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ScienceDirect

Wear 263 (2007) 905–911

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Erosion and abrasion of chromium carbide based cermets produced by different methods

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Received 15 August 2006; received in revised form 18 December 2006; accepted 19 December 2006
Available online 23 March 2007

Abstract

This paper is on comparison of the abrasive and erosive wear resistance of chromium carbide based and nickel bonded cermets prepared by two different methods: conventional powder metallurgy sintering and the new developed one—reactive carburizing sintering. The nickel content was varied at the weight percents of 10, 20 and 30%. Results indicate that sintering process and microstructural parameters influence materials resistance to erosion and abrasion. It is shown, that cermets produced by reactive carburizing sintering have some advantage in erosion and abrasion resistance over conventionally produced ones.

Keywords: Chromium carbide based cermets; Microstructure; Erosive wear; Abrasive wear; Reactive sintering

1. Introduction

Cermets are ceramic–metal composites which are made of ceramic phase and metal binder phase. Cermets are designed to have the optimal properties of both a ceramic, such as high temperature stability and hardness, and those of a metal, such as the ability to undergo plastic deformation. Combination of such important properties as high hardness, good strength, medium fracture toughness and excellent oxidation resistance results in growing interest to Cr_3C_2 based cermets. The presence of metallic phase lowers the sintering temperatures of the ceramics to the levels at which full densification can be readily achieved by forming liquid phase.

Primarily covalent bonding exhibited by carbides provides many of the key properties required for advanced applications, including high stiffness and high specific strength at elevated temperatures. However, covalent bonding makes these compounds brittle at ambient temperature. As a result these materials have a low damage tolerance. Despite of limitations, refractory chromium carbide based composites have a wide use in industry. The controlled modification of hard particle–binder composition, properties (particle size, alloying, etc.) and production technology gives opportunities for applications in different areas that involve tribo-corrosion processes. Structural applications include bearings, seals, valve seats and orifices.

The method of fabrication may influence the properties and therefore reliability of cermets to a great extent. Wear resistance of composites is not strictly a material property, but mostly depends on microstructural features that determine the materials response to the specific stress state imposed by aggressive media. In this study, the erosive and abrasive behaviors of the Cr_3C_2–Ni cermets produced by different methods and possessing the similar composition have been evaluated. This topic has a long tradition of study but wear mechanisms and models of erosion and abrasion of materials like cermets are not yet fully assessed.

It is well known that microstructure plays the most important role in the tribological performance of multiphase materials [1–3]. It is generally agreed that carbide particle size and porosity as well as binder content and composition have to be taken into consideration when wear resistance is discussed [1–5]. The method of materials manufacturing may determine the final microstructure and, therefore, a behavior of cermet subjected to erosive and/or abrasive wear.

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doi:10.1016/j.wear.2006.12.027

Table 1
Mechanical properties of cermets

Grade	Chromium carbides content (wt%)	Density ($g\,cm^{-3}$)	HV_{10}	TRS (MPa)	K_{IC} ($MPa\,m^{0.5}$)	Method of production
C1	90	6.9	1420	730	9.5	Conventional PM
C2	80	7.1	1140	1110	13.8	Conventional PM
C3	70	7.3	920	1200	18	Conventional PM
C4	90	6.9	1450	960	9.8	Reactive sintering
C5	80	7.05	1270	1100	14.2	Reactive sintering
C6	70	7.25	990	1260	18.5	Reactive sintering

The present study is undertaken to examine the microstructure, mechanisms of material removal and erosive and abrasive resistance of chromium carbide based and nickel bonded cermets produced by method of reaction sintering in so far as the Cr_3C_2–Ni composite has been sintered by the mentioned way for the first time.

2. Materials processing and properties

Chromium carbide powder for the cermet sintering can be produced by two different techniques. It may be direct or indirect synthesis [6,7]. Cr_3C_2–Ni alloys are usually formed by standard powder metallurgy technology including processes of cold pressing and sintering [8]. The relatively new method of high-energy milling or reactive sintering has cleared the way to obtain fine grained and low porous cermets [9].

The two ways of cermets preparing produced two different materials. The binder metal content was of 10, 20 and 30 wt%. The purpose in using various amounts of nickel is to find material exhibiting the best resistance to erosive and/or abrasive wear taking into account that increase in binder metal content results in decrease in material hardness while increase in fracture toughness (Table 1).

2.1. Materials prepared by conventional powder metallurgy technique

The first group of materials was produced by conventional powder metallurgy (PM) routine. Powders of Cr_3C_2 with average grain size of 3.4 μm and elemental nickel were mixed together, cold isostatically pressed at 80 MPa into prismatic compacts. The green bodies were pre-sintered in a hydrogen atmosphere at 600° C for 30 min to reduce the oxides present on the surface of the particles. The samples were sintered in a programmable vacuum furnace at the sintering temperature in between 1220 °C for the cermet with binder content of 30 wt% and 1320 °C for the material with 10 wt% of Ni. Analysis of Cr–C–Ni phase diagram shows the cooperative eutectic crystallization of two-phase (Cr_3C_2)–(Ni) and three-phase (Cr_3C_2)–(Cr_7C_3)–(Ni) solutions at the sintering temperature [10]. Fig. 1a represents a microstructure of the cermet with a binder fraction of 20 wt%. In Fig. 1a, different grey color levels indicate Ni phase as the lightest area, Cr_3C_2 particles as the middle grey area, and Cr_7C_3 grains as the darkest area. The irregular shaped elongated carbide grains form a skeleton with increased rigidity. The dihedral angle, that represents the balance between interfacial energies, is large enough and the liquid spread over the solid surfaces is not sufficient. The adjacent grains may weld together and the resulting structure consists of connecting carbide particles with fractionated metallic phase. Voids indicate that densification is not complete and attribute to the partial wetting of the nickel binder on the carbide particles.

The mean grain size (Feret diameter) was measured with an image analysis system from the digital SEM micrographs as an average value of 5 fields to get the more reliable results. For each measurement at least 1000 particles were counted. The carbides particle size in cermets produced by conventional routine was

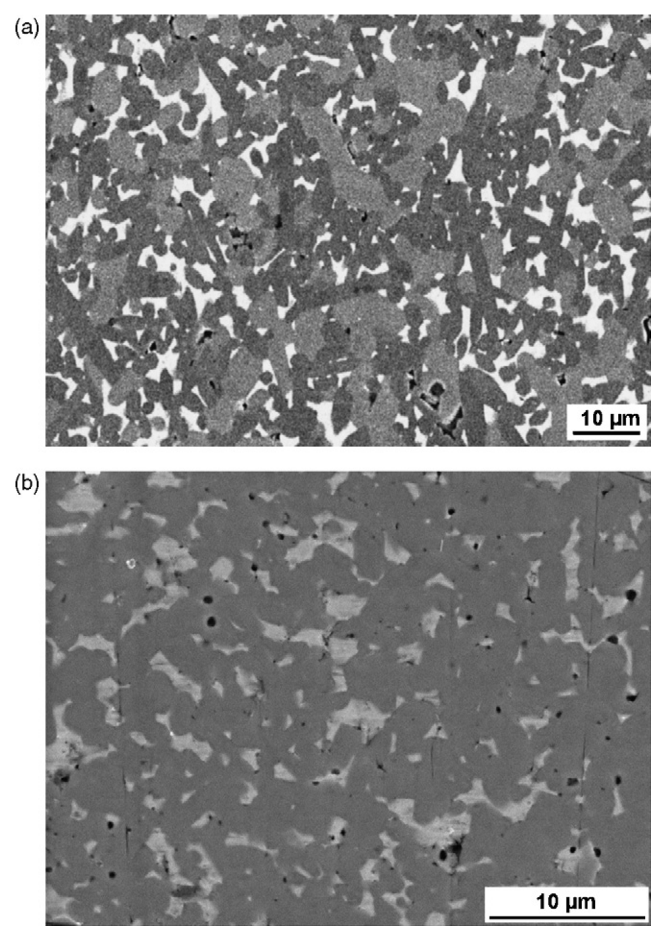

Fig. 1. Microstructure of (Cr_3C_2)–(Cr_7C_3)–(Ni) cermets produced: (a) by conventional PM technique; (b) reactive sintering at 1250 °C and during 60 min.