Transactions of the Materials Research Society of Japan 28 [2] 255-257 (2003)

Refinement of Sn-Pb Alloy by Local Imposition of Electromagnetic Force

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Oscillation has useful functions such as refinement of solidified structure and promotion of refining. However, these functions have not been used in liquid metal process in industrial scale because of the difficulties of imposition of oscillation on a liquid metal due to high temperature environment and large mass. To overcome these difficulties, we propose a new process in which oscillation is excited by a local imposition of periodical electromagnetic force in a liquid metal. In this research, one of the functions of the proposed method has been confirmed. That is, refinement of a Sn-Pb alloy was achieved by imposing a periodical electromagnetic force during its solidification.

Keywords: crystal refinement, solidification, electromagnetic processing of materials, static magnetic field, alternating current local imposition

1. Introduction

Oscillation is an attractive tool in materials processes because it has a lot of useful functions such as refinement of solidified structures[1-4], promotion of reaction rate[1-3,5] and so on. However, when the oscillation is introduced to industrial scale processes by using the conventional ways of an electrostrictive or a magnetstrictive vibrator, several problems such as the destruction of a transmitter due to high temperature environment[6] and the power limitation of vibrators[7] have to be solved. Therefore, direct generation of oscillation in a liquid metal has been strongly desired for the refinement of solidified structures of metals with a high temperature melting point such as aluminum and iron. Amano et al.[8] directly excited oscillation in a liquid metal by applying an alternating magnetic field though the intensity of the oscillation was weak. To obtain intense oscillation, another method[9] has been proposed in which a static and an alternating magnetic fields were simultaneously imposed on a liquid metal and the pressure change over an atmospheric pressure was achieved. Then, the utilization of electromagnetic fields has become a promising way to introduce the oscillation to materials processing.

Refinement of solidified structures can be achieved by applying the oscillation excited by the mechanical or the electromagnetic methods. One of examples is the refinement of aluminum alloy structures by the simultaneous imposition of a static magnetic field and an alternating current on the whole of a sample during solidification [10-12]. However, these methods are not suitable for industrial applications because the oscillation has to be imposed on the whole of a product, especially for large size products, and an intense electrical current density and/or a high magnetic field are also required for the oscillation enough to refine solidified structures [13]. Then, a new method of supplying oscillation to a metal in industrial scales is desired. A new generating method of oscillation suitable for a high temperature process has been proposed[14] ,in which a static magnetic field and an alternating current were simultaneously imposed on a local area of the liquid metal. The theoretical expressions of the oscillation have been derived and confirmed in experimental works in the previous paper[14]. In this paper, the effect of the oscillation excited by this method on the refinement of solidified structures has been studied.

2. Refinement of Solidified Structure

A mother alloy of Sn-10mass%Pb was prepared by alloying a pure Sn (99.9mass%) and a pure Pb(99.9mass%).The schematic view of experimental apparatus is shown in Fig.1. When the temperature of the sample set in the bore of the super conducting magnet was 300℃, its cooling was started. The imposition of the alternating current was started when the temperature dropped to 250℃, which is higher than the liquidus temperature (219℃), and it was finished when the temperature reached 170℃, which is just below the solidus temperature of 183℃, while the static magnetic field had been applied during all the solidifying period as shown in Fig.2. The temperature was measured by a thermocouple set in the middle of the long wall at the height of 20mm from the bottom. The measured histories of the temperature under the imposition of 10T static magnetic field are shown in Fig.3. Recalescence was not observed under the simultaneous imposing condition of the static magnetic field and the electrical current while it was observed when only the static magnetic field was imposed. The sample without the alternating current solidified slightly faster compared to that with the alternating current.

After solidifying of the samples, their horizontal cross-sections cut parallel to the long wall were observed. The macrostructures and microstructures of the samples under the different experimental conditions are shown in Fig.4. The observed plane of the macro-structure is shown in (a). In the case (b) without the electrical current, coarse grains composed of dendrites were obtained in the whole of the observed

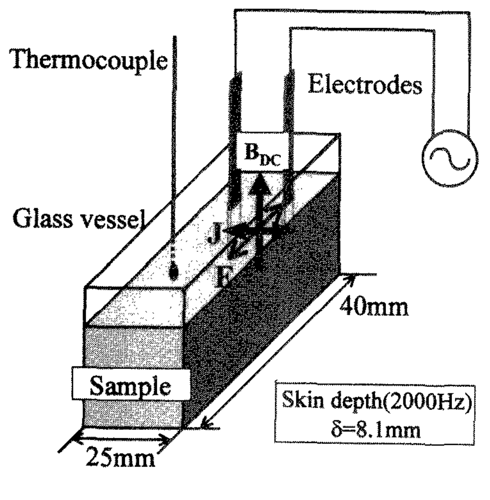


Fig.1 Schematic view of experimental apparatus

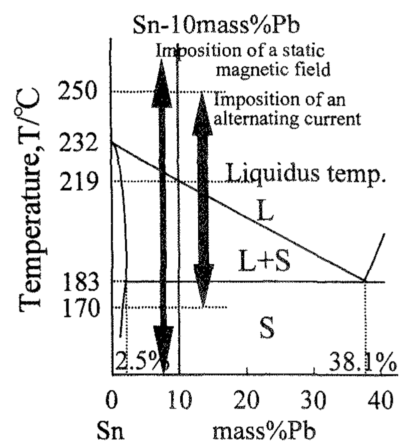


Fig.2 Imposing periods of static magnetic field and alternating current to Sn-Pb alloy

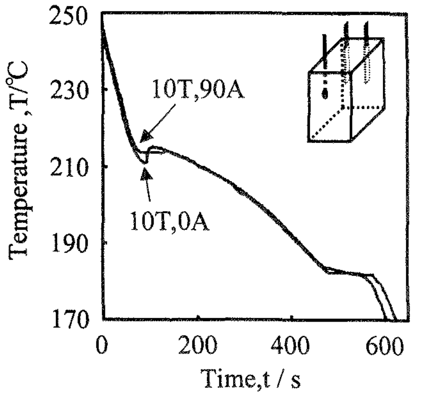


Fig.3 Cooling curves of samples under the imposition of 10T static magnetic field

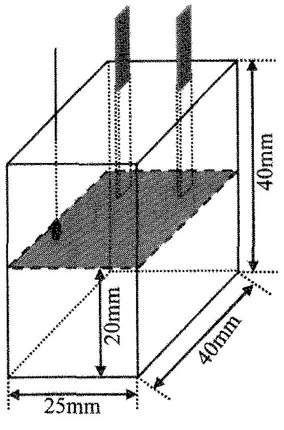
cross-section since an electromagnetic force was not excited in the alloy. In the case (c) of the simultaneous imposition of the static magnetic field and the alternating current, all of the observed area was refined though the region on which the electromagnetic force was acting was limited only in the electromagnetic skin layer calculated as 8.1mm. Then, the whole area of the sample was refined by using this method while only the limited region was oscillated by the electromagnetic force. Clarification of the refining mechanism is the future work.

3. Conclusion

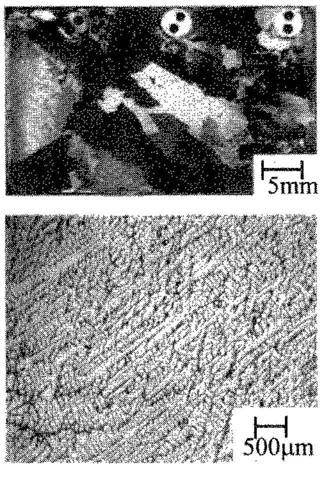
A new refining method of a solidified structure has been proposed in which a static magnetic field and an alternating current are simultaneously imposed on a liquid metal during its solidification. This method was applied to a Sn -Pb alloy. In the case of the simultaneous imposing of a static magnetic field and an alternating current, all of the solidified structure were refined even though the coarse structure was obtained in the case that only a static magnetic field was imposed on the sample during the solidification.

4. Reference

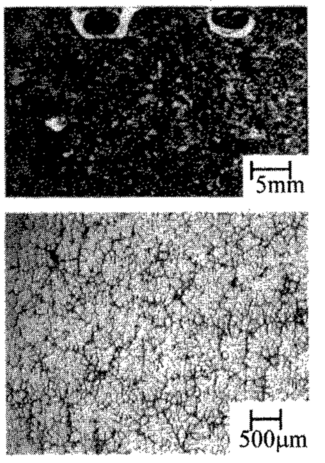
1) O.V.Abramov: *Ultrasound in Liquid and Solid Metals*, CRC Press Int., Florida, (1994), pp.273-405.
2) E.A.hiedemann: the Journal of the Acoustical Society of America, **26**(1954), 831-842.
3) J.Campbell: International Metals Reviews, **26** (1981), 71-108.
4) Y.Osawa, G.Arakane, S.Takamori, A.Sato and O.Ohashi: Journal of Japan Foundry Engineering Society, **71**(1999), 98-103.
5) Q.Wang, T.Momiyama, K.Iwai and S.Asai: Materials Transactions, *JIM*, **41**(2000), 1742-1747.
6) M.Ide: Metals and Technology, **51**(1981), 27-32.
7) J.Miyoshi, Y.Kikuchi and O.Noumoto: *Ultrasonic Technique Handbook*, Daily Industry Newspaper Publication Company, Tokyo, (1983), pp.394-402.
8) S.Amano, K.Iwai and S.Asai: ISIJ Int., **37**(1997), 962-966.
9) Q.Wang, T.Momiyama, K.Iwai and S.Asai: Materials Transactions, *JIM*, **41**(2000), 1742-1747.
10) C.Vivès: Metall. Mater. Trans. *B*, **27B**(1996), 445-455.
11) A.Radjai, K.Miwa and T.Nishio: Metall. Mater. Trans. *A*, **29A**(1998), 1477-1484.
12) A.Radjai and K.Miwa: Metall. Mater. Trans. *A*, **31A**(2000), 755-762.
13) S.Asai, K.Yasui and I.Muchi: Tetuto-to-Hagane, **64**(1978), 34-41.
14) Wang Chang, Satoru Kawai, Kazuhiko Iwai and Shigeo Asai: *CAMP-ISIJ*, 13, 150(2000)



(a) Observed plane of a sample



(b) B=10T, I=0T



(c) B=10T, I=0T

Fig.4 Macro-and microstructures on the horizontal section of samples under different electric conditions

(Received December 21, 2002; Accepted March 30, 2003)