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Cutting properties of the ceramic tool materials based on Si_3N_4 and Al_2O_3 coated with PVD and CVD Process*

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The paper presents comparison of cutting properties of inserts made from tool ceramics based on Al_2O_3 and Si_3N_4 uncoated and coated with coatings in the PVD and CVD processes. Dry cutting tests were carried out at high speeds, with simultaneous monitoring of the machined material roughness.

1. INTRODUCTION

These days, the security margins are so tight, that even our safety depends on the quality of the materials that we use every day, so it is very important to be able to manufacture parts at high level of productivity and quality. Parallel to the materials development there was also the improvement of tool materials, especially ceramic tool materials. The most popular kinds of ceramic tool materials are: the pure oxide $Al_2O_3 + ZrO_2$ ceramic and the Si_3N_4 (silicon nitride) based ceramic [1-2].

The pure oxide $Al_2O_3 + ZrO_2$ were thin particles of Al_2O_3 (between 1 and 10 microns) together with ZrO_2 (with the purpose of offering higher tenacity to the cutting tool), is obtained by a cold pressing procedure, but this makes it very porous, so to eliminate those, the material is sintered at a temperature of 1700ºC or more. The major advantages of oxide ceramic are: high hardness at high temperatures, no chemical reaction with steel, high compression resistance and possibility of high cutting speed nevertheless it has also disadvantages like: high brittleness and low thermal shock resistance [1-5].

The Si_3N_4 (silicon nitride) based ceramic, is a relatively new material (developed around 1970), single-phase Si_3N_4, is a highly covalent compound which exists in two hexagonal polymorphic crystalline forms, α and the more stable β. In comparison to other kind of ceramic tool materials, it presents several improvements, like: better chock resistance, considerable hardness at high temperatures, although it does not present equal chemical stability as the aluminium based ceramics when working with steel, it is excellent to use against grey cast iron, with high removal percentage of material [1-5].

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The application of thin coatings deposited at PVD and CVD processes on both of the substrates is the possibility to improve the tribological behaviour of the pure oxide Al_2O_3 + ZrO_2 ceramic as well as the nitride Si_3N_4 based ceramic [3-5].

2. EXPERIMENTAL PROCEDURE

Tests were carried out on the multipoint inserts made from the Si_3N_4 nitride ceramics and Al_2O_3 oxide ceramics, uncoated and coated with hard wear resistant coatings in the PVD and CVD processes (Table 1).

Table 1
Characteristics of the investigated cutting tools

Substrate	Coatings	Coatings thickness, µm	Process type
Si_3N_4	TiN+TiAlSiN+AlSiTiN	3.5	PVD
	TiN+Al_2O_3	6.0	CVD
Al_2O_3	TiN+TiAlSiN+AlSiTiN	2.5	PVD
	TiN+Al_2O_3	10.0	CVD

Machining properties of tested materials were defined on the basis of technological tests of the continuous machining of grey cast iron EN-GJL-250 with the hardness of 215 HB. The width of the wear band on the surface of the tool used VB=0.3 mm for precise machining was the main criterion of the cutting edge consumption evaluation. These were the parameters used in the research:

- The rate of feed, f=0.2 mm/turn
- The width of turning, a_p=2 mm
- Machining speed, v_c= 400 m/min

The examination of deposited coatings wear was made on the light microscope and scanning electron microscope (SEM) using several types of magnification.

The roughness measurement of the machined surface of the grey cast iron EN-GJL-250 (after the machining process) was made on the TAYLOR-HOBSON's SURTRONIC 10 appliance.

3. DISCUSSION OF INVESTIGATION RESULTS

Basing on the cutting ability test results, the high abrasion wear resistance was revealed of the TiN+Al_2O_3 coating put down onto the nitride ceramics substrate and of the TiN+TiAlSiN+AlSiTiN coating put down onto the oxide ceramics, compared to the uncoated cutting inserts. As regards the uncoated cutting inserts, the wear trace width on the tool flank varied from VB=0.22 mm for the oxide ceramics to VB=0.30 mm for the nitride one. The assumed tool flank wear of criterion VB=0.30 mm was reached after 8 minutes of cutting. The smallest tool flank wear width of VB=0.08 mm for the cutting speed of v_c=400m/min was demonstrated by the oxide ceramics with the TiN+TiAlSiN+AlSiTiN coating (Fig. 1) and the nitride ceramics with the TiN+Al_2O_3 coating (VB=0.16 mm).

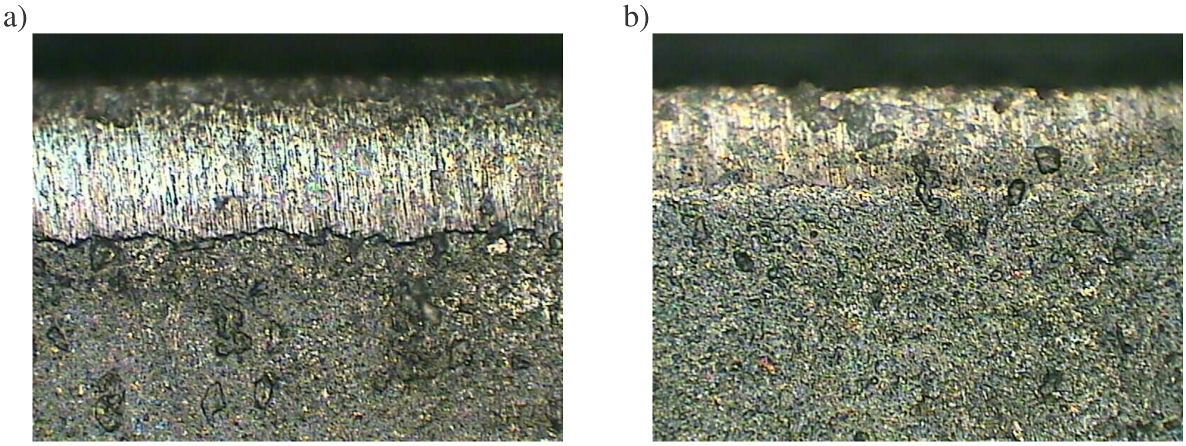

Fig. 1. Wear trace width on the Al_2O_3 ceramics cutting insert flank: a) uncoated, b) covered with the TiN+TiAlSiN+AlSiTiN coating – cutting time 8 min. (magnification 160x)

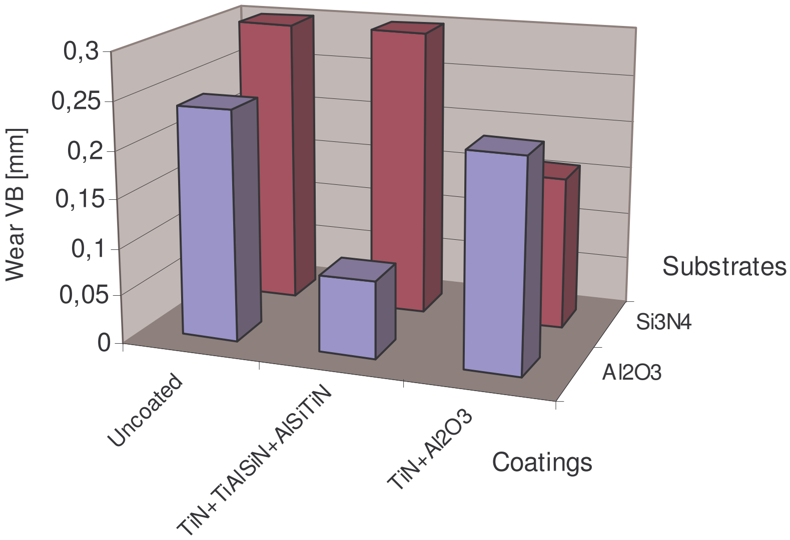

Fig. 2. Values of flank wear width VB after 8 min of cutting the EN-GJL-250 grey cast iron for the nitride and oxide ceramics - coated and uncoated

Measurements of the roughness parameter R_a of the EN-GJL-250 grey cast iron surface after cutting tests with the cutting speed of v_c=400 m/min reveal that the lowest roughness parameter value R_a=1,5 µm is characteristic for the cast iron surface machined with the oxide ceramics coated with TiN+TiAlSiN+AlSiTiN. Measurement results revealed that putting down the TiN+TiAlSiN+AlSiTiN coating onto the oxide ceramics in the PVD process and the TiN+Al_2O_3 coating onto the nitride ceramics in the CVD process decreases the roughness parameter of the machined material, compared to cutting with the uncoated tool, which results in quality improvement of the manufactured products.

4. SUMMARY

It was demonstrated, basing on the technological cutting tests of grey cast iron, that putting down onto the tool ceramics the thin anti-wear coatings in the PVD and CVD processes increases their abrasion wear resistance, which has a direct effect on extending the tool edge life. Basing on the roughness parameter R_a of the machined cast iron surface after the cutting tests, improvement was revealed of the machined material properties, cut with the oxide ceramics with the TiN+TiAlSiN+AlSiTiN coating, and with the nitride ceramics with the TiN+Al_2O_3 coating, compared to material machined with the uncoated tools.

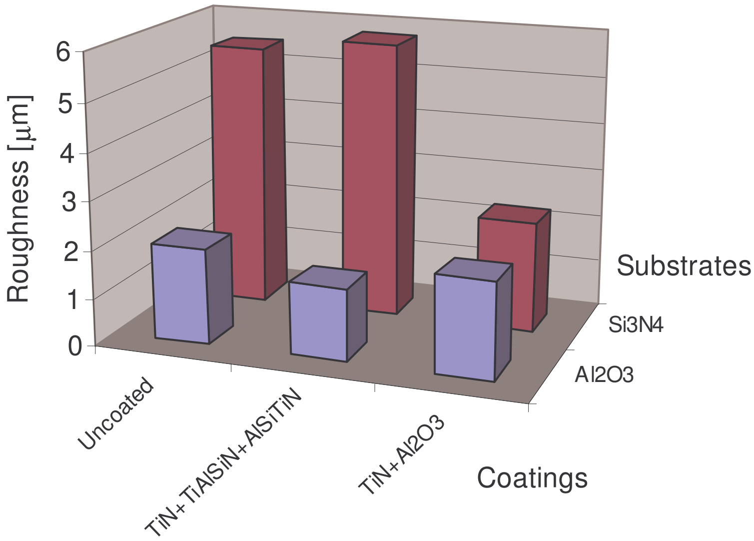

Fig. 3. Roughness parameter R_a values of the EN-GJL-250 grey cast iron surface after cutting tests

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REFERENCES

1. L.A. Dobrzański: Fundamentals of materials science and physical metallurgy. Engineering materials with fundamentals of materials design., WNT, Warszawa, 2002. (in Polish)
2. Noyes/William A. Publishing Ceramic Cutting Tools, Edited by Whitney, E.D., 1994.
3. Dobrzański L.A., Pakuła D., Gołombek K., Mikuła J.: Structure and properties of the TiAlSiN coating obtained in the PVD process on inserts from the Si_3N_4 nitride ceramics, 11th Scientific International Conference „Achievements in Mechanical and Materials Engineering" AMME'2002, Gliwice-Zakopane, 2002, s. 131-134. (in Polish)
4. Mikuła J., Dobrzański L.A.,: „Properties of Al_2O_3 based ceramic materials with thin coatings put down in the PVD processes", XXXI School of Materials Engineering, Kraków-Krynica 2003, s.515-518. (in Polish)
5. Holmberg K., Mathews A., Tribological Properties of Metallic and Ceramic Coatings, chapter 23. CRC Press LLC, 2001.