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CHARACTERISATION OF HARD COATINGS ON CUTTING TOOLS

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ABSTRACT

One of the main pre-requisites for successful industrial production is the use of quality coated cutting tools with defined mechanical and technological properties. Therefore, for the development and introduction of new coated cutting tool (new combination of cutting material and hard coatings), it is necessary to carry out a number of studies with the purpose to optimize the coatings composition and processing procedures, and also to test new tools in working conditions.

In this paper, an attempt is made to present the possible approach for successful characterisation of hard coatings on cutting tools in the practice.

Keywords: characterisation of surface, hard coatings, cutting tools

1. INTRODUCTION

The requirements from industry: produce faster, better, safety and more ecologically, force us to develop new effective tools and innovative technologies. The use of coated cutting tools to machine various materials now represents *state-of-the-art technology*. Developments in coating equipment and processes now enable us to produce a wide range of different hard nitridic and oxidic films and to deposit them on various tool substrates as monolayer, multilayer, or composite coatings. Irrespective of whether cutting tool materials are being coated, the primary concern is to control and optimise properties such as coating adhesion, coating structure, coating thickness, etc., which determine the performance of the coated cutting tool [1-3].

The aim of this paper is to establish the practical approach for characterisation of thin hard coatings on cutting tools (from development phase to practical use in manufacturing industry).

2. STRATEGIC APPROACH IN THE DEVELOPMENT OF HARD COATINGS

Since the beginning of the nineteen-eighties, PVD coating has been used for large scale industrial coating of geometrically complex tools such as twist drills, reamers, taps, end mills, form tools, etc. Hard coating led to a major advance in the performance of these tools. Modern design of coated cutting tools place such high demands on the materials for specific applications. In particular, the requirements for substrate (bulk) properties, on the one hand, and tool surface properties, on the other hand, differ so much that the surfaces have to be specially treated and modified to meet the particular demands [4]. The quality of coated cutting tools often depends on three main parameters:

- **Substrate (tool) material.** One key area of interdisciplinary development work, which cannot be discussed in greater detail here, is improvement of the substrate materials.
- **Coating.** A second key area of interdisciplinary work, which is very complex, is the sophistication of the coatings and achieving reproducibility and high quality in coated tooling.
- **Interface.** The study of interface problems in coating advanced tool material included the following parameters [5]:
  - The surface morphology and microstructure of the substrate and the hard coating;
  - The distribution of the elements at the interface;

- Possible reactions between elements from the substrate and the coating.

Machinability tests. Despite great advanced in the analysis of thin films, machinability tests are still needed to demonstrate the performance potential of hard coatings on cutting tools. The following experiments are intended to help isolate and interpret the interface characteristics between hard coating and substrate and theirs influence on the parameters in the machining process, and resulting forms and causes of tool wear.

3. CHARACTERISATION OF HARD COATINGS

The basic elements of the characterisation of thin coatings by development and introducing of coated tools are [3]:

- Selection of the substrates and coatings,
- Preparation of hard coatings,
- Testing of hard coatings (in laboratory and workshop conditions),
- Industrial applications.

The first step is selection of appropriate hard coatings (monolayer, multilayer, gradient, nanolayer, nanocomposite) and their characterisation, which means the quantitative assessment of the relevant properties by means of physical, chemical, and technological effects. Here it is practical to distinguish between characterisation with respect to structure and composition, and characterisation with respect to the other properties. Obviously it is not sufficient to characterise only the function and structure of a few atomic layers; the entire modified zone has to be taken into account, and the problems of the interface also have to be dealt with. The complexity of the system is shown in Fig. 1 [5,6].

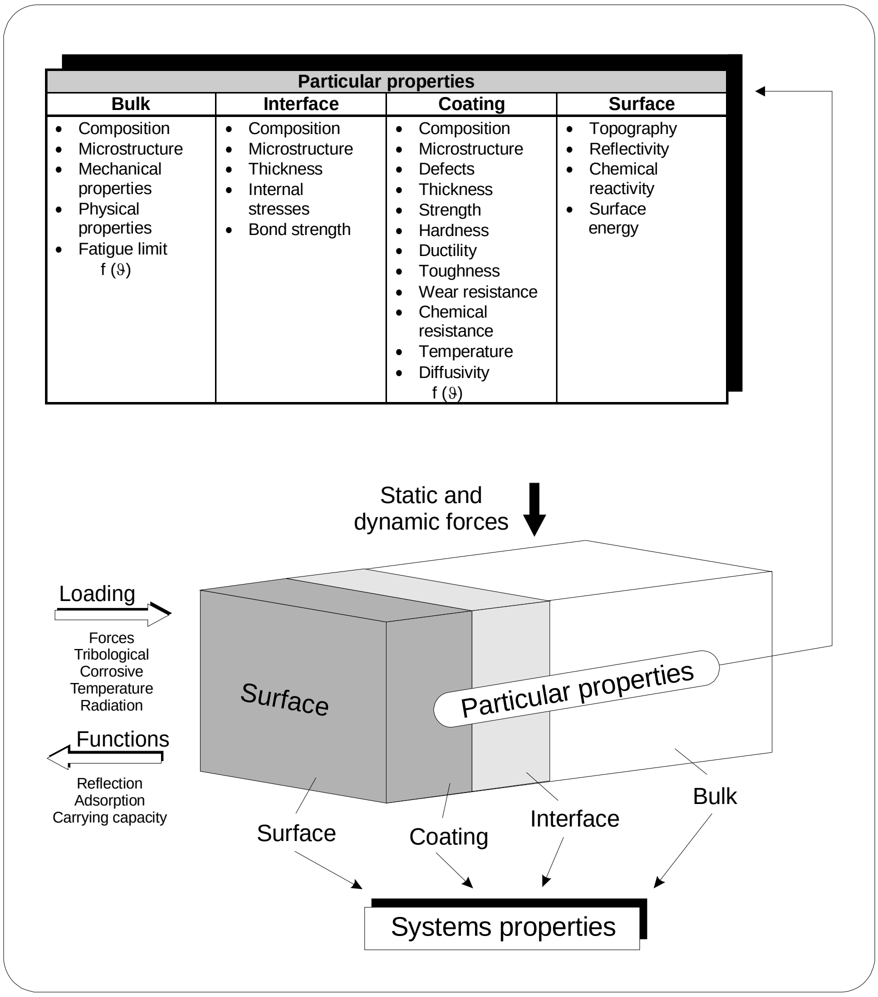

Figure 1. System properties of a component as a result of interactions.

The second step, which cannot be discussed in greater detail here, is selection and optimisation of the methods (PVD, CVD, PACVD...) of preparation of hard coatings on cutting tools for previous (in the first step) selected type of coatings.
The third step is strongly connected with quality control of hard coatings after producing and practical testing of coated tools in laboratory and workshop conditions. Quality assurance procedures have to be applied to maintain the standard achieved during development work. These procedures are of the same nature as the ones used during the production of substrate (bulk) and can be categorized as follows:

- Process parameter control
- Random sampling
- Non-destructive testing
- Monitoring in service

Quality control of hard coatings on tools or tool tips presents a difficult problem because the coatings are thin, mostly less than 5 μm, and coating and adhesive properties have to be excellent if the coating is not to fail during use. In Fig. 2, the relevant properties are listed together with the testing methods that can be applied.

Testing methods	Property
Metallography (MET) Scanning electron microscopy (SEM)	Structure
MET SEM Feeler gauge (FG)	Topography
MET SEM FG Ball cratering	Thickness
Scratch test	Hardness
Scratch test	Adhesion Cohesion
Pin/disc Ball/disc	Friction wear

Figure 2: Possible testing sequence for hard coatings.

Monitoring in Service. Most surface-engineered components are subjected to very special and often complex loading profiles in service, which is particularly the case in corrosive aqueous and gaseous environments and for tribological applications, Fig. 3 [3]. In order to obtain data on the actual performance in service, the coated tools have to be tested under closely simulated service conditions. In the case of a coated cutting tool it is almost impossible to conduct direct research of events going on in the coating surface *during the cutting process itself*. What is usually done is identification of post-process changes on the coating surface (cracks, B.U.E.) and under the surface in the interface (coating delaminating, efficiency of diffusion barrier) [7].
Analysis of tribo-system in cutting processes. Understanding of tribological problems, nature and characteristics of the cutting material, cooling agent and its application are of significant importance for the predictability of the tool life for a reliable production in a given application. If all parameters of the tribo-system are mutually optimally combined, it can be expected with high probability that the selected technological values with existing machinery will give an optimal product. The theory of resistance of tool is very complicated since it is necessary to know several scientific disciplines.

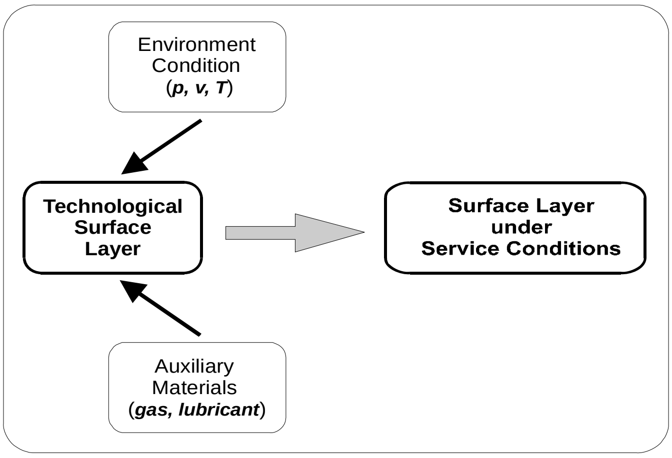

Figure 3. Schematic display of transformation of the technological surface layer into a surface layer in service conditions.

4. CONCLUSIONS

One of the pre-requisites for successful production is the use of quality cutting tools with defined mechanical and technological properties. Therefore, for the development and introduction of new kind of cutting tool (cutting material or coating), it is necessary to carry out a number of studies with the purpose to optimize the substrate and coating composition, coating processing procedures, and the resulting workpiece material machinability.

Stimulated by the many innovative surface technologies reaching commercial maturity last decade, the discipline of surface engineering has been seen to flourish. As a new area of engineering, its future development should be amenable to planning, through the adoption of a logical interdisciplinary approach. Such an approach will provide the manufacturing industry with many new opportunities in the design of effective cutting tools and production processes.

The cutting tool surface and surface coatings characterisation, as well as quality assurance, are very important parts of effective coated cutting tools development. A great variety of powerful testing methods exists both to characterise surface hard coatings and to ensure that the quality is adequate. Non-destructive coatings methods that can be used for 100 % testing are, however still in the development stage, and further work has to be done in this area.

5. REFERENCES

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