(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 312 294 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 88309487.2

(51) Int. Cl.4: C22C 1/09 , C22C 21/04

(22) Date of filing: 11.10.88

(30) Priority: 14.10.87 CA 549282

(43) Date of publication of application:
19.04.89 Bulletin 89/16

(84) Designated Contracting States:
DE ES FR GB IT SE

(71) Applicant: ALCAN INTERNATIONAL LIMITED
1188 Sherbrooke Street West
Montreal Quebec H3A 3G2(CA)

(72) Inventor: Gallerneault, Willard Mark Truman
74 Robert Wallace Drive
Kingston Ontario K7M 1X8(CA)
Inventor: Lloyd, David James
865 Berwick Place
Kingston Ontario K7M 6B7(CA)

(74) Representative: Wilkinson, Stephen John et al
c/o Stevens, Hewlett & Perkins 5 Quality
Court Chancery Lane
London WC2A 1HZ(GB)

(54) Modification of aluminium-silicon alloys in metal matrix composites.

(57) A process is described for forming a composite cast article comprising an aluminum-silicon alloy matrix containing strontium as a modifier and a preform of bonded-together Al_2O_3 fibres incorporated in the matrix, in which the preform is infiltrated under pressure by a melt of the alloy and the composite article thus formed is allowed to solidify by cooling. According to the novel feature, by utilizing a specific amount of strontium as modifier in the range of about 0.5 to 1.0% by weight, it is possible to obtain a satisfactory modification of the alloy within the composite.

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Modification of aluminum-silicon alloys in metal matrix composites

Background of the Invention

This invention relates to the production of metal matrix composites, and, more particularly, to methods of producing cast aluminum alloy composite articles.

Among metal matrix composites (MMC) having important commercial utility are fibre-reinforced articles of aluminum and its alloys, particularly aluminum-silicon alloys. One of the most popular techniques used to manufacture metal matrix composites is melt infiltration. In this procedure a preform of preferably fibrous alumina reinforcing material is infiltrated under pressure by liquid metal. The composite is then allowed to solidify by cooling. The resulting microstructure of the metal matrix is generally not the same as that found in non-reinforced castings.

If the cooling rate of an Al-Si casting is such that the free growth dendrite arm spacing is greater than the average fibre spacing, the metal matrix dendrites will be in the order of that size as they grow avoiding the alumina fibres. This leads to the rejected solute accumulating at the fibres. For Al-Si alloys the solute build up is comprised of large particles or coarse plates of silicon. These large silicon particles have poor physical properties (brittle, different coefficient of thermal expansion) and it degrades the ultimate performance of the composite.

In the case where the cooling rate is high enough to ensure the average dendrite size is less than the average fibre spacing, the metal matrix microstructure appears identical to that in the non-reinforced region. However, large casting cross sections of greater than about 20 mm make it impossible to ensure a high enough cooling rate to keep the dendrite size less than the fibre spacing.

It has been known for many years to obtain a fine eutectic structure in Al-Si alloys containing about 5 to 15% silicon, by the use of additives and, thus, to improve the mechanical properties of these alloys. For instance, it is well known to use alkali metals and alkaline-earth metals, e.g. sodium or strontium, as additives in Al-Si alloys. The process of making such additions is known as modification. These chemical additions to a melt reduce the silicon size by affecting the normal growth kinetics of the solidification process and thereby modify the alloy microstructure. It would, therefore, be expected that in a similar manner additives such as sodium or strontium would suitably modify the metal matrix microstructure of a metal matrix composite. However, it has been found that when the melt contains a fibrous preform reinforcement, sodium and strontium are remarkably ineffective when used in their normal amounts in modifying the metal matrix microstructure of the metal matrix composite. Sodium appears to be almost totally ineffective in this situation, while strontium can be used only with difficulty.

It has been stated in U.S. Patent Number 3,446,170 that strontium can be added to aluminum-silicon alloys in amounts up to 2% by weight. However, the examples of that patent do not show amounts of strontium above 0.1% by weight and it has been known within the industry for many years that strontium functions best as a modifier for aluminum-silicon alloys in amounts well below 0.1% by weight. It has been found that when strontium is present in amounts above about 0.1% by weight, large intermetallics of Al_4Sr and SiSr begin to form. Such intermetallics seriously degrade the strength of the alloy.

Unmodified aluminum-silicon alloy matrix composites typically contain large silicon particles and/or large intermetallics which tend to filter out and thereby accumulate at the preform/alloy melt interface during infiltration. These large silicon particles and intermetallics degrade the property significantly at the composite/alloy interface and to a lesser extent, in the entire composite. For many uses of the metal matrix composites, this loss of properties can be tolerated. However, if the composites are to be used in high stress situations where thermal fatigue is a major consideration, then such loss of properties is not tolerable.

It is the object of the present invention to develop a process for forming a composite cast article in which adequate refining or modification of the eutectic silicon will occur within the preform.

Summary of the Invention

The present invention relates to a process for forming a composite cast article comprising an aluminum-silicon alloy matrix containing strontium as a modifier and a preform of bonded-together alumina-reinforcing fibres incorporated in the matrix, wherein the preform of reinforced fibres is infiltrated under pressure by a melt of the alloy and the composite article thus formed is allowed to solidify by cooling. According to the novel feature, it has been found that by utilizing the strontium modifier in a very specific amount in the range of about 0.5 to 1.0% by weight, adequate refining or modification of the eutectic silicon is achieved within the preform.

The process of the present invention is particularly effective in the situation where the reinforcing fibres of the preform are bonded together by silica. The alloy melt is infiltrated at high temperatures typically above about 700°C and, at such temperatures, the silica in the preform binder reacts with the hot aluminum to form free silicon and this inevitably leads to excess silicon forming adjacent the reinforcing fibres. This increased silicon level renders the matrix very difficult to modify and it is surprising that suitable modification can be achieved with strontium when used according to this invention.

The procedure of the present invention is particularly effective when used in the method of producing composite cast articles described in Lloyd and Gallerneault, European application Serial No. 87309973.3, filed November 11, 1987.

The invention will now be further explained by means of the following non-limitative examples and the following drawings wherein:

Fig. 1 is a photomicrograph of a composite article with 0.25% Sr shown at the interface between the alloy and composite;

Fig. 2 is a photomicrograph of the same composite article as Fig. 1 shown within the composite region;

Fig. 3 is a photomicrograph of a composite article with 0.5% Sr shown at the interface between the alloy and composite;

Fig. 4 is a photomicrograph of the same composite article as Fig. 3 shown within the composite region;

Fig. 5 is a photomicrograph of a composite article with 1.0% Sr shown at the interface between the alloy and composite; and

Fig. 6 is a photomicrograph of the same composite article as Fig. 5 shown within the composite region.

Example 1

A commercial Al-Si alloy containing 12% silicon (Alcan 46020) was melted and modified with strontium. Several such melts were prepared with different amounts of strontium, including 0.25%, 0.5% and 1% by weight. In all cases, the melt was held at a temperature of 700°C for times ranging from 60 to 90 minutes, with occasional stirring to help dissolution.

A preform of reinforcing material was prepared from 3 µm diameter alumina fibre (Saffil® fibre available from ICI). The preform, which was bonded with silica, contained 15 volume % of fibre and had a height of 30 mm and a diameter of 70 mm. Preforms of this type are commercially available from Millmaster-Onyx of Fairfield, N.J..

The preform was heated to 800°C and placed into a 75 mm diameter die preheated to 500°C. A melt as prepared above was immediately poured on top of the hot preform and a cold ram (25°C) was used to force the molten alloy into the porous preform. The infiltration pressure was nominally 20 MPa and sufficient of the melt was used to totally infiltrate the preform and result in a composite with free matrix alloy both above and below the preform. Each composite thus formed was allowed to solidify by cooling to obtain the desired composite cast articles.

Cross sections of the composite cast articles obtained were subjected to metallographic examination by means of optical microscopy. In particular, they were examined to determine the extent to which the eutectic microstructure was modified to the preferred fine fibrous form.

When the alloy contained 0.25% by weight strontium, it can be seen from Fig. 1 that the interface between alloy and composite was comprised of high concentrations of Al_4Sr and SiSr intermetallics, while at a distance of 6 mm from the interface within the composite as shown in Fig. 2, the eutectic was clearly non-modified. When the amount of strontium in the alloy was increased to 0.5% by weight, it can be observed in Fig. 3 that large intermetallics of Al_4Sr and SiSr have formed near the alloy/composite interface and that some overmodification of the alloy itself has occurred, while substantial modification has occurred within the composite region as can be seen from Fig. 4. When the content of modifying strontium was increased to 1% by weight, in Fig. 5 large SiSr and Al_4Sr intermetallics can be observed at the alloy/composite interface with substantial overmodification of the alloy, while in Fig. 6 it can be seen that the center of the composite was completely modified.

It is to be understood that the invention is not limited to the procedures and embodiments hereinabove specifically set forth, but may be carried out in other ways without departure from its spirit.

Claims

1. In a process for forming a composite cast article comprising an aluminum-silicon alloy matrix containing a strontium modifier to reduce the particle size reached by the silicon during eutectic solidification and a preform of fibres bonded together by SiO_2 incorporated in the matrix, wherein the preform of reinforcing fibres is infiltrated under pressure by a melt of said alloy and the composite article thus formed is allowed to solidify by cooling,

the improvement which comprises incorporating the strontium modifier in the alloy in an amount of about 0.5-1.0% by weight, whereby adequate refining or modification of the eutectic silicon occurs within the preform.

2. A process according to Claim 1 wherein the preform fibres are alumina fibres.

3. A process according to Claim 1 wherein the aluminum-silicon alloy contains about 5 to 15 percent by weight of silicon.

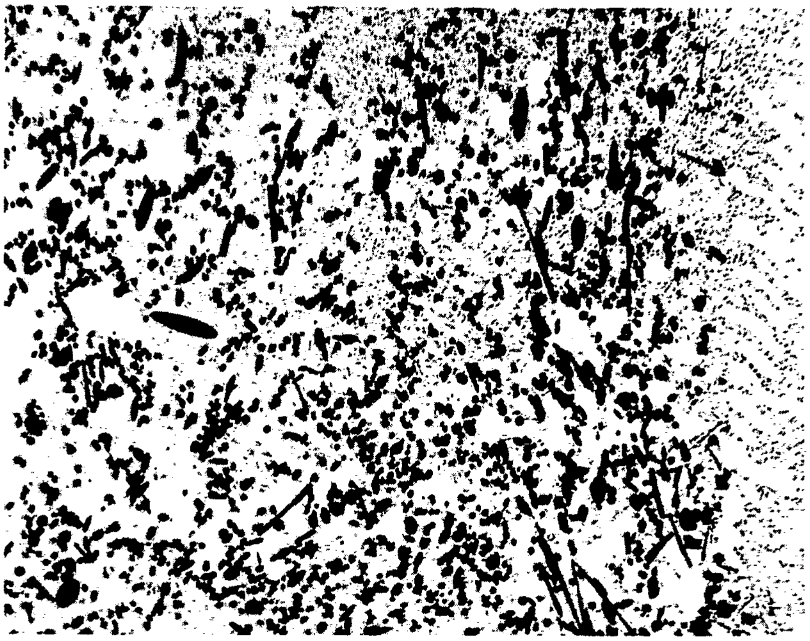

FIG. 1

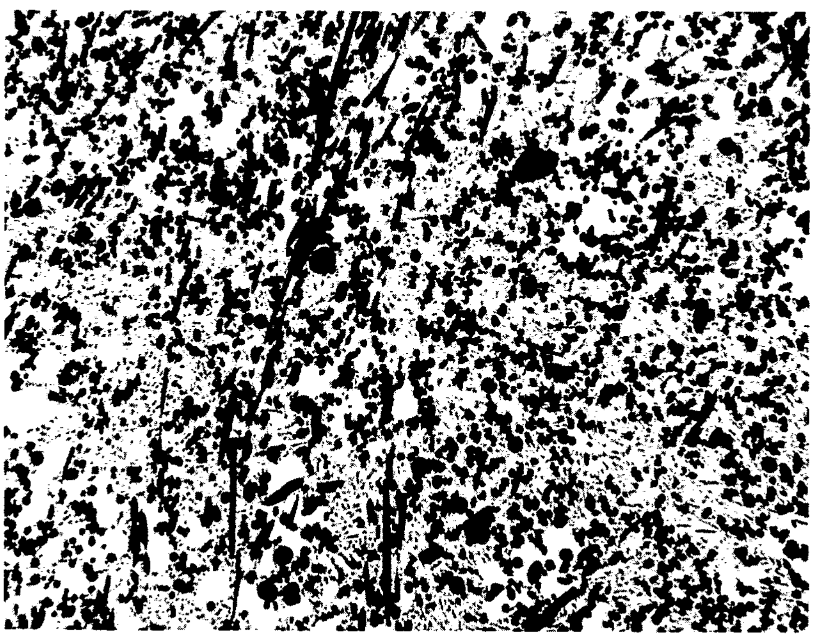

FIG. 2

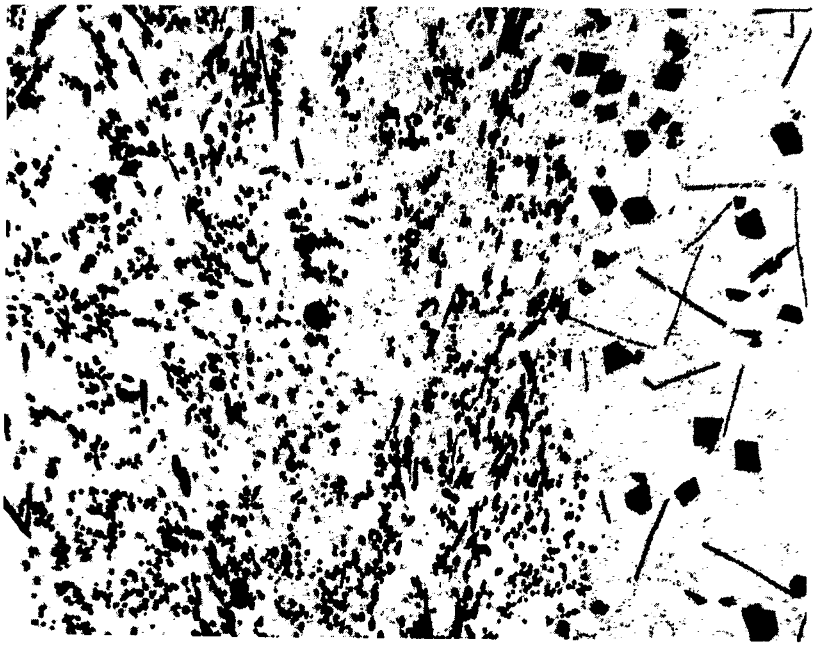

FIG. 3

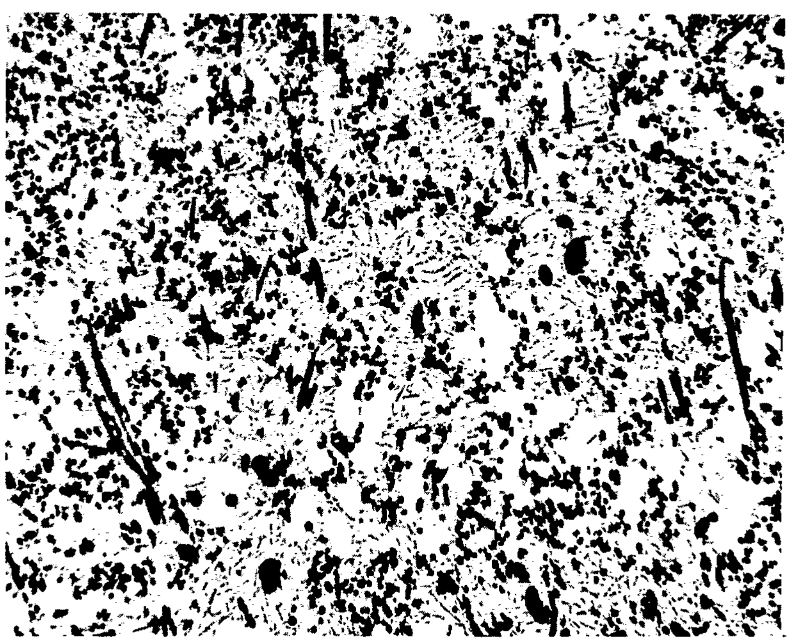

FIG. 4

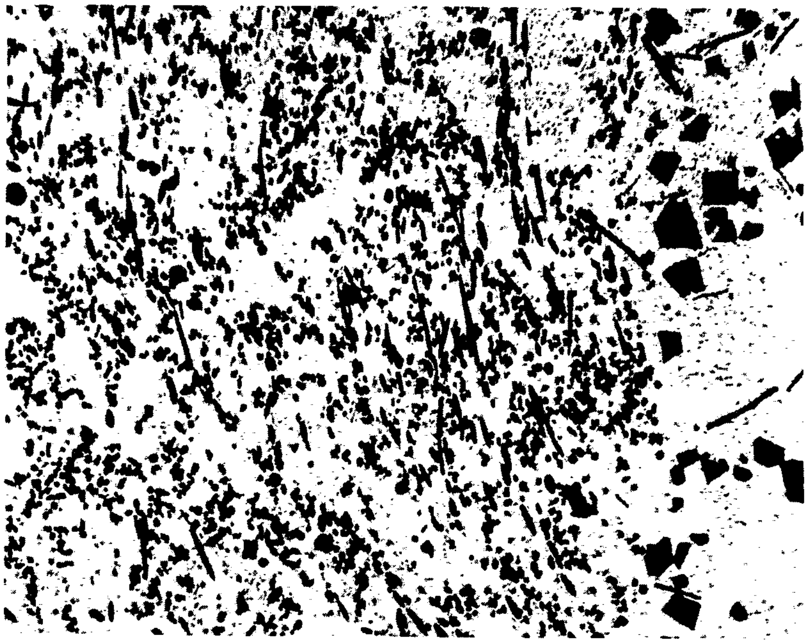

FIG. 5

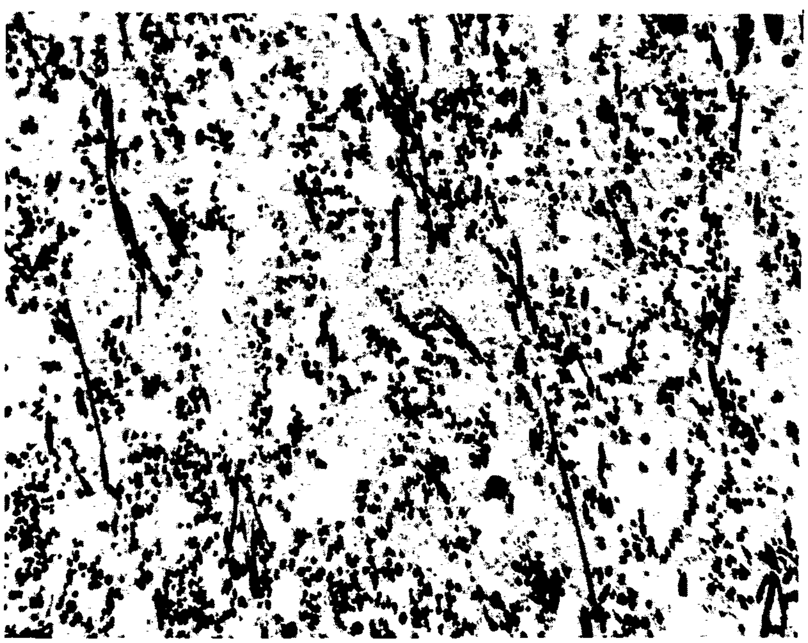

FIG. 6

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 30 9487

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
D,A	LU-A- 52 759 (METALLGESELLSCHAFT AG) * Claim 1 * ---	1	C 22 C 1/09 C 22 C 21/04
A	DE-A-3 509 944 (DAIDO METAL CO., LTD) * Claims 1,3; page 11, lines 5-20 * ---	1,3	
A	FR-A-2 314 261 (KAWECKI BERYLCO INDUSTRIES INC.) * Claims 6,8 * ---	1,3	
D,A	EP-A-0 271 222 (ALCAN INTERNATIONAL LTD) * Abstract; page 5, lines 21-27 * ---	1,2	
A	GIESSEREI-PRAXIS, no. 4, 1981, pages 61-66, DE; E. BRUNHUBER: "Kurz- und Langzeit-Veredelung von Aluminium-Silicium-Gusslegierungen" -----		

TECHNICAL FIELDS SEARCHED (Int. Cl.4)
C 22 C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	23-01-1989	GREGG N.R.

CATEGORY OF CITED DOCUMENTS

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