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ScienceDirect
Trans. Nonferrous Met. Soc. China 26(2016) 895−904
Transactions of Nonferrous Metals Society of China
www.tnmsc.cn

Characteristics evolution of 6009/7050 bimetal slab prepared by direct-chill casting process

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Received 18 May 2015; accepted 10 October 2015

Abstract: 6009/7050 alloy bimetal slab was prepared by a direct-chill (DC) casting process. Homogenizing annealing, hot rolling and T6 treatment were successively performed and their effects on microstructure and properties of the slab were studied. The results reveal that the average diffusion layer thickness of as-cast slab, determined by interdiffusion of elements Zn, Cu, Mg and Si, was about 400 μm. Excellent metallurgical bonding was achieved because all tensile samples fractured on the softer 6009 alloy side after homogenizing annealing. After homogenizing annealing plus rolling, the average diffusion layer thickness decreased to 100 μm, while the network structure of 7050 alloy side transformed to dispersive nubby structure. Furthermore, subsequent T6 treatment resulted in diffusion layer thickness up to 200 μm and an obvious increase of the Vickers hardness for both 7050 and 6009 sides. The layered structure of the as-cast 6009/7050 bimetal is retained after hot rolling and T6 treatment.

Key words: 7050 alloy; bimetal slab; direct-chill casting; heat treatment; hot rolling

1 Introduction

Bimetallic materials have been widely used in many industrial fields due to the combination of excellent physical and chemical properties of the base metals, which cannot be achieved by the individual alloy acting alone [1]. Several conventional approaches have been used to manufacture the bimetallic materials including rolling bonding [2−5], explosive welding [6−9], diffusion bonding [10−13], extrusion cladding [14,15], centrifugal casting [16], laser cladding [17], and so on. LI et al [18] prepared 7075/6009 aluminum composite ingot by double-stream-pouring continuous casting. Compared with these methods, direct-chill (DC) casting provides many advantages, such as lower cost, superior metallurgical bonding and high productivity, and has been applied to prepare lots of industrial used bimetals. WAGSTAFF et al [19] investigated the clad ingot produced by the well-known Novelis fusion process. SUN et al [20] produced Al−Si alloy and Al−Mn alloy bimetal slab using continuous casting. FU et al [21] illustrated the microstructure and mechanical properties of Al−1Mn and Al−10Si alloy circular clad ingot prepared by DC casting. LIU et al [22] produced the 3003/4045 clad hollow billet via horizontal continuous casting. WANG et al [23] investigated the development of Al−Li and Al−Mn bimetal slab prepared by a modified DC casting process. However, up to date, few literatures exist reporting on the successful using DC casting to produce bimetals containing Al−Zn−Mg−Cu high-strength alloys, which can be used widely in aerospace field.

The 7050 alloy, typical Al−Zn−Mg−Cu high-strength alloy, is considered as an ideal material for preparing aircraft skin due to its high specific strength [24]. However, it suffers from the poor corrosion resistance and is prone to cracking during solidification and rolling process. The 6009 alloy has superior corrosion resistance and good formability, and is widely applied in automobile plates, but its applications limited in the low strength [25]. The 6009/7050 bimetal material combines the advantages of two alloys and features high strength and superior corrosion resistance as well as good formability, which could meet the requirements of mass reduction and safety improvement

Foundation item: Project (51375070) supported by the National Natural Science Foundation of China
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DOI: 10.1016/S1003-6326(16)64184-5

in automobile and airplane industries.

In this work, a 6009/7050 bimetal slab was prepared by a DC casting process. The fabricated slabs were subjected to homogenizing annealing, hot rolling, solid solution and aging. The microstructure, composition distribution and mechanical properties of the as cast, rolled and heat treated slab were studied in detail.

2 Experimental

2.1 Materials and ingot preparation

The chemical compositions of the 6009 and 7050 alloy are given in Table 1. The schematic diagram of experimental setup is shown in Fig. 1. Three dominant factors influencing the metallurgical bonding between two alloys are pouring temperature, elevating speed and cooling water flow rate. As presented in Fig. 1, the hot top was fixed on the top of a mold. The water-cooled baffle was placed into the mold as inner mold and the cooling water flow can be controlled. A layer of refractory material to insulate the heat covered on one side of the water-cooled baffle and the water passage was embedded on the other side. The 6009 alloy melt at 670 °C was firstly poured into the left part of the mold and a semisolid shell would be formed once the melt contacted with the water cooled side of water cooled dividing baffle. The 7050 melt at 730 °C was then poured into the right part of the mold when the 6009 semisolid shell was strength enough, at the same time, the dividing baffle was drawn up to keep the relative motion between the bimetal slab and the water-cooled baffle at the speed of 60 mm/min, and the cooling water flow rate is 140 L/h. After the baffle and melts were separated, the bimetal ingot (130 mm × 120 mm × 100 mm) was fabricated successfully. After a series of systematic experiments, the optimized experimental parameters were as follows: the pouring temperatures were 730 °C and 670 °C for 7050 and 6009 alloys, respectively; the drawing speed of the dividing baffle was 60 mm/min, and the cooling water flow rate was 140 L/h.

Table 1 Chemical compositions of experimental alloys (mass fraction, %)

Alloy	Zn	Cu	Mg	Si
7050	6.5327	2.2728	2.2852	0.0557
6009	−	−	0.6032	0.9547
Alloy	**Fe**	**Mn**	**Cr**	**Al**
7050	0.1090	0.0026	0.0256	Bal.
6009	0.1307	0.0034	0.0209	Bal.

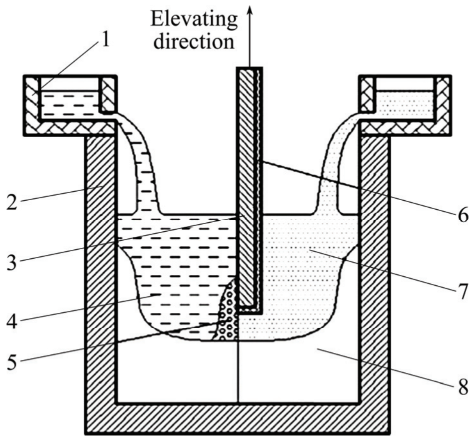

Fig. 1 Schematic illustration of modified direct-chill casting process: 1—Hot top; 2—Mold; 3—Water cooled baffle; 4—6009 alloy melt; 5—6009 alloy semisolid shell; 6—Heat insulation layer; 7—7050 alloy melt; 8—Bimetal slab

2.2 Homogenizing annealing, rolling, solid solution and aging

As presented in Fig. 2, the test sample was prepared with a length of 100 mm, width of 15 mm and thickness of 15 mm by wire-electrode cutting technique from the bimetal slab (130 mm × 120 mm × 100 mm).

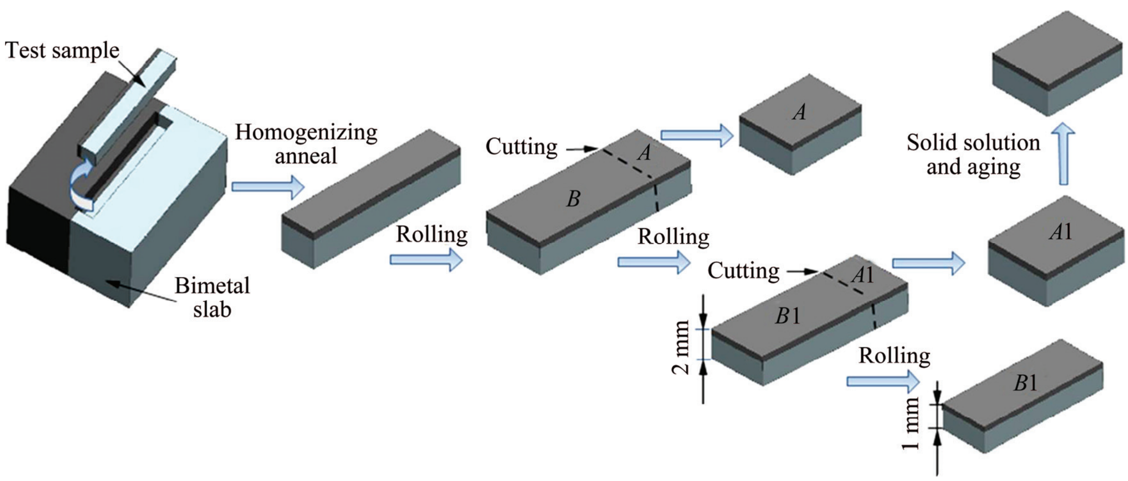

Fig. 2 Schematic illustration of heat treatment and plastic deformation procedures of bimetal sample