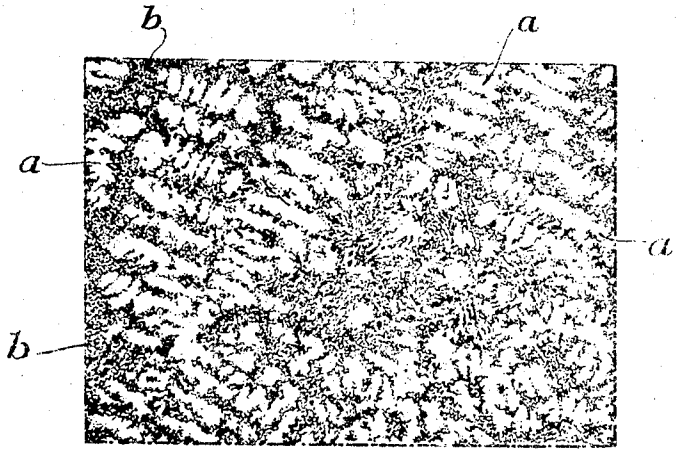
Feb. 9, 1926. 1,572,459

R. S. ARCHER ET AL

MAKING CASTINGS OF ALUMINUM SILICON ALLOYS

Filed Nov. 27, 1920



Robert S. Archer
and Junius D. Edwards
INVENTORS

BY
Cooper, Kerr & Dunham
ATTORNEYS

Patented Feb. 9, 1926. 1,572,459

UNITED STATES PATENT OFFICE.

ROBERT S. ARCHER, OF EAST CLEVELAND, OHIO, AND JUNIUS D. EDWARDS, OF PITTSBURGH, PENNSYLVANIA, ASSIGNORS TO ALUMINUM COMPANY OF AMERICA, OF PITTSBURGH, PENNSYLVANIA, A CORPORATION OF PENNSYLVANIA.

MAKING CASTINGS OF ALUMINUM-SILICON ALLOYS.

Application filed November 27, 1920. Serial No. 426,839.

To all whom it may concern:

Be it known that we, ROBERT S. ARCHER and JUNIUS D. EDWARDS, both citizens of the United States of America, residing at, respectively, East Cleveland, in the county of Cuyahoga and State of Ohio, and Pittsburgh, in the county of Allegheny and State of Pennsylvania, have invented certain new and useful Improvements in Making Castings of Aluminum-Silicon Alloys, of which the following is a full, clear, and exact description.

This invention relates to aluminum alloys containing silicon in substantial amount, and its chief object, stated briefly, is to provide a simple and effective method of making aluminum-silicon alloy castings of greatly improved physical properties, such as tensile strength and ductility. The invention is based on the discovery that these properties of aluminum-silicon alloys are markedly affected by the rate of solidification of the molten alloy, rapid cooling to complete solidification producing a very notable and advantageous increase in tensile strength and elongation.

The drawing, taken from a photomicrograph made with a magnification of 250 diameters, illustrates the structure of an aluminum alloy containing ten per cent silicon and cast according to our present invention.

While it is well known that casting an aluminum alloy in a chill mold produces a finer grain and somewhat better physical properties, we have discovered that in the case of the aluminum-silicon alloys this method of casting instead of producing merely a general reduction in grain size, and thereby obtaining the advantages which would be expected from such an alteration in structure, actually produces a fundamental change in the character of the structure of the alloy, and not a simple reduction in the size of all of the grains as would be expected from the prior art. In general, the tendency of rapidly chilling an aluminum alloy is to produce a uniformly fine-grained structure composed of constituents essentially similar to those found in the slowly cooled alloy, but in smaller particles. In the case of these silicon alloys, however, the effect is to fundamentally change not only the relative sizes and arrangement of the silicon and aluminum constituents but also their relative quantities. This change and its resulting effects will now be further described.

When commercially pure aluminum is cast in such manner that it cools at about the same rate as in an ordinary sand mold it has good elongation but rather low tensile strength. Thus cylindrical test bars two inches long and a half inch in diameter show a tensile strength of about 12,000 pounds per square inch and an elongation of about 25 per cent. With the addition of silicon to the aluminum the tensile strength of the bar increases to an extent dependent upon the amount of silicon added, but the elongation is at the same time considerably diminished. For example, sand-cast bars of approximately 90 per cent aluminum and 10 per cent silicon show a tensile strength of about 20,000 pounds per square inch and an elongation of only about 3 per cent. Under the microscope silicon appears in the form of relatively large plates or needles, which weaken the metal and induce brittleness.

On the other hand we have found that, in general, if the alloy is cast under conditions which cause rapid freezing of the metal the granular structure of the alloy is greatly refined, with concomitant increase in the desirable properties of tensile strength and ductility. The most convenient method of producing rapid freezing is casting the alloy in what is known as a "chill" mold, that is, one having walls capable of rapidly removing heat from the molten metal. Such molds are usually made of ferrous metal, say iron or steel. They are usually called permanent molds or dies and are in use for gravity casting as well as for pressure die casting. The high rate of heat removal usually found in pressure die casting makes this method in general especially advantageous for our purpose. Bars one half inch in diameter cast in an iron mold having walls averaging about an inch and a quarter thick were found to be completely solidified in from fifteen to twenty seconds, the temperature of the molten alloy when poured being about 760° C. Bars of the same size poured at the same temperature in a sand mold required over one hundred seconds to change

from the liquid to the completely solid state. The test bars used to obtain the values herein given were made under the conditions just described.

The amount of silicon in the alloy can be varied considerably, but should not, in general, be less than about 3 nor more than about 15 per cent. The best results have been obtained with alloys having low iron content, preferably not exceeding 0.6 per cent, but the advantages of the invention can be realized to a substantial degree in pressure castings with a much higher iron content. Test bars containing about 13 per cent silicon and less than 0.6 per cent iron, cast in a chill mold of the kind described above, showed a tensile strength as high as 31,000 pounds per square inch and an elongation up to 9 per cent in two inches; representing an increase of more than 50 per cent in tensile strength and about 300 per cent in elongation, over non-chilled bars of the same size and composition.

The eutectic alloy of the aluminum-silicon system has a composition of about 11 per cent to 12 per cent silicon and the remainder aluminum. When solidified by slow cooling, alloys containing less than 11 to 12 per cent silicon consist of eutectic and excess aluminum while those containing more than 11 to 12 per cent consist of eutectic and excess silicon; and those containing 11 to 12 per cent silicon are composed substantially of eutectic.

We have observed that the rapid solidification apparently changes the composition of the eutectic alloy, the silicon content being greater, at least up to a certain point, the more rapid the rate of solidification. For example, an alloy containing about 13 per cent silicon when solidified slowly, as by sand casting, consists of eutectic and particles of excess silicon. The same alloy cast in an iron mold with relatively heavy mold sections is found to consist of eutectic plus excess aluminum dendrites. While the physical nature, that is, the arrangement and size of particles of the eutectic in the latter case, is greatly modified due to chilling, the chemical composition of the eutectic has apparently also been changed. In an alloy containing less than the eutectic amount of silicon, the chilling effect produces a larger quantity of excess aluminum and a smaller quantity of eutectic than obtains with slow cooling. With higher silicon content, say 15 per cent or more, excess silicon may separate even in the chilled castings, although the quantity separated is not in general as great as with slow cooling. This tendency for the eutectic composition to be changed by rapid solidification may produce in high-silicon alloys excess silicon and in addition, what is very singular, aluminum dendrites.

In an alloy containing, for example, about 10 per cent silicon, the difference between the micro-structure produced by chill casting and that produced by ordinary sand casting seems to consist not only in a change in the arrangement and relative size of the silicon and aluminum constituents but also in their relative quantities. If such an alloy is cooled slowly, microscopic examination shows it to consist of fairly large needles or plates of silicon (producing the weakness hereinbefore referred to), imbedded in a matrix which is probably aluminum containing a small amount of silicon dissolved in it. The same alloy rapidly chilled presents an entirely different appearance, as will be seen from the drawing, which illustrates the structure of the alloy when rapidly chilled. The relatively large plates or needles of silicon have disappeared, and prominent in the field are relatively large dendritic crystals, such as indicated at *a* in the drawing, which appear to be aluminum, probably containing a very small amount of dissolved silicon. The matrix *b* is made up of an extremely fine-grained and intimate mixture of minute particles of silicon and aluminum. Our work indicates that many at least of the minute particles of silicon tend to the globular rather than the needle or plate form. We believe that this difference in structure is connected with the relatively slow rate of crystallization of the metalloid silicon, as compared with the metal aluminum, and that the rapid chilling intensifies the effects of this difference in rate of crystallization. This difference in structure gives us in the case of a chill casting a material composed of ductile dendrites in a very fine-grained matrix, with none of the large particles of hard and brittle silicon which characterize high silicon alloys that have solidified slowly. In the form of relatively large plates or needles, silicon does not impart to the alloy the best properties of which it is capable.

The invention is not limited to alloys composed of aluminum and silicon alone. For example metals which are capable of forming solid solutions in aluminum may be added. Thus in many cases copper up to about 5 per cent, preferably from 3 to 4 per cent, has been observed to have an advantageous effect upon alloys containing silicon, especially if the silicon content is from 3 to 6 per cent, preferably about 5 per cent, and if the castings are subjected to the novel heat treatment described in the copending application of Robert S. Archer and Zay Jeffries, Serial No. 435,024. For some purposes, a higher copper content is desirable. It has been found, however, that lower copper and higher silicon content can be used to advantage. Thus an alloy containing silicon 8 per cent and copper 2 per cent, approxi-

mately, gives a good combination of physical properties and excellent casting qualities, especially in pressure die casting, due to its fluidity and reduced shrinkage.

The presence of zinc is sometimes advantageous, especially if the casting is heat-treated by the method just referred to. Thus a heat-treated chill-cast test bar of an alloy containing 6 per cent silicon, 3 per cent copper and 12 per cent zinc, showed a tensile strength of 44,000 pounds per square inch and an elongation of 6 per cent. With 8 per cent silicon, 1 per cent copper and 5 per cent zinc the tensile strength after heat-treatment was 31,000 pounds per square inch but the elongation was 13 per cent. Without copper the presence of zinc is in general more desirable in alloys to which alkali metal has been added, as described in the copending application of Junius D. Edwards, Harry V. Churchill and Francis C. Frary, Serial No. 426,796 than in a plain aluminum-silicon alloy.

We are aware that a fine-grained state of the silicon may be produced in other ways, for example by addition of alkali metal to the alloy as disclosed in the above-mentioned application of Edwards, Churchill and Frary, but we have found it advantageous to superimpose the chilling effect even in such cases, as it produces an improved combination of physical properties, and finer structure of the silicon-aluminum eutectic, than would result with the same alloy (containing alkali metal) cast by a method in which the rate of cooling is relatively slow. This is particularly the case in alloys of relatively high iron content, where the alkali metal addition produces only a moderate improvement in the size of the particles, plates or needles of the iron-rich constituent. The chilling, however, has a much greater effect in this direction.

What we claim is—

1. The method of making castings of aluminum-silicon alloy, comprising filling the mold with the molten alloy and causing the silicon in the alloy to take the form of minute particles by solidifying the alloy rapidly.

2. The method of making castings of aluminum-silicon alloy, comprising filling the mold with the molten alloy and by rapid cooling producing a fine-grained structure in the solidified alloy and causing fine dispersion of the precipitating silicon in the form of minute particles.

3. The method of making castings of aluminum-silicon alloy containing a metal capable of forming a solid solution in aluminum, comprising filling the mold with the molten alloy and by rapid solidification causing fine dispersion of the silicon in the form of minute particles.

4. The method of making castings of aluminum-silicon-copper alloy, comprising filling the mold with the molten alloy and by rapid cooling causing the alloy to solidify with a fine-grained structure and the precipitating silicon to take the form of minute particles.

5. The method of making castings of aluminum-silicon alloy containing substantial amounts of copper and zinc, comprising filling the mold with the molten alloy and cooling the alloy rapidly at a rate adequate to cause the metal to solidify with a fine-grained structure and with the silicon in the form of finely dispersed minute particles.

6. As a new product, a chill casting of aluminum-silicon alloy, characterized by minute subdivision of the silicon, and increased strength and ductility.

7. As a new product, a chill casting of aluminum-silicon alloy containing not less than about 3 nor more than about 15 per cent silicon, characterized by minute subdivision of the silicon, and high strength and ductility.

8. As a new product, a chill casting of aluminum alloy containing 8 to 13 per cent silicon, approximately, characterized by minute subdivision of the silicon and concomitant high tensile strength and ductility.

9. As a new product, a chill casting of aluminum-silicon alloy containing not more than about 0.6 per cent of iron, characterized by minute subdivision of the silicon and increased strength and ductility.

10. As a new product, a chill casting of aluminum-silicon alloy containing not less than about 3 nor more than about 15 per cent silicon and having an iron content not exceeding about 0.6 per cent, characterized by minute subdivision of the silicon and high strength and ductility.

11. As a new product, a chill casting of aluminum alloy containing 8 to 13 per cent silicon, approximately, and having an iron content not exceeding about 0.6 per cent, characterized by minute subdivision of the silicon and concomitant high tensile strength and ductility.

12. As a new product, a chill casting of aluminum alloy containing not less than about 3 per cent silicon, and a metal capable of existing in solid solution in the aluminum, characterized by minute subdivision of the silicon and increased strength and ductility.

13. As a new product, a chill casting of aluminum alloy containing substantial amounts of silicon and copper, characterized by minute subdivision of the silicon and increased strength and ductility.

14. As a new product, a chill casting of aluminum alloy containing substantial amounts of silicon, copper and zinc, characterized by minute subdivision of the silicon and increased strength and ductility.

15. As a new product, a chill casting of aluminum alloy containing substantial amounts of silicon and zinc, characterized by minute subdivision of the silicon and increased strength and ductility.

16. As a new product, a chill casting of aluminum-silicon alloy containing copper and zinc and not less than about 3 nor more than about 15 per cent silicon, characterized by minute subdivision of the silicon and increased strength and ductility.

17. As a new product, a chill casting of aluminum-silicon alloy containing zinc and not less than about 3 nor more than about 15 per cent silicon, characterized by minute subdivision of the silicon and increased strength and ductility.

18. As a new product, a chill casting of aluminum alloy containing copper and zinc and about 8 per cent silicon, approximately, characterized by minute subdivision of the silicon and concomitant high tensile strength and ductility.

19. As a new product, a chill casting of aluminum alloy containing copper and from 3 to 8 per cent silicon, approximately, characterized by minute subdivision of the silicon and concomitant increased tensile strength and ductility.

20. As a new product, a chill casting of aluminum alloy containing about 6 per cent silicon and about 4 per cent copper, characterized by minute subdivision of the silicon and concomitant increased tensile strength and ductility.

21. As a new product, a pressure die casting of aluminum alloy containing between 3 and 15 per cent silicon, approximately, characterized by minute subdivision of the silicon and increased tensile strength and ductility.

In testimony whereof we hereto affix our signatures.

ROBERT S. ARCHER.
JUNIUS D. EDWARDS.

DISCLAIMER

1,572,459.—*Robert S. Archer*, East Cleveland, Ohio, and *Junius D. Edwards*, Pittsburgh, Pa. MAKING CASTINGS OF ALUMINUM-SILICON ALLOYS. Patent dated February 9, 1926. Disclaimer filed November 14, 1941, by the assignee, *Aluminum Company of America*.

Hereby disclaims:

From claim 1 of the patent, any method of making castings of aluminum-silicon alloy in which the amount of silicon in the alloy is less than about 3 or more than about 15%;

From claim 2 of the patent, any method of making castings of aluminum-silicon alloy in which the amount of silicon in the alloy is less than about 3 or more than about 15%;

From claim 3 of the patent, any method of making castings of aluminum-silicon alloy in which the amount of silicon in the alloy is less than about 3 or more than about 15%;

From claim 4 of the patent, any method of making castings of aluminum-silicon-copper alloy in which the amount of silicon in the alloy is less than about 3 or more than about 15%, and any method of making castings of aluminum-silicon-copper alloy in which the amount of copper in the alloy is more than about 5%;

From claim 5 of the patent, any method of making castings of aluminum-silicon alloy containing substantial amounts of copper and zinc, in which the amount of silicon in the alloy is less than about 3 or more than about 15%, any method of making castings of aluminum-silicon alloy containing substantial amounts of copper and zinc in which the amount of copper in the alloy is more than about 5%, and any method of making castings of aluminum-silicon alloy containing substantial amounts of copper and zinc in which the amount of zinc in the alloy is more than about 12%;

Claim 6 of the patent;

Claim 9 of the patent;

From claim 12 of the patent, any chill casting of aluminum alloy which contains more than about 15% of silicon;

From claim 13 of the patent, any chill casting of aluminum alloy which contains less than about 3 or more than about 15% of silicon, and any chill casting of aluminum alloy which contains more than about 5% of copper;

Claim 14 of the patent;

Claim 15 of the patent;

From claim 16 of the patent, any chill casting of aluminum-silicon alloy which contains more than about 5% of copper, and any chill casting of aluminum-silicon alloy which contains more than about 12% of zinc;

From claim 17 of the patent, any chill casting of aluminum-silicon alloy which contains more than about 12% of zinc;

From claim 18 of the patent, any chill casting of aluminum alloy which contains more than about 5% of copper, and any chill casting of aluminum alloy which contains more than about 12% of zinc;

From claim 19 of the patent, any chill casting of aluminum alloy which contains more than about 5% of copper.

[*Official Gazette December 9, 1941.*]