Metal Mesh Reinforced Metallic-Glass Composites Prepared by High-Pressure Die Casting

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Abstract： Using high-pressure die casting, metallic-glass composites (MGC) with improved plasticity and strength were successfully fabricated by introducing different metal mesh. Experimental results demonstrate that the prepared interpenetrating structure composites exhibit a fracture plastic strain of 6.7% and a fracture strength of 1900 MPa in compression tests. This outstanding performance is attributed to the effective suppression of shear band propagation by the high hardness Mo woven toughening agents. The discussion emphasizes that the hardness of the toughening agent material is the dominant factor influencing the mechanical properties of MGC.

Keywords: Bulk metallic glass composite; HPDC; plasticity; toughening agent

1 Introduction

High-pressure die casting (HPDC) is a widely utilized metal forming technique [1]. Recent advancements in HPDC have expanded its application in the production of bulk metallic glass (BMG) engineering components, such as amorphous alloy hinges and middle frames for 5G folding mobile phones, allowing the fabrication of metallic glass parts with intricate structures [2]. Despite the exceptional properties of BMGs, such as high strength and superb surface finish, their brittleness at room temperature remains a significant limitation [3].

To address these limitations, this study employs HPDC to inject a glass-forming liquid into a metal mesh under high filling ratios and pressures, resulting in a dual continuous interpenetrating phase composite structure. The study focuses on investigating the impact of the metal mesh hardness on the performance of the metallic-glass composite (MGC).

2 Experimental procedure

This study fabricates interpenetrating MGCs using HPDC. Reinforcement is achieved using Mo, Ni, and Ti materials with a 200-mesh size. The matrix consists of a commercial $Zr_{41.2}Ti_{13.8}Cu_{12.5}Ni_{10}Be_{22.5}$ (at. %) bulk metallic glass (Vit1) known for its high glass-forming ability. The phase constitution of the composites is characterized using X-ray diffraction (XRD). The microstructure and fracture morphology are investigated and analyzed using scanning electron microscopy (SEM). Additionally, the Vickers hardness of the different material wire meshes and the room temperature compression properties of the MGCs are tested and evaluated.

3 Result and discussion

Microstructure characterization

The die-casting process, illustrated in Fig. 1(a-c), is conducted in a high vacuum environment. Fig. 1(d) shows the SEM image of the 200-mesh Mo material used as a 3D reinforcement. The uniformly distributed woven mesh effectively suppresses the propagation of shear bands, enhancing the plasticity of the MGC. Fig. 1(e) presents the XRD patterns of the toughened MGC with various woven mesh materials and their corresponding prepared meshes. From the normalized XRD in Fig. 1(f), typical halo diffraction peaks of the metallic glass, superimposed with crystallization peaks of Mo, Ni, and Ti, can be observed, with no additional crystallization peaks appearing in the diffraction patterns of the prepared MGC. The SEM morphology of the MGC is shown in Fig. 1(g-i), demonstrating that the woven meshes of different materials have achieved good bonding with the metallic glass matrix, with no obvious pores or cracks around the bonding interfaces.

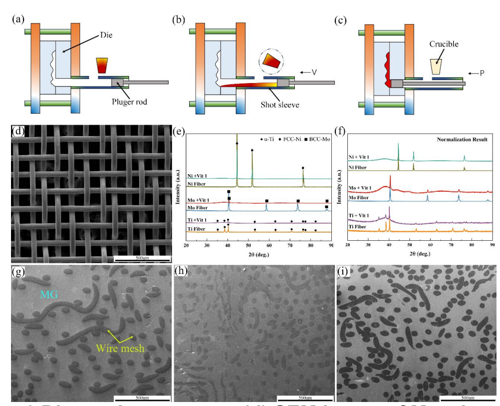

Fig. 1 (a-c) Die casting process; (d) SEM image of Mo wire meshes; (e-f) XRD spectrum of MGC; (g-i) SEM morphology of MGC prepared using different material (In sequence: Mo, Ni, Ti).

Compression deformation behavior

The hardness of metal meshes made from different materials is shown in Fig. 2(a). Mo displays the highest hardness. Fig. 2(b) presents the room temperature compression curves of the toughened MGC and Vit 1. It can be observed that all composite materials exhibit a significant brittle-to-ductile transition. Notably, the MGC reinforced with Mo wire mesh demonstrates the best plasticity under room temperature compression conditions, with a fracture strain of approximately 6.74% and a fracture strength of around 1900 MPa.

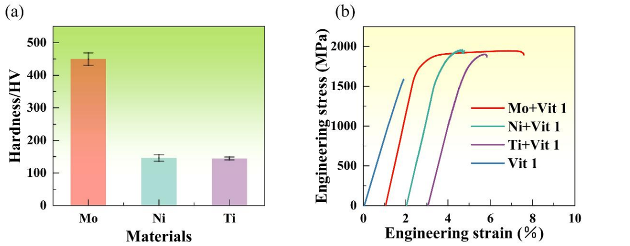

Fig. 2 Mechanical properties of metallic-glass composites materials; (a) Hardness of wire meshes; (b) Room temperature compressive performance of MGC.

Fig. 3 shows the compressive fracture surface morphology of the MGC, where the metallic glass exhibits a typical river-like pattern. Observations from Fig. 3(a-c) reveal that debonding occurred at the interfaces between the Mo, Ti, and Ni wire meshes and the amorphous matrix after plastic deformation, leading to crack formation at these interfaces. Fig. 3(d-f) illustrates the fracture modes of different material metal frameworks. The SEM image in Fig. 3(d) shows clear cleavage steps on the fracture surface of the Mo wire, indicating cleavage fracture during compression. In Fig. 3(e), the fracture surface of the Ni wire appears relatively smooth, suggesting a ductile fracture mode similar to brittle shear fracture. In Fig. 3(f), the fracture surface of the Ti wire shows a certain degree of necking, indicating significant plastic deformation before fracture.

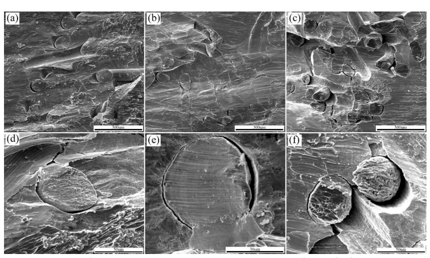

Fig. 3 Compressive fracture morphology of MGC (In sequence: Mo, Ni, Ti); (a) wire mesh and metallic glass; (b) Metallic scaffold fracture surface.

As shown in Fig. 4, the process of shear propagation in interpenetrating structure MGC is illustrated. The extension and propagation of shear bands will be hindered by the metallic mesh, thereby enhancing the plasticity of the material. Furthermore, the higher the hardness of the metallic mesh, the more pronounced the hindrance effect on shear propagation, which is beneficial for enhancing the plasticity of the MGC.

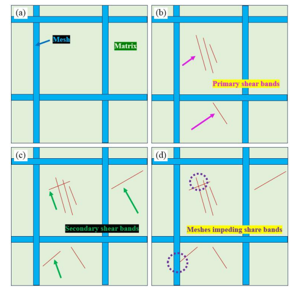

Fig. 4 Schematic diagram of the shear process in metallic-glass composites materials.

4 Conclusion

A novel HPDC method has been successfully employed to prepare MGC with a greater tensile elongation. The outstanding mechanical performance mainly stems from the effective suppression of shear band extension and propagation by the high-hardness Mo woven mesh. The hardness of the toughening agent material is the dominant factor influencing the mechanical properties of MGC. This work provides insights for the design of metallic-glass composites.

5 Acknowledgments

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