

Application of Innovative PVD Coating to Stamping Dies for Processing Ultra-High Tensile Strength Steel Sheets

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ABSTRACT

A novel nitride based coating system (BELCOAT-SS) was developed for the stamping dies for ultra high-tensile strength steel. It is characterized by an excellent wear resistance and low deposition temperature compare to the conventional diffusion coatings such as VC or TiC. High temperature wear test indicate that the wear rate of the new coating is 2 to 10 lower than conventional diffusion coatings. The result of stamping test using ultra-high tensile steel sheets indicate that life time of the die can be prolonged by the factor of at least 5 to 10 times.

INTRODUCTION

As the fuel economy and amount of CO₂ emission per km becomes serious concerns for automobiles, while maintaining same quality of safety and comfort, reduction of the vehicle weight is mandatory to meet these requirements. Use of high-tensile strength steel is reliable, proven and cost effective choice for weight reduction, while recent reports indicate that lifetime of stamping dies and trimming blades can be significantly shortened when ultra high-tensile strength steel sheets is formed. To improve the lifetime of such dies,

conventional surface treatment is thermal diffusion process for forming hard carbide coating such as VC and TiC [1]. While these carbide diffusion coatings show relatively good wear resistance at moderate stamping condition, it becomes clearer that durability of such carbide coating is not satisfactory anymore when ultra high-tensile steel is formed under minimum lubrication. Another drawback of such diffusion process is the process temperature, which is usually close to 1000 °C. Conventional cold working die steels, such as D2, are tend to be thermally deformed by such high process temperature and this can result change in the dimension of the stamping die itself as well as deviation of the final stamped products. In this work, a novel nitride based coating system based on physical vapor deposition was developed for the stamping dies for ultra high-tensile strength steel and property and its application to actual stamping dies is reported.

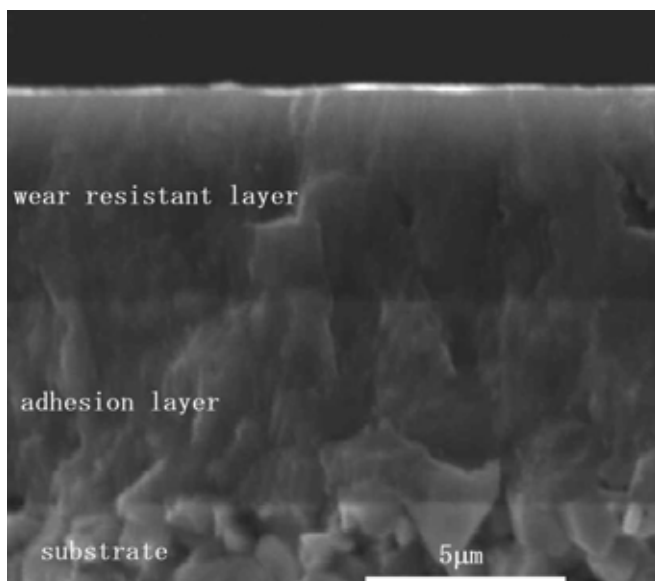


Fig.1 Typical fractured cross-section of BELCOAT-SS

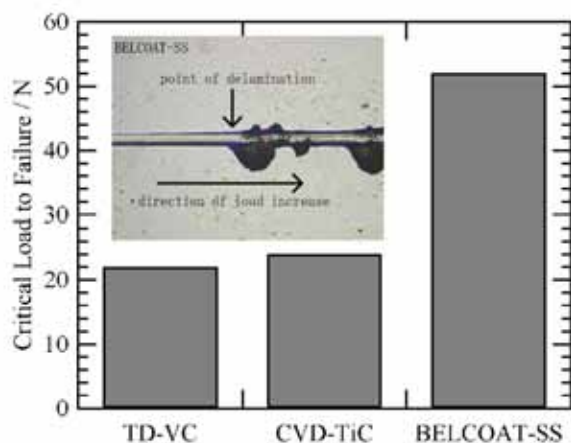


Fig.2 Comparison of adhesion strength of coatings used for stamping dies, TD-VC, CVD-TiC and BELCOAT-SS.

RESULT AND DISCUSSION

All PVD coatings are deposited by AIP (Arc Ion Plating) process. AIP is one type of PVD (Physical vapor deposition) process which utilizes high current-low voltage vacuum arc discharge to evaporate solid target in reactive environment (in this work N_2 gas was used as reactive gas) for forming hard nitride coatings. AIP method is characterized by high deposition rate and high degree of ionization of evaporated species [2]. High deposition rate is favorable for industrial applications and high degree of ionization ratio results a dense and wear resistant coating. AIP process is nowadays widely used for many industrial wear resistant coatings such as cutting tools [3]. Figure 1 shows a SEM image of typical fractured cross-section of the developed coating (BELCOAT-SS). The coating has two layered structure and each individual layer has a function. The outer layer acts as a wear resistant layer and it is characterized by high hardness (35 GPa) and high oxidation resistance.

However it has relatively high Young's modulus of 400 GPa and under the external stress, elastic deformation behavior is quite different from steel based substrate such as D2 steel. Hence just depositing the wear resistant layer directly on the steel based substrate likely to induce a large shear stress at the interface and causes delamination of the coating. The inner layer on the substrate is relatively soft (approx. 15 GPa) and has a Young's modulus of about 250 GPa, which is close to ones of common alloyed steel materials of 210 GPa. This inner layer acts as a buffer layer to avoid the formation of large shear stress at the interface.

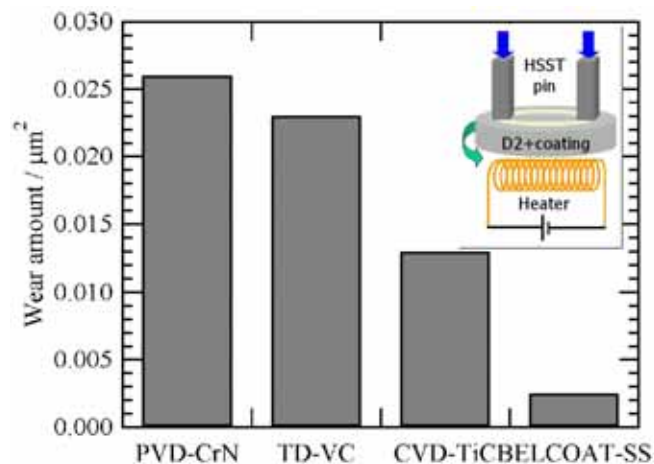


Fig.3 Result of high temperature wear test of BELCOAT-SS and other conventional coatings used for stamping dies

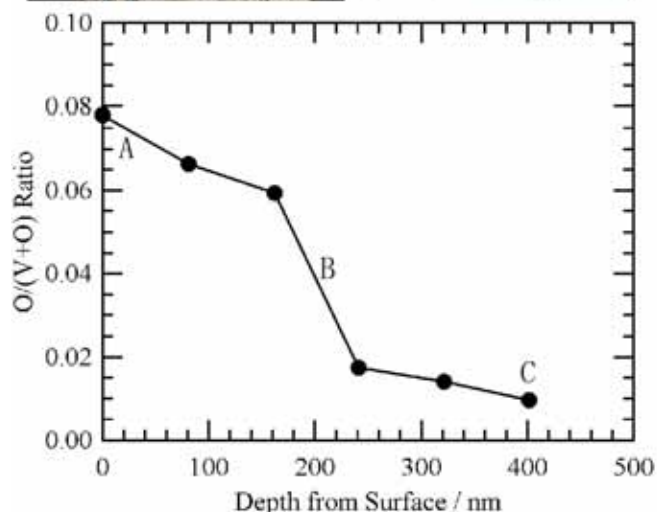
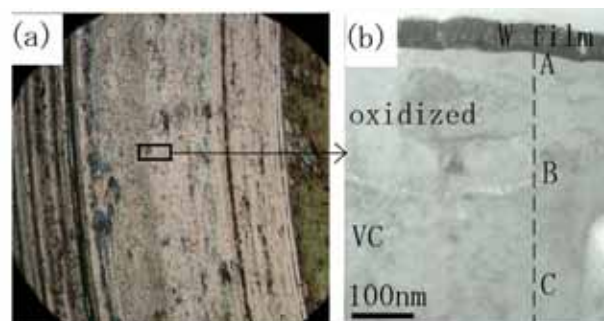


Fig.4 (a) Surface optical image, (b) cross-sectional TEM image and (c) cross sectional O distribution of wear track of TD-VC after the sliding test.