Tool Wear of (Al,Cr,W)/(Al,Cr,W,Si)-Based-Coated Cemented Carbide Tools in Cutting of Hardened Steel

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INTRODUCTION

The hardened steel AISI D2 has high hardness, strength and wear resistance. In cutting hardened steel AISI D2, the tool wear increases. Polycrystalline Cubic Boron Nitride (PCBN) is generally used as the cutting tool material in cutting hardened steel. Linhu Tang et al. investigated the wear performance and mechanisms of the PCBN tool in dry hard turning of AISI D2 hardened steel at various hardness levels (40-60 ± 1 HRC) [1]. However, in milling, a major tool failure of c-BN readily occurs by fracture because c-BN has poor fracture toughness. Coated cemented carbide tools, which have good fracture toughness and wear resistance, seem to be effective cutting tool materials. TiN, Ti(C,N) and (Ti,Al)N are generally used for the coating film [2].

Cr-Al-N is expected to play a very important role in the future of Surface Engineering, manufacturing industry and in preventing wear of critical components in a wide range of applications [3]. When investigating the potentials of newly developed (Cr,Al)N coatings compared to uncoated tools, CrxAlyN coatings with different chromium to aluminum contents were deposited onto indexed carbide inserts. In order to find improved coatings for dry machining operations both tribological and wear tests were performed [4].

The machining performance of AlCrN and AlTiN coated cemented carbide inserts were investigated during end milling of MDN 250 maraging steel. As a result, the AlCrN coating had better wear resistance and machining performance compared to the AlTiN coating [5]. The performance of mono-layered AlCrN and multi-layered AlTiN PVD coatings on mixed alumina inserts were investigated in the turning of hardened AISI 52100 steel. As a result, the AlCrN coating exhibited superior machining behavior at higher cutting speeds indicating the suitability of the coating at elevated machining speeds [6]. Tadahiro Wada et al. reported that an (Al,Cr)N coated cemented carbide is an effective tool material for cutting sintered steel [7] and hardened sintered steel [8].

The incorporation of Si [9], Y [9], W [10], Fe [11], Zr [12] or Ti [13] into (Cr, Al) N was reported. In cutting hardened steel [14] or sintered steel [15], the wear resistance of (Al, Cr, W) N coated tools with W added to (Al, Cr) N coated tools was improved. The wear resistance of (Al, Cr, W)(C,N) coated tools with C added to (Al,Cr,W) N coated tools was improved [14]-[17]. Furthermore, the wear resistance of (Al, Cr, W,Si)N coated tools with Si added to (Al, Cr,W) N coated tools was improved [18].

On the other hand, gradient and multilayered coatings composed of different nitride layers show superior mechanical strength, such as hardness and wear resistance, as compared to mono-layered coatings due to their specific interfaces [19]. For this reason, many studies on multilayer coatings have been conducted [19]-[24].

In addition, many studies dealing with multi-layer (Al,Cr,W)/(Al,Cr,W,Si) coating films handled in this study have been reported [25]-[28]. As a result of comprehensive judgment of the study results of Tadahiro Wada et al., the following two points were clarified. (1) The wear resistance of PVD-coated tools was improved by adding W and Si to (Al, Cr) targets. (2) Multi-layer coating films have better wear resistance than single-layer coating film. However, the effect of components (Al, Cr, W, Si) on tool wear have not been clarified.

In this study, two types of aluminum/chromium/tungsten/silicon target cathode materials with varying constituents were used to improve the wear resistance of coated cutting tools in cutting hardened steel. For comparison, a cathode material of one type of aluminum/chromium/tungsten target was also used. In addition, multi-layer coating materials were used, including combinations of aluminum/chromium/tungsten/silicon based coating films and aluminum/chromium/tungsten based coating films. Using these three types of targets, the hardened steel was cut with a cutting tool in which cemented carbide K10 substrate metal was PVD coated and the tool wear was examined.

Conclusions

In this study, a carbonitride coating film was deposited on a cemented carbide ISO K10 using three different Al-Cr-W-Si targets. The coating film structure consisted of mono-layer film and multi-layer films. The hardened steel ASTM D2 was cut with five types of coated cemented carbide tools. The tool wear of the coated tools was experimentally investigated.

The following results were obtained:

(1) Comparing the wear progress of the (Al53,Cr23,W14,Si10)(C,N)- and (Al58,Cr25,W7,Si10)(C,N)-coated tool, the wear progress of the (Al58,Cr25,W7,Si10)(C,N)-coated tool is slightly slower than that of the (Al53,Cr23,W14,Si10)(C,N)-coated tool.

(2) Comparing the wear progress of the (Al60,Cr25,W15)(C,N)/(Al53,Cr23,W14,Si10)(C,N)- and the (Al53,Cr23,W14,Si10)(C,N)/(Al58,Cr25,W7,Si10)(C,N)-coated tool, the wear progress of the (Al53,Cr23,W14,Si10)(C,N)/(Al58,Cr25,W7,Si10)(C,N)-coated tool is slightly slower than that of the (Al60,Cr25,W15)(C,N)/(Al53,Cr23,W14,Si10)(C,N)-coated tool.

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