Preparation and tensile property of a high-strength, anticorrosion functionally graded 2024/3003 composite

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In many practical applications of structural materials, different properties are desired on the surface and in the internal region. The most economical way to meet this demand undoubtedly lies in the realization of an ideal composition distribution of the alloy by one step, for example, in the as-cast state. Based on such an idea, a novel method named double-stream-pouring continuous casting (DSPCC) technology has been proposed [1, 2]. The main difference between this method and the conventional continuous casting is the pouring system, which is equipped with two sets of ladles for liquid metals of different alloy compositions. The experimental verification of this method has been carried out in binary Al–Si and Al–Cu systems [2, 3].

A normal requirement in engineering practice is the combination of high strength in the internal region and good corrosion resistance on the surface of aluminum alloys. 2024 and 3003 aluminum alloys are two widely used commercial alloys. 2024 has excellent strength and toughness but poor corrosion resistance. 3003 has excellent corrosion resistance but poor strength. If a new material could combine the advantages of 2024 and 3003, the application fields would be remarkably enlarged [4]. In this letter, the preparation of gradient materials in which the internal composition is approximate to the composition of 2024 alloy and the external composition is nearly that of 3003 alloy is reported based on the foregoing method.

The experiment was carried out on a laboratory-made semicontinuous casting facility (Fig. 1). The raw materials included industrial pure aluminum, industrial pure magnesium, Al–10%Mn (wt%) master alloy, and Al–50%Cu (wt%) master alloy. Two samples of 2024/3003 gradient composite ingots with a diameter of 65 mm were obtained. Some major parameters are listed in Table I.

Fig. 2 is the macrograph of cross sections at different locations of the specimen at a distance from the head of the ingot (L), (a) $L = 50$ mm and (b) $L = 200$ mm, respectively. From the figures, the morphological differences between the external and internal regions can be seen clearly.

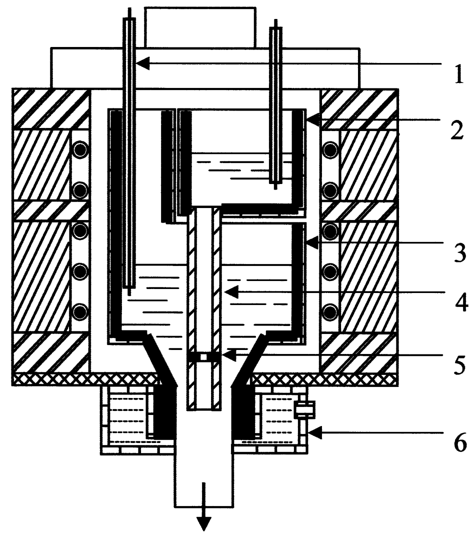

Figure 1 Schematics of the semicontinuous casting equipment: 1—thermocouple, 2—inside ladle, 3—outside ladle, 4—entry nozzle, 5—throttle bore, 6—mold.

Fig. 3 shows the macrostructure of the longitudinal section of the ingot. The macrostructures of the external and internal regions are distinctly different and the boundary is obvious. However, the two alloys were integrated into a single piece with a smooth transition layer.

Fig. 4 shows the copper content versus the distance to the center (R) in two different samples at $L = 50$ mm and $L = 200$ mm. The copper content was measured by energy dispersive spectrum analysis by scanning an area of about 1 mm^2. Every datum was the average values measured in four symmetrical directions on the same cross section. The copper distributions are consistent at different locations under the determined casting parameters. The value of copper content gradually decreases from the center to the

TABLE I Casting parameters

Composition (wt%)		Temperature (K)		Throttle bore diameter (mm)	Casting speed (mm · s^{-1})	Cooling rate (kg · s^{-1})
Inside	Outside	Inside ladle	Outside ladle			
Al–5Cu–2Mg–1Mn	Al–1.5Mn	1023	1003	2.0	2.5	0.85

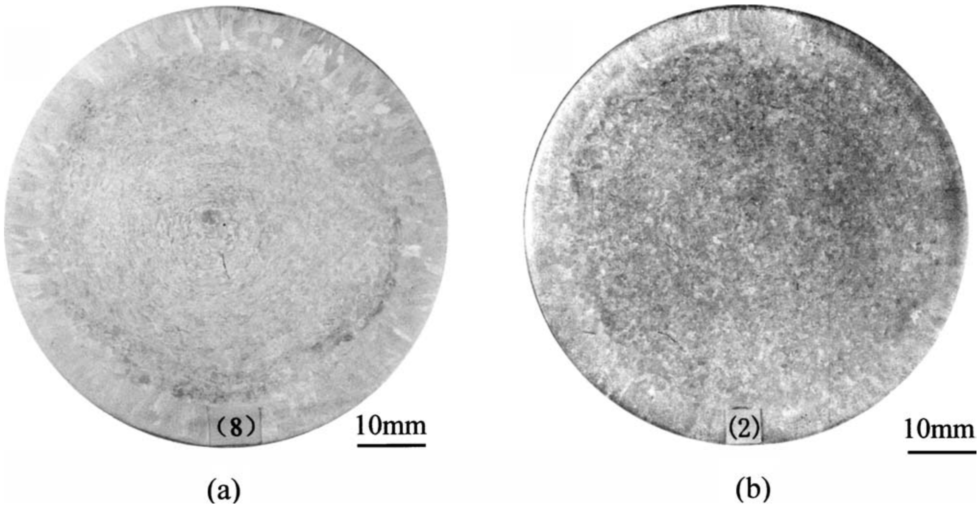

Figure 2 Cross section of the specimen: (a) distance from the head of ingot $L = 50$ mm and (b) distance from the head of ingot $L = 200$ mm.

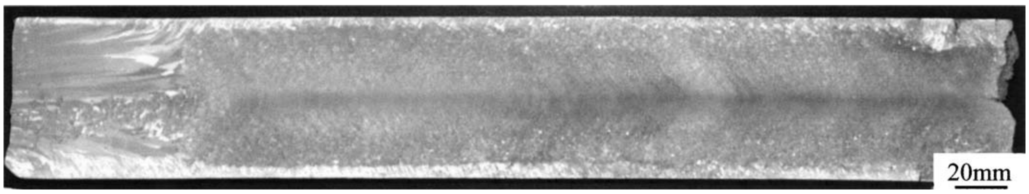

Figure 3 Macrograph of longitudinal section of the specimen.

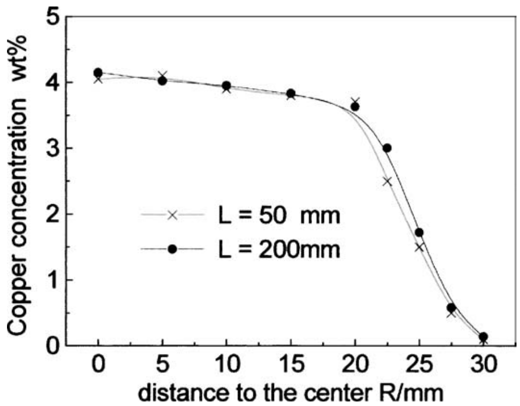

Figure 4 Compostion distribution in cross section of the specimens.

surface. The decrease of copper content is very little in the region $R < 20$ mm and sharply decreases in the $R > 20$ mm region. The tendency is that the composition in the internal layer is approximate to the nominal composition of 2024, whereas the composition in the external layer is nearly the same as the nominal composition of 3003. The region at $20.0 \text{ mm} < R < 27.5$ mm, which shows abrupt decrease in copper content, is the transition region of the prepared gradient composite.

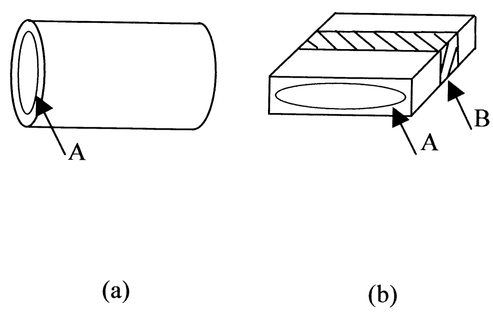

Figure 5 Schematic of the billet (a) before and (b) after free compression. A indicates the location of the transient layer and B indicates the location for tensile specimen.

The ingot was cut and pressed into billets with the thickness of 16.5 mm by free compression at 450 °C. Tensile samples were cut from billets as illustrated in Fig. 5. The mechanical properties are listed in Table II.

It can be concluded that the tensile strength and yield strength of 2024/3003 gradient alloy in the pressed state are, respectively, 53.3% and 47.1% higher than those of 3003. It is well known that 3003 alloy is not heat treatable whereas 2024 is. Heat-treated 2024/3003 tensile samples were prepared by solutionization at 768 K for 45 min, followed by an immediate quenching in

TABLE II Tensile properties of the alloys

Alloy	State	Tensile strength σ_b (MPa)	Yield strength $\sigma_{0.2}$ (MPa)	Elongation δ_5 (%)
3003	As-pressed	120	68	24
2024/3003	As-pressed	184	100	18
2024/3003	Heat-treated*	300	132	16

*Solutionized at 768 K for 45 min, water quenched and aged at 458 K for 12 hr.

ambient water and then artificial aging at 458 K for 12 hr. The tensile strength and yield strength of the heat-treated 2024/3003 alloy are, respectively, 63% and 32% higher than those of the as-pressed 2024/3003 alloy.

Acknowledgments
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