QUALITY AND CUTTING PERFORMANCE OF NANOCOMPOSITE COATINGS

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Introduction

Nanomaterials for machining operations prevails with high Vickers hardness (above 40 GPa) and high hot resistance (800-1,100°C) and are formed as very thin layers (1-4 μm) protecting the contact surfaces of cutting inserts against abrasion and diffusion mainly [1]. Typically, the substrate material is based with cemented carbides and the coatings consist of a few nanometers small crystals of a hard transition metal nitride (TiN) embedded in nanocrystalline or nearly amorphous covalent silicon nitride (Si_3N_4) phase, as an integrating binding. Such quasi-binary composites make a new material synergistically; significantly better in mechanical properties compared to the individual phases with many industrial applications [2].

State of the art

The superhardness and ultrasuperhardness ($\geq$100 GPa) change completely so needed cutting performance of machining tools and support new technologies like high speed cutting, hard machining, dry cutting, etc. Although the ubiquitous Friedel oscillations in electronically perturbed solids adjacent to their surfaces and interfaces weakens the bond between Ti and N atoms and the SiNx interface [3], this new material reaches unique cutting performance for machining of hardened steels, difficult-to-cut materials, reinforced composites, etc.
The quality of the coatings depends on the complex physical and chemical properties of the deposited material, but also on the state of the interphase and anchoring conditions. These nanocomposite materials are still under development, but many preliminary results are very encouraging for wide use of the "low-temperature" physical vapor depositions (PVD) – over 450°C – like reactive sputtering and vacuum arc evaporation. New cutting tools can be made not only from cemented carbides, but also from HSS - milling, turning, drilling and tapping, without any significant degradation of their edge sharpness or substrate softening.

Experimental

Materials

Steel DIN X40CrMoV51 – Nr.1.2344 hardened to Rm=1080-1100 MPa was used as workpiece material in blanks 60x80-200 mm. Monolithic whole carbide milling cutter ϕ 12 mm, 83 mm in total length, with chamfering 0.15x45°, 3 flutes, grade ISO K15-20, cutting speed v_c=200 m/min, v_f=1380 mm/min, f_z=0.087 mm, a_p=8 mm, a_e=0.5 mm, Cimcool emulsion Cimstar 560-5%, cooling rate 10 l/min.
Commercially available standard (Ti,Al)N coatings (35 GPa Vickers hardness) and nc-$(Ti_xAl_{1-x})N$/a-Si_3N_4 (45 GPa), both as monolayers, with thickness of 3.2-3.5 μm, made with the LARC®-technology of the company Platit, Switzerland, were used. The down-milling operations of shoulder milling and the FV 25A/ Heidenhain iTNC530 (O.S.O. Olomouc, CZ) were used as CNC machining technology.

Apparatus and Procedures

The Kistler piezoelectric dynamometer 9275B, fully PC controlled, sampling frequency 50 Hz in each channel, low-pass filter and the long time constant were used and set-up for the data acquisition. The precise measurement of loading forces – equation (1) - could directly reflect the changes in the geometry of chip–tool contact without any interruption of testing and a manipulation with cutting tool. Modern methods of advanced metrology [4] were applied onto the actual cutting tools geometry measurement.

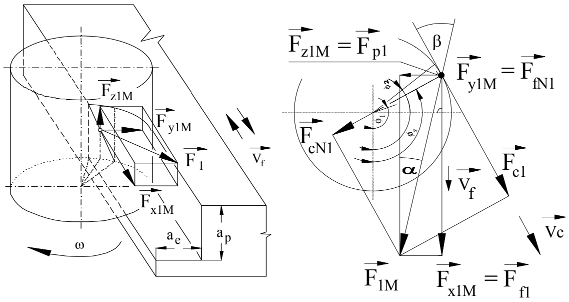

Fig. 1 Experimental set-up, force analysis.

All statistical data were worked out with Statgraphics v.5 software within time series procedures, regression analysis and ANOVA. Analytical electron microscopy (AEM) was done with REM PHILIPS XL30.

$$dF = \sqrt{\left(\frac{\partial F_{x1M}}{\partial t}\cdot dt\right)^2 + \left(\frac{\partial F_{y1M}}{\partial t}\cdot dt\right)^2 + \left(\frac{\partial F_{z1M}}{\partial t}\cdot dt\right)^2} = \qquad (1)$$

$$= \sqrt{\left(\frac{\partial F_{c1}}{\partial t}\cdot dt\right)^2 + \left(\frac{\partial F_{f1}}{\partial t}\cdot dt\right)^2 + \left(\frac{\partial F_{p1}}{\partial t}\cdot dt\right)^2}$$

Results and Discussion

The nc-(TixAl1-x)N/a-Si3N4 coating reached three times higher total cutting length of the machined material – Fig. 2. Force resolution was similar, but intensity of the changes in time were lower – Fig. 3. All the wear morphology of the cutting tool (Fig. 4) showed prevailing abrasive mechanism, but some marks of plastic deformations of the coatings have been observed also.

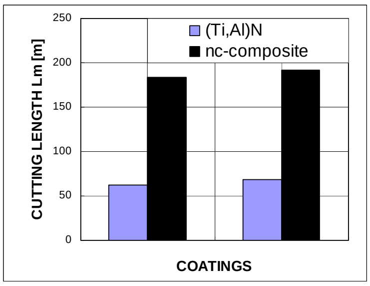

Fig. 2 Total cutting lengths for all tools.

Conclusion

The nanocomposites coatings are definitely a very promising material for cutting tool applications with a high potential of use today.

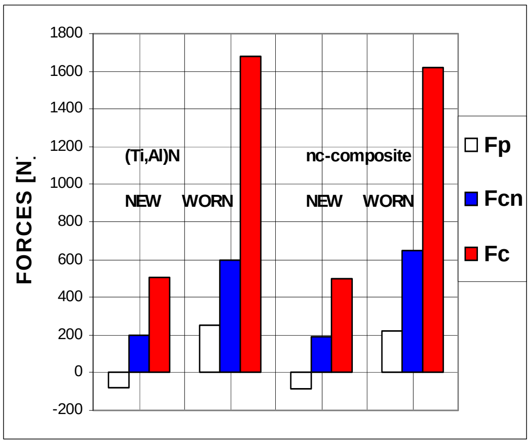

Fig. 3 A force resolution for new and worn tools.

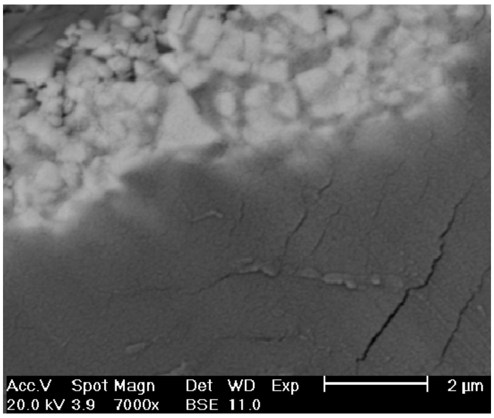

Fig. 4 A morphology of the wear on the rake.

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