Quicker from Science to Society - About a Design Tool for Optimum Multi-Scale Film Structures

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Introduction

Fig. 2: Dry milling with coated tool

Nowadays, nearly every surface is protected by coatings or by surface treatment in order to protect it from degradation and the final product from failure. Such material degradation can be caused by wear, corrosion, fatigue, fracture etc. This work will focus on wear, because it is a major influence on

- the energy efficiency of components,
- the wastage of scarce raw materials,
- the environmental protection,
- and industrial competitiveness of companies.

For instance, if the consumption of raw materials in Germany could be reduced by 20%, the industry would save 100 billion Euro per year. Hence, wear is a critical success factor for the manufacturing industry.

There has been a noticeable progress in the development of wear-resistant coatings so far. Figure 1 shows these developments in relation to the coefficient of friction for carbon-based thin films at a glance.

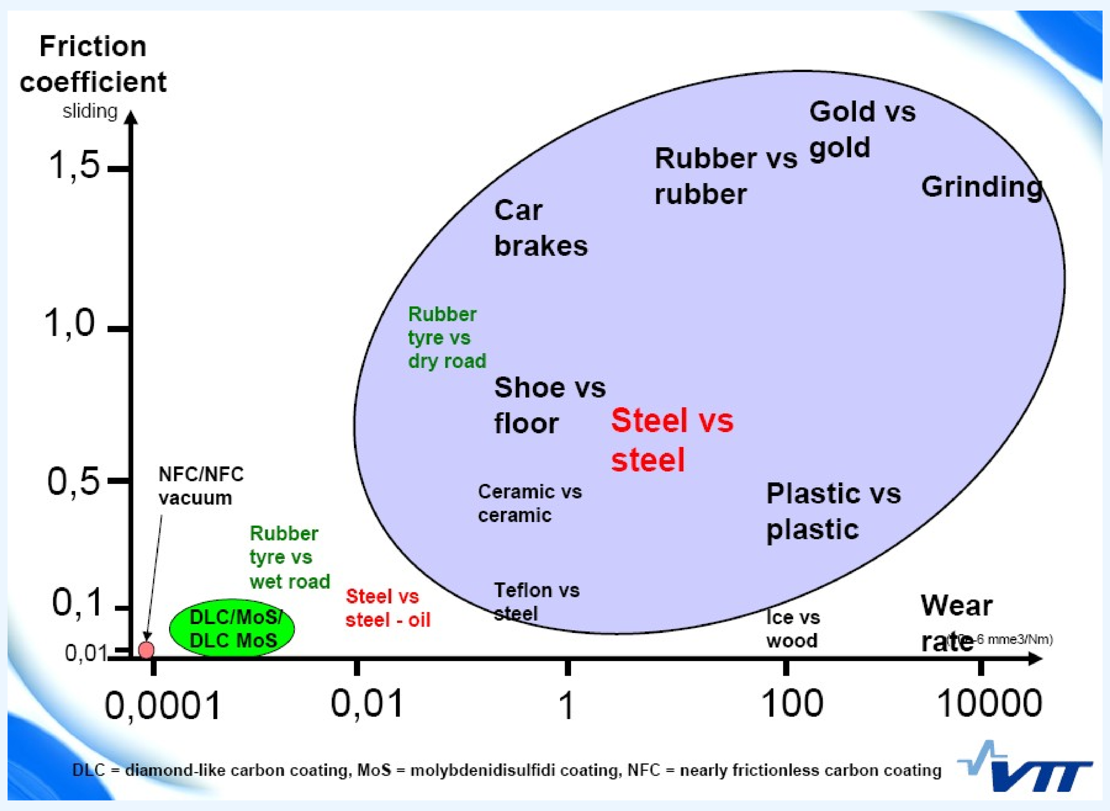


Fig. 1: Research progress in wear-resistant materials

State-of-the-Art of Surface Design

The process of designing a coating can be subdivided in four knowledge steps as shown in figure 3: coating processing, material structure (in all scales), generic material properties, and tribological performance.

There are two main conventional ways to design a coating: Empirical trial-and-error testing and element-based modelling (e.g. Finite Element Modelling). Using this coating design process chain to illustrate these conventional ways of surface development, it turns out that they are both neither integrated nor natively invertible. But there are often complex interdependencies between variables of each step and non-linear relations between these knowledge steps. Thus, both conventional methods cannot guarantee to find the optimal coating design for a given application. Meaning, that they are:

Fig. 3

PVD, CVD etc.	no. of layers, layer thickness etc	Young's modulus, yield strength etc.	Wear-rate, lifetime etc.
Processing	Material Structure	Generic Properties	Tribo Performance

trial-and-error testing

modelling: - MDS, FEM, BEM → complex
- limited invertible → very limited suitability

slow, expensive & dangerous

Objective of Future Surface Design

In the future, it should be possible to develop wear-resistant surface structures without these disadvantages and risks. Therefore, an integrated surface design tool will be developed. It will be based on analytical solutions, which are partly already available (e.g. Oliver & Pharr method extended for coatings, lateral loads, and tilting)[1,2], it will be invertible and, thus, allows the application-tailored design of wear-resistant coatings.

Fig. 4

ISA OptiWear

Processing	Material Structure	Generic Properties	Tribo Performance

integrated coating design tool

→ quicker & invertible

application-tailored design of surface structures

Available Analytical Solutions for the Multi-Scale Design of Surface Structures

In order to obtain generic mechanical material properties it is necessary to evaluate not only instrumented indentation measurements but also scratch tests by means of correct models which consider all measurement conditions like material structure, surface topography, actual indenter shape and so on. As illustrated in fig. 3 and 4, such analytical solutions are already available, namely the O&PfC®, SSA® and ISA[3,4,5], which are based on a completely analytical solution of the governing differential equation of elasticity for arbitrary load and contact problems in the elastic-plastic regime.

Whereas OptiWear simulates a pin-on-plate experiment utilizing an extended Archad's law model and, thus, is able to predict the tribological performance of surfaces by means of wear depth as a function of the wear track[6].

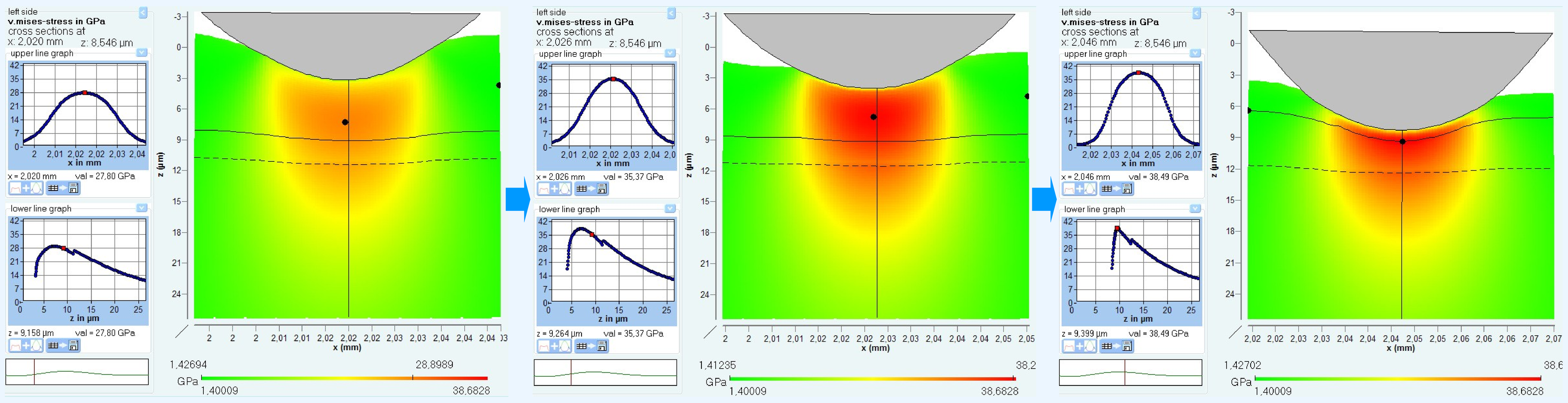
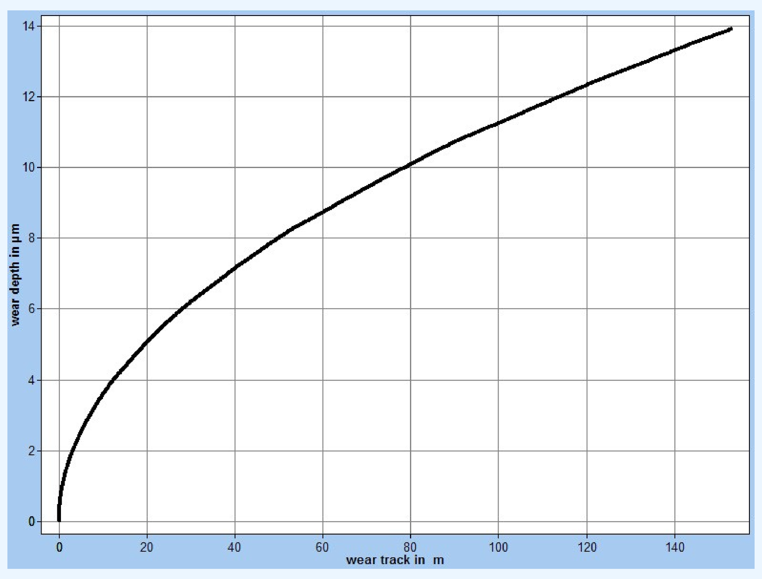


Fig. 5: **Physical analysis of a scratch test[7]** by means of animated distribution of von-Mises-stress as cross section through the sample beneath the stylus in scratch direction. It indicates where and why material has started to plastically flow.



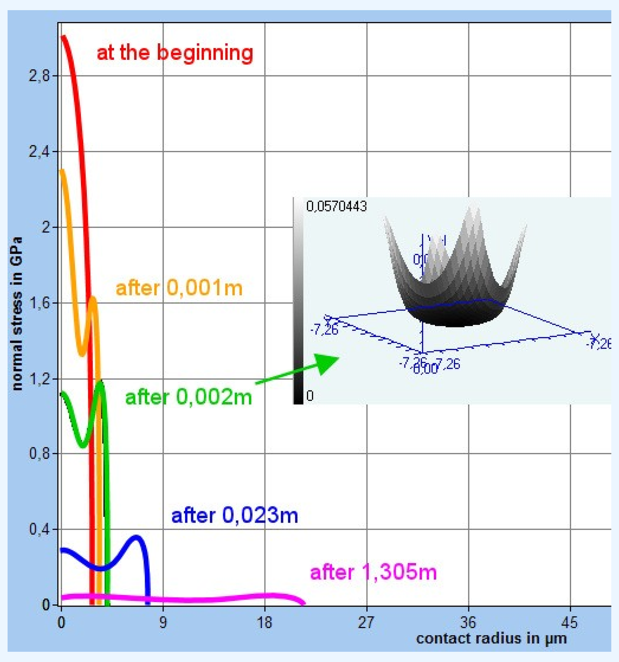


Fig. 6: Wear depth and normal stress evolution of a pin-on-plate experiment simulated by OptiWear.

Conclusions

There are still analytical models missing for the first and second knowledge step, which are necessary to complete the surface design tool. **Hence, your knowledge and support as coating process expert for PVD or plasma spraying is requested.**

Please, contact us!

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[5] Indent and Scratch Analyzer (ISA): indentation and scratch test analysis software, http://www.siomec.de/ISA
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