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ABSTRACT

TRIBOLOGICAL ASPECTS ON SURFACE LAYERS AND WEAR PARTICLES

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The rubbing process in a tribological sliding dry contact produces commonly wear products, transfer layers and reaction layers. These have a considerable influence on the friction and wear properties. However, still today in the tribological literature reporting tribotesting results these products and layers are very often poorly described and they have not attracted the attention they would deserve. Today there is no standard nor no generally agreed manner how to describe these products and layers formed in the tribocontact.

The presentation described a typical rubbing wear experiment and how the experimental parameters involved are typically described. The focus was especially on how to accurately describe the wear products, transfer layers and tribolayers. Different means of isolating the rubbing process and collecting the wear products was shown to ensure that the wear products analysed really are those originating from the rubbing contact. On-line monitoring of wear products have been performed by particle counter, ferrography and wear particle analyser. Pattern recognition and diagnostic computer programmes can be used for identifying the particles and their origin. After the test the wear products can be collected and analysed by optical microscopy with polarised light, SEM, EDS and XRD. Parameters for identifying the wear particles are diameter, form, area, volume, shape, contour line, topography, hardness, colour, magnetic property, chemical composition, crystalline structure and phase.

The formation of layers in the tribocontact was discussed. There formation mechanisms were described and depending on that they can be divided into transfer layers and reaction layers. It was shown how layers can be formed from wear products to conglomerations of wear debris, to wear debris beds and to layers. Analytic tools for identifying surface layers are e.g. optical microscopy, SEM, EDS, Auger, ESCA, SIMS and Raman. Parameters to define the layers with are thickness, roughens, topography, coverage, hardness, colour, chemical composition, crystalline structure and phase.

The described mechanisms were illustrated by experimental observations from rubbing contacts with steel and ceramic balls sliding against hard carbon coatings (a-C, a-C:H and a-C:H(Ti)) and ceramic surfaces (alumina, silicon nitride and silicone carbide).

The usefulness of the different analysing tools as well as the influence of the different parameters on the tribological properties were discussed, and a suggestion for how to describe wear products and surface layers in tribotesting was proposed. Wear particles can be reported by quantity, colour, shape and size, chemical composition, and for more detailed reporting also by size distribution, hardness, edge, surface texture, magnetism and crystalline structure. Surface layers can be reported by coverage, area, thickness, colour, chemical composition and gradient, discussion on transfer or reaction layers, and for more detailed reporting also by surface roughness, surface texture, section profile, hardness and gradient, topography and crystalline structure.

CHARACTERIZATION PARAMETERS AND ANALYSIS TECHNIQUES FOR WEAR PARTICLES

Characterization parameters \ Measuring and analysis techniques	Magnetic plug	Particle counter	DR Ferrography	Analytic Ferrography	On-line particle analysis*	Sieving	Optical microscopy	Nanoindenter	SEM + EDS	TEM + EDS	XRD	Auger	XPS	SIMS	Raman	FTIR	Balance
Total quantity of wear particles, *m*	⊕	⊕	+	+	⊕	⊕	-	-	-	-	+	-	-	-	-	+	+
Size distribution	-	⊕	+	+	⊕	+	-	-	-	-	-	-	-	-	-	-	-
Size: - diameter, D_{max}	-	+	-	⊕	⊕	+	⊕	-	⊕	⊕	-	-	-	-	-	-	-
- diameter, D_{min}	-	+	-	⊕	⊕	-	⊕	-	⊕	⊕	-	-	-	-	-	-	-
- projected area, A_x	-	+	-	⊕	⊕	-	⊕	-	+	-	-	-	-	-	-	-	-
- thickness, *h*	-	-	-	-	-	-	-	-	⊕	-	-	-	-	-	-	-	-
Colour	-	-	-	⊕	+	-	⊕	-	-	-	-	-	-	-	-	-	-
Shape	-	-	-	⊕	+	-	⊕	-	⊕	⊕	-	-	-	-	-	-	-
Edge	-	-	-	⊕	+	-	⊕	-	⊕	⊕	-	-	-	-	-	-	-
Surface texture	-	-	-	+	+	-	⊕	-	-	-	-	-	-	-	-	-	-
Hardness	-	-	-	-	-	-	-	⊕	-	-	-	-	-	-	-	-	-
Magnetism	⊕	-	⊕	⊕	+	-	-	-	-	-	-	-	-	-	-	-	-
Chemical composition	-	-	-	+	-	-	-	-	⊕	⊕	⊕	⊕	-	⊕	+	+	-
Crystalline structure	-	-	-	+	-	-	-	-	-	⊕	+	-	-	-	+	-	-

- = *no information*
\+ = *some information*
⊕ = *good information*

* e.g. VTT/KOHOS device (Enwald et al, 1994)

CHARACTERIZATION PARAMETERS AND ANALYSIS TECHNIQUES FOR SURFACE LAYERS

Characterization parameters \ Measuring and analysis techniques	Optical microscopy	2D roughness/profilometer	3D topography analyser	Nanoindenter	SEM + EDS	TEM + EDS	XRD	Auger	XPS	SIMS	Raman	FTIR
Coverage, %	⊕	+	⊕	-	⊕	-	-	-	-	-	-	-
Area	⊕	-	⊕	-	+	-	-	-	-	-	-	-
Thickness	⊕	+	⊕	+	⊕	+	-	+	-	+	-	-
Surface roughness	+	⊕	⊕	-	+	-	-	-	-	-	-	-
Surface texture	⊕	+	⊕	-	⊕	-	-	-	-	-	-	-
Topgraphy	+	+	⊕	-	⊕	-	-	-	-	-	-	-
Hardness	-	-	-	⊕	-	-	-	-	-	-	-	-
Colour	⊕	-	-	-	-	-	-	-	-	-	-	-
Chemical composition	-	-	-	-	⊕	⊕	-	⊕	⊕	⊕	+	⊕
Crystalline structure	-	-	-	-	-	⊕	⊕	+	+	+	+	+

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