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METAL-WORKING PROCESS AND PRODUCT

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This invention relates to a method of extruding and cold working certain aluminous materials which creates a condition in the materials that makes it possible to anneal them at a lower temperature and the extruded and cold worked product having that characteristic.

The extrusion process of shaping metal has been employed in the metal working art for many years and it has been used very extensively in the production of aluminum articles and aluminum base alloys. As applied to the manufacture of such aluminous products the process has generally involved heating the metal body to be extruded to a high enough temperature to permit a ready flow of the metal, placing the body in a heated cylinder and forcing the metal out of a die mounted at one end of the cylinder. In extruding aluminum of commercial purity and those aluminum base alloys which do not receive a precipitation treatment to increase their strength it has been the practice to heat the metal bodies, usually ingots, to a temperature within the range of about 750 to 1000° F. before inserting them in the cylinder of the extrusion press. The pressure applied during extrusion often causes some heating of the metal with the result that there is little, if any, cooling of the metal body occurring during the course of the extrusion operation. The temperature to which the body is heated prior to extrusion is therefore considered to be the nominal temperature of the metal during extrusion and is referred to as the extrusion temperature. The extrusion of aluminum and aluminum base alloys within the temperature range of 750 to 1000° F. is regarded as hot working as distinguished from working at room temperature, for example, which results in strain hardening. The extruded product is usually allowed to cool to room temperature before being subjected to any further fabricating operation.

In many cases the extruded article has the desired shape and no further working is required; however, it is often advantageous to produce a semi-finished product by extrusion and to complete the fabrication by cold working, such as cold drawing. The fibering effect of the extrusion operation usually persists in the cold worked product and gives it directional properties not found in rolled or forged articles. If the semi-finished extrusion is cold worked the strength and

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hardness are increased. If a soft instead of a work hardened product is desired then the cold worked article must be annealed. Where the finished article is annealed the treatment is referred to as a final anneal whereas if there is to be further working it is spoken of as an intermediate anneal.

As mentioned above, the effect of an annealing treatment is to decrease the strength and hardness of the worked article to a minimum value. Hence, tensile tests can be used to reveal the progress of softening and when the strength, elongation and hardness values reach a substantially constant minimum it is considered that the material has been fully annealed. From the standpoint of the internal structure of the annealed metal it will be found that the treatment has caused the grain fragments produced by working of the metal to form new grains or crystals that are free from work strains. When tensile tests show that a marked decrease in yield strength and increase in elongation have occurred the formation of new grains has begun.

The temperature at which new grains or crystals form is called the recrystallization temperature. This temperature is not the same for all purities of aluminum and all aluminum base alloys. The principal factors which control the recrystallization temperature are the composition of the metal, the length of the period allowed for annealing and the amount of cold working which the article has received immediately prior to annealing. However, for practical purposes in manufacturing operations it has been found that a temperature between 640 and 670° F. is required to effect recrystallization of cold worked aluminum and aluminum base alloys within reasonable periods of time.

In the production of some articles it is highly desirable to have a very low temperature of recrystallization. For example, where an aluminum sheath has been cold drawn upon an insulated telephone or power cable it is necessary to anneal the sheath to obtain the desired flexibility in the cable. The conventional annealing temperature would destroy the usual insulation provided on cables. Hence, to soften the sheathing without damage to the insulation requires annealing at a much lower temperature.

The recrystallization of cold worked aluminum

can be reduced, it has been found, by controlling the iron to silicon ratio and by the addition of small amounts of at least one of the metals of the group composed of beryllium and nickel. For convenience, these metals and others having the same effect may be here designated as recrystallization temperature reducing alloy additions. The foregoing discoveries form the subject matter of co-pending applications Serial Nos. 172,001, 172,002 and 172,003. It has now been found that the advantages of such compositions can be more fully realized and the effect of the beryllium and nickel enhanced in the production of extruded and cold worked articles by the steps described below. It is therefore a general object of this invention to provide a method of making articles having a low recrystallization temperature. A particular object is to enhance this characteristic in certain aluminum base alloy articles.

Our invention is based on the discovery that the recrystallization temperature can be reduced in extruded and cold worked aluminum base alloy articles consisting essentially of aluminum, an element which reduces the recrystallization temperature, such as one selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, and a total of 0.01 to 0.8% iron and silicon impurities, the ratio of iron to silicon not exceeding 4/3 of the silicon content, and preferably only 3/4 of the silicon content, by a preliminary treatment of the body to be extruded, extruding at a relatively low temperature, and intermediate annealing at a relatively low temperature where annealing is required, prior to cold working. Each of the steps affects the results obtained in the succeeding operation and therefore it is only by close observance of the limitations on each step that the final product can be obtained which has the desired low recrystallization characteristic. The individual steps in the process will now be described in greater detail.

The metal body, in the form of an ingot or a rolled or forged billet, having the proper chemical composition is given an initial thermal treatment, called a preheat, followed by a controlled cooling to an intermediate temperature range and holding within this range for a period of time, prior to extrusion. The treatment consists of heating the body to a temperature between 850 and 950° F. and holding or soaking it within this temperature range for a period from 1 to 12 hours. The temperature and length of the treatment will vary with the composition of the alloy and the size of the load being processed.

Upon completion of the preheat or initial treatment the alloy body is cooled at a controlled rate, not exceeding 50° F. per hour, to a temperature within the range of 500 to 650° F. and maintaining the body within this temperature range for a period of 1 to 12 hours. For the sake of convenience this may be referred to as an intermediate soaking treatment. Following this the hot body may be cooled to room temperature or it may be transferred to an extrusion press if the temperature of the body is such as to permit extrusion within the range referred to below. The effect of the two thermal treatments is not altogether understood but both have been found to be necessary to obtain the low recrystallization characteristic in the final worked product.

If the body has been allowed to cool to room temperature, or a temperature below that at which it is to be extruded, the body is heated to a temperature between 400 and 550° F., transferred to the heated cylinder of an extrusion press and extruded. The temperature of the metal is considered to remain within this range during the extrusion process. It is desirable, in any case, to use as low an extrusion temperature as possible, the temperature selected generally being determined by the power of the press, more power being required as the extrusion temperature decreases. If extrusion temperatures above 550° F. are used, such as are normally employed in the extrusion of aluminum the desired recrystallization characteristic in the final worked product will not be obtained. The resulting semi-finished extruded product is usually referred to as a bloom. It may be a solid or a hollow shape depending on the die used. The combination of preheating, intermediate soaking and extrusion at a low temperature establishes a condition and internal structure in the bloom which is essential to obtaining a low recrystallization temperature in the subsequent cold worked article.

The extruded bloom is then subjected to further working at a much lower temperature, usually at room temperature or slightly above it. The working may consist of rolling, drawing, pressing or similar operations which effect a reduction in the thickness of the article. In making tubular products a machine may be employed known as a tube reducer. It is to be understood that the working may be conducted in one or more steps and with one or more types of working operations employed in succession. In any event, if the final product is to be produced at this stage, i. e., reduced to final shape and thickness, the reduction should amount to at least 40% and for the best results it should exceed 90% if the benefits of a low recrystallization temperature are to be realized.

If the preceeding operation is not a final working step, the cold worked product may then be given an intermediate annealing within the temperature range of 400° to 600° F. from 1 to 12 hours. It has been found to be necessary to use such a relatively low temperature range for intermediate annealing to insure a low recrystallization temperature in the finally fabricated article.

After the intermediate anneal the article should receive further cold working which produces a reduction in thickness of the article of at least 40% and preferably more than 90% to obtain the benefit of a reduced temperature of recrystallization. This working may include two or more working operations. In the case of tubing, for example, the operations may consist of drawing and sinking. Since sinking produces but slight change in wall thickness the drawing must be relied upon to provide most of the required cold working.

The article which has received the foregoing cold work and the proper thermal treatment will have the capacity to recrystallize at a lower temperature than the same article fabricated by conventional procedures. In general, the temperature of recrystallization will be below 600° F. and in many cases it will be less than 450° F.

One application of this invention is to be found in the provision of a seamless sheath for an insulated telephone cable. The effects of preheating and extrusion temperatures upon the tensile properties of a sheath are illustrated in the following tests.

The fabricating schedule of the sheaths were identical except for variations in the preheating practice and the reheating for extrusion. The constant factors were the size of ingot, rate of

extrusion, cold drawing the extruded bloom with a reduction of about 61%, annealing at 460 to 480° F. for 12 hours, and further cold drawing to a tube having 0.460" O. D. and 0.050" wall thickness with a reduction of 95%. The final cold drawn sheath was then annealed at 375° F. for ½ hour to simulate the treatment which might be used on an insulated cable. The tensile properties of the final annealed product were determined which provided a comparison with the other annealed products to show the effects of varying the preheating practice and the extrusion temperature. The alloy employed consisted of aluminum, 0.01% beryllium, 0.03% iron and 0.04% silicon. The tubular ingots had an O. D. of 9" and I. D. of $1\frac{3}{16}$".

In the first tests designed to determine the effect of preheating and intermediate soaking the ingot, one ingot was not preheated, but merely heated to the extrusion temperature of 510° F. while the other one was preheated 2 hours at 880 to 900° F., cooled slowly, at less than 50° F. per hour, to 580 to 600° F. and held at that temperature for 4 hours. The tensile properties of the cold drawn and annealed sheaths are given in the table below.

TABLE I

Effect of preheating on properties of sheathing

Ingot Condition	Tensile Strength, p. s. i.	Yield Strength, p. s. i.	Percent Elongation
Non-preheated	16,800	15,200	7.0
Preheated	10,200	5,900	17.0

It is quite apparent that the preheating and intermediate soaking has had a very pronounced effect upon the tensile properties. The low values exhibited by the sheath made from the preheated ingot indicate that recrystallization had occurred.

The influence of the extrusion temperature upon the tensile properties of annealed sheathing is illustrated in tests in which two ingots received the preheating and intermediate soaking treatments described above. One ingot was extruded at 905° F., which is in the range of temperatures normally used in extruding aluminum of commercial purity and the other one was heated to 510° F. and extruded. The tensile properties of the final products appear below in Table II.

TABLE II

Effect of extrusion temperature on properties of sheathing

Extrusion Temp.	Tensile Strength, p. s. i.	Yield Strength, p. s. i.	Percent Elongation
905° F	14,600	12,800	9.0
510° F	10,200	5,900	17.0

The tensile property values for the sheathing made from a bloom extruded at the low temperature again show that recrystallization had occurred while that had not taken place in the other sheath.

Although the full benefit of our invention is not obtained unless the extruded article is cold worked more than 40%, it has been found that tensile properties of blooms produced from preheated and intermediate soaked ingots differ significantly from the properties of blooms extruded from ingots which did not receive these treatments. This is illustrated in Table III by the strength and elongation values of the tubular bloom, 2⅝" O. D. with a wall thickness of 0.433", from which the sheathing was produced referred in Table I.

TABLE III

Effect of preheating on properties of extruded bloom

Ingot Condition	Tensile Strength, p. s. i.	Yield Strength, p. s. i.	Percent Elongation
Non-preheated	15,000	12,400	29.5
Preheated	9,000	4,800	50.0

These test results and others have demonstrated that preheating, intermediate soaking and a low extrusion temperature have a definite beneficial effect upon the blooms and hence the blooms possess distinctive characteristics not found in the usual extruded product.

Having thus described our invention and certain embodiments thereof, we claim:

1. The process of producing aluminous metal extrusions having low temperature recrystallization characteristics when cold worked comprising providing a body consisting essentially of aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 4/3 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, heating said body to a temperature between 850 and 950° F., holding said body at said temperature for a period of 1 to 12 hours, cooling said body to a temperature between 500 and 650° F. at a controlled rate not exceeding 50° F. per hour, holding said body within said temperature range for a period of 1 to 12 hours, and thereafter extruding it at a temperature between 400 and 550° F.

2. The process of producing aluminous metal extrusions having low temperature recrystallization characteristics when cold worked comprising providing a body consisting essentially of aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 4/3 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, heating said body to a temperature between 850 and 950° F., holding said body at said temperature for a period of 1 to 12 hours, cooling said body to a temperature between 500 and 650° F. at a controlled rate not exceeding 50° F. per hour, holding said body within said temperature range for a period of 1 to 12 hours, cooling it to room temperature, reheating said cooled body to a temperature between 400 and 550° F. and extruding it.

3. The process of producing cold worked aluminous metal extrusions having low temperature recrystallization characteristics comprising providing a body consisting essentially of aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 4/3 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, heating said body to a temperature between 850 and 950° F., holding said body at said temperature for a period of 1 to 12 hours, cooling said body to a temperature between 500 and 650° F. at a controlled rate not

exceeding 50° F. per hour, holding said body within said temperature range for a period of 1 to 12 hours, extruding said heated body at a temperature between 400 and 550° F. to form a bloom, and cold working the extruded bloom at least 40%.

4. The process of producing cold worked aluminous metal extrusions having low temperature recrystallization characteristics comprising providing a body consisting essentially of aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 4/3 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, heating said body to a temperature between 850 and 950° F., holding said body at said temperature for a period of 1 to 12 hours, cooling said body to a temperature between 500 and 650° F. at a controlled rate not exceeding 50° F. per hour, holding said body within said temperature range for a period of 1 to 12 hours, cooling it to room temperature, reheating said cooled body to a temperature between 400 and 550° F., extruding said heated body at a temperature between 400 and 550° F. to form a bloom, and cold working the extruded bloom at least 40%.

5. The process of producing cold worked aluminous metal extrusions having low temperature recrystallization characteristics comprising providing a body consisting essentially ol aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 4/3 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, heating said body to a temperature between 850 and 950° F., holding said body at said temperature for a period of 1 to 12 hours, cooling said body to a temperature between 500 and 650° F. at a controlled rate not exceeding 50° F. per hour, holding said body within said temperature range for a period of 1 to 12 hours, extruding said heated body at a temperature between 400 and 550° F. to form a bloom, cold working the bloom, annealing said worked article at a temperature between 400 and 600° F. for a period of 1 to 12 hours and further cold working the article at least 40%.

6. The process of producing cold worked aluminous metal extrusions having low temperature recrystallization characteristics comprising providing a body consisting essentially of aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 3/4 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, heating said body to a temperature between 850 and 950° F., holding said body at said temperature for a period of 1 to 12 hours, cooling said body to a temperature between 500 and 650° F. at a controlled rate not exceeding 50° F. per hour, holding said body within said temperature range for a period of 1 to 12 hours, cooling it to room temperature, reheating said cooled body to a temperature between 400 and 550° F., extruding said heated body to form a bloom, cold working said bloom, annealing said worked article at a temperature between 400 and 600° F. for a period of 1 to 12 hours and further cold working the article at least 90%.

7. The process of producing aluminous cable sheathing having a low temperature recrystallization characteristic comprising providing an ingot consisting essentially of aluminum, a total of 0.01 to 0.8% iron and silicon impurities, the amount of iron not exceeding 4/3 of the silicon content, and an element selected from the group composed of 0.005% to 0.25% beryllium and 0.04 to 1% nickel, heating said ingot to a temperature between 850 and 950° F., holding the ingot at said temperature for a period from 1 to 12 hours, cooling said ingot to a temperature between 550 to 650° F. at a rate not exceeding 50° F. per hour, holding said ingot within said temperature range for a period of 1 to 12 hours, thereafter extruding said ingot to tubular bloom form at a temperature between 400 and 550° F., cold drawing said bloom, annealing the cold drawn tube at a temperature between 400 and 600° F. for a period of 1 to 12 hours, and further cold drawing said annealed tube at least 90% to form the sheathing.

8. An extruded bloom which when cold worked at least 40% can be recrystallized at a temperature below 600° F., said bloom consisting essentially of aluminum, 0.01 to 0.8% total iron and silicon impurities, the iron not exceeding 4/3 the silicon content and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, said bloom having an internal structure resulting from preheating the body from which the bloom is formed at a temperature between 850 to 950° F., cooling said body at a rate not exceeding 50° F. per hour to a temperature between 500 and 650° F., holding the body within this temperature range and extruding it at a temperature between 400 and 550° F.

9. An extruded bloom which when cold worked at least 90% can be recrystallized at a temperature below 450° F., said bloom consisting essentially of aluminum, 0.01 to 0.8% total iron and silicon impurities, the iron not exceeding 3/4 of the silicon content and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, having an internal structure resulting from preheating the body from which the bloom is formed at a temperature between 850 and 950° F., cooling said body at a rate not exceeding 50° F. per hour to a temperature between 500 and 650° F., holding the body within this temperature range and extruding it at a temperature between 400 and 550° F.

10. An extruded and cold worked article consisting essentially of aluminum, 0.01 to 0.8% total iron and silicon impurities, the iron not exceeding 4/3 of the silicon content and an element selected from the group composed of 0.005 to 0.25% beryllium and 0.04 to 1% nickel, said article having an internal structure resulting from preheating the body from which an extruded product is formed to a temperature between 850 and 950° F., cooling said body at a rate not exceeding 50° F. per hour to a temperature between 500 and 650° F., holding the body within this temperature range, extruding it at a temperature between 400 and 550° F., and finally cold working at least 40%, and characterized by its capacity to recrystallize below 600° F.

11. An extruded and cold drawn cable sheath consisting essentially of aluminum, 0.01 to 0.8% total iron and silicon impurities, the iron not exceeding 3/4 of the silicon content, and an element selected from the group composed of 0.005 to 0.25% beryllium, and 0.04 to 1% nickel, said sheath having an internal structure resulting from preheating the body from which an extruded bloom is formed to a temperature be-

tween 850 and 950° F., cooling said body at a rate not exceeding 50° F. per hour to a temperature between 500 and 650° F., holding the body within this temperature range, extruding it at a temperature between 400 and 550° F., cold drawing the extruded product, intermediate annealing said cold drawn article between 400 and 600° F., and further cold drawing the article with a reduction of at least 90%, and characterized by its capacity to recrystallize below 450° F.

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