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Corrosion behaviors, mechanical properties and microstructure of the steel matrix composites fabricated by HP–HT method

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ABSTRACT

Steel-based composites with varying content of TiB_2 were manufactured by HP–HT process. The main objective of the study was to determine the effect of sintering conditions and TiB_2 content on the mechanical properties and corrosion behavior of steel–TiB_2 composites. The corrosion resistance of the composites was examined in H_2SO_4 solution using two measurement techniques. The mechanical properties were determined in a compression test allowing also for the effect of elevated temperatures (600 °C and 800 °C).

The results showed that both TiB_2 content and sintering temperature affected the properties tested. The highest compressive strength was obtained in the composites with 8 vol% TiB_2. The corrosion properties of composites showed only insignificant variations. The microstructure was characterized by a homogeneous distribution of the TiB_2 reinforcing phase.

1. Introduction

Austenitic steels are widely used in automotive, aerospace, marine, biomedical, and food industries. This wide range of applications is certainly due to their excellent properties, such as the high resistance to corrosion and abrasion, high resistance to oxidation at elevated temperatures and satisfactory strength [1–3]. Powder metallurgy creates opportunities for the manufacture of small parts with complex shapes. This brings savings in both materials and energy, and gives products characterized by high dimensional accuracy [4,5]. Sintering of steel by conventional methods is usually done under the conditions of relatively low temperature and pressure [6–8]. The resultant properties of sintered austenitic steel depend on the density and on the presence or absence of porosity. Therefore, the main problem in the conventional methods of sintering is open porosity, which considerably deteriorates the corrosion resistance. Open porosity increases the surface area of material exposed to the effect of corrosive environment. To improve the corrosion resistance of austenitic steel, the effect of various additives, including copper, tin, and other elements was investigated [9,10]. Another way to improve the corrosion resistance of steel is by adding the ceramic particles [11–13]. Steel-based composites reinforced with ceramic particles were tested not only for the corrosion resistance but also for the mechanical properties. One of the positive effects of the addition of ceramic particles to stainless steel was an obvious improvement of the wear resistance. Corrosion resistance was also improved [14–17].

Steel-based composites reinforced with ceramic particles form a group of materials characterized by attractive physical and mechanical properties. A lot of work was devoted to the sintering process of these materials [18–20]. As a reinforcing phase mostly oxides [21,22], carbides [23–25] or borides [26,27] were used. Studies were mainly related with the optimization of a sintering process and with the effect of sintering conditions on physical properties and microstructure. Tribological and mechanical properties of steel-based composites reinforced with ceramic particles were also taken into consideration [21,24,27,28]. For example, Patankar and Tan [25] examined the role of SiC in the sintering process of composites based on the 316L stainless steel. It was found that the addition of SiC significantly improved the density of the composites. This fact was attributed to the reaction of SiC with a steel matrix, resulting in the formation of a low-melting Fe–SiC phase. In contrast, Mukherjee and Upadhyaya [22] investigated the effect of Al_2O_3 particles (added in an amount of up to 8%) on the sintering behavior and properties of ferritic steel. The highest mechanical properties were obtained in materials containing 4–6 vol% Al_2O_3. Tjong and Lau [27] studied composites with matrix based on the 304 L steel reinforced with TiB_2 particles (5–20 vol%). They proved that the addition of TiB_2 particles was very effective in improving the wear resistance, hardness and toughness of the composite.

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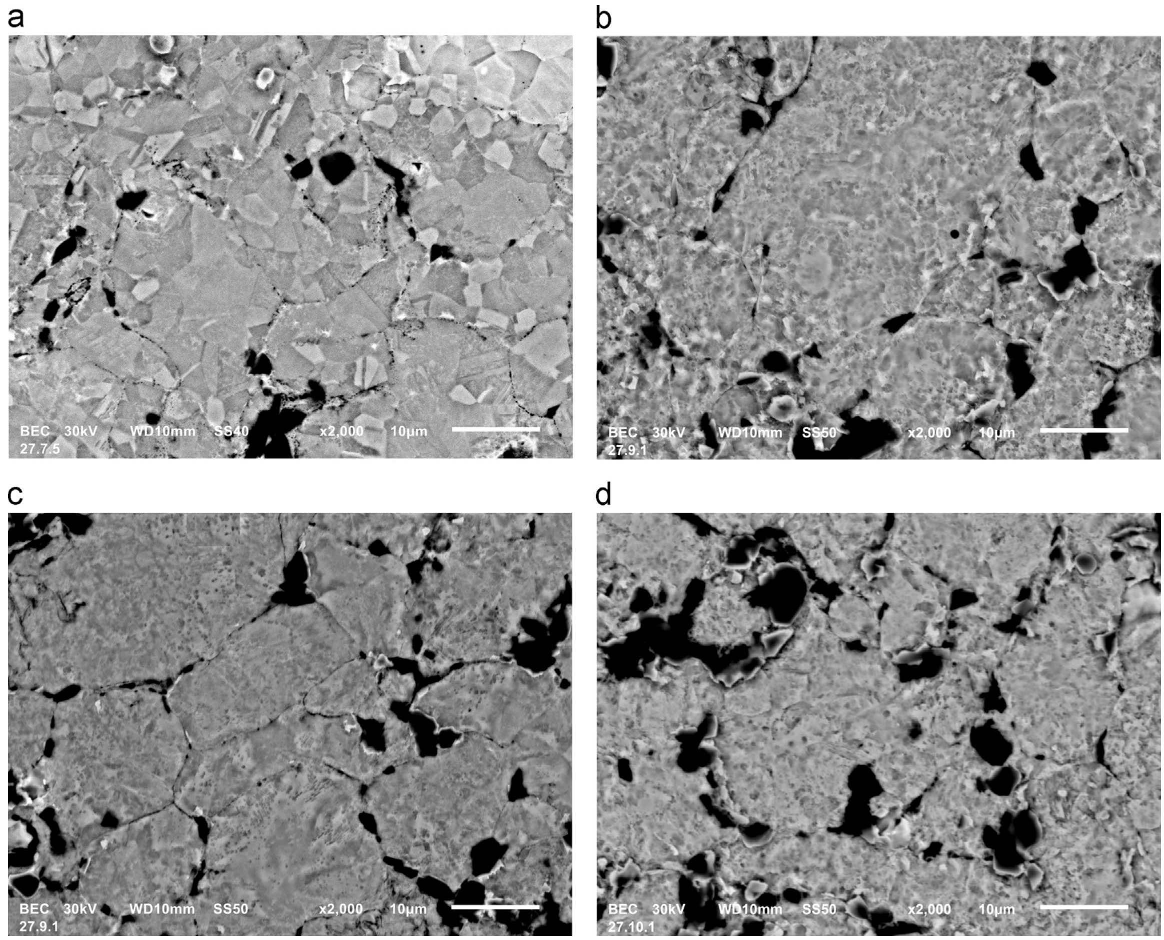

Fig. 1. SEM microstructure of composites with: (a) 2 vol% TiB_2, (b) 4 vol% TiB_2, (c) 6 vol% TiB_2 and (d) 8 vol% TiB_2.

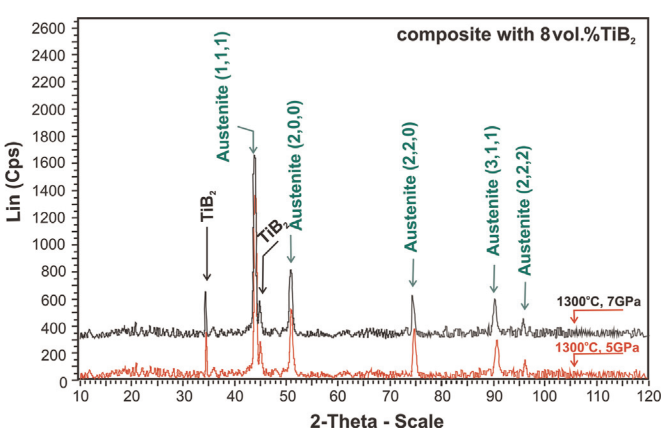

Fig. 2. XRD diffraction patterns of the composites with 8 vol% TiB_2 (sintered at 1300 °C–5 GPa and 1300 °C–7 GPa).

Available literature on the electrochemical behavior of composites based on an austenitic steel matrix is very limited. Corrosion behavior is a very important parameter determining the potential use of these materials. Introduction of a ceramic phase to the steel matrix improves hardness, abrasion resistance and strength, but problems of corrosion resistance are often neglected. There are no published studies on the corrosion resistance of stainless steel composites reinforced with borides. Ceramic particles can interact electrochemically, chemically or physically with the steel matrix, leading to rapid corrosion. In addition, voids at the reinforcement/matrix interface can play the role of potential corrosion sites. The appearance of new phases as a result of the ceramic reinforcing phase–matrix interaction can also lead to fast penetration into the large interfacial areas of composites [19,29]. In most cases, all these phenomena promote and accelerate the corrosion of composite materials. Another important factor influencing the corrosion behavior is type of the sintering process. The use of conventional methods often gives the steel composites characterized by low density and high porosity reducing the corrosion resistance of these materials [30,31]. The sintering methods based on the application of high-pressure produce materials with a very high density and minimum porosity.

Therefore, the main aim of this study was to evaluate the mechanical properties and corrosion resistance of steel–TiB_2 composites. The AISI 316L steel matrix composites were sintered by a high-pressure method. The next step was determination of the effect of TiB_2 volume fraction (2–8 vol%) and sintering conditions (pressure and temperature) on corrosion resistance, mechanical properties and microstructure of the composites.

2. Methodology

The study used composites based on the AISI 316L austenitic steel matrix reinforced with 2–8 vol% TiB_2. Additionally, to the composite matrix containing 8 vol% TiB_2, boron was added in an amount of 1 vol%. The composites were fabricated by the technique of High Pressure–High Temperature (HP–HT) sintering, applying the pressure of 5 ± 0.2 GPa and 7 ± 0.2 GPa at a temperature of 1000 °C and 1300 °C. The time of sintering was 60 s. Details of the sintering technology applied in the case of the tested