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ALUMINUM ALLOY FASTENING ELEMENT

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This invention relates to the manufacture of aluminum base alloy fastening elements, such as nails, having upset heads, shanks and points, and it is particularly concerned with the production of elements which have properties superior to those in commercial use heretofore.

Nail fastening means are commonly used to establish firm, durable joints between members where the nail can be driven into at least one of the members and become anchored therein. To maintain the joint, the nail must, of course, remain firmly imbedded over a substantial portion of its length in the member. This means that the nails must be strong enough and sufficiently resistant to bending to penetrate the wood or other material the required distance under only a few hammer blows, without buckling. In addition to having these driving characteristics, the nails should also possess sufficient ductility to permit straightening without fracture should they become bent during driving. Likewise, they should be capable of being clinched after having been driven. The nails necessarily must possess adequate strength in tension and shear to prevent separation of the joined members. In addition to such physical qualities, the nails should withstand for a considerable period of time any corrosion incident to their service. The extent of corrosive attack is not severe enough in many instances to weaken the nails but where exposure to the weather is involved or where there is contact with dissimilar metals in a moist environment, corrosive attack may be severe.

Iron nails have the above-mentioned mechanical properties but they are deficient in respect to corrosion resistance, the rusting of such nails being a common and frequently objectionable occurrence. This shortcoming has been minimized in some instances by coating the nails with zinc, cadmium, or similar metals or alloys of these metals capable of affording protection to the iron base. Nonmetallic coatings have also been used. In every case, however, where a coating is employed there is a possibility of local failure of the coating with a resultant failure of the iron article. Provision of such coatings adds materially to the cost of the nail.

Other metals than iron have been used for making nails such as copper and its alloys, especially brass and bronze. While these materials have had better resistance to corrosion than the ferrous articles, they do frequently cause stains upon the members being joined, such stains being highly objectionable.

The extensive use of aluminum alloy roofing

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sheet and other aluminum alloy building materials requiring fastening by nails has presented a problem of providing corrosion resistant fastening means. Ferrous and cuprous metal fastening elements in contact with aluminum alloy articles promote electrolytic corrosion and are therefore undesirable. On the other hand, available aluminum alloy nails, as mentioned below, did not have satisfactory mechanical properties.

Aluminum alloy nails have been used to a very limited extent under conditions where corrosion of other materials is severe. The materials used in such alloy nails have not, however, possessed as great a yield strength and resistance to bending as desired, which has considerably restricted their field of usefulness. Furthermore, the aluminum alloys having the highest resistance to corrosion had too low a strength to recommend them for nails. Also, the nails made of heat treated alloys were formed prior to heat treatment, thus introducing problems of handling before, during and after the heat treatment operations. Such treatment of individual nails was necessarily expensive and time consuming. To heat treat and age harden the stock before forming the nails has not been considered practical heretofore because of the high resistance to deformation of such material and its rapid rate of hardening by cold work. As a result of the factors named, aluminum alloy nails have not been widely made and used.

It is an object of this invention to provide an improved heat treated aluminum alloy nail. Another object is the provision of a method for fabricating heat treated and age hardened aluminum alloy nail stock in a temper which can be employed in producing nails on existing machines. A further object is to provide heat treated and age hardened aluminum alloy nails having a higher yield strength which also possess superior resistance to corrosion than have been commercially available.

I have discovered that superior quality aluminum alloy fastening elements, having upset heads, shanks and points, can be made from wire stock of an alloy containing, as the essential components, magnesium and silicon in amounts and proportion to each other to form from 1 to 2.5% of the intermetallic compound Mg_2Si , (without excess of either element) and 0.1 to 0.5% copper, by subjecting the stock to the combination of thermal and cold working treatments described hereinbelow. To obtain the desired combination of tensile properties and resistance to corrosion it is necessary that the magnesium and silicon be

present in the foregoing proportions. The alloy may or may not contain at least one of the hardening metals chromium and manganese within the ranges: 0.1 to 0.5% chromium and 0.25 to 1% manganese. Fastening elements made from such material have, in the shank section, a minimum tensile strength of 50,000 p. s. i., a yield strength of over 45,000 p. s. i., and an elongation of not less than 12% as determined over a length four times the diameter of the wire. The yield strength, in particular, exceeds that which has been exhibited by aluminum alloy nails commercially available heretofore, and the resistance to corrosion is better than that of the aluminum-copper or dural type of alloy nail.

This improvement in yield strength has served to render them more resistant to bending during driving. The increase in yield strength has been obtained, surprisingly, without significant loss in ductility. This is of great practical importance for it is thus possible not only to easily fabricate the fastening elements in conventional manner but to straighten them if bent by a glancing blow of the hammer, without fracturing the nail shank. Furthermore, the nails may be clinched without breakage. Tests have demonstrated that the ductility of the improved nails is such that they may be bent back upon themselves over a radius equal to that of the shank without developing any breaks.

From the standpoint of resistance to corrosion my improved nails are considerably superior to those made from the well known dural type of alloy containing 4% copper, 0.5% magnesium, 0.5% manganese and balance aluminum. In an alternate immersion corrosion test in a 3.5% sodium chloride solution over a period of months, nails made in accordance with my invention exhibited but slight pitting of the surface, whereas those made of the dural alloy were severely attacked. Under the same conditions iron nails would have been severely rusted. This improvement in resistance to corrosion is gained without coating the nails with either metallic or non-metallic substances.

To obtain the high strength and ductility referred to above the wire stock should receive a solution heat treatment in any type of conventional furnace at a temperature between 925 and 1050° F. for a long enough period to cause substantially complete solution of constituents which are soluble at the selected temperature. The period will vary with the size of load being treated, but generally from about 10 minutes to 2 hours will suffice. Upon completion of the solution treatment the stock is quickly withdrawn from the furnace and quenched or otherwise rapidly cooled to room temperature. The wire is then cold worked by effecting a reduction in cross sectional area of 20 to 80%. This is most conveniently done by cold drawing the wire to the desired final size. The cold worked material is then artificially aged by heating to a temperature between 300 and 400° F. for a period of 1 to 100 hours. The wire stock in this condition is said to have a -T81 temper. The aged wire is then fed into a conventional fastening element or nail forming machine wherein the heads are formed by upsetting and the points are cut. Any shaping of the shank is also performed in the machine.

I have discovered that the desired properties or temper can only be attained in nails by cold working the wire within certain limits between solution heat treatment and artificial aging treat-

ments. The same results are not obtained if the wire is cold worked the same amount after artificial aging, in particular, the ductility is considerably reduced by such a practice. The magnitude of the reduction by cold working before artificial aging is also an important factor. It must not be less than 20% nor more than 80% if the minimum yield strength and elongation values are to be obtained however a range of 20 to 50% is preferred.

It has been found that the aluminum alloy wire in the aforementioned temper is well adapted to the production of nails. The wire handles well in conventional nail making machines and in particular it can be cold headed without breakage and a clean cut point is produced. In view of previous experience of producing heat treated nails, it was surprising to find a material which could be handled on existing nail making machines without excessive hardening and yet possess the desired strength for driving purposes.

The wire prepared in accordance with my invention may be made into any one of the standard nail sizes and styles. It has been found to be adaptable to the manufacture of common, roofing, slating, siding and shingle nails as well as gutterspikes. These nails may have smooth shanks or they may be provided with the conventional rings, barbs or spiral flutes. Because of the difference in properties between steel and aluminum alloys, it may be preferable to employ a slightly greater diameter shank for the aluminum alloy nails where an equivalent strength is demanded, but in many cases, aluminum nails of the same diameter as the iron article will serve satisfactorily.

The aluminum alloy nails described herein find special application in attaching aluminum or aluminum alloy articles to a wood base. They can be used to attach aluminum roofing, sheet, siding, shingles, gutters, downspouts, etc., without encountering the corrosion troubles incident to the use of iron or cuprous metal nails.

Although it has been observed that smooth shank aluminum alloy nails have good holding power, that is, resistance to creep under stress, it may be desirable in some cases to increase this power. This can be done by giving the shank surface a roughened contour such as provided by rings or barbs. There is also evidence that an artificially produced aluminum oxide coating is beneficial for this purpose. Such a coating may be applied in the conventional manner by immersing the nails in a suitable solution and withdrawing when the coating has attained the desired thickness.

The aluminum base alloy from which the improved nails are made should contain magnesium, silicon and copper within the proportions stated above. In a preferred form of the invention the range for each of the elements should be as follows: 1.25 to 1.75% Mg₂Si, and 0.15 to 0.35% copper. If chromium and/or manganese are to be included the preferred ranges are 0.15 to 0.35% chromium and 0.4 to 0.8% manganese. An alloy which we have found to be highly satisfactory has a nominal composition of 0.95% magnesium, 0.55% silicon, 0.25% chromium, 0.25% copper and balance aluminum with impurities. If desired, at least one of the group of well known grain refining metals titanium, boron, zirconium, molybdenum, and the like may be included in amounts of 0.001 to 1%, the total amount in no case exceeding 1%. With the preferred composition which has received the proper solution heat

treatment, cold working and artificial aging a tensile strength of 55,000 p. s. i., a yield strength of 50,000 p. s. i. and an elongation of 19% have been frequently attained.

Among the various types of nails those designed for attaching aluminum alloy roofing sheet have demonstrated the outstanding value of nails made in accordance with this invention. Nails of this kind possess a somewhat larger than normal head, usually about $\frac{3}{8}$ to $\frac{7}{16}$ inch in diameter. The nail shank is about 0.135 to 0.145 inch in diameter and is about $1\frac{1}{4}$ inches in length. It has been possible to produce consistently under commercial operating conditions nails of the above nominal composition which have in the shank section a yield strength exceeding 45,000 p. s. i. and a ductility adequate to meet all fabricating requirements. This is accomplished by heat treating coils of wire stock of approximately 0.193 inch in diameter at 970° F. followed by quenching to room temperature and drawing to a diameter of about 0.135 inch which represents a reduction of 30%. After the cold drawing the wire is aged at 350° F. for eight hours. The stock is then fed to a conventional nail making machine where the head and point are formed and any shape is applied to the shank.

Having thus described the invention and certain embodiments thereof, I claim:

1. A fastening element composed of an aluminum alloy containing magnesium and silicon in the proportion necessary to form 1 to 2.5 per cent Mg_2Si , without excess of either element, 0.1 to 0.5 per cent copper, at least one of the hardening metals of the group consisting of 0.1 to 0.5 per cent chromium and 0.25 to 1 per cent manganese, at least one of the grain refining metals of the group consisting of boron, titanium, zirconium and molybdenum, in amounts of 0.001 to 1 per cent, and balance aluminum and impurities, said fastening element being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the element upon itself over a radius equal to that of the shank without developing any breaks.

2. A fastening element composed of an aluminum alloy containing magnesium and silicon in the proportion necessary to form 1.25 to 1.75 per cent Mg_2Si , without excess of either element, 0.15 to 0.35 per cent copper, at least one of the hardening metals of the group consisting of 0.15 to 0.35 per cent chromium and 0.4 to 0.8 per cent manganese, at least one of the grain refining metals of the group consisting of boron, titanium, zirconium and molybdenum, in amounts of 0.001 to 1 per cent, and balance aluminum and impurities, said fastening element being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the element upon itself over a radius equal to that of the shank without developing any breaks.

3. A fastening element composed of an aluminum base alloy containing magnesium and silicon in the proportion necessary to form 1 to 2.5 per cent Mg_2Si , without excess of either element, 0.1 to 0.5 per cent copper, and at least one of the hardening metals of the group consisting of 0.1 to 0.5 per cent chromium and 0.25 to 1 per cent

manganese, said fastening element being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the element upon itself over a radius equal to that of the shank without developing any breaks.

4. A fastening element composed of an aluminum base alloy containing magnesium and silicon in the proportions necessary to form 1 to 2.5 per cent Mg_2Si , without excess of either element, 0.1 to 0.5 per cent copper, and at least one of the grain refining metals of the group consisting of boron, titanium, zirconium, and molybdenum, in amounts of 0.001 to 1 per cent, said fastening element being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the element upon itself over a radius equal to that of the shank without developing any breaks.

5. A fastening element composed of an aluminum base alloy containing magnesium and silicon in the proportion necessary to form 1 to 2.5 per cent Mg_2Si , without excess of either element, and 0.1 to 0.5 per cent copper, the said fastening element being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the element upon itself over a radius equal to that of the shank without developing any breaks.

6. A cold headed nail composed of an alloy consisting of magnesium and silicon in the proportions necessary to form 1 to 2.5 per cent Mg_2Si , without excess of either element, 0.1 to 0.5 copper, at least one of the hardening metals of the group consisting of 0.1 to 0.5 per cent chromium and 0.25 to 1 per cent manganese, and the balance aluminum and impurities, said nail being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the nail upon itself over a radius equal to that of the shank without developing any breaks.

7. A cold headed nail composed of an alloy consisting of 0.95 per cent magnesium, 0.55 per cent silicon, 0.25 per cent chromium, 0.25 per cent copper, and the balance aluminum and impurities, said nail being characterized by an internal structure in its shank section produced by solution heat treatment, cold working 20 to 80 per cent and artificial aging, a yield strength exceeding 45,000 p. s. i. and a ductility that permits bending back of the nail upon itself over a radius equal to that of the shank without developing any breaks.

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