Co-sintering of M2/316L Layers for Fabrication of Graded Composite Structures

V. Firouzdor[1,a], A. Simchi[1,b], A.H.Kokabi[1,c]

[1] Department of Material Science and Engineering, Sharif University of Technology,
P.O.Box 11365-9466, Azadi Avenue, 14588 Tehran, Iran
[a]Firouzdor@mehr.sharif.ir, [b]Simchi@sharif.edu, [c]Kokabi@sharif.edu

Abstract

This paper presents the densification and microstructure evolution of bilayer components made from 316L stainless steel and M2 High speed steel during co-sintering process. The sintering was carried out at temperatures ranging from 1230 -1320 ^{0}C in a reducing atmosphere. The addition of boron to 316L was examined in order to increase the densification rate and improve the sintering compatibility between the two layers. It was shown that the mismatch strain bettwen the two layers induces biaxial stresses during sintering, influencing the densification rate. The effect of boron addition was also found to be positive as it improves the bonding between the two layers.

Keywords : Co-Sintering, Functional graded material, Densification, M2 and 316L steels

1. Introduction

Design and fabrication of functional graded materials which endows unique properties is an important research topic worldwide. Although different methods are available, co-powder injection molding process [1] is an attractive and economical mean to integration of different parts. The key stage of the fabrication route is the sintering step, which requires careful control of the sintering shrinkage of the two parts to ensure densification and bonding while avoiding differential stresses that might induce cracking or distortion [2]. The objective of this work is to study the co-sintering behavior of M2/316L steel composite layers. The compatibility of the two materials for the co-powder injection molding process has been investigated previously [2-4]. Such a combination imparts toughness, corrosion resistance and an economical advantage as compared to tool steel components. In this paper, the densification and microstructural evolution during co-sintering are presented.

2. Experimental Procedure

Gas atomized M2 and 316L powders produced by OSPREY. Co., UK were used as the staring materials. In order to increase the sintering compatibility of the two materials, boron powder in the amount of 0.2 and 0.5wt% was added to the stainless steel powder. For blending, Turbula mixer/shaker was employed for 60 min.

A pressurless sintering in conjunction with a powder layering technique [5] was used for the preparation of the stepwise graded composite layers. The composite samples were sintered in a laboratory furnace under a reducing atmosphere (Ar-30vol% H_2) for 120 min. The sintering temperature was between1220-1320 ^{0}C and the heating ramp was 5 K min^{-1}. The same sintering run was also applied for the individual layers of 316L and M2 steels. The density of the sintered samples was measured by Archimedes method. Optical and SEM microscopes were used for microstructural study. The variation of the hardness along the interface was also examined according to Vickers method at 100 g load.

3. Results and Discussion

Fig. 1 shows the result of density measurement versus the sintering temperature. The dash lines present the average density of the individual layers. One can notice that the density of the bi-layer parts is higher than the average densities of M2 and 316L individual samples. It appears that the densification of the bilayer composite is higher than that of the individual layers. As it was reported elsewhere [5,6], this phenomenon is attributed to the mismatch strain rates developed during co-sintering. This incompatibility induces mismatch stresses at the interface, which in fact, influence the densification rate. The results also determine that the amount of densification of the powders, especially 316L, is low at temperatures below 1260 ^{0}C.

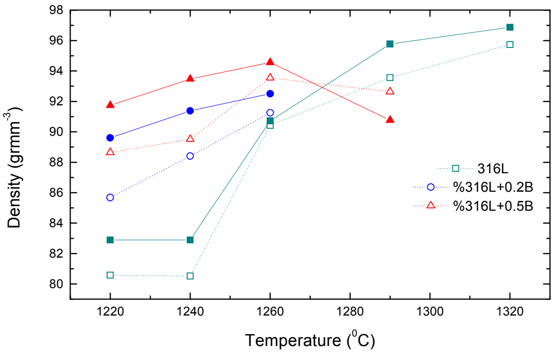

Fig. 1. Density of the M2 and 316L composite layers versus sintering temperature. The dash lines show the average of the density of the individual layers.

The experimental results also showed that a better densification and sintering compatibility can be attained with the boron addition. Fig. 2 shows a metallographic picture of the co-sintered composite layer containing boron which was sintered at 1260 ^{0}C. As it is seen, the interface zone is fully dense whilst having longitudinal grains, in spite of equaxied structure of grains in the M2 and 316L layers. The result of hardness measurement along the interface is shown in Fig.3. It is noticeable that the hardness of boron containing samples is significantly higher than the other. The higher density of the interface layer and the effect of boron on the hardness of the steels are responsible for this observation. The EDX line scan analysis thorough the interface also showed a wider distribution path of alloying elements in the boron added samples. For example, the distribution of Cr is shown in Fig. 4. The deeper diffusion of the alloying element is mainly linked to the formation of a liquid phase at the grain boundaries, which provide a path for fast diffusion of the alloying element

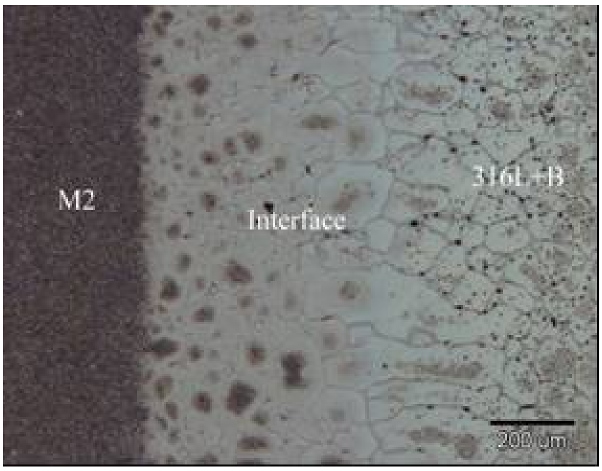

Fig. 2. Optical micrograph shows the microstructure of M2/316L+0.5wt%B layer sintered at 1240 ^{0}C.

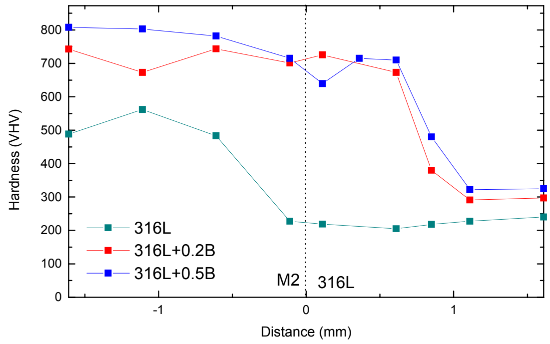

Fig. 3. Variation of the hardness along the interface of the composite layers sintered at 1240 ^{0}C.

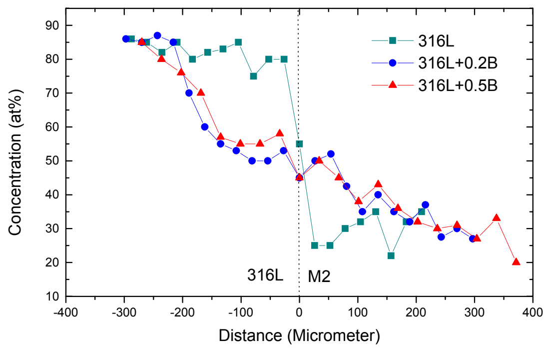

Fig. 4. EDX analysis of the Cr concentration along the interface of the composite layer sintered at 1240 ^{0}C.

4. Summary

The co-sintering behavior of M2/316L graded composite was studied. It was found that sound composite layers with high density can be fabricated by boron addition at 1260 ^{0}C. Meanwhile, mismatch strain rate between the two layers during co-sintering induces mismatch stresses at the interface, leading to an enhanced densification rate. The results of microhardness measurement were found to be in agreement with the microstructural observation.

5. References

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