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MANUFACTURE OF ALUMINUM ALLOYS

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This invention relates to aluminum alloys and is concerned principally with the production of such alloys from finely divided metal powders containing a relatively large proportion of aluminum and a relatively small proportion of one or more metals that are alloyable with aluminum. The invention aims to produce improved aluminum alloy metal objects in a dense form or with controlled porosity.

Aluminum oxidizes very readily, particularly when it is finely divided. Particles of aluminum or aluminum alloys do not bond together when subjected to ordinary sintering operations, even when they have been compressed together under high pressures. I attribute this to the presence of a thin film of aluminum oxide or other aluminum compound upon the surface of the metal particles which prevents the particles from sticking together. However, as a result of my investigations I have discovered that powders of aluminum or aluminum alloy may be bound together by compressing them into a coherent mass, heating the coherent mass in a desiccated non-oxidizing atmosphere and maintaining the coherent mass in said atmosphere for a relatively long period of time at a temperature below the melting point of aluminum but at which diffusion of aluminum occurs between the particles. Thus by diffusion welding the particles become bound together, despite the presence of relatively small amounts of oxidation products on the surface of the powder particles. A reducing atmosphere is preferable, but oddly enough, any non-oxidizing atmosphere is suitable provided that it is substantially desiccated.

If copper, nickel, manganese, silicon, iron, chromium, zinc or other metal which alloys with aluminum is included with the finely divided aluminum that is subjected to the compression and heat treatment operation described above, the resulting alloy mass may be tempered or age-hardened provided that the mass is quenched from an elevated temperature prior to the tempering or age-hardening operation.

The aluminum alloys which result from the practice of my invention may be produced in any desired density ranging from slightly above the density of the unconsolidated powders to the density of wrought aluminum alloys. A porous aluminum alloy may be produced in the process of my invention by employing a pressure such that the resulting coherent mass contains voids or by including in the mixture of finely divided metals volatile substances such as camphor or a volatile salt. If such a volatile substance is employed,

high pressures may be used and a dense mass formed. Thereafter, the volatile material is driven off during the heating operation so that the desired porous structure results.

The powders employed should be very finely divided. Preferably, they should pass through 325 mesh, although the presence of some minus 200 mesh material may be tolerated. Moreover, they should be employed in a fresh condition with a minimum of oxidation productions on their surfaces. The aluminum and the alloy ingredients such as magnesium, copper, nickel, manganese, silicon, iron, chromium and zinc may be employed as powders of the elements or as alloy powders. Thus I have found it convenient to form a master alloy of aluminum and silicon in powdered form by atomizing the molten alloy in an atmosphere of hydrogen or city gas.

In forming an alloy metal object, there may be added to the master alloy such proportions of magnesium or other metals in finely divided form as may be required for the particular product. In all cases the powders employed must be thoroughly mixed prior to compression. The powders should be retained in a dry condition during and prior to compression in order to avoid the formation of excessive amounts of oxidation products.

The powdered mixture formed as described above is subjected to compression employing pressures of from 5 to 100 tons per square inch. No binding material is necessary, although the presence of camphor or a volatile salt or the like is desirable when an alloy of controlled porosity is required.

Better results are obtained when the powders are compressed into a coherent mass in a relatively cold condition. Compression of hot powders into a coherent mass is not recommended.

The slugs or other consolidated pieces which are formed in the compression operation are subjected to heat treatment. The treatment temperature should be approximately two-thirds of the weighted average of the melting points of the elements present in the mass. Generally, the heat treatment should take place at temperatures ranging from 450 to 650° C., and should endure from 30 minutes to 24 hours. The heating must be carried out in a non-oxidizing atmosphere from which substantially all water has been removed. Thus the heating may be conducted in a vacuum or in a desiccated atmosphere of hydrogen, city gas, natural gas, carbon monoxide or carbon dioxide.

After heat treatment the resulting alloy should

be subjected to quenching in order to render it amenable to hardening by subsequent heating or aging. This quenching may take place immediately after heat treatment, in which case the hot alloy is removed from the furnace and plunged directly into a quenching bath, (preferably of water at about 20° C.) or the heat treated object may be allowed to cool down slowly to-atmospheric temperatures or thereabouts and later reheated and quenched. In this latter procedure the heat treated alloys should not be allowed to cool at a rate greater than 600° C. per hour. The cooling should take place in the non-oxidizing atmosphere. The cooled object should be reheated to a temperature ranging from 450° C. to 550° C. and held at this temperature for one-half to two hours in a non-oxidizing atmosphere prior to quenching (preferably in water at about 20° C.).

The quenched alloys formed from aluminum powders as hereinbefore described may be tempered and hardened by heating them to and maintaining them at a temperature ranging from 100 to 200° C. for a time ranging from 15 minutes to 24 hours. They may also be age-hardened (precipitation hardening) at room temperature by retaining them at this temperature for a period ranging from one hour to thirty days.

If it is desired to produce a very dense or hard aluminum alloy the heat treated alloy should be subjected to a second pressing or repressing operation either before or after quenching.

Aluminum alloys prepared in the manner described briefly above possess physical properties considerably superior to those of corresponding alloys prepared by heretofore customary methods, for example, casting. Moreover, my invention possesses an advantage in that it permits the manufacture of alloys of any desired degree of porosity and also permits the production of alloys of uniform porosity. A further advantage resides in the fact that alloys may be prepared in accordance with the invention with proportions of ingredients that would not be possible or practical in cast alloys. Fourthly, porous alloys may be prepared according to my invention which possess a hardness and malleability corresponding to dense cast alloys.

My invention will be more thoroughly understood in the light of the following detailed description of the preparation of an aluminum silicon alloy according to the process of my invention.

Aluminum and silicon powders in a relatively clean condition and advantageously of sufficient fineness to pass 200 to 325 mesh screens are thoroughly mixed. If a porous alloy is desired non-metallic volatile ingredients such as camphor may also be added and thoroughly incorporated. The volatile non-metallic ingredients of the mixture should be as finely divided as the metallic powders.

The aluminum may constitute from 70 to 97% by weight of the metallic constituents of the mixture and the silicon from 3 to 30% by weight. Preferably, the aluminum should constitute from 85 to 95% by weight of the mixture, the balance being made up of silicon.

The powders after thorough mixing are placed in a mold and subjected to compression under a piston or the like. As indicated hereinbefore the powders subjected to compression should be in a relatively cold condition. The pressure employed will vary depending upon the desired density of the final product. If a very porous struc-

ture is desired the pressure may well be as low as five tons per square inch (or even less provided that a coherent mass is formed). When very dense objects are desired, the pressure employed may be as high as 100 tons per square inch. For objects having a density comparable with the density of cast or forged aluminum alloys, a pressure of 45 to 65 tons per square inch is generally satisfactory.

The object produced in the compression operation is relatively fragile but sufficiently coherent to stand considerable handling and to hold together during the heating operation.

The heating operation is designed to bind the particles of metal powder securely together by diffusion welding or alloying. A closed furnace is employed. Reducing or inert atmosphere is maintained within the furnace by passing a current of hydrogen gas or the like through it. In order to assure that the atmosphere within the furnace is completely desiccated the hydrogen or other gas supplied to the furnace should first be passed over a desiccating agent such as metallic calcium. It is desirable to maintain a boat of metallic calcium within the furnace during the sintering operation as a further safeguard against the presence of moisture.

In the case of the aluminum silicon alloy described hereinbefore, the temperature of treatment should be in the neighborhood of 500° C. This temperature is high enough to permit diffusion welding without melting either the silicon or the aluminum and is also high enough to expel any volatile material which has been included in the mass for purposes of developing porosity. The volatile matter escapes as vapors and in escaping forms minute channels through the product.

In the event that an absorptive porous structure is desired, it is better to form a porous alloy by including volatile material in the primary mixture, as contrasted with employing no volatile material and relying upon a low pressure of consolidation to give the required porosity. This is because the volatile material in escaping assures the presence of channels to the outside surface of the alloy object, whereas the other method may result in blind pores which cannot absorb.

The coherent mass is held at the elevated temperature for about 8 hours. Thereafter, it is either quenched immediately in water or permitted to cool down to room temperature at a rate not to exceed 600° C. per hour. In case the alloy is allowed to cool, it is then heated up to from 450 to 550° C., held at this temperature for from one-half to two hours in a non-oxidizing atmosphere, and then quenched in water at room temperature.

A silicon aluminum or other aluminum alloy produced as described hereinbefore is satisfactory for many uses without further treatment. However, it may be desirable to increase its strength by a second pressing or repressing operation which may occur either before or after quenching and with the material in a substantially cold condition. The repressing operation may increase the strength of the product but its principal function is to increase its density. The repressing operation should be carried out in substantially the same manner as the original pressing operation. If the original pressing operation has been conducted with the metal powder in suitable dies, the same dies or dies of virtually the same size and shape may be em-

ployed in the repressing operation. In general the pressures employed in the repressing operation range from 45 to 65 tons per square inch.

The kind and proportion of the metal alloying ingredients employed with the aluminum vary depending upon the intended use. The following proportions are intended to be illustrative and not restrictive.

When a binary alloy of silicon and aluminum is desired the aluminum content should range from 70 to 97% and preferably from 85 to 95% by weight, with silicon making up the balance.

When aluminum-silicon-copper-magnesium alloys are desired the following are satisfactory composition ranges:

	Per cent
Aluminum.....	83 to 96
Silicon.....	3 to 10
Copper.....	1 to 5
Magnesium.....	0.1 to 2

Aluminum - silicon-copper-nickel - magnesium alloys should correspond to the following composition:

	Per cent
Aluminum.....	61 to 94
Silicon.....	5 to 25
Copper.....	0.5 to 5
Nickel.....	0.5 to 5
Magnesium.....	0.1 to 4

When binary alloys of copper and aluminum are desired the aluminum should range from 80 to 98% by weight, and the copper from 2 to 20% by weight.

The function of the magnesium, copper, nickel, manganese, silicon, iron, chromium or zinc included in the alloy is to increase the hardness and to form an alloy which is susceptible to age-hardening and tempering.

The invention provides a method for producing alloy products that heretofore have been made only by forging, by die-casting operations or by complicated machining processes. The method of the invention achieves substantially the simplicity and high output rate of die-casting opera-

tions while permitting the use of alloy compositions that cannot be die-cast and hence have been fabricated heretofore largely by complex machining operations. Alloy products prepared in accordance with the invention are especially suited for use wherever a combination of strength, lightness and accuracy of configuration is important.

I claim:

1. In a process for producing a porous mass of aluminum alloy, the improvement which comprises compressing into a coherent mass a mixture of a solid substance that is volatile at a relatively low temperature and finely-divided metal powders containing a relatively large proportion of aluminum and a relatively small proportion of a metal alloyable with aluminum and heating said coherent mass for a considerable period of time at a temperature below the melting point of aluminum but at which diffusion of aluminum occurs between the metal powder particles while said particles remain in a substantially solid condition, said temperature being above the volatilizing temperature of the volatile substance and said heating taking place in a desiccated non-oxidizing atmosphere, whereby the metal powder particles become welded together and the volatile substance is expelled to produce a porous mass.

2. A process for producing aluminum alloys which comprises compressing into a coherent mass finely-divided metal powders containing a relatively large proportion of aluminum powder particles having relatively small amounts of oxidation products on the surface thereof and a relatively small proportion of a metallic alloying ingredient, and heating said coherent mass for a considerable period of time at a temperature at which the metal powder particles remain in a solid condition but at which diffusion of aluminum occurs between the metal powder particles, said heating taking place in the presence of metallic calcium in an atmosphere that is desiccated and inert with respect to metallic aluminum.

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