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Preparation of composite aluminum automobile radiator by inversion casting①

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[Abstract] The inversion casting technics of producing three-ply Al-Mn/Al-Si composite strap used in automobile radiator was studied. The physical processes of inversion casting, including the flux-supporting reacting and volatilizing at high temperature, the melting and solidification when the elements of solid and liquid fresh alloys meet with each other, the mutual diffusion of elements in solid and liquid, the crystallization and forming of metallurgical combination and the following rolling process, were analyzed. At the same time, the composite mechanism of this technique was also discussed.

[Key words] composite aluminum alloy; inversion casting; automobile radiator; composite mechanism

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1 INTRODUCTION

It has been several years since aluminum became the material used for automobile radiator. This was developed slowly before, for the industry threw doubt on whether or not the aluminum radiator could stand the working conditions. After numbers of experiments in Europe and North America, industry has been full of confidence on using aluminum alloy radiator[1]. Based on lots of studies on materials and welding technics, aluminum products were chosen to be the materials on automobile radiator.

Radiator lies in the front of an automobile, it stands harsh road conditions such as rainwater, salt volatilized from road surface, waste gas exhausted by vehicle, pollution of dust and mud. There is cooling water in radiator, the water contacts with some mixed metals which may contain some compositions harmful to aluminum. Meanwhile, the whole radiator system stands repeatedly heat cycle and vibration produced in action cycle. Things mentioned above bring up a rigid challenge to the materials and welding methods, the composite foil with Al-Mn alloy as base strip and Al-Si alloy as cladding can meet its requirement.

The manufacturing technics of automobile radiator has gone through three stages: copper radiator, mechanical assembling aluminum radiator and tube or strip welding aluminum radiator. The technics is developing towards high efficiency, longevity, less weight and environmental protection[2]. The manufacture technique of composite foil aluminum radiator includes rolling composite method, prompt cast-rolling method and so on[3]. By experiments, we can conclude that the technique of inversion casting[4] which possesses many advantages such as simple, making full use of casting heat, economizing on rolling power[5], high quality and liability to produce composite plate, is more practical than cool-rolling[6]. The continuous production of non-oxygen copper wire by the technique of inversion casting has been achieved[7].

2 EXPERIMENTAL

2.1 Chemical composition of test samples

The chemical composition of base strip and cladding materials is shown in Table 1.

Table 1 Chemical composition of test samples(%)

Sample	Si	Fe	Cu	Mn	Ti	Al
Base strip 3003	0.55	0.65	0.15	1.45	0.09	Bal.
Cladding material 4343	7.20	0.40	0.02	0.45	0.12	Bal.

3003 alloy strips are rolled while 4343 alloy is as-cast

2.2 Composite technology

During the experiment, 4343 alloy was smelted in furnace, protected by gas. When its temperature reached a certain degree, put the base strip whose surface was dealt with into the liquid alloy promptly and drew out quickly after a certain time. Deoxidizer was put in constantly during the process above. In this experiment Pt-Rh thermal couple which was protected by Mg-Mo ceramics tube was used to measure the temperature of liquid alloy.

The technological parameters was transformed properly, they became the working parameters in

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continuous experiment.

The technological process of inversion casting was

3003 alloy → surface treatment
4343 alloy → smelt
→ continuous inversion casting → rolling → cooling → strip receiver → performance test and analyze structure.

2.3 Equipment of inversion casting technology

The main equipments used in the experiment include smelting furnace, continuous casting equipment, cooler, release facilities, receiver and roll mill.

The whole equipment to accomplish continuous inversion casting process is shown in Fig. 1. The whole is placed on the main supporter, except the release facilities and receiver. The supporter can support, modify the relative place of each device and fix their positions.

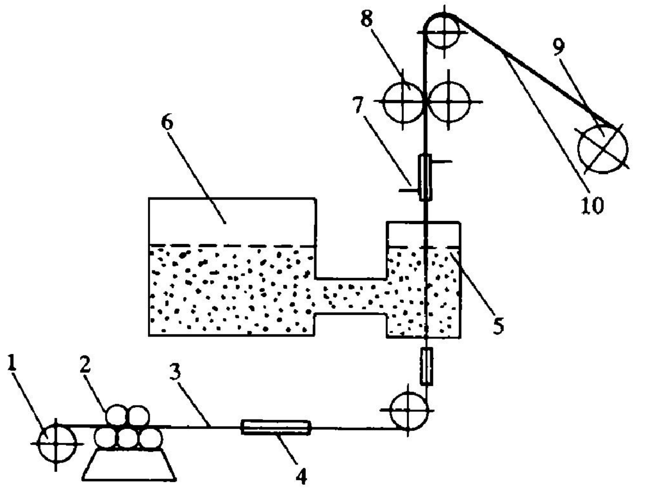

Fig. 1 Equipment of inversion casting technology
1- Release facilities; 2- Base strip straightener; 3- Base strip; 4- Surface treat; 5- Liquid alloy; 6- Casting device; 7- Cooler; 8- Roller; 9- Receiver; 10- Compound strip

3 PHYSICAL PROCESS

3.1 Flux-supporting reaction at high temperature

The flux-support is used to treat the surface of base strips in the experiment for it is liable to engender Al_2O_3[8] in the surface of aluminum alloy. At the beginning of the experiment, the flux-supporting covering on the surface of base strip meets the liquid aluminum alloy at the temperature of 640 ℃ and reacts at once. The flux-supporting must be cleared off the interface area, avoiding affecting the compound results. The reaction is

$$K_2ZrF_6 \longrightarrow 2KF + ZrF_4$$

The gas product ZrF_4 volatilizes away from the interface carrying the solid product KF. Then the fresh metals of base strip and liquid alloys meet with each other. Aluminum, silicon, manganese and some other elements become solid solution and diffuse. The composite process come into the next stage if the surfaces of both base strip and liquid alloys are well treated and K_2ZrF_6 reacts completely.

3.2 Fusion and solidification of solid and liquid fresh metals

The temperature varies greatly between the liquid and solid metals when they meet with each other, so the temperature of base strip surface rises extremely while that of liquid part which meet the solid alloy drops exceedingly. During this process, the outer metal of base strip melts at first, which can be conclude in metallurgy photo. In Fig. 2, the composition of base strip structure spreads finely in all directions near the interface area compared with those extending along the rolling direction farther from interface. The melting parts of strip solidify back to the strip promptly by the cooling function of themselves. At the same time, part of liquid alloy begins to solidify. Temperature variation causes convection within the liquid alloy. So the flow of liquid and the undulation of energy make it to melt the solidification layer again. In fairly short time, the two opposite courses reach their equilibrium. Then a solidification layer of certain thickness remains around the base strip. According to this, the two aluminum alloys are combined by weld instead of simple coat.

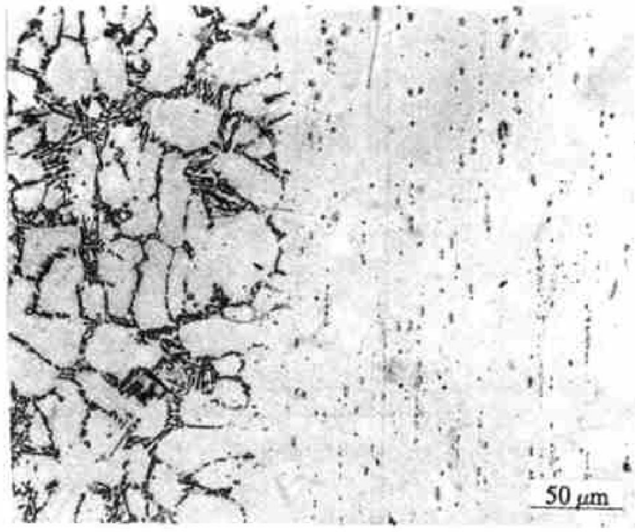

Fig. 2 Morphology of interface area

3.3 Diffusion of liquid and solid alloys

The atoms in the surface of solid alloy were activated after they met the liquid one which was in high temperature. For all the atoms of the two alloys possess high energy, elements diffusion can happen promptly after the atoms contact fully and reach melting and solidifying equilibrium. As a result, there forms a transition region at the interface. The diffusion of aluminum is not evident for the two aluminum alloys, while the diffusion of silicon and manganese can be observed through scanning electron microscope. From the line scanning photo of manganese, silicon and aluminum shown in Fig. 3, it is clear that manganese and silicon have diffused. The element silicon lies in 4343 alloy at the state of monocrystalline silicon. Massive monocrystalline silicon can be seen in Fig. 4, the fine and dispersal phase is co-crystal Al-$FeSiAl_5$-Si[9]. From the surface scanning photo of silicon shown in Fig. 4 we can see the diffusion of silicon in 3003 alloy though silicon congregate in 4343 alloy.

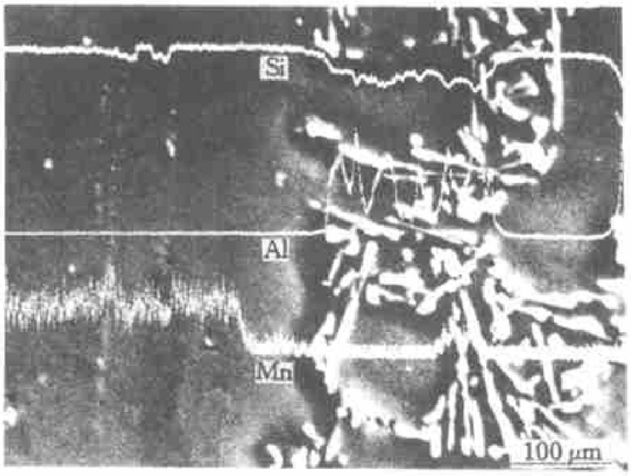

Fig. 3 Line scanning of manganese and silicon

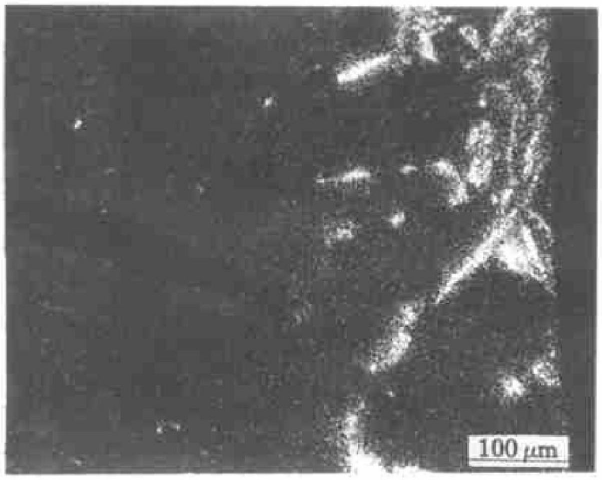

Fig. 4 Surface scanning of silicon

3.4 Crystallization and formation of metallurgy combination

Temperature drops rapidly when the base strip is drawn out from liquid alloy with its cladding. The liquid alloy on the surface crystallizes completely. During this course the liquid and solid metals rearrange to become metallurgy combination at the interface. On the other hand, different atoms become solid solution in the alloy during solidification process, so the composite intensity enhances more. The two alloys dissolve into each other and unite together tightly at the composite interface which is difficult to be distinguished. There is no evident composition segregation for the cladding is very thin.

3.5 Rolling process

The solidified composite strip is deformed and extended by rolling mill. Founding structure turns into rolling structure. The two alloys compound better after rolling, the two elements diffuse more by the function of rolling stress. The monocrystalline silicon in 4343 alloy elongate along rolling direction. Fig. 5 shows the section photo after rolling.

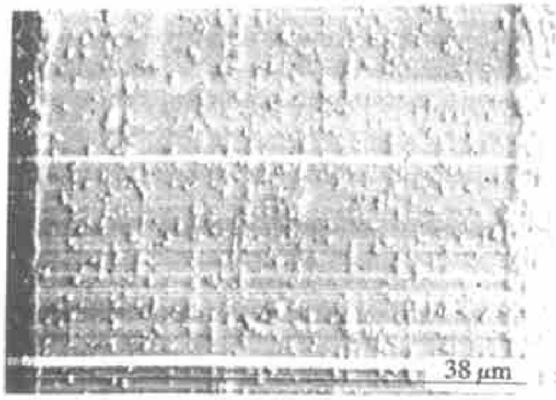

Fig. 5 Morphology of section after rolling

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