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METHOD OF MAKING ALUMINUM ALLOY TUBING AND PRODUCT

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This invention relates to improved precipitation hardened seamless aluminum alloy tubing and the method of making such tubing.

Aluminum alloy tubing is at present made from two types of alloys, one which requires no thermal treatment to increase the strength and the other which receives such treatment. The thermal treatment referred to is that which is well-known in the art for increasing the strength and hardness of certain alloys. These alloys contain components which are soluble in aluminum, the solubility of which increases with the temperature. The first step in the thermal treatment is that of causing solution of the soluble components and this is generally carried out at a temperature between about 850 or 1000° F. The heated article is then rapidly cooled to a much lower temperature, usually room temperature, whereby the condition existing in the alloy at the higher temperature is preserved in large degree. The last step in the treatment consists of permitting or inducing precipitation to occur whereby the strength and hardness of the alloy is greatly increased. In case of many alloys, the precipitation treatment is carried out by heating them to a temperature between about 300 and 500° F. Because the last step brings about a considerable increase in strength and hardness, it is often referred to as a precipitation hardening treatment while the first treatment at a higher temperature is commonly spoken of as being a solution treatment.

In making tubular products of alloys which are precipitation hardened, it has been a common practice heretofore to form the tube and then subject it to solution heat treatment, quenching and precipitation hardening. In following this procedure, the tubing acquires a dull, dark finish as a result of exposure to the solution heat treating temperature. The discoloration is usually non-uniform. The quenching and drying operation may likewise cause a streaking of the tubing. Although the surface appearance has no significant effect upon the serviceability of the tubing from a structural standpoint, nevertheless for many applications a brighter surface is desired. It has not been possible to achieve this result by following the usual practices mentioned above.

The process which has generally been used for manufacturing seamless aluminum alloy tubing has consisted of forming ingots with a longitudinal concentric hole therein or casting a solid cylindrical ingot and drilling a centrally located

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hole of the desired diameter. The hollow cast body is then heated to extrusion temperature of about 700 to 850° F. and extruded. The tubing so produced may be of a size and have a wall thickness which is suitable for use without further reduction. In other cases, the tubular product is of a larger size than desired and it is therefore cold drawn to finish size. In either case the tubing of finished size is subjected to solution heat treatment and precipitation hardening as mentioned above and it is discolored as has been previously mentioned.

One of the most common types of heat treatable alloys employed for making tubing is that which contains magnesium and silicon in such proportions as to form the intermetallic compound Mg_2Si. These alloys usually contain about 0.5 to 3% by weight of this compound as the principal alloy component. Other elements than magnesium and silicon may be present in smaller quantities to modify the properties of the alloys. Alloys of the foregoing type are popular for the manufacture of extruded products as they are easily extruded and can attain a strength and hardness considerably above that of the non-heat treatable compositions. Alloys of the aluminum-Mg_2Si type often suffer the disadvantage of having a relatively coarse grain structure. Large grains, as is well-known, do not permit the attainment of as high a strength and hardness as does a fine grained article of the same composition. The development of the coarse grain size is apparently an inherent property of this type of alloy, especially when the aluminum has a relatively low total impurity content. The large grain size is developed as a result of exposing the alloy to the solution heat treating temperature.

The large grain size is not only objectionable because of its adverse effect upon the strength and hardness, but it tends to produce an "orange peel" surface on articles which are stretched subsequent to solution heat treatment.

The grain size of the alloys can be controlled to a considerable extent by the addition of certain high melting point elements such as titanium. However, such additions are not wholly effective in every case and they add to the cost of the product.

Still another disadvantage encountered in the previous practice of making precipitation hardened aluminum alloy tubing is that the tubing becomes warped upon being rapidly cooled from the solution heat treating temperature. The rapid cooling is usually carried out by submerg-

ing the hot article in a tank of water. In order to obtain straight tubing it is frequently necessary to stretch the quenched product. This, of course, further adds to the cost of fabricating the tubing and its elimination would be highly desirable.

It is an object of our invention to provide a method for making stain-free precipitation hardened seamless aluminum alloy tubing. Another object is to provide a method of making seamless precipitation hardened tubing which is not coarse grained. Still another object is to provide a method of making precipitation hardened aluminum alloy tubing at lower cost without sacrifice in strength. A further object is to provide a cold work and precipitation hardened aluminum alloy tubular product that is free from heat treating stain and yet possesses the strength of a conventionally solution heat treated hardened article of similar size and shape.

We have discovered that a highly satisfactory precipitation hardened aluminum-Mg_2Si type alloy seamless tubing can be made which is free from the objections named above. The tubular product can be produced by the following method. An ingot or a previously worked body of suitable size for extrusion is first prepared. For example, a cylindrical ingot may be cast having a hole of suitable diameter through the entire length of the body or a solid cylindrical ingot may be provided in which a hole is drilled. The central hole or bore is generally concentrically located. Alternatively, a worked body may be employed as stock for extrusion such as one that has been rolled and pierced. It is also possible to employ a solid body and with appropriate extrusion dies produce a tube bloom. In any case, the body to be extruded is heated to a temperature between 850 and 1100° F. for a period long enough to cause solution of a substantial portion of the intermetallic compound Mg_2Si. Following this the body is cooled to the extrusion temperature which generally lies between 600 and 1000° F. and is extruded to a size that is substantially greater than that of the finished product. The product of this operation is commonly referred to as a bloom. The bloom is quenched as it leaves the extrusion press. The quenching may be done by an air blast or water spray or even by cooling in air under some conditions. The cooled bloom is then cold drawn to the desired finish size of tubing with a reduction in cross sectional area of the metal of 20 to 88%. The cold drawn article is thereupon subjected to a precipitation hardening treatment consisting of heating it to a temperature between 275 and 500° F. for a period up to 24 hours. The period of heating depends upon the particular combination strength and elongation desired, as well as the size of the load being treated.

As stated above the tubing which is fabricated by the foregoing process is made of an aluminum-Mg_2Si type of alloy. This kind of alloy has many characteristics that recommend it for extrusion and for service as a structural material. For our purposes the alloy should contain magnesium and silicon in such proportions as to form 0.5 to 3% by weight of Mg_2Si. The proportions of magnesium and silicon necessary to produce this quantity of intermetallic compound are 0.3 to 1.9% magnesium and 0.18 to 1.1% silicon. A slight excess of magnesium may be present beyond that required to form the intermetallic compound. Silicon, on the other hand, may be present in amounts up to 1.5% above that needed to form Mg_2Si without too seriously affecting the properties of the alloy. In addition to magnesium and silicon the alloy may contain from 0.1 to 1% copper to increase the strength. If desired 0.05 to 0.5% chromium and/or from 0.1 to 0.75% manganese may be included to improve the alloy. Iron may be present in amounts as high as 1%, however it is preferred to restrict this impurity to less than 0.5%. Other elements than those named may be employed providing they do not adversely affect the properties conferred by the intermetallic compound Mg_2Si. Since this compound in combination with aluminum establishes the fundamental properties of the alloy, the intermetallic compound is referred to herein to be an essential component of the alloy.

Referring to the individual steps in the process in greater detail the first heating or soaking treatment should take place within the temperature range between 850 to 1100° F. Under most conditions, however, a range of 900 to 1000° F. is preferred. The heating must continue for a long enough time to effect a solution of a substantial portion of the intermetallic compound Mg_2Si. Generally a period of 1 to 12 hours will be sufficient for this purpose. The time and temperature employed in any particular case will be determined by the amount of Mg_2Si which is present, its state of subdivision and distribution throughout the alloy and the size of the load being treated. Where other elements are present in addition to Mg_2Si, it may be necessary to restrict the maximum temperature in order to avoid incipient fusion of any low melting point constituents.

The cooling of the ingot or wrought body of metal to the hot working temperature may be effected in any convenient manner, generally cooling in air will be found to be most practical. However, an artificial cooling such as an air blast may be employed if properly controlled to avoid non-uniform cooling.

Extrusion, as is well-known in the art, is a form of hot working and the extruded product therefore has many of the characteristics of bodies which have been worked above the recrystallization temperature. On the other hand, extruded products have some unique properties as the result of the nature of the flow of metal through the die. The size, shape and orientation of the grains give definite directional properties to the extruded product. Furthermore, it is often observed that a peculiar type of strain hardening may take place in an extrusion which results in a somewhat higher strength than might normally be expected in a hot worked alloy of a particular composition. For extrusion purposes in our process the metal body should be cooled to a temperature between about 600 and 1000° F. before being introduced to the extrusion press. Usually a temperature range between 750 and 850° F. is most suitable for working alloys of the type herein described. To facilitate extrusion it may be desirable to heat the extrusion cylinder according to usual practice in order to minimize heat loss during the extrusion operation.

As the extrusion issues from the die it should be chilled either by an air blast, a water spray or by some other coolant. Cooling in air may be effective in some cases, however, in all cases the temperature of the bloom should be lowered to a point where no substantial changes in structure will occur. Generally it is safe to cool the extrusion to a temperature below about 500° F., but to insure stability of the structure of the

product it is preferable to cool the bloom to room temperature.

The cooled bloom is next subjected to a cold drawing operation to produce tubing of the desired finished size. The cold drawing should be sufficient to develop a cold worked structure in the product. We have found that this can be accomplished by effecting a reduction in cross sectional area of the metal of at least 20%. On the other hand, it is unnecessary to go beyond 88% reduction to gain the desired properties. The cold drawing operation may be conducted in a single step or in a plurality of operations depending upon the size of the reduction being made.

The final step in our process consists in reheating the cold drawn tubing to a temperature between 275 and 500° F. for a predetermined period of time. The length of the treatment is generally determined by the temperature employed, a longer period of time being required at temperature in the lower portion of the foregoing range. On the other hand, merely heating up to the temperature in the upper part of the foregoing range may be sufficient. A period of up to 24 hours is generally sufficient to effect the desired increase in strength and hardness. Within the foregoing range of temperature and time it is possible to develop varying combinations of strength and elongation. For example, an alloy composed of aluminum and 1% Mg_2Si which is treated for 8 hours at 350° F. yields a product having a typical tensile strength of about 37,000 p. s. i., a yield strength of 35,000 p. s. i., and an elongation of 10%. By heating the same alloy and size of tubing for 1 hour at 450° F., a tensile strength of 30,000 p. s. i., yield strength of 27,000 p. s. i., and an elongation of 10% are obtained. The higher tensile and yield strengths are desirable for some structures and it is therefore advantageous to meet such requirements merely by varying the time and temperature of the precipitation hardening treatment.

The process has important advantages as mentioned herein above in that both solution heat treating of tubing in the finish size is avoided and straightening or stretching operations are substantially reduced or eliminated. The omission or reduction of these operations are important items in reducing fabricating costs. This reduction in cost is accomplished however, without substantial change in strength and elongation. The product is free from the heat treating stains which have characterized solution heat treated tubing in the past and, therefore, is available for a wider field of service. The improved surface condition reduces the cost of such finishing operations as grinding or polishing or may entirely eliminate the need for these operations. In addition the cold worked structure of the product eliminates the possibility of a large grain size with the attendant disadvantages. The cold worked structure consists of grain fragments instead of true grains. Further, the yield strength of the tubing is higher than that of the same tubing which receives a solution treatment after cold drawing.

An example will serve to illustrate the process of our invention. An alloy having as a nominal composition 0.65% magnesium, 0.40% silicon, a maximum of 0.25% iron, a maximum of 0.10% copper and balance aluminum was cast in the form of a hollow ingot. The ingot had an O. D. of 9 inches, an I. D. of 1.19 inches and a length of 9 inches. The ingot was heated to a temperature between 950 and 1000° F. for 4 hours, cooled in air to 750 to 850° F. and extruded into a tubular bloom having an O. D. of 1.315 inches and an I. D. of 1.049 inches. The extrusion was quenched in an air blast as it issued from the die. The extruded bloom was then cold drawn to a finish size of .706 inch O. D., and I. D. of .622 inch which represents a reduction of 82.3% of cross sectional area. Following this, one portion of the tubing was heated to 335 to 355° F. for 8 hours while the other portion was heated to 435 to 455° F. for 1 hour. The average tensile strength of samples taken from the first portion of tubing was 38,070 p. s. i., the yield strength was 35,900 p. s. i. and the elongation was 12%. The average values from samples from the second portion were 32,560 p. s. i. tensile strength, 29,700 p. s. i. yield strength and 13% elongation. Microscopic examinations revealed that all samples had a typical cold work structure, i. e. structure consists of grain fragments rather than grains.

In comparison with the foregoing product the typical properties of an extrusion of the same alloy which received a solution heat treatment at 975° F., was quenched in water and heated to 350° F. for 8 hours, were 35,000 p. s. i. tensile strength, 30,000 p. s. i. yield strength, and an elongation of 12%. When the solution heat treatment was omitted and the extrusion was heated to 450° F. for 1 hour, the typical properties were 27,000 p. s. i. tensile strength, 21,000 p. s. i. yield strength and an elongation of 12%.

The tubing produced according to our process was free from the characteristic heat treating stains and did not possess a coarse grain structure. In addition, the yield strength of our product was higher than that of similar extruded material which received no cold work.

This application is a continuation-in-part of our co-pending application Serial No. 106,486, filed July 23, 1949, now abandoned.

Having thus described our invention, we claim:

1. The method of making seamless tubing of an aluminum base alloy containing as the essential added alloy component 0.5 to 3% by weight of Mg_2Si, said method comprising providing a body of said alloy adapted to be extruded, heating said body to a temperature between 850 and 1100° F. for a period of time sufficient to cause solution of a substantial portion of the Mg_2Si component, cooling said body to an extrusion temperature between 600 and 1000° F., extruding said body into the form of a tubular bloom, quenching said bloom as it issues from the extrusion die, to a temperature below 500° F., cold drawing said bloom to tubing with a reduction in cross sectional area of 20 to 88%, heating said tubing to a temperature between 275 and 500° F. for a period up to 24 hours and cooling it to room temperature.

2. The method of making seamless tubing of an aluminum base alloy containing as the essential added alloy component 0.5 to 3% by weight of Mg_2Si, said method comprising providing a body of said alloy adapted to be extruded, heating said body to a temperature between 900 and 1000° F. for a period of time sufficient to cause solution of a substantial portion of the Mg_2Si component, cooling said body to an extrusion temperature between 750 and 850° F., extruding said body into the form of a tubular bloom, quenching said bloom as it issues from the extrusion die to a temperature below 500° F., cold drawing said bloom to tubing with a reduction in cross sectional area of 20 to 88%, heating said

tubing to a temperature between 275 and 500° F. for a period up to 24 hours and cooling it to room temperature.

3. The method of making seamless tubing of an aluminum base alloy containing as the essential added alloy component 0.5 to 3% by weight of Mg_2Si, 0.1 to 1% copper and 0.05 to 0.5% chromium, said method comprising providing a body of said alloy adapted to be extruded, heating said body to a temperature between 850 and 1100° F. for a period of time sufficient to cause solution of a substantial portion of the Mg_2Si component, cooling said body to an extrusion temperature between 600 and 1000° F., extruding said body into the form of a tubular bloom, quenching said bloom as it issues from the extrusion die, to a temperature below 500° F., cold drawing said bloom to tubing with a reduction in cross sectional area of 20 to 88%, heating said tubing to a temperature between 275 and 500° F. for a period up to 24 hours and cooling it to room temperature.

4. A tube composed of an aluminum base alloy containing 0.5 to 3 per cent by weight of the intermetallic compound Mg_2Si as the essential added alloy component, said tube having an internal structure resulting from heating a body of said alloy adapted to be extruded to a temperature between 850 and 1100° F. for a period of time sufficient to cause solution of a substantial portion of the Mg_2Si component, cooling said body to a temperature between 600 and 1000° F., extruding said body to tubular bloom form, quenching said bloom as it issues from the extrusion die to a temperature below 500° F., cold working said bloom to tubing with a reduction of 20 to 88 per cent and precipitation hardening said tubing by heating it to a temperature between 275 and 500° F. for a period up to 24 hours, said tubing being characterized by freedom from heat treating stain and coarse grains and having a yield strength greater than that possessed by a tube of the same size and of the same alloy and precipitation hardened at the same temperature which has been solution heat treated after cold working.

5. A tube composed of an aluminum base alloy containing 0.5 to 3 per cent by weight of Mg_2Si, 0.5 to 1 per cent copper, 0.05 to 0.5 per cent chromium, and less than 0.5 per cent iron impurity, said tube having an internal structure resulting from heating a body of said alloy adapted to be extruded to a temperature between 850 and 1100° F. for a period of time sufficient to cause solution of a substantial portion of the Mg_2Si component, cooling said body to a temperature between 600 and 1000° F., extruding said body to tubular bloom form, quenching said bloom as it issues from the extrusion die to a temperature below 500° F., cold working said bloom to tubing with a reduction of 20 to 88 per cent and precipitation hardening said tubing by heating it to a temperature between 275 and 500° F. for a period up to 24 hours, said tubing being characterized by freedom from heat treating stain and coarse grains and having a yield strength greater than that possessed by a tube of the same size and of the same alloy and precipitation hardened at the same temperature which has been solution heat treated after cold working.

6. A tube composed of an aluminum base alloy containing 0.5 to 3 per cent by weight of Mg_2Si and up to 1.5 per cent silicon in excess of that required to form the said Mg_2Si, said tubing having an internal structure resulting from heating a body of said alloy adapted to be extruded to a temperature between 850 and 1100° F. for a period of time sufficient to cause solution of a substantial portion of the Mg_2Si component, cooling said body to a temperature between 600 and 1000° F., extruding said body to tubular bloom form, quenching said bloom as it issues from the extrusion die to a temperature below 500° F., cold working said bloom to tubing with a reduction of 20 to 88 per cent and precipitation hardening said tubing by heating it to a temperature between 275 and 500° F. for a period up to 24 hours, said tubing being characterized by freedom from heat treating stain and coarse grains and having a yield strength greater than that possessed by a tube of the same size and of the same alloy and precipitation hardened at the same temperature which has been solution heat treated after cold working.

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