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A survey of the abrasive wear resistance of hard and low friction coatings against TiO_2 particles

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Extended abstract

The aim of this study is the evaluation of the microabrasive wear resistance of a range of commercially available hard and/or low friction coatings. These coatings are typically used or are nowadays introduced on components in the paint and plastic industry. The main abrasive in the processing of these materials is rutile (TiO_2). Ball cratering tests have been set up with a suspension of TiO_2 abrasive in water to simulate the real micro-abrasion as accurate as possible.

The tests were performed on a TE66 micro-scale abrasion tester manufactured by Plint. As abrasive suspensions, a typical rutile powder with small particle size (Ø 0.1-0.4 μm) and spherical grains in distilled water (at a concentration of 100 g/l) was used. The viscosity of the suspension was 0.0018 Pa s. A new ball bearing of hardened DIN 100Cr6 (AISI 52100) steel and 25 mm in diameter was used for each experiment. The applied load was 0,35 N and the ball rotated at 150 rpm.

The selected coatings are given in table 1. The coatings have been characterised with SEM, profilometry and depth sensing indentation. The results are summarised in table 1. Two different types of substrates have been used for all coatings, namely a X42Cr13 steel (mn 1.2083 with hardness 50 HRc) and X36CrMo17 steel (mn 1.2316 with hardness 32 Hrc). The ball cratering test resulted in a clear ranking of the coatings in function of the wear coefficient of the coating. The results are shown in figure 1. The substrate here was the X42Cr13 steel. These results are obtained with the Archard equation for the abrasive wear.

Some influences of the substrate and coating characteristics and of the measurement methods have been studied.

The results of the ball cratering test under the same conditions but on the coatings deposited on the softer X36CrMo17 steel were nearly unchanged and well within the experimental error compared to the X42Cr13 substrate. No influence of the substrate hardness has been observed. The coating hardness did not show a correlation with the wear coefficient when all coatings were taken into account (fig. 2a). Only when the results of the three very similar PACVD coatings are considered separately, the wear coefficient is significantly increasing with decreasing coating hardness (fig. 2b).

In order to check the reliability of the measurements, several experiments have been repeated two or more times (fig. 3). The results are within the experimental errors. The influence of the surface roughness on the measured wear volumes has also been calculated and compared to the experimental error (fig. 4). The accuracy of the measurement of the diameters in the binocular was assumed to be 0.01 mm. It is shown that a surface roughness of 0.2 μm, as was the case on the measured samples, does not deteriorate significantly the accuracy of the measurement.

Finally, the wear coefficients of different types of coatings has been determined with a SiC abrasive and compared to the results obtained with the TiO_2 abrasive (fig. 5). The F1200 SiC had average diameter 6 μm and was suspended in distilled H_2O at a concentration of 350 g/l.

It is clear that the two compared abrasives are quite different: the TiO_2 particles are much smaller and are spherical, while the SiC particles are angular. This results in a completely different wear mechanism. While the use of TiO_2 abrasive results in a three body abrasion, which is rather a polishing, the SiC cause a grooving wear of the surface. Moreover, embedded SiC particles in the steel ball have been found after testing the hard ceramic coatings. This explains the large difference in wear coefficient values. When using the SiC particles, the wear mechanism also was different for the softer hard chromium layer, resulting in a confusing lower absolute value of the wear coefficient compared to the ceramic coatings. It can be concluded that the TiO_2 abrasive is ideal for simulating rolling wear for a large range of materials, though the measuring time is increased drastically.

Coating	Process	Hardness DSI	Elasticity	Thickness SEM	Roughness
		H GPa	E GPa	t µm	Ra µm
TiN	PVD	33,10	374,78	3,5	0,063
CrN	PVD	26,96	265,97	4,1	0,094
TiCN	PVD	31,31	307,43	3,1	0,021
TiN	CVD (900°C)	15,44	312,68	7,8	0,040
CrN	LTPVD (200°C)	21,94	292,09		0,823
DLC	PACVD	23,92	162,47	1,9	0,009
DLN180	PACVD	16,32	127,24	1,9	0,008
DLN360	PACVD	11,62	106,66	1,7	0,007
Hard Chromium	electrolytic	12,28	246,73	22,5	
NiFlor	NiP + PTFE			13,6	1,405

Table 1: Selected coatings and characteristics. The coatings were deposited on X42Cr13 polished steel samples (Ra of the substrate was 0.007 µm).

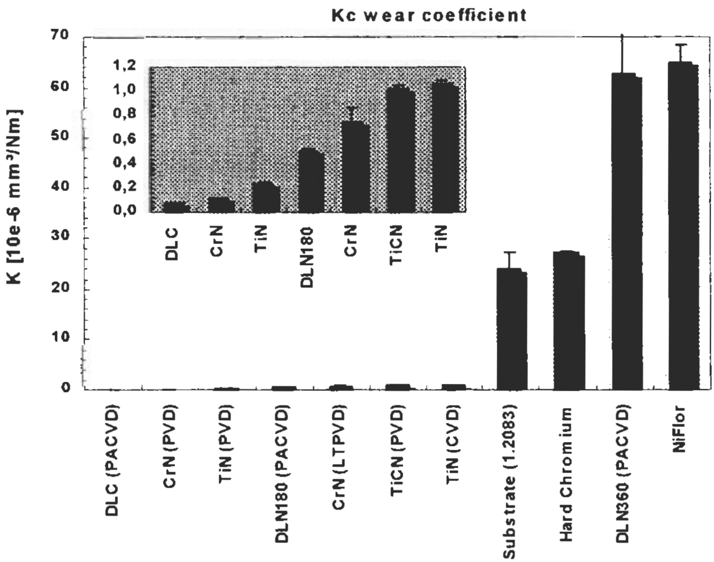

Figure 1: Ranking of the selected coatings in function of their micro-abrasive wear resistance against TiO2 particles. The substrate was X42Cr13 steel with Ra = 0.2 µm.

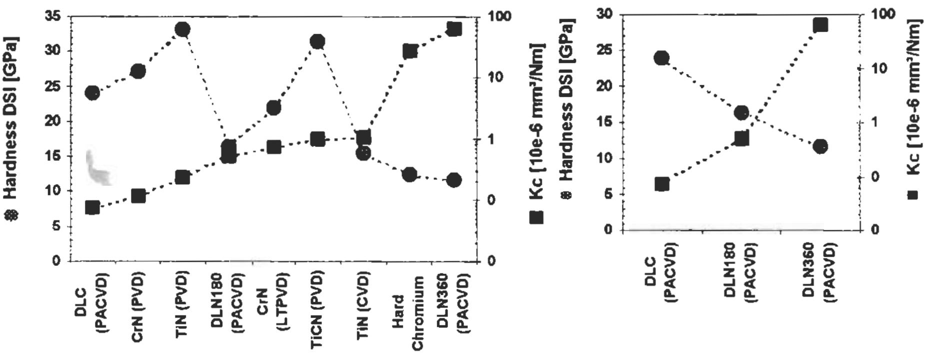

Figure 2: Coating hardness and wear coefficient for all coatings (a) and for the PACVD coatings (b) resp.

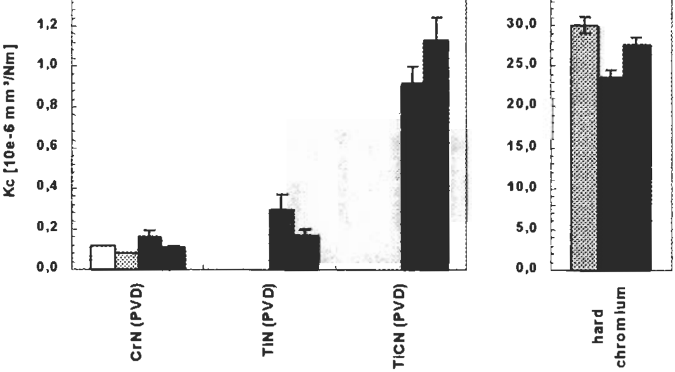

Figure 3: Repeated measurements on different types of coatings. The indicated error bars are the calculated standard deviations, which are derived from the estimated experimental error.