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METHOD OF TREATING ALUMINUM ALLOY RIVETS AND PRODUCT

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This invention relates to precipitation hardening aluminum base alloy rivets, and it has particular reference to minimizing the occurrence of cracks in the heads of driven rivets.

In the fabrication of aircraft structures at present many aluminum base alloy rivets are employed, most of the rivets being made of the so-called strong aluminum base alloys which undergo considerable precipitation hardening at room temperature after they have received a solution heat treatment and have been suitably quenched. The rivets, of course, are first formed from wire or rod and then heat treated, quenched, and hardened. In precipitation hardening alloys wherein copper is the principal added component and a smaller amount of magnesium is present, this hardening at room temperature progresses so rapidly that substantially the maximum strength is attained in from 2 to 4 days. When rivets made of alloys of this type containing more than 3 per cent copper and a smaller amount of magnesium are cold driven after they have thus hardened at room temperature, it has been found that the heads of the rivets tend to crack. This tendency is especially evident in solution heat treated, quenched, and room temperature hardened rivets of an aluminum base alloy nominally containing 4.5 per cent copper, 1.5 per cent magnesium, and 0.6 per cent manganese. While cracking of this character does not decrease the strength of the fabricated structure, it is undesirable nevertheless, and should be minimized or eliminated to improve the appearance of the fabricated part and reduce rejection and replacement of rivets. The head cracking mentioned herein refers to cracking of the heads during the driving operation and not to cracking of the manufactured heads, i. e., the heads formed in the fabrication of rivets. The expression "cold driving" as herein employed refers to the driving of rivets which are at about room temperature and is distinguished from the practice of driving heated rivets. It is to be understood also that the rivet heads produced by cold driving as herein described are of the normal size for the size of rivet used.

To overcome the difficulties associated with the cold driving of the fully room temperature hardened rivets, without subjecting them to another solution heat treatment and quenching, it has been a common practice to store the freshly quenched rivets at a sub-zero temperature until needed, and thus either greatly retard the progress of precipitation hardening or stop it entirely. This refrigeration practice is both costly and time-consuming. It would therefore be desirable to eliminate it, if possible, without substantial loss in the favorable working characteristics of the rivets.

The primary object of my invention is to provide a process for substantially eliminating the head cracking tendency of solution heat treated, quenched, and precipitation hardened aluminum base alloy rivets which contain more than 3 per cent copper as the principal added alloy component and a smaller amount of magnesium. A further object is to provide a solution heat treated, quenched, and precipitation hardened aluminum base alloy rivet which does not exhibit head cracks when cold driven to a normal head size and yet has at least the same shear strength as the same rivet would have if similarly treated, driven in the freshly quenched condition, and then hardened at room temperature. Another object is to provide a precipitation hardening treatment for solution heat treated and quenched aluminum base alloy rivets which will prevent any substantial change in the driving characteristics of the rivets when they stand at room temperature for a long period of time.

My invention is predicated on the discovery that precipitation hardened rivets made of aluminum base alloys containing at least 3 per cent copper and from 0.1 to 2.5 per cent magnesium can be cold driven with very few, if any, cracked heads where the rivets first receive a conventional solution heat treatment followed by a suitable quench and then are heated to between 375 and 450° F. for a period of about 1 to 12 hours, and finally cooled to room temperature before being driven. Rivets given the foregoing final heating are substantially free from cracks in driven heads of normal size as compared to rivets which have received the same solution heat treatment and quenching but have been hardened at room temperature before driving. It has also been found that the shear strength of the rivets treated in the manner described above is at least equal to, and in some cases considerably higher than, that of corresponding rivets which have been driven in the freshly quenched condition and subsequently hardened at room temperature. It has also been observed that the shear strength of rivets which have been treated in accordance with my invention possess about the same or sometimes a higher shear strength than corresponding rivets driven after being hardened at room temperature. The subsequent heating of solution heat treated and quenched rivets develops an internal structure in the alloy which is dis-

tinguishable from the structure found in rivets of the same alloy which have hardened at room temperature. In the rivets which have been hardened above room temperature, the precipitated particles are of larger size and there is considerably less grain contrast evident in an etched surface than in rivets hardened at room temperature. Heretofore it has been the general observation that articles made of solution heat treated and quenched aluminum base alloys which have been precipitation hardened above room temperature are not as workable as articles that have received the same solution heat treatment but have been precipitation hardened at room temperature. I have found, however, that there is a marked difference in the head cracking tendencies between rivets of the same alloy in the room temperature hardened condition and in the condition brought about by hardening at an elevated temperature. This difference in behavior appears to be confined to aluminum base alloys having more than 3 per cent copper as the principal added alloy component and from 0.1 to 2.5 per cent magnesium. It is possible, of course, to develop cracks in the heads of rivets of these alloys even though they are hardened at an elevated temperature by attempting to produce heads of an excessive diameter, i. e., larger than required in normal practice. Such abnormal driving practice, therefore, is not to be considered as a measure for determining the tendency of rivets to show head cracks.

By treating solution heat treated and quenched room temperature hardening rivets of the kind herein described, it is possible to eliminate the loss of time and expense of re-heat treating and quenching rivets which have become too hard by standing too long at room temperature after quenching. This advantage is of particular importance in a plant where it is not always possible properly to control the flow of rivets to the operators and where there are no refrigeration facilities. Still another advantage gained from my treatment is that the necessity for refrigerating the as quenched rivets is eliminated, since my treatment produces a product having stable properties, i. e., one in which there is substantially no further hardening after completion of the treatment. In some instances I have also discovered that the shear strength of rivets treated in accordance with my invention is somewhat increased over that obtained in rivets of the same alloy which are hardened at room temperature, but in any event the shear strength is not diminished by my treatment below that of rivets driven in the freshly quenched condition and then hardened at room temperature. Furthermore, the driving characteristics of the rivets remain unchanged when they are stored at room temperature for a long period of time.

The precipitation treatment which I have found will give the results described above consists of heating the solution heat treated and quenched rivets to a temperature between about 375 and 450° F. for a period of 1 to 12 hours, the length of time depending upon the temperature employed, i. e., a longer time being required at the lower temperatures. The solution heat treatment and quenching which precedes the precipitation treatment is of the usual type known to those skilled in the art and generally consists of heating the rivets to a temperature between about 900 and 980° F. for a period of time sufficient to produce substantially complete solution of soluble constituents without melting any low melting point constituent, which may vary from a few minutes to an hour or longer depending on the size of the load being treated. The solution heat treated rivets are then quenched in any suitable medium such as cold water.

As mentioned hereinabove, aluminum base alloys which respond to my treatment are of the precipitation hardening type containing more than 3 per cent copper as the principal added alloy component and a smaller amount of magnesium. The maximum amount of copper that can be employed is determined by the workability required in the alloy, which in the case of rivets refers to behavior during rolling, wire drawing, and heading processes. Generally alloys containing more than about 6 per cent copper are not suitable for manufacture of rivets, while rivets made of alloys containing less than 3 per cent copper do not ordinarily exhibit head cracks. To obtain a high strength rivet which can be readily manufactured, it is preferable to use copper within the range of 3 to 6 per cent. The magnesium content of the alloys may range from 0.1 to 2.5 per cent, but for many commercial compositions the range is confined to between 0.5 and 1.5 per cent. Other alloying components are frequently used in combination with the copper and magnesium, such as manganese, and silicon. In my preferred practice I recommend compositions containing between about 0.1 and 1.5 per cent manganese. The iron and silicon are generally present as impurities in the alloys, but in some instances it may be desirable to use from about 0.25 to 1.5 per cent silicon as an intentional alloying component. Small amounts of one or more of the well known grain refining elements, such as titanium, zirconium, boron, chromium, and the like, may be included in the alloys also, if desired. It has been found that rivets made of an alloy nominally comprising 4.5 per cent copper, 1.5 per cent magnesium, 0.6 per cent manganese, and the balance aluminum with impurities are particularly benefitted by my treatment.

As an example of the advantage gained from using rivets precipitation hardened at an elevated temperature, the following case may be cited. In this instance two lots of ⅛ inch diameter rivets were prepared of the same alloy, namely, one nominally comprising 4.5 per cent copper, 1.5 per cent magnesium, 0.6 per cent manganese, and the balance aluminum. Both lots of rivets were given a solution heat treatment at 920° F. for 30 minutes and quenched in cold water. One lot was aged 1½ hours at 412° F. before being driven, while the other lot was allowed to age for 4 days at room temperature before being cold driven. On driving it was shown that the first lot of rivets could be driven to the conventional or normal head size of 1.5 times the shank diameter without head cracks, whereas in the second lot of rivets this was impossible. The average shear strength of the first lot of rivets was 51,500 lbs. per sq. in., whereas the average shear strength of the second lot was 49,000 lbs. per sq. in. The average shear strength of rivets of the same alloy driven in the freshly quenched condition and subsequently hardened at room temperature is 42,000 lbs. per sq. in.

The term "aluminum base alloy" as herein employed refers to those compositions which contain at least 85 per cent aluminum, and where the expression "balance substantially aluminum" is used it is intended to include the presence of impurities and small amounts of other elements

which may be added to modify or improve certain properties of the rivets without adverse effect upon the freedom from head cracks.

I claim:

1. A method of hardening solution heat treated and quenched undriven rivets of an aluminum base alloy containing more than 3 per cent copper and from 0.1 to 2.5 per cent magnesium, whereby head cracks are substantially eliminated when the rivets are driven at room temperature, said method comprising heating the solution heat treated and quenched rivets at a temperature between about 375 and 450° F. for 1 to 12 hours to harden them and cooling to room temperature prior to driving them.

2. A method of hardening solution heat treated and quenched rivets of an aluminum base alloy containing from 3 to 6 per cent copper, 0.1 to 2.5 per cent magnesium, and 0.1 to 1.5 per cent manganese, whereby head cracks in the rivets are substantially eliminated when driven at room temperature, said method comprising heating the solution heat treated and quenched rivets at a temperature between about 375 and 450° F. for 1 to 12 hours to harden them and cooling to room temperature prior to driving them.

3. A method of hardening solution heat treated and quenched rivets of an aluminum base alloy containing from 3 to 6 per cent copper, 0.1 to 2.5 per cent magnesium, 0.1 to 1.5 per cent manganese, and 0.25 to 1.5 per cent silicon, whereby head cracks in the rivets are substantially eliminated when driven at room temperature, said method comprising heating the solution heat treated and quenched rivets at a temperature between about 375 and 450° F. for 1 to 12 hours to harden them and cooling to room temperature prior to driving them.

4. A method of hardening solution heat treated and quenched rivets of an aluminum base alloy nominally containing about 4.5 per cent copper, 1.5 per cent magnesium, 0.6 per cent manganese, and balance substantially aluminum, whereby head cracks in the rivets are substantially eliminated when driven at room temperature, said method comprising heating the solution heat treated and quenched rivets at a temperature between about 375 and 450° F. for 1 to 12 hours to harden them and cooling to room temperature prior to driving them.

5. A rivet of an aluminum base alloy containing more than 3 per cent copper and from 0.1 to 2.5 per cent magnesium having an internal structure produced by solution heat treatment, quenching, and heating at a temperature between 375 and 450° F. for a period of 1 to 12 hours, and characterized by the substantial absence of head cracks when cold driven.

6. A rivet of an aluminum base alloy containing from 3 to 6 per cent copper, 0.10 to 2.5 per cent magnesium, and 0.1 to 1.5 per cent manganese, said rivet having an internal structure produced by solution heat treatment, quenching, and heating at a temperature between 375 and 450° F. for a period of 1 to 12 hours, and characterized by the substantial absence of head cracks when cold driven.

7. A rivet of an aluminum base alloy containing from 3 to 6 per cent copper, 0.10 to 2.5 per cent magnesium, 0.1 to 1.5 per cent manganese, and 0.25 to 1.5 per cent silicon, said rivet having an internal structure produced by solution heat treatment, quenching, and heating at a temperature between 375 and 450° F. for a period of 1 to 12 hours, and characterized by the substantial absence of head cracks when cold driven.

8. A rivet of an aluminum base alloy nominally containing about 4.5 per cent copper, 1.5 per cent magnesium, 0.6 per cent manganese, and the balance substantially aluminum, said rivet having an internal structure produced by solution heat treatment, quenching, and heating at a temperature between 375 and 450° F. for a period of 1 to 12 hours, and characterized by a substantial absence of head cracks when cold driven.

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