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The structure and properties of the PM material Vanadis 30 with surface treatment

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High speed steels (HSS) produced by powder metallurgy (PM) are characterised by homogeneous microstructure with uniformly distributed carbid phases resulting from suitable chemical composition and optimum thermal processing. The PM process tends to improve surface stability of tools during exposure to thermal stress and to achieve better mechanical properties compared to the conventional HSS [1].

The lifetime of tools is directly related to their surface wear, development of fatigue cracks and corrosion. These effects manifest themselves first on the surface of tools and because of that it is necessary to influence the mechanical and structural properties exactly in this zone. To resolve this problem it is necessary to study the complex of physical and chemical processes on the surface of tools.

The tools manufactured from PM steels have to be processed thermally before their use. Quenching and tempering are generally used to reach suitable hardness for the direct use. If further improvement of some properties of tools appears necessary, particularly regarding their surface characteristics, various forms of post-thermal treatment have been used, such as plasma nitriding, coating by various PVD methods, or combination of these two methods termed duplex coating [2, 3].

The tools produced from PM steel Vanadis 30 were treated by pulse plasma nitriding at selected temperatures and time and the optimum nitriding parameters were determined on the basis of evaluation of microhardness of the layer produced by nitriding on specimen cross-sections. Within the subsequent surface treatment, the material Vanadis 30 was PVD-coated by an ARC evaporation method (cathodic arc) producing TiN and TiAlN layers.

PVD-coating., i.e. depositing of thin, hard, abrasion-resistant coats to finished materials, ensures high hardness, decreases friction coefficient, secures high resistance to adhesive and abrasive wear and imparts high chemical stability [4, 5].

The aim of the paper was to point to some processes that take place during plasma nitriding and coating of the PM steel–Vanadis 30–1.13% C, 6.3% W, 4.2% Cr, 3.0% 1 V, 5.0% Mo, 8.4% Co). The properties of the layers produced by plasma nitriding fulfil all expectations, for example increased cutting life of tools made from high speed steels, increased surface hardness and decreased coefficient of friction.

The specimens obtained were evaluated for the hardness of nitrided layers, microstructure, surface composition by EDX-analysis, hardness of coats at 500 g loading and geometry of indentations, bending strength and the cutting properties.

The PM material was produced by rapid solidification (RS), compacted by hot isostatic pressing (HIP) and heat treated (HT) under optimum conditions. The surface treatment included plasma nitriding at 500 and 530°C and holding times 60 and 120 min using RÜBIG-PLASNIT equipment and coating by the PVD-method with TiN and TiAlN layers [6].

The microstructure of the nitrided material after etching (Fig. 1) was observed on cross-sections using light microscopy and the phase analysis was carried out by an X-ray analyser. The matrix consisted of fine, uniformly distributed carbide phases and tempered martensite. After etching, the nitrided layer differs from the matrix by darker colouring due to more intensive etching of the developed nitrides (Fig. 1). The X-ray analysis of the matrix allowed us to identify carbid phases of the following types: MC (V), M_6C (Fe,W), M_7C_3(Fe,Cr). In the zone of nitrided layers we identified phases of the type of Fe_4N, VN and various non-stoichiometric nitrides of V, Mo and Cr. Saturation of the surface layer with nitrogen and redistribution of carbon was reflected in the microhardness and surface hardness.

Fig. 2 shows microhardness values measured in the direction from the nitrided surface towards the matrix for individual processes with varying temperature and time. The microhardness HV0.05 in the nitrided layer of the material reached approx. 1516 while its surface hardness was 1196 HV10. The hardness decreased towards the core of specimens and in the depth of about 50 μm reached the values typical of the basic material.

Test rods prepared from the material Vanadis 30 were coated by the PVD-method employing ARC evaporation (cathodic arc) which allowed us to deposit 2 μm thick TiN and TiAlN layers at 530°C and process time 20 min. The coating layer was analysed under a light microscope Neophot 21, scanning electron microscope BS 340 with by EDX-analysis and its HV0.5 hardness was determined by a microhardness meter manufactured by Leco. The EDX-analysis of coats deposited to the experimental specimens (Fig. 3) confirmed composition of the respective coats.

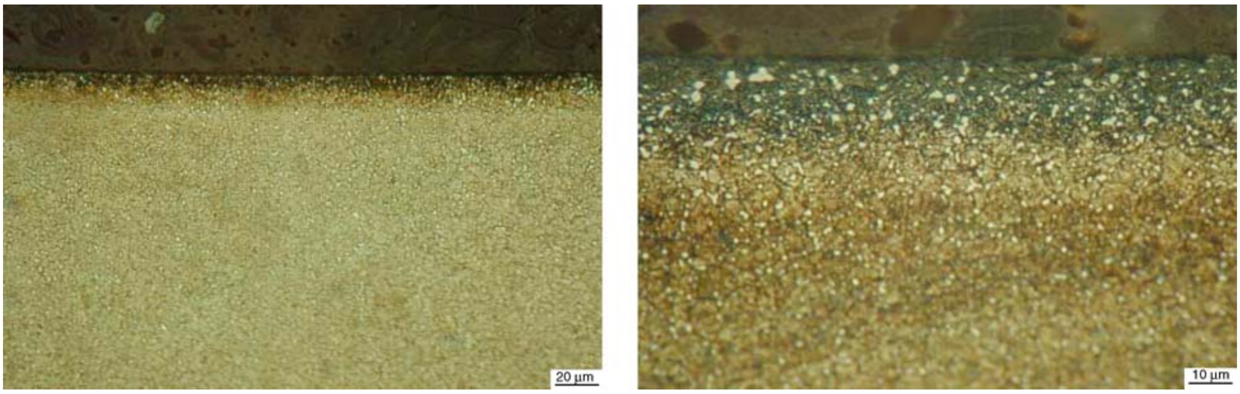

Figure 1 The microstructure of material Vanadis 30, produced at 530°C/120 min, observed in specimen cross-section (left) and its detail (right).

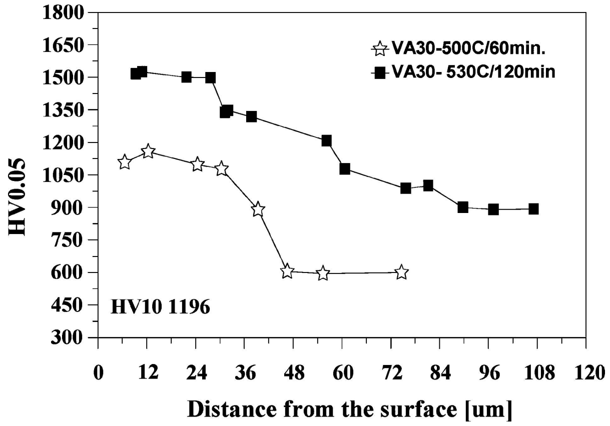

Figure 2 Microhardness values in dependence on the depth below the surface.

Microhardness is one of the basic characteristics determining mechanical properties of a system. Measurements of microhardness provide information about elastic and plastic behaviour of the material on a local volume. The HV0.5 hardness of the TiN and TiAlN layers reached approx. 1380 and 1460, showed no marked variations, which indicates uniformity of the coat deposited on the specimens. Fig. 4 shows the morphology of indentation impression in the TiN layer at 500 g load. The edges of the indentation plan are non-linear. The shape of the indentation plan is related to high hardness of the coat and penetration of the indenter is associated with rebounding due to elastic properties of the coat [7].

Test rods were used to carry out the three-point bending strength test. The Fig. 5 which shows the bending strength values R_{po} indicates an increase of 20 to 30% in strength for the material Vanadis 30 coated with TiN and TiAlN in comparison with materials after heat treatment as it is explained in detail in [8].

Fig. 6 shows the fracture surface of a TiN-coated rod. The fracture acquires mostly a quasi-cleavage shape with regions of plastic fracture. The proportion of plastic fracture is related to more homogeneous distribution of primary carbides.

Cutting tools, the so-called cutting tips, made from steel Vanadis 30 were subjected to short-term cutting test, i.e. cutting edge wear according to ISO 3685-1977 using steel (ISO 683/1-87 or SN 41 2050) as the machined material. A decrease in the cutting depth by more than 20% or complete loss of cutting ability was used as a criterion of wear [9]. Evaluation of the cutting properties from the point of view of reaching the highest cutting speeds and comparison with the material produced by conventional melt metallurgy (MM) showed almost 60% increase in the critical wear of the cutting tip in favour of the coated material Vanadis 30 (Fig. 7).

The differences in mechanical and surface properties observed can be explained by different content of alloying additions in the solid solution

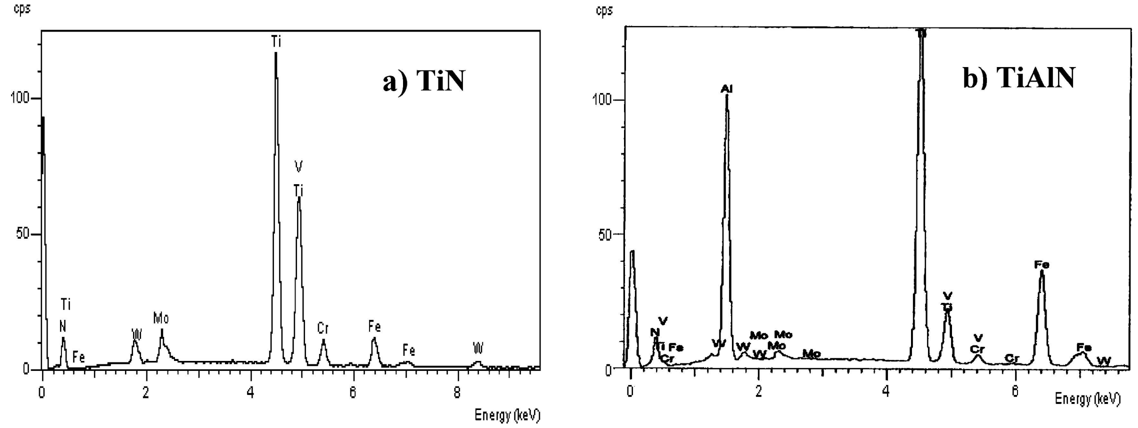

Figure 3 EDX-analysis of TiN and TiAlN coats.

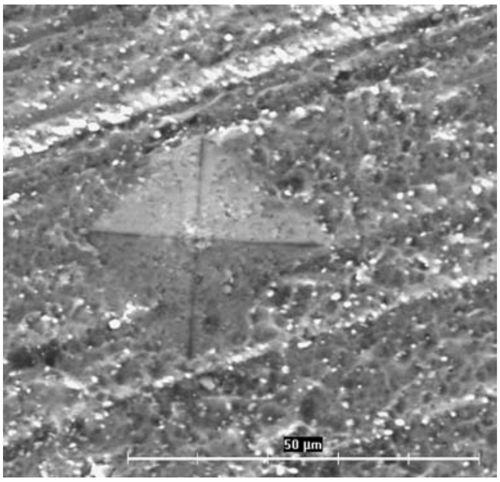

Figure 4 Plan of indentation produced in the TiN layer.

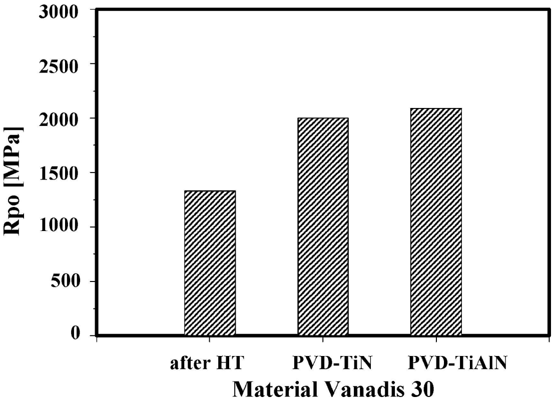

Figure 5 Bending strength (R_{po}) values of the test specimens after heat treatment and PVD-coating with TiN and TiAlN layers.

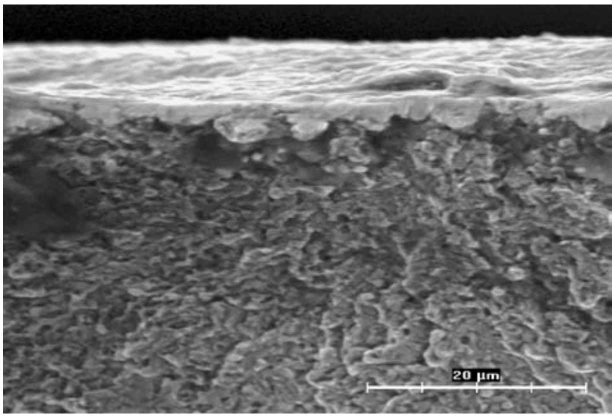

Figure 6 Fracture surface of TiN coat/substrate subjected to strength testing.

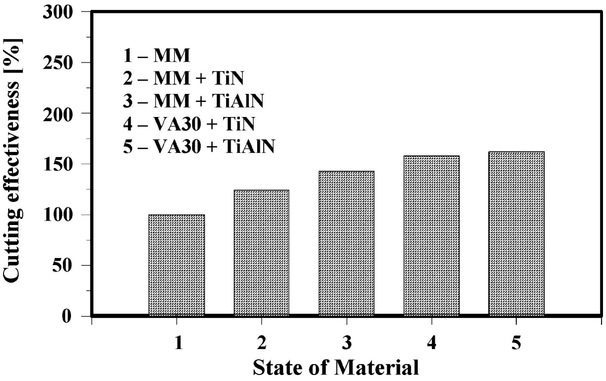

Figure 7 Cutting effectiveness of PM and MM materials (critical wear of the cutting edge).

and thermal-temporal parameters of the process and therefore also the capability of materials to produce special nitrides.

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