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(54) METHOD OF PREPARING IMPROVED HYPER-EUTECTIC ALLOYS AND COMPOSITES BASED THEREON

VERFAHREN ZUR HERSTELLUNG VON VERBESSERTE HYPEREUTEKTISCHE LEGIERUNGEN UND AUF DIESEN BASIERTE VERBUNDWERKSTOFFE

PROCEDE DE PREPARATION D'ALLIAGES AMELIORES HYPER-EUTECTIQUES ET COMPOSITES BASES SUR CES ALLIAGES

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The file contains technical information submitted after the application was filed and not included in this specification

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Description

Technical Field

This invention relates to a method of preparing improved hyper-eutectic alloys and metal matrix composites containing such alloys.

Background Art

Metal matrix composite materials have gained increasing acceptance as structural materials. Such composites typically are composed of reinforcing particles, such as fibres, grit, powder or the like that are embedded within a metallic matrix. The reinforcement imparts strength, stiffness and other desirable properties to the composite, while the matrix protects the fibres and transfers load within the composite. The two components, matrix and reinforcement, thus cooperate to achieve results which are improved over what either could provide on its own. A typical composite is an aluminum alloy reinforced with particles of silicon carbide or alumina.

A major difficulty in the production of good quality metal matrix composites is segregation of the reinforcing particles. The segregation of particles occurs in the liquid state as well as during solidification. The segregation in the liquid state can be overcome by a proper mixing of the liquid. However, even if the particles are uniformly distributed in the liquid state, they may still segregate during solidification. When metal matrix composites are in the process of solidifying, the reinforcing particles can be rejected ahead of the solidification interface, and may agglomerate in the interdendritic liquid which solidifies last. For instance, in aluminum matrix composites, solid α-aluminum dendrites are formed and the reinforcing particles are pushed ahead of the growing dendrites to be finally trapped in the last to solidify interdendritic liquid. The reinforcing particles are not found inside the aluminum dendrites and, in this sense, it can be said that the aluminum dendrites do not "wet" the reinforcing particles. This results in a highly inhomogeneous distribution of reinforcing particles in the as-cast materials.

Whether reinforcement particles are pushed by the solidification interface or are engulfed is primarily dependent upon the degree of wetting between the particles and the solid surface. If the solid surface wets the particles, they are engulfed by the solid surface. In this case the particle distribution in the solidified material is as uniform as it was in the liquid state. On the other hand, if the solid surface, e.g. aluminum dendrite surface, does not wet the particles, they are pushed away, resulting in interdendritic segregation.

In certain alloy systems, such as eutectic or hyper-eutectic systems, intermetallic compounds may precipitate directly from a melt of the alloy. These intermetallic compounds often tend to be coarse, brittle particles, and these particles tend to segregate due to density difference, particularly when the solidification rate is slow.

There is some evidence in the prior art of a degree of wetting between refractory particles and intermetallic surfaces. For instance P.K. Rohatgi, "Interfaces in Metal Matrix Composites", p. 185, The Metallurgical Society/AIME, New Orleans, 2-6 March 1986, has shown an example of primary $NiAl_3$ nucleating on graphite particles during the solidification of a hyper-eutectic Al-Ni alloy. He also noted that there is a tendency for primary Si to nucleate on graphite and alumina particles during the solidification of a hyper-eutectic Al-Si alloy.

Solidification studies of grain refining Al-Ti-B alloys are described in K. Kuisalaas and L. Backerud, Solidification Process 1987, p. 137, Institute of Metals, Sheffield, U.K., 21-24 September, 1987. These studies noted that $TiAl_3$ intermetallics tended to adhere to the surface of TiB_2 particles.

A study on aluminum alloys far elevation temperature applications is described in D.A. Granger et al.,

"Aluminum Alloys for Elevated Temperature Applications" p. 777-778, AFS Transactions, 86-143. Traditionally, casting alloys for elevated temperature applications were made by adding large amounts of Cu or Ni, e.g. up to about 8 wt% Cu and 5.5 wt% Ni. It has been generally understood that high volume fractions of the intermetallics so formed improve the high temperature properties. However, the amount of these elements which could be added was restricted because they formed large brittle intermetallic primaries on solidification if the addition was beyond a certain limit. The amount of Mn that could be added was limited to less than 0.5 wt%.

U.S. Patent No. 3,951,651 issued April 20, 1976 describes aluminum-silicon-iron alloys which can also contain reinforcing particles. However, the US patent does not describe a system where the excess elements from a hyper-eutectic alloy solidify first thereby engulfing the reinforcing particles by the intermetallics thus formed.

In S. Das et al., "Some Modified Structures of the Matrix in Cast Al-Alloy-Graphite Particle Composites", Z. Metallkde., Vol. 80 (1989) 6, p. 444-446, a hypereutectic LM30 Al-Si alloy containing 3 wt.% of graphite particles is analyzed. The LM30 alloy specification defines an alloy composition which contains,among others, from 16 to 18 wt.% Si, from 0.3 to 0.7 wt.% Mg, up to 1.1 wt.% Fe, and up to 0.3 wt.% Mn. Fig. 2 shows a preferential nucleation of primary silicon on the surface of the graphite.

It is the object of the present invention to provide a technique for improving hyper-eutectic alloys and for solving the problem of the segregation of the reinforcement particles in metal matrix composites made from hyper-eutectic

alloys which tends to occur during solidification. It is a further object of the invention to produce new alloy products having improved high temperature properties.

Disclosure of the Invention

According to the present invention, it has now been discovered that non-metallic refractory particles when added to a molten hyper-eutectic Al-Si-Mn alloy can be engulfed durina solidification by an intermetallic phase which solidifies first from the molten hypereutectic alloy during solidification thereof such that the refractory particles are engulfed by the intermetallic phase as it grows during solidification. Because the intermetallics engulf the refractory particles, there is no longer a tendency for the refractory particles to segregate to the interdendritic regions and they remain homogeneously distributed throughout an as-solidified ingot. The presence of excess alloying elements in the hyper-eutectic alloy beyond eutectic amounts is the mechanism for the formation of the desired intermetallic phase and this intermetallic phase forms automatically during cooling provided the alloy being cooled is a hyper-eutectic alloy.

One embodiment of the invention is a method for preparing a composite of an aluminum alloy and particles of a non-metallic refractory material, which comprise melting an aluminum alloy; adding particles of non-metallic refractory material to the molten aluminum matrix; mixing together the molten aluminum alloy and the particles of refractory material; and casting the resulting mixture. According to the novel feature, the aluminum alloy is a hyper-eutectic aluminum alloy comprising, in percentages by weight, 7-16% silicon, 0.5-3.0% manganese, 0-5.0% copper, 0-5.0% nickel, 0-1.0% iron, 0-0.2% titanium and 0.3-2.0% magnesium and the balance of the alloy being aluminum and inevitable impurities and the excess alloying element or elements of the hyper-eutectic molten aluminum alloy solidify first from the molten aluminum matrix during solidification thereof to form intermetallics comprising $Mn_3Si_2Al_{15}$ which engulf said refractory particles and keep them homogeneously distributed throughout the solidified product.

Best Modes For Carrying Out the Invention

In one preferred embodiment of the invention, the refractory particles act as a refiner for precipitating intermetallics. The use of unreinforced hyper-eutectic alloys is very restricted because they often form coarse, brittle intermetallic particles on solidification, and the intermetallic particles tend to segregate due to the density difference, particularly when the solidification rate is not rapid. For instance, in commercial hyper-eutectic Al-Si alloys, such as A390 alloy, used for engine block applications, phosphorus additions and fluxing have previously been required to refine the primary silicon to a size suitable for good wear properties. However, the efficiency of phosphorus to refine primary silicon decreases with increasing holding time of the melt, complicating the casting practice. On the other hand, the addition of refractory particles, such as silicon carbide particles, according to the present invention can nucleate and refine these intermetallics, as well as modify their morphology, so that the deleterious effect of coarse intermetallics is reduced. This is of particular value for alloys that are intended for high temperature use.

There is a need for aluminum alloy products capable of extended use at high temperatures. Such high temperature alloys may be used in casting applications, or as wrought products, such as forgings and extrusions. The alloy composites of this invention in which the refractory particles act as a refiner for precipitating intermetallics have superior high temperature strength, making them useful for applications such as cast brake rotors.

According to a further preferred embodiment, the refractory particles may also serve as reinforcing particles in a composite with a hyper-eutectic alloy. Thus, they may be used not only to refine a hyper-eutectic alloy, but also to form a composite therewith. When the particles are used solely to refine an alloy, they are typically used in very small sizes, e.g. less than 1 μm. On the other hand, when they are used also for reinforcing the alloy, they may be used in much larger sizes, e.g. up to 20 μm. For reinforcing, they are typically used in sizes in the range of 5-20 μm and preferably 10-15 μm. When the particles are used in reinforcing sizes, the wetting and engulfment of them by the intermetallic phase prevent the problem of segregating to the interdendritic regions during cooling.

The non-metallic refractory material is preferably a metal oxide, metal nitride, metal carbide or metal silicide. The most preferred refractory material is silicon carbide or aluminum oxide particulate.

The procedure of the present invention for making a composite functions best with reinforcing particles which are relatively equi-dimensional, e.g. having an aspect ratio in any direction of no more than 5:1. The reinforcing particles are typically added in amounts of 5-40% by volume, preferably 10-25% by volume. It has been found that silicon carbide reinforcing particles are engulfed by silicon crystals formed during solidification of the composite.

The invention also relates to new aluminum alloy products having improved high temperature properties. One of the novel products is a particle reinforced aluminum alloy casting in which the alloy is a hyper-eutectic alloy and the excess alloying element or elements of the hypereutectic alloy have solidified first from the molten metal matrix and have formed intermetallics during solidification which have engulfed the refractory particles and kept them homogeneously distributed throughout the solidified product. Another novel product is a refined aluminum alloy casting in which intermetallics formed during solidification are uniformly dispersed as fine particles because of the refining effect of

particles of non-metallic refractory material contained in the alloy.

The alloy of the novel products is a hyper-eutectic aluminum alloy containing silicon, magnesium and manganese, preferably in the amounts 7-16 wt% silicon, 0.5-3.0 wt% manganese, 0-5.0 wt% copper, 0-5.0 wt% nickel, 0-1.0 wt% iron, 0-0.2 wt% titanium and 0.3-2.0 wt% magnesium and the balance of the alloy being aluminum and inevitable impurities. The silicon assists fluidity and stabilizes the refractory particles; below 7% silicon the refractory material tends to be unstable while above 16% coarse intermetallics are formed and the composite becomes embrittled. The magnesium improves wetting and provides strengthening; below 0.3% magnesium the wetting is poor, while above 2% there is shrinkage porosity. The manganese forms intermetallics providing uniform refractory particle distribution and improved high temperature strength; below 0.5% manganese there is no improvement in high temperature strength and above 3.0% the casting temperature becomes too high.

The alloy also preferably contains up to 5.0 wt% copper. This improves elevated temperature strength with amounts above 5.0% providing poor casting fluidity and embrittlement. Another optional component is nickel which may also be present in amounts up to 5.0 wt%. It also improves elevated temperature strength, although amounts above 5.0% cause coarse intermetallics and embrittlement.

A further common optional element is iron which may be present in amounts up to 1.0 wt%. At amounts above 1.0 wt% there is the danger of forming coarse intermetallics which cannot be refined by the refractory particles.

The alloy may also contain up to 0.2 wt%, preferably 0.1-0.2 wt%, titanium as a grain refiner.

A series of aluminum alloys and the intermetallic phases that precipitate therefrom are shown in Table 1 below:

Table I

Alloy	Intermetallic
Al - 16 wt% Si ---	Si
Al - 12 wt% Si - 1.5 wt% Fe	$FeSiAl_5$
Al - 7 wt% Si - 2 wt% Fe	Fe_2SiAl_8
Al - 12 wt% Si - 1.5 wt% Mn	$Mn_3Si_2Al_{15}$
Al - 11 wt% Si - 5 wt% Ni	$NiAl_3$
Al - 10 wt% Si - 10 wt% Mg	Mg_2Si
Al - 10 wt% Si - 2 wt% Cr	$Cr_5Si_8Al_2$
Al - 16 wt% Si - 0.3 wt% Ti	$Ti(AlSi)_2$
Al - 10 wt% Si - 0.5 wt% Zr	$ZrAl_3$

Alloys of particular interest for high temperature applications are those containing substantial amounts of Mn. Such alloys may be produced by adding Mn to traditional high temperature alloy compositions until the hyper-eutectic range is reached. This is mixed with refractory particles, e.g. which refine the intermetallics and distribute the particles uniformly throughout the matrix.

Examples of new composites thus produced are given in Table II below:

Table II

Alloy
Al-10 wt% Si-1.2 wt% Mn-0.4 wt% Mg-15 vol% SiC
Al-10 wt% Si-1.2 wt% Mn-0.4 wt% Mg-5 wt% Ni-15 vol% SiC
Al-10 wt% Si-1.2 wt% Mn-1.0 wt% Mg-5 wt% Ni-2.5 wt% Cu -15 vol% SiC

While a typical intermetallic is a compound formed of at least two metallic components, within the process of this invention, silicon behaves in the manner of an intermetallic in its ability to wet and engulf refractory particles. Accordingly, the term "intermetallic" as used in this invention includes silicon.

Brief Description of the Drawings

In the drawings which illustrate the present invention:

Figure 1 is a photomicrograph of an A-356 alloy casting with refractory particles,
Figures 2-7 are photomicrographs of hyper-eutectic castings with refractory particles,
Figure 8 is a photomicrograph of a hyper-eutectic alloy casting without refractory particles,
Figure 9 is a photomicrograph of a hyper-eutectic alloy casting with refractory particles,
Figure 10 is a photomicrograph of a further hyper-eutectic alloy casting without refractory particles,

Figure 11 is a photomicrograph of a casting of the alloy of Fig. 10 with refractory particles,
Figure 12 is bar graphs showing yield strengths of different matrix alloys and composites of the invention, and
Figures 13-15 are plots of stress as a function of soak time for three different cast composites of the invention.

Example 1 (Comparative)

An aluminum matrix composite was prepared by mixing 15% by volume of silicon carbide particles having sizes in the range of 10-15 μm with a melt of A356 aluminum alloy containing 6.5 to 7.5% Si and 0.3 to 0.45% Mg. This was cast and solidified to form an ingot having the microstructure shown in Figure 1. It will be seen that the reinforcing particles have been pushed ahead of the solidification interface and are not uniformly dispersed throughout the ingot.

Example 2 (a) (Comparative)

Another ingot was prepared from a melt of Al - 16% Si alloy and 15% by volume of silicon carbide particles having particle sizes in the range of 10-15 μm. These were thoroughly mixed and the mixture was then cast and solidified to form an ingot. The ingot formed had the microstructure shown in Figure 2 and it will be seen that the reinforcing particles are uniformly spaced and are engulfed by silicon crystals. The silicon carbide particles also refined the silicon.

Example 2 (b) (Comparative)

The above procedure was repeated using a melt of Al-12 Si-1.5 Mn, to which was added 15% by volume of the same silicon carbide particles. The results in Figure 3 show particle engulfment by $Mn_3Si_2Al_{15}$ crystals.

Example 2 (c) (Comparative)

The above procedure was again repeated using a melt of Al-7Si-2Fe, to which was added 15% by volume of the same silicon carbide particles. The results in Figure 4 show particle engulfment by α-AlFeSi crystals (Fe_2SiAl_8).

Example 2 (d) (Comparative)

The above procedure was again repeated using a melt of Al-12Si-1.5 Fe, to which was added 15% by volume of the same silicon carbide particles. The results in Figure 5 show particle engulfment by β-AlFeSi crystals ($FeSiAl_5$).

Example 2 (e) (Comparative)

The above procedure was again repeated using a melt of Al-11Si-5Ni, to which was added 15% by volume of the same silicon carbide particles. The result in Figure 6 show particle engulfment by $NiAl_3$ crystals.

Example 2 (f) (Comparative)

The above procedure was again repeated using a melt of Al-10Si-10Mg, to which was added 15% by volume of the same silicon carbide particles. The results in Figure 7 show particle engulfment by Mg_2Si crystals.

Example 3 (Comparative)

Two melts were prepared by heating aluminum containing 16 wt% silicon to a temperature of 750°C. One melt was cast "as is" to form an ingot and a second melt was mixed with 15% by volume of silicon carbide particles having sizes in the range of 10-15 microns and then cast to form an ingot. The ingots were identical in size and were cooled and solidified under identical conditions. Figure 8 shows the microstructure of the ingot without the refractory particles, while Figure 9 shows the microstructure of the ingot with the refractory particles. The refinement of the silicon is clearly evident.

Example 4 (Comparative)

To illustrate the effectiveness of the refinement according to this invention, the procedure of Example 2 was repeated using a melt of Al - 7% Si - 2% Mn alloy. One cast ingot was made from the alloy itself and a second cast ingot was made from a composite of the alloy and 15% by volume of silicon carbide particles. Fig. 10 shows the microstructure of the cast alloy and Fig. 11 shows the microstructure of the cast composite. It can be seen that the primary $Mn_3Si_2Al_{15}$

intermetallic dendrites in the cast alloy are completely refined by the SiC particles.

Example 5

Three aluminum matrix composites were prepared by mixing 15% by volume of silicon carbide particles having sizes in the range of 10-15 μm with three different aluminum alloy melts. The matrix alloys had the following compositions:

Alloy A: Al - 10 wt% Si - 1.2 wt% Mn - 0.4 wt% Mg
Alloy B: Al - 10 wt% Si - 1.2 wt% Mn - 0.4 wt% Mg - 5 wt% Ni
Alloy C: Al - 10 wt% Si - 1.2 wt% Mn - 1.0 wt% Mg - 5 wt% Ni - 2.5 wt% Cu

The composites so formed were cast and solidified in the form of 12.7 mm diameter as-cast test bars and 57 mm diameter ingots. The as-cast test bars were held for 100 hours at 250°C, and tensile tested at the soak temperature. The 57 mm diameter ingots were extruded at 450°C to 9.5 mm diameter rod. Test bars were machined from the rod, and held at between 200 and 400°C for various times to examine the effect of long time exposure on the high temperature strength. The results are shown in Figure 12-15.

High temperature composite alloys may be used in casting applications, or as wrought products such as forgings and extrusions. Figure 12 shows the strength retention of as-cast material after 100 hrs at 250°C, which is relevant for applications such as cast brake rotors. The figure shows that the new alloy composites have superior high temperature strength to the presently used A356-SiC composite. It is also apparent that adding SiC reinforcement to the unreinforced alloys adds to the high temperature performance of these materials.

In wrought products additional softening mechanisms, such as sub-structure and grain size coarsening, may operate which are usually absent in as-cast material. Figures 13-15 show the time dependence of the softening at 250, 300 and 400°C. All 3 alloys show rapid softening in the first 10 hours of exposure, but beyond this are relatively stable. This initial softening is due to normal, precipitate coarsening and resolution, while after this has occurred the alloys have excellent long term stability. Comparing the extrusion results with those for as-cast test bars in Figure 12, the extruded composites have somewhat superior strength.

Industrial Applicability

It will be apparent from the above disclosure that the invention provides techniques for improving hyper-eutectic alloys, which alloys can be used for the manufacture of a variety of industrial products by conventional techniques.

Claims

1. A method for preparing a composite of an aluminum alloy and particles of a non-metallic refractory material, comprising:

   melting an aluminum alloy;
   adding particles of non-metallic refractory material to the molten aluminum matrix;
   mixing together the molten aluminum alloy and the particles of refractory material; and
   casting the resulting mixture;

   characterized in that the aluminum alloy is a hyper-eutectic metal alloy comprising, in percentages by weight, 7-16% silicon, 0.5-3.0% manganese, 0-5.0% copper, 0-5.0% nickel, 0-1.0% iron, 0-0.2% titanium and 0.3-2.0% magnesium and the balance of the alloy being aluminum and inevitable impurities and the excess alloying element or elements of the hyper-eutectic molten aluminum alloy solidify first from the molten aluminum matrix during solidification thereof to form intermetallics which comprise $Mn_3Si_2Al_{15}$ and which engulf said refractory particles and keep them homogeneously distributed throughout the solidified product.

2. A method according to claim 1 characterized in that the refractory particles are selected from the group consisting of a metal oxide, metal nitride, metal carbide and metal silicide.

3. A method according to claim 2 characterized in that the refractory particles comprise silicon carbide.

4. A method according to any one of claims 1-3 characterized in that the refractory particles are reinforcing particles

and have sizes up to 20 μm.

5. A method according to any one of claims 1-3 characterized in that the refractory particles are reinforcing particles having sizes in the range of 10 - 15 μm.

6. A method according to any one of claims 1-3 characterized in that the refractory particles have sizes of less than 1 μm.

7. A method according to claim 6 characterized in that the refractory particles nucleate and refine the intermetallics.

8. An aluminum alloy composite casting comprising a matrix of aluminum alloy having dispersed therethrough particles of non-metallic refractory material,

characterized in that the aluminum alloy is an Al-Si-Mn hyper-eutectic alloy comprising, in percentage by weight, 7-16% silicon, 0.5-3.0% manganese, 0-5.0% copper, 0-5.0% nickel, 0-1.0% iron, 0-0.2% titanium and 0.3-2.0% magnesium and the balance of the alloy being aluminum and inevitable impurities, in which the excess alloying element or elements of the hyper-eutectic alloy have solidified first from the molten aluminum matrix and have formed intermetallics comprising $Mn_3Si_2Al_{15}$ during solidification which have engulfed the refractory particles and kept them homogenerously distributed throughout the solidified product.

9. A casting according to claim 8 characterized in that the refractory particles are selected from the group consisting of a metal oxide, metal nitride, metal carbide and metal silicide.

10. A casting according to claim 8 characterized in that the refractory particles comprise silicon carbide.

11. A casting according to any one of claims 8-10 characterized in that the refractory particles have sizes up to 20 μm.

12. A casting according to any one of claims 8-10 characterized in that the refractory particles have sizes in the range of 10 - 15 μm.

13. A casting according to any one of claims 8-10 characterized in that the refractory particles have sizes of less than 1 μm.

14. A casting according to any one of claims 8-13 characterized in that the particles have an aspect ratio in any direction of no more than 5:1.

15. A casting according to any one of claims 8-14 characterized in that the particles are present in an amount of 5-40% by volume.

16. A casting according to any one of claims 8-15 characterized in that titanium is present in the alloy in an amount of 0.1-0.2%.

Patentansprüche

1. Verfahren zur Herstellung eines Verbundwerkstoffs aus einer Aluminium-Legierung und Teilchen aus einem nicht-metallischen, feuerfesten Material, umfassend:

Schmelzen einer Aluminium-Legierung;

Zugeben von Teilchen aus nicht-metallischem, feuerfestem Material zur geschmolzenen Aluminiummatrix;

Vermischen der geschmolzenen Aluminium-Legierung und der Teilchen aus feuerfestem Material; und

Gießen der resultierenden Mischung;

dadurch **gekennzeichnet**, daß
die Aluminium-Legierung eine übereutektische Metall-Legierung ist, die in Gew.-% 7-16 % Silicium, 0,5-3,0 % Mangan, 0-5,0 % Kupfer, 0-5,0 % Nickel, 0-1,0 % Eisen, 0-0,2 % Titan und 0,3-2,0 % Magnesium umfaßt, wobei

der Restanteil der Legierung Aluminium und unvermeidbare Verunreinigungen sind, und das überschüssige Legierungselement oder die -elemente der übereutektischen geschmolzenen Aluminium-Legierung zuerst aus der geschmolzenen Aluminiummatrix während deren Festwerdens erstarren, um intermetallische Verbindungen zu bilden, die $Mn_3Si_2Al_{15}$ umfassen und die feuerfesten Teilchen einhüllen und sie durch das erstarrte Produkt hindurch homogen verteilt halten.

2. Verfahren gemäß Anspruch 1,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen ausgewählt sind aus der Gruppe, die aus einem Metalloxid, Metallnitrid, Metallcarbid und Mitallsilicid besteht.

3. Verfahren gemäß Anspruch 2,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Siliciumcarbid umfassen.

4. Verfahren gemäß einem der Ansprüche 1 bis 3,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Verstärkungsteilchen sind und Größen von bis zu 20 µm aufweisen.

5. Verfahren gemäß einem der Ansprüche 1 bis 3,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Verstärkungsteilchen mit Größen im Bereich von 10 bis 15 µm sind.

6. Verfahren gemäß einem der Ansprüche 1 bis 3,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Größen von weniger als 1 µm aufweisen.

7. Verfahren gemäß Anspruch 6,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Kristallkeime bilden und die intermetallischen Verbindungen raffinieren.

8. Aluminiumlegierungs-Verbundwerkstoff-Gußstück, umfassend eine Matrix aus Aluminium-Legierung mit darin dispergierten Teilchen aus nicht-metallischem, feuerfestem Material,
dadurch **gekennzeichnet**, daß
die Aluminium-Legierung eine übereutektische Al-Si-Mn-Legierung ist, umfassend in Gew.-% 7-16 % Silicium, 0,5-3,0 % Mangan, 0-5,0 % Kupfer, 0-5,0 % Nickel, 0-1,0 % Eisen, 0-0,2 % Titan und 0,3-2,0 % Magnesium, wobei der Restanteil der Legierung Aluminium und unvermeidbare Verunreinigungen sind, worin das überschüssige Legierungselement oder die -elemente der übereutektischen Legierung zuerst aus der geschmolzenen Aluminiummatrix erstarrten und intermetallische Verbindungen, umfassend $Mn_3Si_2Al_{15}$, während des Erstarrens bildeten, welche die feuerfesten Teilchen eingehüllt und sie durch das erstarrte Produkt hindurch homogen verteilt gehalten haben.

9. Gußstück gemäß Anspruch 8,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen ausgewählt sind aus der Gruppe, die aus einem Metalloxid, Metallnitrid, Metallcarbid und Metallsilicid besteht.

10. Gußstück gemäß Anspruch 8,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Siliciumcarbid umfassen.

11. Gußstück gemäß einem der Ansprüche 8 bis 10,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Größen von bis zu 20 µm aufweisen.

12. Gußstück gemäß einem der Ansprüche 8 bis 10,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Größen im Bereich von 10 bis 15 µm aufweisen.

13. Gußstück gemäß einem der Ansprüche 8 bis 10,
dadurch **gekennzeichnet**, daß
die feuerfesten Teilchen Größen von weniger als 1 µm aufweisen.

14. Gußstück gemäß einem der Ansprüche 8 bis 13,
dadurch **gekennzeichnet**, daß
die Teilchen ein Längenverhältnis in jede Richtung von nicht mehr als 5:1 aufweisen.

15. Gußstück gemäß einem der Ansprüche 8 bis 14,
dadurch **gekennzeichnet**, daß
die Teilchen in einer Menge von 5 bis 40 Vol.-% vorhanden sind.

16. Gußstück gemäß einem der Ansprüche 8 bis 15,
dadurch **gekennzeichnet**, daß
Titan in der Legierung in einer Menge von 0,1 bis 0,2 % vorhanden ist.

Revendications

1. Procédé de préparation d'un composite d'un alliage d'aluminium et de particules d'une matière réfractaire non métallique comprenant:

la fusion d'un alliage d'aluminium;
l'addition de particules de matière réfractaire non métallique à la matrice d'aluminium fondue,
le mélange ensemble de l'alliage d'aluminium fondu et des particules de matière réfractaire; et
le coulage du mélange résultant;

caractérisé en ce que l'alliage d'aluminium est un alliage métallique hyper-eutectique comprenant, en pourcentage en poids, 7-16% de silicium, 0,5-3,0% de manganèse, 0-5,0% de cuivre, 0-5,0% de nickel, 0-1,0% de fer, 0-0,2% de titane et 0,3-2,0% de magnésium et le complément de l'alliage étant de l'aluminium et des impuretés inévitables, et le ou les éléments d'alliage en excès de l'alliage d'aluminium hyper-eutectique fondu se solidifiant d'abord dans la matrice d'aluminium fondue pendant sa solidification pour former des composés intermétalliques qui comprennent du $Mn_3Si_2Al_{15}$ et qui engloutissent lesdites particules réfractaires et les maintiennent uniformément distribués dans tout le produit solidifié.

2. Procédé selon la revendication 1, caractérisé en ce que les particules réfractaires sont choisies dans le groupe constitué d'un oxyde métallique, un nitrure métallique, un carbure métallique et un siliciure métallique.

3. Procédé selon la revendication 2, caractérisé en ce que les particules réfractaires comprennent du carbure de silicium.

4. Procédé selon l'une quelconque des revendications 1-3, caractérisé en ce que les particules réfractaires sont des particules de renfort et ont des tailles allant jusqu'à 20 µm.

5. Procédé selon l'une quelconque des revendications 1-3, caractérisé en ce que les particules réfractaires sont des particules de renfort ayant des tailles dans la gamme de 10 - 15 µm.

6. Procédé selon l'une quelconque des revendications 1-3, caractérisé en ce que les particules réfractaires ont des tailles inférieures à 1 µm.

7. Procédé selon la revendication 6, caractérisé en ce que les particules réfractaires assemblent en noyau et affinent les composés intermétalliques.

8. Coulée de composite d'un alliage d'aluminium comprenant une matrice d'aluminium dans laquelle sont dispersées des particules de matière réfractaire non métallique,
caractérisée en ce que l'alliage d'aluminium est un alliage hyper-eutectique Al-Si-Mn comprenant, en pourcentage en poids, 7-16% de silicium, 0,5-3,0% de manganèse, 0-5,0% de cuivre, 0-5,0% de nickel, 0-1,0% de fer, 0-0,2% de titane et 0,3-2,0% de magnésium et le complément de l'alliage étant de l'aluminium et des impuretés inévitables,

dans lequel le ou les éléments d'alliage en excès de l'alliage hyper-eutectique se solidifient d'abord dans la matrice d'aluminium fondue et forment des composés intermétalliques comprenant du $Mn_3Si_2Al_{15}$ pendant la solidification qui engloutissent les particules réfractaires et les maintiennent uniformément distribués dans tout le produit solidifié.

9. Coulée selon la revendication 8, caractérisée en ce que les particules réfractaires sont choisies dans le groupe constitué d'un oxyde métallique, un nitrure métallique, un carbure métallique et un siliciure métallique.

10. Coulée selon la revendication 8, caractérisée en ce que les particules réfractaires comprennent du carbure de silicium.

11. Coulée selon l'une quelconque des revendications 8-10, caractérisée en ce que les particules réfractaires ont des tailles allant jusqu'à 20 μm.

12. Coulée selon l'une quelconque des revendications 8-10, caractérisée en ce que les particules réfractaires ont des tailles dans la gamme de 10 - 15 μm.

13. Coulée selon l'une quelconque des revendications 8-10, caractérisée en ce que les particules réfractaires ont des tailles inférieures à 1 μm.

14. Coulée selon l'une quelconque des revendications 8-13, caractérisée en ce que les particules ont un rapport des côtés dans n'importe quelle direction inférieur à 5:1.

15. Coulée selon l'une quelconque des revendications 8-14, caractérisée en ce que les particules sont présentes en une proportion de 5-40% en volume.

16. Coulée selon l'une quelconque des revendications 8-15, caractérisée en ce que du titane est présent dans l'alliage en une proportion de 0,1-0,2%.



500X

FIG.1



500X

FIG.2

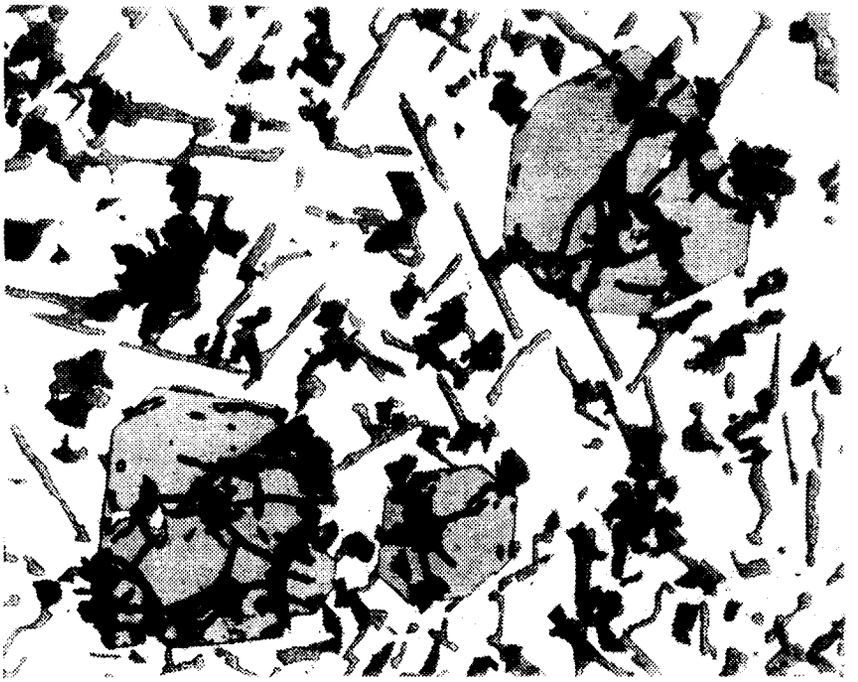


FIG.3

400X

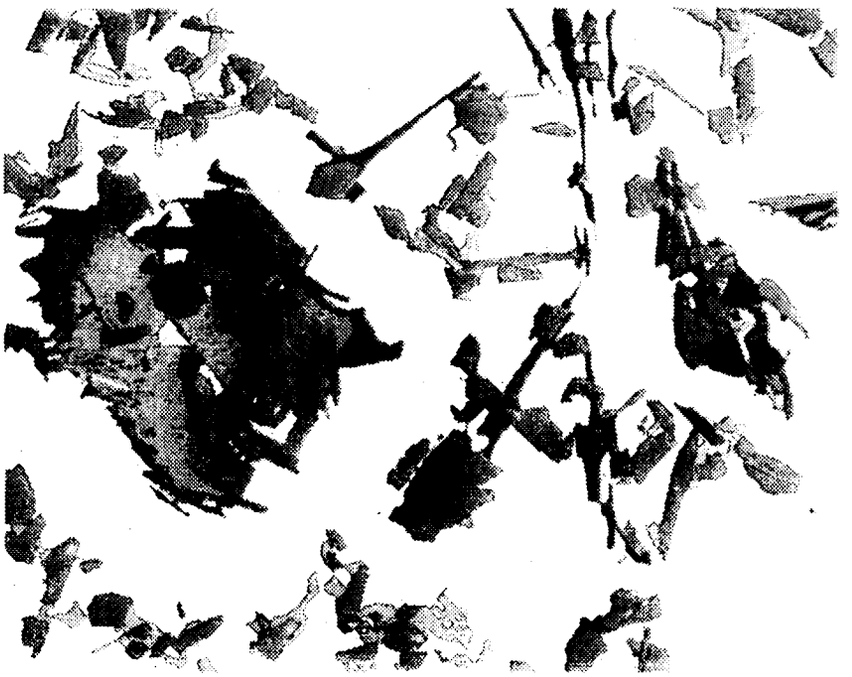


FIG.4

400X



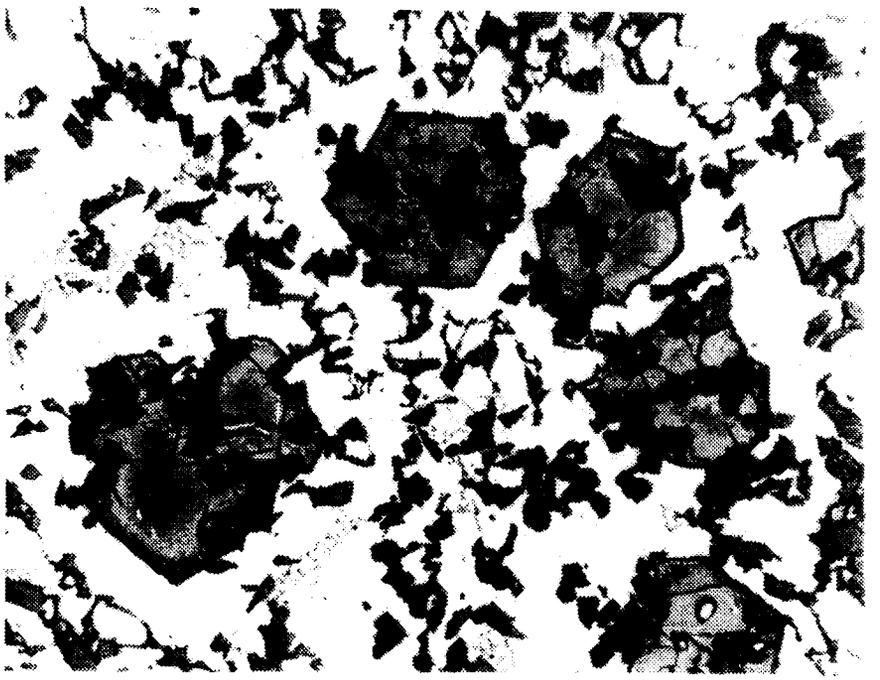
400X

FIG.5



500X

FIG.6



200X

FIG.7

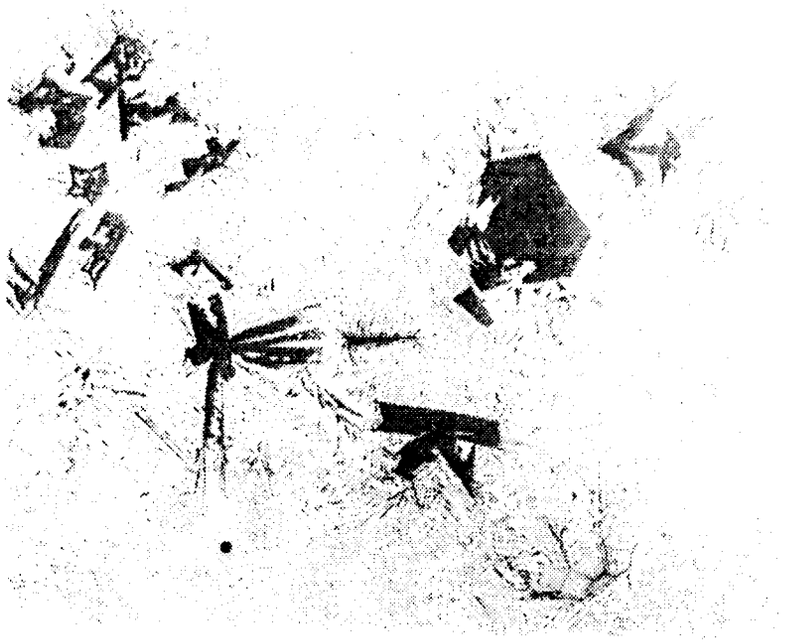


FIG.8

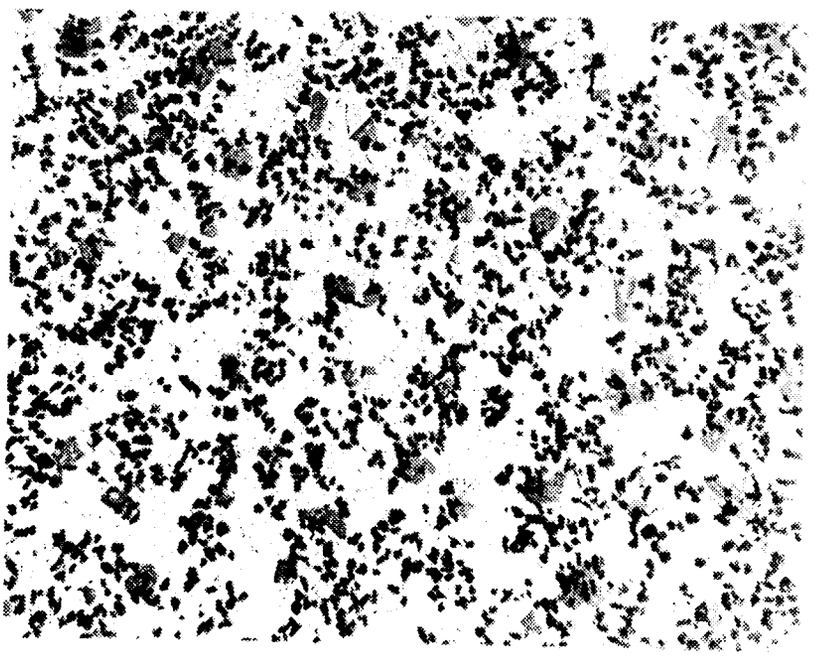


FIG.9

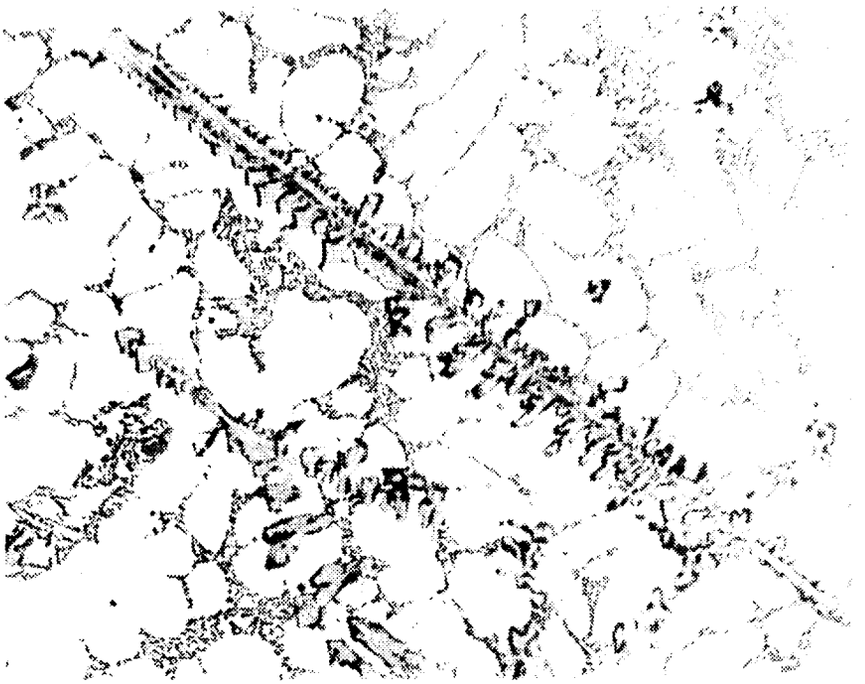


FIG.10

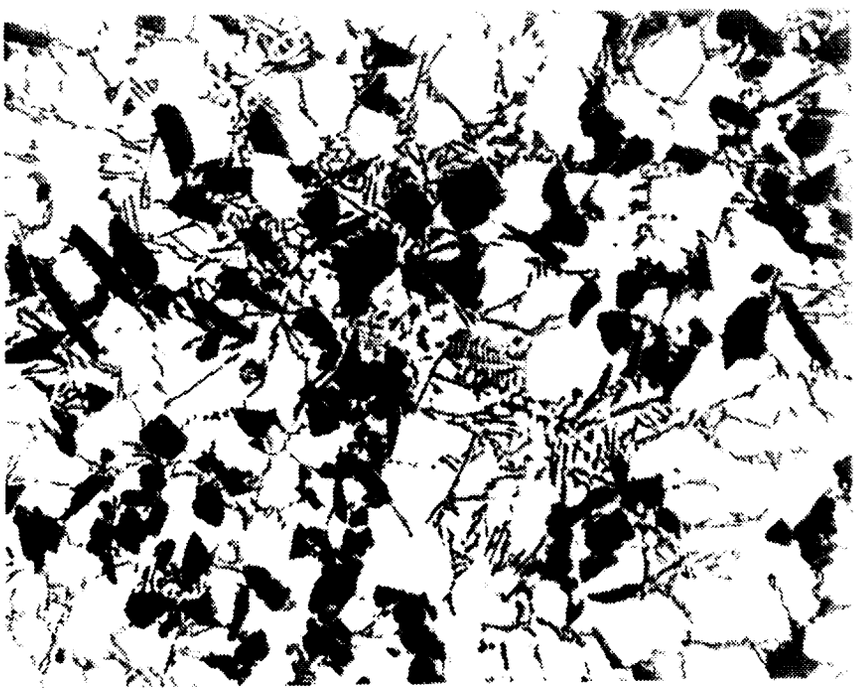


FIG.11

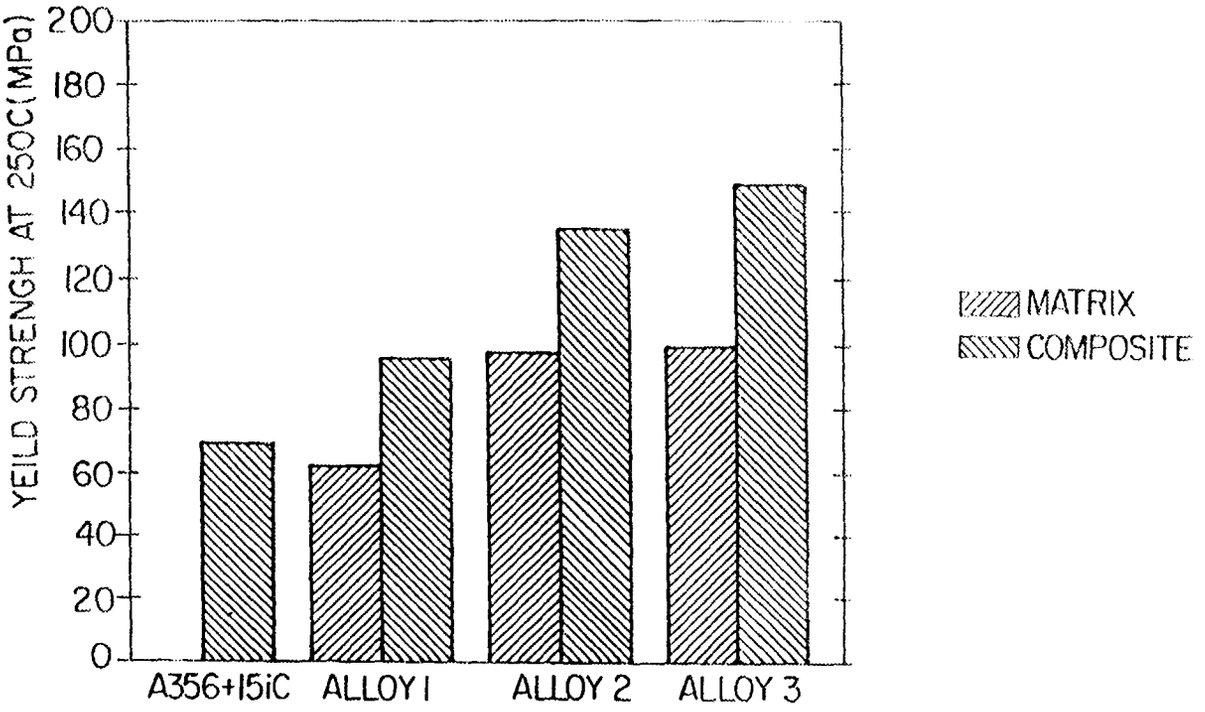

YEILD STRENGH AT 250C(MPa)
200
180
160
140
120
100
80
60
40
20
0
A356+15iC
ALLOY 1
ALLOY 2
ALLOY 3
MATRIX
COMPOSITE

FIG. 12

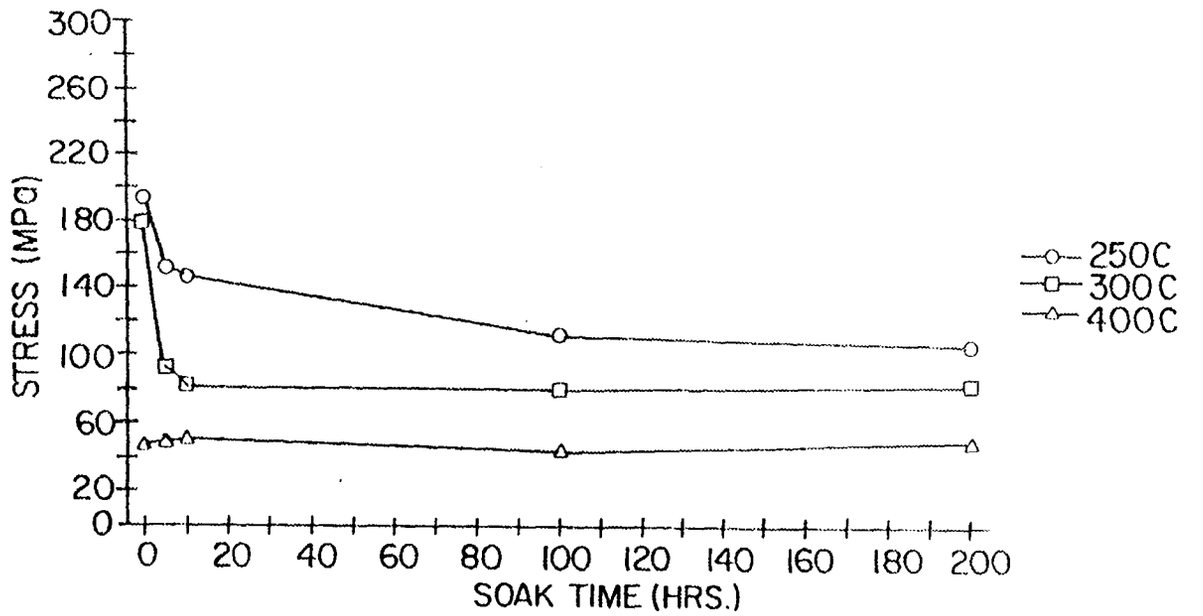

STRESS (MPa)
300
260
220
180
140
100
60
20
0
0
20
40
60
80
100
120
140
160
180
200
SOAK TIME (HRS.)
250C
300C
400C

FIG. 13

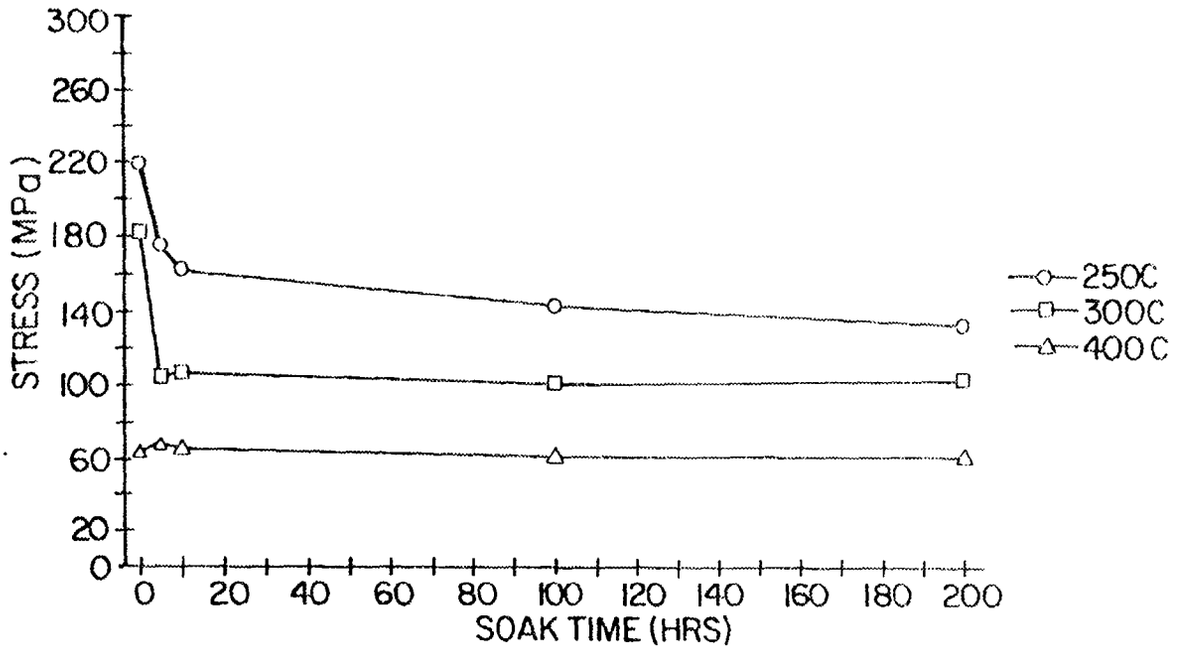

300
260
220
180
140
100
60
20
0
STRESS (MPa)
0 20 40 60 80 100 120 140 160 180 200
SOAK TIME (HRS)
250C
300C
400C

FIG.14

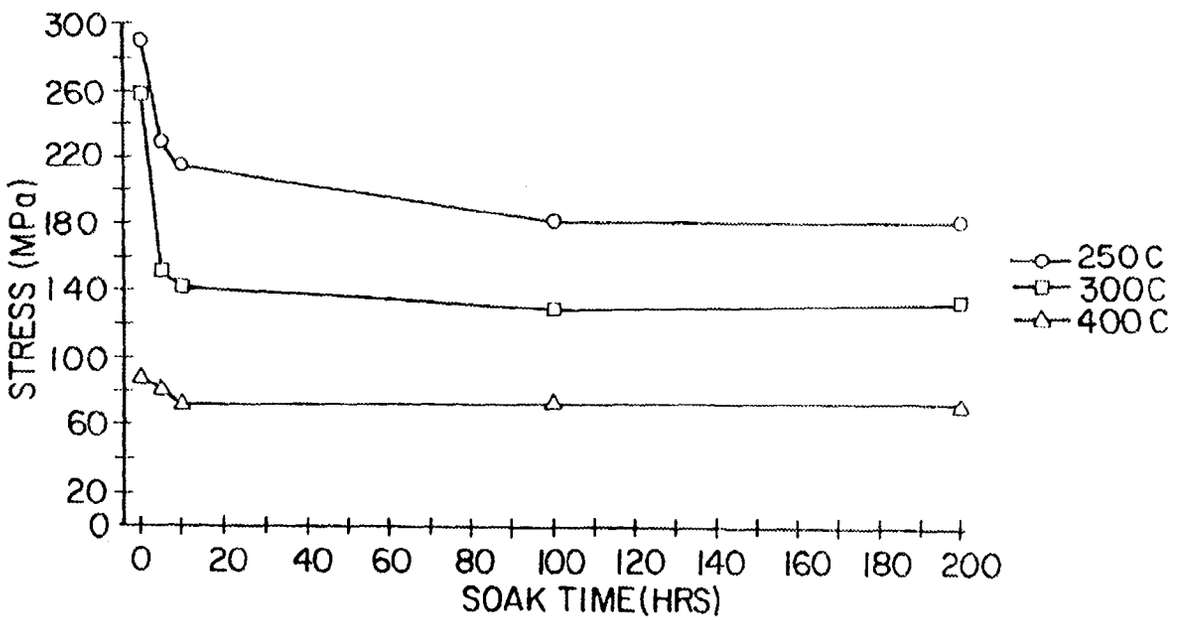

300
260
220
180
140
100
60
20
0
STRESS (MPa)
0 20 40 60 80 100 120 140 160 180 200
SOAK TIME(HRS)
250C
300C
400C

FIG.15