Characterization of sputtered laboratory scale V-Al-C-N hard coatings and industrial scale-up for deposition on segmented forming tools for the automotive industry

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Abstract. An emerging new approach is the design of carbon-based nanostructured composite coatings being composed of nanocrystalline metastable hard phases homogeneously dispersed in an amorphous carbon matrix or covered by an amorphous carbon grain boundary phase. Such coatings could be used to locally tailor the friction coefficient of forming tools in order to optimize the steel sheet forming process, to increase the manufacture accuracy, to reduce the error rates and to increase the tool service life as planned in the related publicly funded project IMAUF (‘‘Innovative methods for the design of forming tools in the automotive industry’’). Nanocrystalline quaternary V-AI-C-N hard coatings were deposited by reactive r.f.-magnetron sputtering in Ar/CH_4 plasma on a laboratory scale Leybold Z550 machine using a combinatorial materials science approach. In each experiment, six coatings of different composition and/or microstructure were obtained simultaneously by placing six substrates in individual positions relative to a segmented target, composed of ceramic VC and AlN half plates. The CH_4 flow rate was systematically varied up to CH_4 volume fractions of 8 % in the process gas. The chemical composition of the coatings was determined by electron microprobe analysis and the topography, crystal structure and microstructure were characterized by atomic force microscopy, X-ray diffraction, scanning as well as transmission electron microscopy. By using nanoindentation and ball-on-disk tribometer tests against 100Cr6 steel balls the correlation with the mechanical and the tribological properties was investigated. Significant changes in the coatings topography, microstructure and in the related mechanical and tribological properties were observed both as a function of the sample position and of the carbon content. In particular, a wide range variation of the friction coefficient (0.15-0.45, s. Fig. 1) of the hardness (15-35 GPa) and of the reduced elastic modulus (120-600 GPa) was achieved and correlated with constitution, microstructure and effective wear mechanisms. After the successful development of V-Al-C-N coatings with adjustable local friction coefficient on flat substrates on the laboratory scale the processes have been scaled up to an industrial-scale CemeCon CC800/8 machine by using graphite and VAl_{20}-targets (metallic V target with 20 Al-plugs). Both non-reactive and reactive sputtering in Ar/CH_4 atmosphere has been applied in order to deposit the coatings on Si (100) substrates and polished 1.2379 steel substrates. After a thorough characterization and optimization the coatings have been deposited onto model forming tools from ThyssenKrupp Steel Europe AG and segmented industrial forming tools from Volkswagen AG. These OEM’s will perform model and production tests in order to validate the approach. The next step would be to develop software that can predict the optimal local variation of the friction coefficient, which could be realized afterwards by depositing the novel V-Al-C-N coatings.

Keywords: quaternary hard coatings, forming tools, scale-up

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Key figure

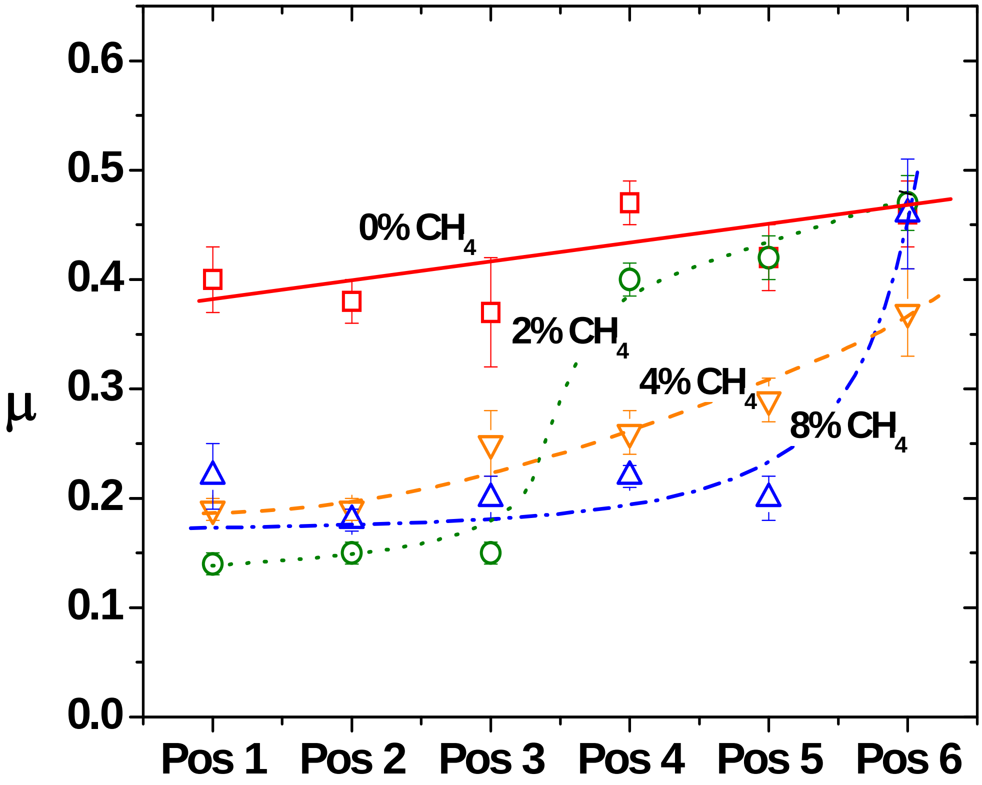

Fig.1 Dependence of the friction coefficient of V-Al-C-N coatings on sample position as a function of CH_4 content.