hydrojet surface processing on the adhesive strength of wear-resistant coatings deposited on a metal-cutting tool of oxynitride ceramics

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**Abstract.** The work represents a new approach of preliminary surface treatment of replaceable polyhedral cutting ceramics inserts for significant increase of adhesion strength with deposited wear-resistant nitride ceramics. By this method the hydrojet treatment was used to repair surface defects occurring during manufacturing process of any required geometry of cutting inserts.

## 1 Introduction

It is well known that insufficient fracture toughness becomes a reason for microcracks formation and propagation on the surface of ceramic cutting tools [1-3]. One of the most effective methods to increase reliability of the ceramic tools is to deposit thin-film wear-resistant coatings by physical vapor deposition (PVD) technique [4, 5]. However, there is a problem of poor adhesion between the coating and substrate due to low conductivity [6, 7]. This article proposes the solution of this problem by using hydrojet treatment as preliminary surface preparation stage.

## 2 Experimental details

The *AWJet Robotics 2020* robotic hydrojet cutting aggregate equipped with a *HPS 6045* (*UHDE*, Germany) high pressure pumping station was used for hydrojet treatment. During the experiment, a cutting head for hydrojet cutting rigidly fastened to the robot was used.

The process of ceramic inserts' surface treatment was abrasive free. Square shaped cutting ceramics inserts SNGN 120408 were placed in a row and fixed in a massive technological equipment, in the working area of equipment. Water jet (distilled water with anti-corrosion additives, Fig.1) was introduced under pressure of $P$=200÷600 MPa, which corresponded to the jet flow velocity of $V$=50÷150 m/s at the nozzle outlet. The distance between the nozzle and the plate was varied within $H$=100÷500 mm. Optimum height was

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chosen experimentally and was $H$=400±3 mm. The speed of movement was constant and was in the range of $S$=0.5÷2.5 m/min.

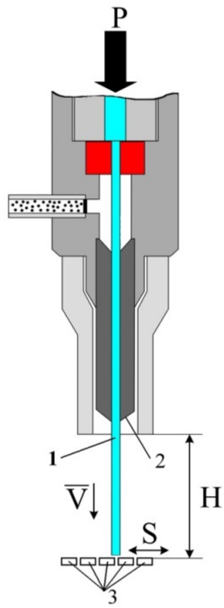


**Fig. 1.** Scheme of hydrojet processing, 1 – water jet, 2 – cutting head nozzle with diameter $d=3\cdot10^{-4}$ m, 3 – ceramic cutting inserts

To study the influence of inclination angle of the head on technological processing parameters, it was exposed at different angles with respect to the plane of the ceramic cutting insert.

After surface hydrojet treatment, the samples were placed in the chamber of a vacuum-plasma machine PLATIT π311 (Platit AG, Switzerland), where they were fixed with tungsten holders and the $CrN$-$(Al,Cr)N/\alpha$-$Si_3N_4$ coating was deposited by PVD technique in accordance with a preinstaled program.

The investigation of surface of cutting tools before and after hydrojet treatment was carried out by scanning electron microscopy (SEM) Tescan Vega 3 LMH (Tescan, Czech Republic).

Evaluation of adhesion strength was carried out in two ways. First, the surface scribing method was used, according to ASTM C-1624-05 Scratch Testing, by stepwise loading of a diamond indentor from 1 N to 40 N on a nanohardness tester (Nanovea M1Mechanical Testing, USA). Then, a non-standard method for qualitative evaluation adhesion of ceramic plates with coatings and the processing material (hardened steel) was used, according to the methodology set forth in the patent for invention № RU2629577 «Method of selecting instrumental material». Counterbodies of bearing steel (HRC 60÷62) were used as a friction couple.

The adhesion strength of the coatings with and without hydrojet surface treatment was compared.

## 3 Results and discussion

It was established experimentally that the factor of the action angle of the liquid jet to the treated surface has a negligible effect on the qualitative parameters during processing by this method, the best quality of the surface being observed at $\theta = 90° \pm 10$ %.

Fig. 2-a shows the surface before treatment and surface defects (1-3) can be observed. However after hydrojet treatment these defects are fixed (Fig. 2-b). It should also be noted that after hydrojet treatment the surface began to have a more developed morphology. The surface roughness deteriorated from Ra 0.45 ÷ 0.6 μm to Ra 0.85 ÷ 1.1 μm, which made it possible to increase the area of the adhesive contact of the coating with the substrate.

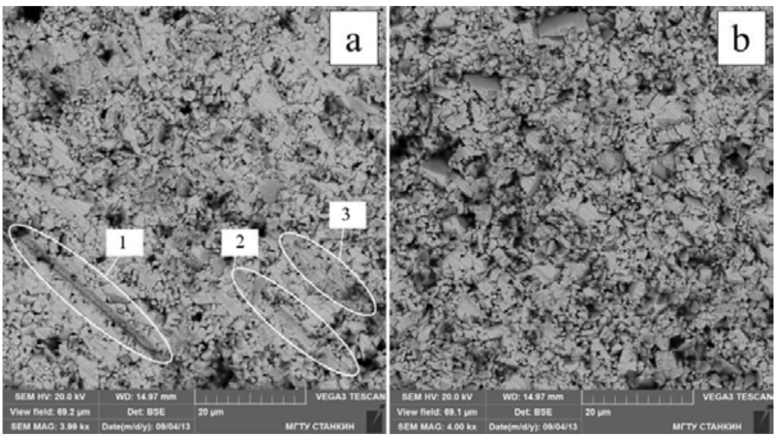


**Fig. 2.** $Al_2O_3$-TiC tool ceramics surface before (a) and after (b) hydrojet treatment

Fig. 3. shows panoramas of scribing nitride wear-resistant coatings applied to substrates of $Al_2O_3$-TiC without preliminary hydrojet machining (1); $Al_2O_3$-TiC (2) and $Al_2O_3$-TiC-SiC (3) after preliminary hydrojet machining. In the selected area of panorama 1, the destruction of the coating, which occurred at normal force Fn = 38.2N, is observed. The destruction of coatings deposited on the substrates after preliminary hydrojetting was not observed on samples 2 and 3. Thus, hydrojetting has significantly increased the adhesive strength, as well as to reduce the coefficient of adhesion by an average of 21%.

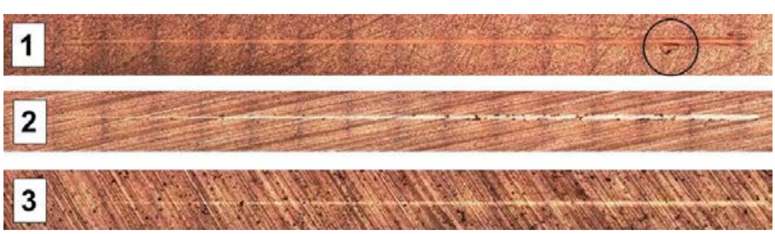


**Fig. 3.** Scribing panoramas: 1 – nitride coating on $Al_2O_3$-TiC without hydrojetting; 2, 3 - nitride coatings on $Al_2O_3$-TiC and on $Al_2O_3$-TiC-SiC samples after hydrojetting

## 4 Conclusions

During the research it was established that high-pressure (P = 200-600 MPa) hydrojet machining makes it possible to repair surface defects occurring during manufacturing process of replaceable polyhedral ceramic cutting inserts and allows to create conditions for better adhesion of the wear-resistant nitride coating to the substrate. In addition, this increases the fracture resistance of the substrate as well.

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