Calo-Wear as an Abrasion Test for Hard Coatings

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Introduction

Many test methods are used to characterize the mechanical properties of coatings. They range from nanoindentation for hardness measurement to scratch testing for adhesion determination, via tribological tests and qualitative observations. Abrasion resistance plays an important role for many coating applications such as protective and decorative coatings, tool coatings or coatings having a tribological function in dust or particle charged environments.

A new instrument has been developed that allows the quantitative determination of the abrasion resistance of materials. A simple methodology makes this test straight forward in the case of coated surfaces.

Instrumentation

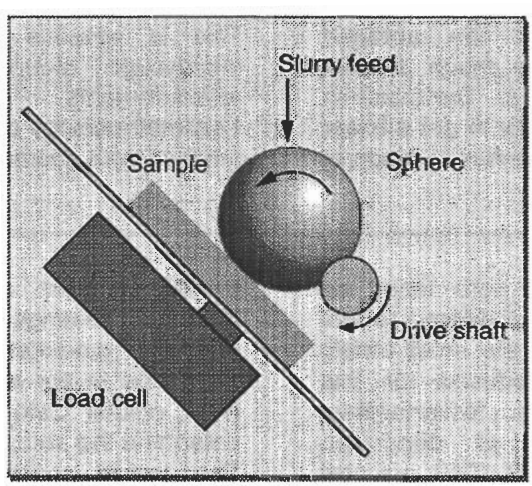

Figure 1: The principle of the CSEM Calowear Tester.

The Calowear tester is a development based on the original Calotest, where a rotating sphere of known diameter is pressed onto the coating surface with a preselected load. Both the position of the sphere relative to the sample and the contact load are kept constant. Upon adding abrasive paste to the contact zone, a depression with the form of a spherical cap is abraded

into both the coating and the substrate.
Optical inspection of the depression reveals the projected surfaces of the abraded coating and substrate sections, from which the coating thickness can be calculated from a simple geometrical equation.
The Calowear Tester (Fig. 1) has taken this one step further and provides additional features, namely an integrated optical microscope, normal force measurement, revolution counter and abrasive slurry mixer. This means that not only the coating thickness can be determined, but also the abrasion coefficients of the coating and substrate.
For this study, we used a 25.4 mm diameter AISI 52100 steel ball. The abrasive slurry was a suspension of SiC particles with a mean size of 3 µm in water. The concentration was 750 g/l.

Methodology

The approach used has been described by Hutchings et al.[i] Briefly, one starts with a simple model for abrasive wear, equivalent to the Archard equation, assuming independent wear coefficients for the coating and the substrate. Taking into account the experimental geometry, the wear volumes are expressed in the approximation that the abraded calotte diameter is much smaller than the ball diameter. The equation is rearranged in order to get a linear plot of wear measurements made at different sliding distances. Abrasion coefficients of the substrate and of the coating are extracted from the slope and intercept of the plot.
Practical tests were performed by sliding the ball on a distance corresponding to 13 m and then measuring the calotte diameter. These steps are repeated four to five times on the same wear calotte. This is possible thanks to the microscope mounted for in-situ measurements.
This methodology can be applied to other contact geometries.[ii]

Results

Results presented here focus on thin hard coatings dedicated to tool protection. Today, the most widely used coating introduced for this application is TiN. Nevertheless, new generations of deposition systems, such as PA-PVD, are now able to produce many different coatings having a broad range of mechanical properties. It is therefore essential to have tests to characterize these properties quickly and with a reasonable effort.
In this context a screening of different coatings coming from different producers is currently performed in our laboratory. These tests include Calo-Wear testing to determine the abrasion resistance.
The tested coatings have been deposited on 440C and AISI52100 steel discs. They consist of PVD TiN, TiCN, TiAlN, CrN and DLC. Wear coefficients for such coatings are shown in figure 2.

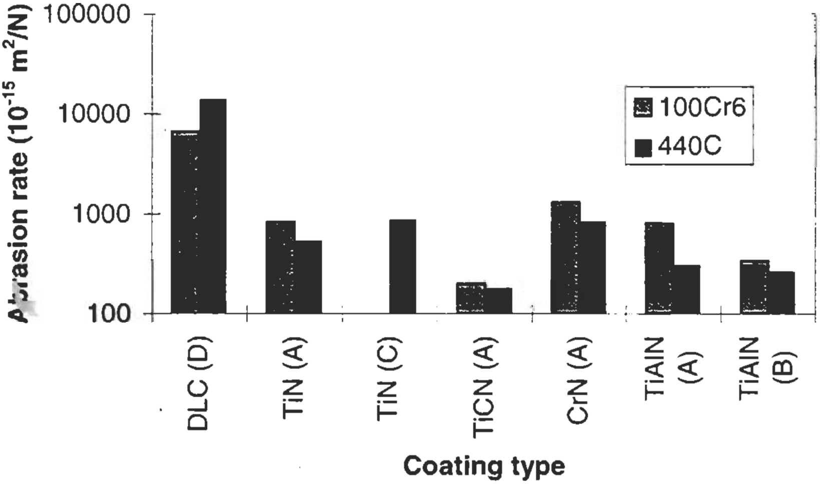

Figure 2: Abrasion rates of different types of hard coatings deposited on steel.

The results clearly show that the tested DLC has a much smaller abrasion resistance than the titanium or chromium based coatings. As DLC may have a large range of properties, this result should not be extrapolated to other similar coatings.

TiCN is the tested coating having the lowest wear rate with the Calo-Wear. This superior behavior to TiN is assumed to be related to the improved performance observed in such applications for TiCN.

Finally, the two different TiAlN samples exhibit much different abrasion resistances. In fact these two samples have different compositions resulting in different mechanical properties. It is therefore very interesting to see that with this method it is possible to distinguish between different types of the same material.

Chromium nitride has an intermediate result, better than DLC but worse than titanium based coatings. It is known that the CrN is not a very hard coating, and this result is not surprising. Nevertheless CrN has other good properties, like the ability to deform with its substrate without cracking, that make it an interesting material for some tool applications.

Many sample parameters may influence the results of this test, for example the adhesion of the coating on its substrate. In our set of measurements, the abrasion rates obtained on 440C steel substrates are generally smaller than the one obtained on 100Cr6 substrates. Although the applied methodology is supposed to decouple the effects of the coating from those of the base material, it seems that further analysis is needed. Amongst others, the influence of the substrate hardness, that may change during the deposition process, will be investigated.

Figure 3 shows the abrasion rates of the substrates determined in the same set of measurements. It appears that the loss of hardness of

100Cr6 steel has little influence on its wear behavior, but this has to be checked through rehardening of the samples. The larger discrepancies for the substrate wear values are observed for TiCN. This can be explained by the fact that it is the more resistant coating tested. In these conditions, the coating properties dominate the abrasion and the values of the substrate are poorly determined.

On the other hand, the abrasion rate of the CrN coating is close to the one of its substrate. Due to mathematical treatment of the data, this situation results in a poor determination of coating properties.

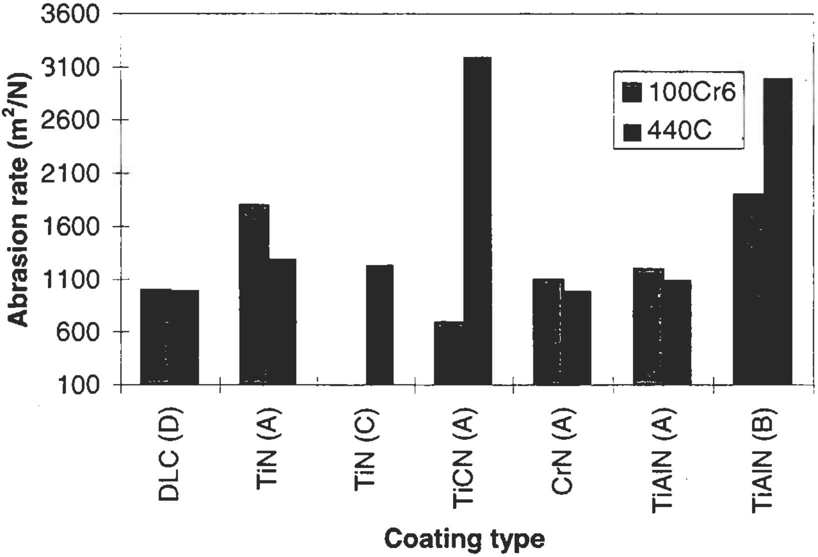

Figure 3: Abrasion rates of the substrates.

Conclusions

A new method has been developed for abrasive resistance determination of thin hard coatings. The results show that one can rapidly distinguish between different types of coatings and depositions.

Further investigations are planned. For example the role of the abrasive particle hardness has to be investigated in order to find the most appropriate slurry for each class of tested materials.

References

[i] K. L. Rutherford and I. M. Hutchings, Surface and Coatings Technology **79** (1996) 231-239, "A micro-abrasive wear test, with particular application to coated systems"

[ii] K. L. Rutherford and I. M. Huthcings, Tribology Letters **2** (1996) 1-11 "Micro-scale abrasive wear testing of PVD coatings on curved substrates"