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Mechanical and tribological characteristics of tungsten cermet composites sintered with Co-based and zirconia mixed binders

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ABSTRACT

The influence of cobalt based and zirconia mixed binder additives on the mechanical properties and tribological characteristics of WC based spark plasma sintered cermet composites was investigated. Varied weight proportions of zirconia stabilized with yttria along with constant weights of 9Co/WC–4.5CO–2Cr–5Ni metallic binder were blended with WC, consolidated and sintered using spark plasma sintering process. The composites produced were characterized using SEM and XRD analyses, density measurements, mechanical properties and wear test evaluations. The results show that the use of the mixed binder additives did not significantly affect the densification process as relative densities above 92% (7.5% less than that achieved using only the Co based metallic binders) were achieved using SPS processing. However, the grain size was observed to increase with increase in zirconia content in the mixed bond composites, and the hardness values decreased with increase in zirconia content. The toughness and fracture toughness showed significant improvement with the addition of zirconia. Also the coefficient of friction for the mixed binder sintered composites were on the average lower than that of the cermet composites without zirconia. Pseudoplastic properties characterized by the presence of delaminations were the primary wear mechanism observed for the zirconia containing cermets; while pits and wear groove formations were observed in the cermets without zirconia.

1. Introduction

Tungsten cemented carbides such as WC–Co are normally selected for the design of hard components such as cutting tools, drill bits, and abrasives [1]. In order to work efficiently, the components are required to exhibit a good combination of mechanical, chemical and tribological properties to meet the extreme conditions of the service environments where they are typically utilized [2,3]. In mine exploration and exploitation activities, hard tools such as drilling and cutting tools are actively utilized. The geology of mine sites often results in the presence of certain aggressive ions in varied concentrations in mine environments [4]. Chlorides and sulphate ions present in most mine environments have been reported to result in lower service life and performance of hard material based mine equipment and tools [5]. Thus component selection for such environments where tribocorrosion susceptibility is potentially high requires critical appraisal to safeguard against in-service component failures. Components for harsh mine environments should be based on material selection criteria where property combinations of high wear, corrosion, oxidation and tribocorrosion resistance, thermal stability, and high fracture and shock resistance (toughness) are major considerations [6]. WC-metallic binder systems which are the most common form of cemented carbides do not satisfactorily meet these property requirements and performance mandate. Notably, their tendency to soften at high temperature, relative low oxidation and corrosion resistance, and relatively low fracture toughness highlights their limitations [6,7]. Resulting from these limitations, a number of works on improvement of properties of tungsten cemented carbide based cermets through compositional formulations and improved synthesis techniques have been reported [8,9].

Complete replacement of metallic binders with ceramic sinter additives for the sintering of tungsten carbide based cermets has been the most explored approach and reported to offer a lot of promise [9,10]. Zirconia which has been majorly explored as a ceramic sinter additive has the advantages of improving wear, toughness, hardness, high temperature and chemical stabilities of the cermets [11,12]. This naturally translates into improved mechanical, corrosion and tribological properties. However, the slower densification rates associated with the solid state sintering characterizing the use of ceramic binders have been a major constrain to the wide scale adoption of this approach [13]. Metallic binders are noted to undergo liquid phase sintering at relatively lower temperatures and offer excellent densification rates compared

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Table 1
Compositions and sample designations of WC based cermet composites produced.

Sample designation	Composition
A0	WC–9Co
A15	WC–9Co + 5%Y_2O_5 + 15% ZrO_2
A20	WC–9Co + 5%Y_2O_5 + 20% ZrO_2
A25	WC–9Co + 5%Y_2O_5 + 25% ZrO_2
B0	WC–4.5CO–2Cr–5Ni
B15	WC–4.5CO–2Cr–5Ni + 5%Y_2O_5 + 15% ZrO_2
B20	WC–4.5CO–2Cr–5Ni + 5%Y_2O_5 + 20% ZrO_2
B25	WC–4.5CO–2Cr–5Ni + 5%Y_2O_5 + 25% ZrO_2

to ceramic binders [14]. Studies in which metallic and ceramic binders are combined as mixed sinter additives for the development of tungsten cemented carbide based cermets appear to be the next in line for comprehensive evaluation. Presently, the use of mixed metallic and ceramic binders for sintering cermets is sparsely reported in literature.

The sintering characteristics, mechanical properties, and tribological behaviour of tungsten cemented carbide based cermets developed with the use of mixed proportions of Co-based metallic and zirconia ceramic binder additives are the thrust of this work. This study is motivated by the need to explore the possibility of harnessing the advantages of Co based metallic binders and yttria stabilized zirconia binders in the development of cemented carbides with improved mechanical and tribological properties suitable for mining applications.

2. Materials and methods

2.1. Materials and cermet composite production

The materials utilized for the composite production are high purity commercial grades of the following: tungsten carbide (WC), cobalt (Co), nickel (Ni), chromium (Cr), and yttria stabilized zirconia nano-powders.

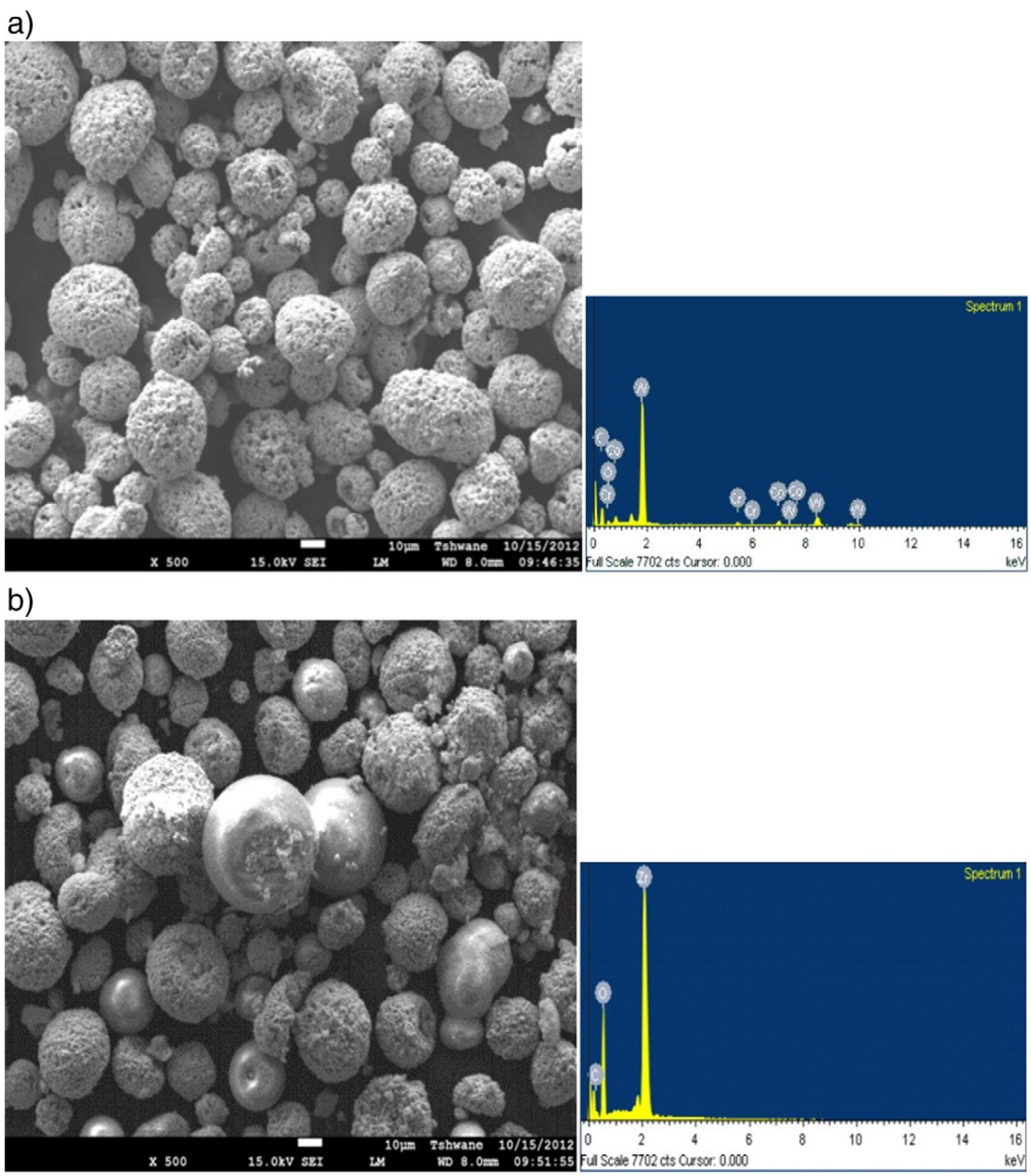

Fig. 1. Representative Secondary electron image (with EDS profile) showing powder morphology of (a) WC–9Co and (b) WC–9Co + 5%Y_2O_5 + 15% ZrO_2.