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METHOD OF ROLLING COMPOSITE METAL STOCK

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The present invention relates to the production of composite metal stock comprising a ferrous body or backing to which there is bonded, preferably by fusion, a cuprous body or facing, preferably copper silicon alloy.

The specific method of uniting the ferrous body and the cuprous body contemplated within the present invention may be varied, but the preferred method is fully disclosed in my copending applications, Serial No. 6,497, filed February 14, 1935 and Serial No. 64,280, filed February 17, 1936, to which reference may be made. It comprises generally the production of a fusion bond between the two bodies of metal by pre-heating the ferrous body and bringing the cuprous body in molten condition into bonding contact with the face of the ferrous body.

The present invention is particularly concerned with the preservation or maintenance of a strong union between the two parts of the composite body or stock, particularly during rolling.

It appears that the presence of silicon at the bond above a certain concentration tends to have a deleterious effect upon the strength of the bond if the said bond is subjected to temperatures above a critical value for periods of time.

In my copending applications above referred to, I have disclosed the fact that silicon copper alloys bond to steel for the manufacture of copper alloy clad steel much more readily and tend to be free from critical temperature ranges in rolling and annealing if nickel in certain relation to the silicon is present at the bond. Without nickel or nickel in correct proportion to the silicon, the material is sensitive to certain critical temperature ranges and treatment which must be avoided if a strong inseparable bond in the rolled product is to be secured.

Although I have shown how to reduce or eliminate these critical temperature ranges, there are certain applications of copper alloy clad steel where such analyses of the cuprous metal and of the steel as will be subject to critical temperature ranges during working are desirable. In such cases, the combination of temperature and time which would be injurious may, according to the present invention, be successfully avoided, and a good bond in the finished product secured. The present application therefore relates more particularly to heating, hot rolling, annealing and cold rolling of the type of material where the analyses are such as to entail the critical time-temperature combination.

The present invention is based upon the discovery that for each particular union of ferrous

backing and copper silicon facing a definite value of temperature-time is required to form the objectionable crystalline structure which destroys the strength of the bond, and that by limiting the product of temperature of heat and the time during which such temperature is applied, the formation of the objectionable structure at the bond may be held below an objectionable value, or may be avoided. While this time-temperature combination varies for different analyses of the bonded metals, that is, the meeting surfaces of the two metals, the general observation may be made that given the information that the strength of the bond is destroyed by the formation of a crystalline structure at the bond and that the formation of this crystalline structure is dependent upon the presence of silicon in sufficient concentration to bring about its formation under a combination of time and temperature, it is now easy to avoid it by limiting one or more of the factors of the combination. That is to say, by limiting the silicon concentration at the bond, the temperature above a certain critical minimum value to which the bond is subjected, or the time over which the bond is maintained at a temperature above such critical minimum value, the reduction in strength of the bond during processing of the composite material may be avoided or reduced below an objectionable value.

Given a certain analysis of the metals at the bond, the time and temperature combination within which operations must be held to avoid objectionable decrease in the strength of the bond may be accurately ascertained very readily by running test pieces through a range of temperatures for different intervals of time. This I have done, and the following specification gives particular values of the three factors and the generalizations that may be employed in governing practice of the invention.

It is the desideratum in forming a composite metal stock of this character to make the physical characteristics of the bonded metals substantially identical throughout the operations of rolling or other working. The simplest way of attaining this is through the use of silicon alloyed with the copper with or without other alloying metals. There is also the advantage in the use of silicon that it has a desirable effect upon the surface of the cuprous alloy when the same is cast in an open mold upon the face of the ferrous backing. It is well known that a small amount of silicon greatly increases the strength

of copper and increases its resistivity to corrosion by certain reagents.

Since the alloying medium of silicon is desirable in the copper facing or the copper portion of the composite stock, and since its presence at the bond appears to be the cause of the formation of a certain crystalline structure under certain conditions of time and temperature, it will be seen at once that the successful production of a composite metal stock employing silicon in relatively high concentration at the bond presents a difficult problem which it is the object of the present invention to meet.

I have found that after securing a good bond in the "as bonded" state or in slab form, between the ferrous backing metal and a silicon copper facing metal certain practices in heating, hot rolling, annealing, and cold rolling are necessary to maintain a good bond in the finished rolled product. These practices are definitely related to the analyses of metals bonded or more accurately speaking, to the analysis of the alloy created at the union.

I find that the bond at the union of the two metals in the "as bonded" state is substantially inseparable, and has a tensile strength of approximately 60,000 pounds per square inch, and is actually stronger than the silicon copper alloy as cast.

Test specimens taken from such a slab usually break through the copper alloy at some distance from the bond.

In spite of the perfect bond secured in the slab "as bonded" some combinations of metals will separate during initial hot rolling. Others show a good bond after hot rolling within a definite temperature range, but separate easily if rolled at temperatures outside this range, particularly with cold rolling of two or more passes below the minimum of the critical temperature range. Other combinations will continue to show a good bond during hot rolling and cold rolling with intermediate anneals between cold rolling if the cumulative time and temperature of heating after hot rolling are held within certain limits, but will show a poor bond if these limits are exceeded.

The difference in the strength of the bond before and after processing at temperatures outside the critical range is very apparent. For instance, a bond that cannot be separated before processing will tear apart easily after processing if that is done at temperatures outside the critical ranges for a given analysis.

This change in the strength of the bonded union appears to be due to the formation of an embrittling constituent and is probably similar to the phenomenon of precipitation hardening. The weakened bond separates easily and the action on separation is very much like the breaking up of a very hard material. A study of the conditions of production of specimens subjected to microscopic examination shows that the formation of this brittle constituent is related to a certain combination of time and temperature, and the reduction in strength of the bond is related to the extent of this formation.

An exaggerated example of what probably takes place at the bonded section is shown by what occurs during the bonding operation when the silicon copper alloy in molten state is maintained on the ferrous slab for an excessively long period of soaking. Large irregular clusters of about one eighth of an inch in diameter are formed and suspended in the copper silicon alloy.

These formations are sometimes partly visible from the upper surface of the silicon copper alloy after it has solidified. These formations are very hard and brittle. They cannot be cut with a chisel, and do not reduce in thickness during rolling but are forced down through the steel backing. If the composite slab is rolled to a thin enough gauge, the formation is rolled through the steel as well as the copper and shows on both sides of the composite sheet. The section including this formation has practically no elongation and breaks with a slight bending. Chemical analyses of these formations show that these consist mostly of insoluble iron and copper with a trace of silicon. However, these formations do not occur under the same conditions with silicon free copper, but are apparent in modified form from longer soaking and higher temperatures. Also, the formation above referred to occurs much more readily with higher silicon content in the copper.

These critical temperature ranges are definitely related to the silicon content of the copper alloy, and are, in my opinion, the result of the formation of iron silicides produced at union during bonding and subsequent reheating for hot rolling and annealing. The iron from the backing material and the silicon from the facing material form the silicides. When nickel is present either in the silicon copper alloy or as an intermediate bonding alloy, or in the ferrous backing metal, nickel silicides are also formed and may have a bearing on the brittle constituent formed at the union. However, I have discovered that nickel definitely tends to correct for these critical temperature ranges. Excessive iron diffusion from the backing ferrous metal into the copper of the facing alloy or insoluble iron in copper has, in my opinion, an effect on forming the brittle compound. Nickel being soluble in iron and copper at all temperatures and in all proportions corrects for this, and makes a more ductile and workable alloy at the union.

I have found that the composite metal stock composed of a high silicon copper alloy or copper alloys containing from 2% to 3.5% silicon, bonded to a ferrous backing metal are much more difficult to roll and maintain a good bond than the lower silicon copper alloys bonded to steel such as 1.8% silicon or less.

Composite slabs of these high silicon copper alloys and a ferrous metal are pretty much limited to hot rolling within the temperature range of 1,600° F. to 850° F. If the upper limit is exceeded, even for a short time and only to 1,650° F., the bond is weakened, so that the slab either separates in rolling or the finished rolled product will have a weakened bond which can be pulled apart readily. Usually if given two or more passes at temperature below 900° to 850° F. the bond is weakened so that it separates readily, but if rolled within the limits of 1,600° F. to 850° F. the bond is inseparable. The material having a good bond after hot rolling within this temperature range will not cold roll to any extent even after annealing without separating at the bond. Cold rolling after annealing is limited to about ten per cent reductions and to two or three cold passes.

Composite stock comprising the lower silicon copper alloys of less than two per cent silicon bonded to steel are much less sensitive to time and temperature in hot or cold rolling practice; in fact, these combinations are not subject to the minimum hot rolling temperature. They

can be hot rolled from a higher maximum temperature of near 1,700° F. and passed without regard for minimum temperature, until the material hardens to the extent that further reduction is impractical and no injurious effect on the bond is apparent. This material can also be reheated numerous times for hot rolling or annealed and cold rolled to any extent that the mill can reduce it in thickness without any apparent weakening of the bond. For instance, the material has been cold rolled after annealing to better than 70 per cent reduction without any noticeable effect on the strength of the bond. However, I find that all heating of the composite stock within the temperature range of 1,150° F. to 1,700° F. tends to form the embrittling constituent at the union which if formed to excess is very destructive to the bond strength, and if care is not taken to avoid certain practices or combinations of time and temperature within this range that this compound is created at the union to the extent that the two metals will separate in rolling or can be pulled apart after rolling. The intermediate temperature range near 1,400° F. is particularly destructive and I believe that in this range of approximately 1,350° F. to 1,450° F. that precipitation of the elements forming the brittle bond is much more rapid than in the lower range of approximately 1,150° F. to 1,325° F.

The higher temperature range of 1,500° to 1,700° F. apparently tends to redissolve the embrittling compounds and maintain them in solid solution. For example, samples taken from the same sheet of 1.34 per cent silicon copper clad steel after hot rolling from the bonded slab showed perfect inseparable bond. One of these specimens was annealed for one hour at 1,425° F. and after cold rolling the copper alloy and steel separated easily. Other specimens from this same sheet heated for one hour at 1,550° F. and at 1,200° F. and cold rolled showed good bond. However, heating for longer periods of one and one-half hours and two hours at 1,550° F. showed failure at the bond, whereas the longer periods at 1,200° F. were not injurious. Shorter periods at the most critical temperature of 1,425° F. were not so destructive but appreciably more so than at 1,550° or 1,200° F. It is therefore obvious that this particular temperature range of 1,350° F.-1,450° F. should be avoided as much as possible. Also the total time and temperature of heating for hot rolling and annealing for cold rolling is important, and that a practice must be established depending on the analysis and size of the slab to successfully convert the cast composite slab into finished rolled products. The soaking period for all heats in the furnace after the material has reached temperature should be held to a minimum and in all cases only sufficient to soften the metal without undue precipitation of the elements during total heating so that the formation of the brittle compound is held to a minimum and insufficient to cause brittle bond.

Generally, the preferred practice for treating steel clad with a silicon copper alloy of 1% to 2% silicon is to heat for hot rolling in the range of 1,500° F. to 1,700° F., and hot roll until material hardens to the extent that further reduction is not practical, reheat within same range for subsequent hot rolling, taking care to limit the soaking period at maximum temperature to approximately fifteen minutes; anneal for cold rolling within the range of 1,100° F. to

1,350° F. The higher the annealing temperature, the shorter should be the soaking period after metal has reached temperature. The initial anneal after hot rolling can be at the maximum of this range or 1,350° but the length of time in the furnace after the metal is soaked through should be limited to twenty minutes. Subsequent anneals between cold rolling should be at the lower part of the range of 1,100° to 1,350° F. At 1,200° F., one and one-half hours soaking has been found satisfactory and at 1,100° F. up to two hours soaking has not produced a brittle bond. The exact detail of the heating or annealing practice is dependent on the original thickness of the composite slab, the number of anneals necessary or the extent of total reduction to finished gauge, and if a great many anneals are scheduled to reduce the material to finished gauge, then care should be taken to work to the minimum time and temperature combinations, so that the accumulation is still within the maximum limits.

For instance, the detail of the preferred practice for rolling composite material composed of a ferrous backing metal and a silicon copper alloy, which forms an analysis at the copper alloy side of the bond union of approximately 1.4 per cent silicon, .65 per cent nickel, 0.8 per cent iron, 0.2 per cent manganese with small amount of carbon is, heat in a furnace to 1,550° F. until the slab is heated through and limit soaking to twenty minutes after saturation; hot roll until material hardens to the extent that further reduction is not practical; reheat within same practice for subsequent hot rolling; anneal initially at 1,325° F. for not more than forty-five minutes after metal has reached temperature; cold roll to any extent that is practical for the rolling mill; reanneal after cold rolling at 1,175° F. for not more than two hours after reaching temperature; repeat this for intermediate anneals between additional cold rolling.

If heating for hot rolling is limited to three heatings for not more than fifteen minutes per heat after metal has reached temperature, annealing for cold rolling at 1,550° F. is satisfactory, but soaking time should be limited to ten minutes per heat after metal is heated through.

The silicon copper alloys may contain from 0.1 per cent to 3.5 per cent silicon and such other elements as nickel, for facilitating bonding, and nickel and iron for increasing the compression resistance of the copper alloy or small amounts of manganese, zinc, tin, aluminum or phosphorous to generally improve the alloy. The ferrous base metal may be any of the carbon steels, low alloy steels or high alloy steels, such as high nickel steels.

I do not intend to be limited to the precise ranges of time or temperature above disclosed, except as the same are specifically recited in the appended claims.

I claim:

1. Method of working, such as rolling, a composite metal stock comprising a 0.1% to 3.5% silicon copper alloy and a ferrous alloy which includes heating the metal for hot rolling or annealing the metal for cold rolling sufficiently to soften the metal but without causing the formation of a brittle constituent at the union of the two metals.

2. Method of working, such as by rolling, an inseparable slab of a 0.1% to 3.5% silicon copper alloy bonded to a ferrous alloy which includes the method of heating the slab for hot rolling

and annealing the slab for cold rolling whereby the bond is maintained in inseparable state in the finished rolled product.

3. Method of reducing the thickness and increasing the area of a composite metal stock comprising a 2% to 3½% silicon copper alloy bonded to a ferrous alloy which includes heating the slab to a maximum temperature of 1,650° F. and hot rolling until the slab has reached a minimum temperature of 850° F.

4. Method of claim 3 further characterized by the presence of nickel in the copper alloy in amounts less than the silicon content.

5. The method of claim 3 wherein the silicon copper alloy is characterized by the presence of iron in the copper alloy in the amount of less than 3%.

6. The method of reducing the thickness and increasing the area of composite metal stock comprising a silicon copper alloy of 2% or less silicon bonded to a ferrous alloy which includes heating the slab to a maximum temperature of 1,700° F. and hot rolling without regard for minimum temperature.

7. The method of claim 6 further characterized by the silicon copper alloy being initially bonded to the steel by fusion of the silicon copper alloy.

8. The method of reducing the thickness and increasing the area of a composite metal slab comprising a silicon copper alloy of less than 2% silicon bonded to a ferrous backing metal which includes heating the slab between 1,500° F. and 1,700° F., hot rolling without regard for minimum temperature, annealing at temperatures between 1,100° F. and 1,300° F., and cold rolling.

9. Method of claim 8 further characterized by the presence of nickel in the copper alloy in amounts less than the silicon content.

10. The method of reducing the thickness and increasing the area of a composite metal slab comprising a silicon copper alloy of less than 2% silicon, bonded to a ferrous backing which includes heating the slab between 1,500° F. and 1,700° F., and hot rolling-annealing initially between 1,500° F. and 1,700° F., and cold rolling with subsequent intermediate anneals between cold rollings in a temperature range of 1,100° F. and 1,300° F.

11. The method of claim 10 further characterized by the presence of nickel in amounts less than the silicon content, iron in amounts less than 3%, and manganese of approximately .25% in the copper alloy.

12. The method of reducing the thickness and increasing the area of composite metal stock comprising a copper alloy of approximately 1.4% silicon, .65% nickel, .8% iron, and .2% manganese, bonded to a ferrous alloy which includes heating the slab to substantially 1,550° F. for not more than twenty minutes after saturation, and hot rolling-annealing initially at 1,325° F. for not more than 45 minutes after saturation and cold rolling-re-annealing at 1,175° F. for not more than two hours after saturation for additional anneals between cold rolling.

13. The method of claim 12 wherein the ferrous alloy is a nickel steel and at least part of the

nickel content and iron content of the copper alloy is diffused from the nickel iron alloy.

14. Method of treating composite metal stock consisting of a ferrous backing and a 0.1% to 3.5% silicon copper alloy facing bonded thereto by fusion of the alloys which comprises heating the stock to a temperature which will soften the same suitable for rolling and limiting the time during which such temperature is maintained to less than that in which embrittlement of the bond between backing and facing occurs, and then rolling the stock to reduce the section.

15. Method of preventing injurious crystallization at the fusion bond between a ferrous backing and a 0.1% to 3.5% silicon copper alloy facing during processing which comprises limiting the product of the temperature to which the bond is subjected and the time during which it is heated to a value below that at which injurious crystallization will occur.

16. Method of maintaining a tenacious bond between a ferrous backing and a 0.1% to 3.5% silicon copper alloy facing during the process of rolling which comprises maintaining the product of time and temperature below that value which is required for the formation of a brittle crystalline structure at the meeting faces of the backing and facing.

17. Method of maintaining in a composite metal body a tenacious bond formed by fusion between a ferrous backing and a 0.1% to 3.5% silicon copper alloy which comprises heating the body to a temperature and for a time less than that required to form crystal silicides at the meeting faces of the backing and facing.

18. Method of reducing by rolling a composite slab consisting of a ferrous backing and a 0.1% to 3.5% silicon copper facing with the presence of nickel at the bond, which comprises heating the slab to a temperature of substantially 1,550° F. and hot rolling to reduce the thickness of the slab until the metal hardens.

19. Method of claim 18 further characterized by limiting the soaking while heating to said temperature of substantially 1,550° F. to a period of substantially 20 minutes.

20. Method of claim 18 further characterized by reheating for further hot rolling again to substantially 1,550° F. and limiting the soaking to 20 minutes.

21. Method of claim 18 further characterized by annealing before cold rolling by heating to substantially 1,325° F. and then cold rolling.

22. Method of claim 18 further characterized by annealing before cold rolling by heating to substantially 1,325° F. and then cold rolling, and subsequently reannealing at substantially 1,175° F. for not more than two hours after reaching temperature for further cold rolling.

23. Method of claim 18 further characterized by limiting the heating for either hot rolling or for annealing prior to cold rolling to a combination of time and temperature which will be less than that required for the formation of an injurious crystalline structure at the bond.

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