ARTICLE IN PRESS

Ceramics International xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Ceramics International

journal homepage: www.elsevier.com/locate/ceramint

Frictional behavior and wear resistance performance of gradient cermet composite tool materials sliding against hard materials

Wenbin Ji[a,b], Bin Zou[a,b,*], Yanan Liu[a,b], Changming Huang[a,b], Peng Guo[a,b]

[a] *Centre for Advanced Jet Engineering Technologies (CaJET), School of Mechanical Engineering, Shandong University, 17923 Jing Shi Road, Jinan 250061, PR China*

[b] *Key Laboratory of High Efficiency and Clean Mechanical Manufacture, Shandong University, Ministry of Education, PR China*

ARTICLE INFO

Keywords:
Gradient cermet
Wear resistance
Friction coefficient
Wear rate

ABSTRACT

Gradient cermet composites possessing high surface hardness, flexural strength and interface bonding strength were fabricated using vacuum hot-pressing sintering. Ball-on-disk tests were performed to investigate the tribological properties of the gradient cermet composites against 440 C stainless steel, Al_2O_3 and Si_3N_4 balls at different sliding speed and load in comparison with traditional Ti(C,N) cermets. The tribological behavior was characterized in terms of friction coefficient and wear rate. The results showed that friction coefficient was significantly dependent on the sliding speed and load when sliding against Al_2O_3 and Si_3N_4. However, there was no obvious relation between them during sliding against 440 C stainless steel due to the formation of metal adhesive layer. Gradient cermet composites exhibited a higher friction coefficient but lower wear rate than traditional Ti(C,N) cermets. The main wear mechanism of gradient cermet composites was adhesion wear during sliding against 440 C stainless steel, while abrasion wear was the predominant mechanism during sliding against Al_2O_3 and Si_3N_4. It was expected that gradient cermet composites would be excellent candidates for cutting tool materials.

1. Introduction

Ti(C,N) and TiB_2-based cermet composites are extensively used in the manufacture of cutting tools and wear resistance parts due to their high hardness, high melting point and high wear resistance [1,2]. They can be applied under various conditions by improving the properties. As a candidate for cutting tool, it has to withstand the abrasion, chemical reaction, plastic deformation, and thermal shock in machining of metal. And the lifetime of cutting tools largely depends on the wear resistance. Many studies [3,4] have focused on the tribological behavior and wear mechanism of cermet composites used as wear-resistant part.

Friction and wear performances of cermet composites closely depend on various factors, e.g., crystal structure, compositions, type of couple material and experimental conditions (sliding speed, load and environment). At 600 °C, the dominant wear mechanism of Ti(C,N)-based cermets was reported to be tribo-oxidation together with the formation and destruction of tribo-layer [4]. Canteli et al. [5] developed a new Ti(C,N) cermet where high-speed steel was used as matrix with hard phase Ti(C,N) and reported a reasonable wear resistance during dry cutting operations and increased lifetime. Klaasen et al. [6] investigated the adhesive wear performance of TiC-based cermet by a special metal cutting method and demonstrated that the surface failure during a combined process (extraction, microcutting) started preferably from the binder which was preceded by the plastic strain. Kumar et al. [7] reported the friction and wear properties of TiCN–Ni cermets, containing 10 wt% of four different secondary carbides (WC, NbC, TaC or HfC) at fretting contacts against bearing grade steel at 550 °C. No significant variation was reported in steady state coefficient of friction (0.43–0.46), and the main wear mechanisms of cermets were explained by the stability of the tribochemical layer as well as mutual transfer of materials at the tribological interface. Vikas et al. [8] investigated the tribological characteristics of conventionally sintered TiCN-WC-Ni/Co cermets against cemented carbide and hard oxide debris particles were responsible for high friction coefficient at low load, whereas their compaction resulted in the tribo-layer formation at high load. In addition, material transfer from cemented carbide ball to the cermet disk enhanced at high load due to increased contact temperature. Ball-on-disk wear test is usually used to investigate wear resistance of cutting tool materials. From the viewpoint of the disk, ball-on-disk wear test is considered as a discontinuous contact with the counter body. The contact frequency, defined by the rotation frequency of the

* Corresponding author at: Centre for Advanced Jet Engineering Technologies (CaJET), School of Mechanical Engineering, Shandong University, 17923 Jing Shi Road, Jinan 250061, PR China.
E-mail address: zou20011110@163.com (B. Zou).

http://dx.doi.org/10.1016/j.ceramint.2017.03.096
Received 14 February 2017; Received in revised form 12 March 2017; Accepted 16 March 2017
0272-8842/

Please cite this article as: Ji, W., Ceramics International (2017), http://dx.doi.org/10.1016/j.ceramint.2017.03.096

Table 1
Composition of GC and TC cermet composites.

Symbols	Ti (C_7,N_3)	TB_2-TiC (7:3)	VC	Mo	Ni	Co	Remarks
GC		86	4	4	6		Surface layer
	84			4	12		Substrate
TC	88			4	3.2	4.8	Homogeneous

disk, is the most influencing parameter on the wear rate of disks when tested in a pin/ball on disk configuration. Ruiz-Andres et al. [9] found that the disk behaves as if it were subjected to a continuous sliding contact when the contact frequencies were above 7 Hz.

Our group pioneered in the field of design and preparation of new types of gradient cermet composites [10,11]. Prior to sintering, the gradient cermet composites are comprised of a TiB_2-TiC cermet surface layer and Ti(C,N)-based cermet substrate. During sintering, a new subsurface layer enriched in metal binder is formed by a self-diffusion of the elements. Compared to traditional Ti(C,N)-based cermet composites, it is found that the newly fabricated gradient cermet composites showed gradient properties, i.e., high hardness and good wear resistance on the surface layer, high fracture toughness on the subsurface layer, and high flexural strength on the substrate. The interface bonding strength of the subsurface layer increases which impedes delamination between the surface layer and substrate. The values of flexural strength, substrate hardness, surface hardness and fracture toughness of gradient cermet composites are 1520 ± 66 MPa, 21.63 ± 0.51 GPa, 27.28 ± 0.55 GPa and 7.04 ± 0.55 MPa $m^{1/2}$, respectively.

The objective of the present work is to investigate the frictional behavior and wear resistance performance of gradient cermets in contrast to the traditional Ti(C,N) cermets. The chemistry components and mechanical properties (flexural strength, hardness and fracture toughness) of the traditional Ti(C,N) cermets in our work are similar with CX50 tool materials made by DIJET Inc., Japan. The effects of sliding speed and load on friction coefficient and wear rate were investigated. In addition, the worn surfaces of gradient cermets were studied and the wear mechanisms were discussed. These results will be useful understanding the wear mechanisms of gradient cermet composites in different conditions, spreading the application of gradient cermet composites and providing the guidelines for selecting the appropriate tribological system contact pairs.

2. Materials and experimental work

2.1. Materials

Ti(C,N)-based cermet composites were named after TC in this work, while the gradient cermet composites were named after GC. TC was composed of Ti(C,N), Mo, Ni and Co, while GC was composed of TiB_2-TiC surface layer and Ti(C,N) substrate. The compositions of these two cermet composites are listed in Table 1. The cermet composites were hot-pressed in a vacuum sintering furnace. Details of preparation procedures were described elsewhere [10,12]. Fig. 1 shows the SEM micrographs of polished surface of the composites. The gradient cermet composite with 200 μm surface layer and 20 μm subsurface layer exhibited a gradient structure zone, as shown in Fig. 1(a). The microstructure and mechanical properties of GC presented a gradient change. The surface layer exhibited a higher hardness, the substrate showed high flexural strength and the subsurface layer presented a high toughness and better interfacial bonding strength. It can be seen that the microstructure of TC composites was homogeneous and the average grain size was less than 1 μm, as shown in Fig. 1(b).

2.2. Sliding wear experiments

Dry sliding friction and wear tests were conducted on a tribo-tester

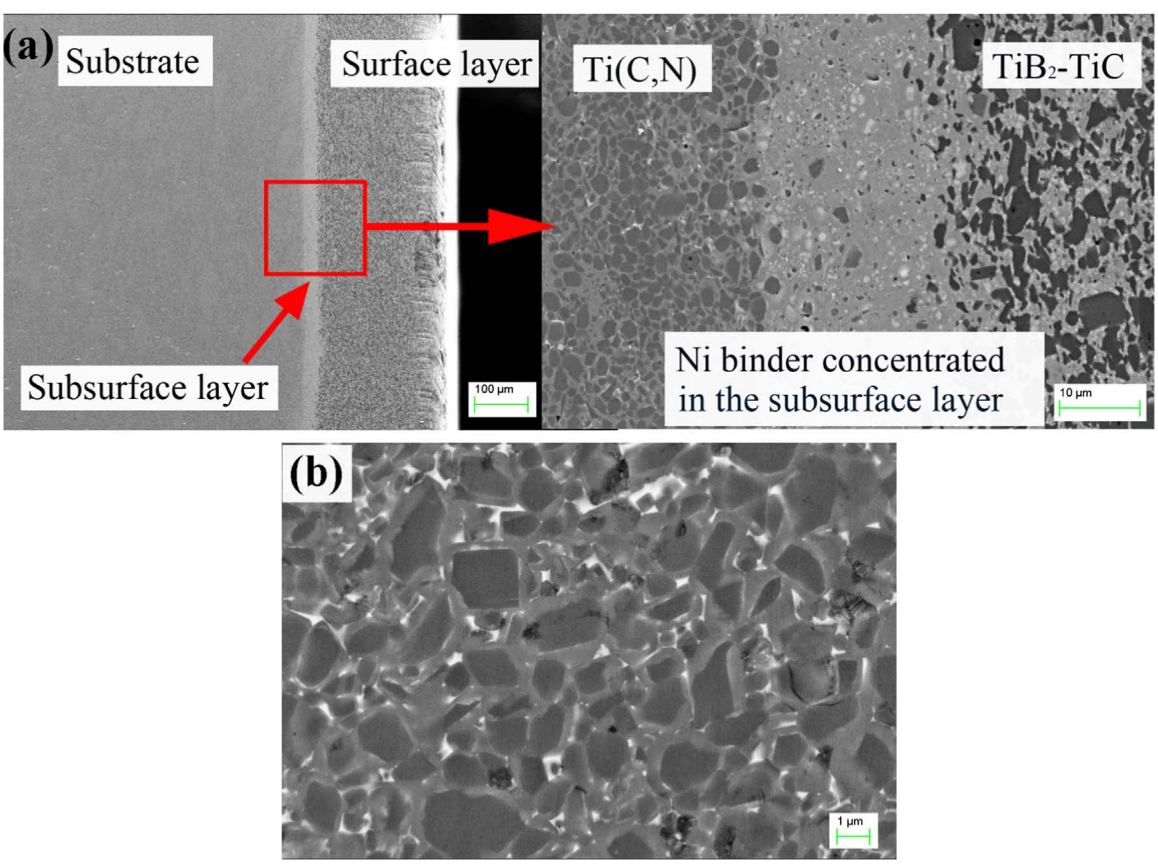

Fig. 1. SEM micrographs of polished surface of (a) Gradient cermet composites (GC), (b) Ti(C, N)-based cermet composites (TC).