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PROCESS FOR MAKING HOLLOW ARTICLES BY DIFFERENTIAL HEAT TREATMENT

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5 Claims. (Cl. 29—157.3)

This application is a division of copending application Ser. No. 323,216, filed Nov. 13, 1963, now U.S. Patent No. 3,290,125, issued Dec. 6, 1966.

The present invention relates generally to improved metal processing and to articles formed thereby, and more particularly to a process for producing a unified composite metal article having distinct but integral layers of different hardness and ductility and having distensions raised from one side thereof to form a series of internal tubular passageways.

The present invention is an improvement over that disclosed in co-pending application S.N. 160,282, filed Dec. 18, 1961, in the names of I. Broverman and M. J. Pryor. That application disclosed a process and articles formed thereby which contemplated the addition of a small amount of zirconium to aluminum alloy 1100 to produce an aluminum-zirconium sheet having improved physical characteristics over the base 1100 alloy. A method was disclosed for fabricating composite bi-alloy articles produced from the base 1100 aluminum and the aluminum-zirconium alloy. The present application is directed to improvements in processing 1100 and other aluminum alloy sheets to produce a similar composite article without the necessity of using any additional alloying elements in the base metal.

As is well known in the art, sheet metal panels having component layers of different hardness and ductility find considerable utility in the heat exchange field and particularly in refrigeration equipment in which the panels are employed as evaporators in the freezing compartments of such equipment. These evaporators are formed of sheet metal panels having internal passageways disposed between bulged out or distended portions of the thickness of the panel, and they are highly susceptible to so called "ice pick" damage. This damage is caused by the use of an ice pick or other sharp instrument in the course of defrosting and removing accumulations of frost or ice from within the freezing compartment.

This difficulty is alleviated to a surprising extent by fabricating the panel which forms the evaporator so as to provide a partially or completely flat smooth exterior surface on a hard layer of metal, and to have the passageways formed at least predominantly or wholly from distensions raised only from the opposite softer, more ductile layer of the unified sheet forming the panel.

It is a primary concern of this invention to develop large differences in mechanical properties between two component sheets of the same base alloy by varying the size and distribution of particles of insoluble constituents in the primary fabrication treatment. In this way, high strength differentials, which are essential for producing superior one side flat products, can be made without incurring the additional charges for expensive alloys for the flat component of the composite. Also, by the practice of the present invention there is achieved a highly desirable and beneficial product without the attendant cost involved in additional processing which is necessary to the addition of other alloying elements.

In achieving the article as generally described above,

certain desirable conditions exist for the formation of an effective one side flat inflation panel containing internal passageways, principal among these being the development of an identity of physical properties during initial formation of the panel blank, coupled with a dissimilarity of these same properties during subsequent formation of the finished article from the panel blank. More specifically, it is desirable to maintain dimensional control and alignment of the component sheets of the blank during initial pressure bonding which is facilitated by a similarity of physical properties such as hardness and ductility between the two component sheets. On the other hand, during the subsequent inflation step, to form the coolant passageways, it is desirable that one of the component sheets remain substantially or entirely undistorted, i.e., flat, and that the passageways be formed by expansion of the other or softer component sheet. Accordingly, one of the principal objects of this invention is the provision of a process by which a pair of component sheets are fabricated and assembled together to form a composite blank having groups of physical characteristics which yield a substantial differential in yield strength between the component sheets of the composite.

It is another object of the present invention to provide a process for making a composite metal article having component layers of different strength in which the component layers are formed from identical alloys.

It is another object of the present invention to provide a process for fabricating a one side flat refrigerator panel.

It is another object of the present invention to provide a process of fabricating a composite sheet metal panel in which differential properties will develop solely from processing of the individual sheet metal components.

It is still another object of the present invention to provide a process for fabricating a composite sheet metal article having layers of different yield strength in which the layers are composed of identical alloys which attain a final differential of physical properties without the addition of other alloying elements.

It is a still further object of the present invention to provide a sheet metal article having a hard and soft component layer in which distensions are raised from one side thereof to form internal tubular passageways.

Other objects and advantages of the present invention will become apparent from the following detailed description thereof.

The foregoing objects of this invention in their broadest aspect, are achieved to a surprising extent by fabricating a composite sheet metal panel having component layers thereof of different hardness by providing a pair of aluminum alloy sheets having substantially identical composition, one of the sheets having a coarse particle size dispersion of insoluble constituents present therein and the other sheet having a fine particle size dispersion of insoluble constituents present therein, forming an integrally unlfied composite panel of the sheets with portions thereof remaining unjoined, partially annealing the composite panel within a critical temperature range in which the sheet having the coarse particle size dispersion undergoes considerable loss of strength by recovery but in which the sheet having the fine particle size dispersion undergoes only slight loss of strength by recovery thereby developing a differential in yield strength between the sheets, and finally inflating the composite panel in the unjoined portions by injecting a fluid under pressure therein.

As an adjunct to the above process, the invention contemplates the provision of a unified sheet metal article having a hard component layer and having distensions raised from an opposite softer component layer in which both of the layers are formed from identical aluminum alloys.

In regard to the selection of materials for the practice of the present invention, an aluminum base alloy is desired which has a major proportion of aluminum with minor proportions of silicon, iron, copper, manganese, magnesium and zinc as impurities, either selectively or collectively. The exact proportions of these impurities are not significant to the practice of this invention so long as they are within limits which yield alloys susceptible to the development of dissimilar particulate precipitates of insoluble intermetallic compounds upon different primary heat treatment. Thus, the principles of this invention are applicable to all aluminum alloys which form stable insoluble constituents in the form of intermetallic compounds which have a decreasing solubility rate with decreasing temperature on primary fabrication treatment, i.e., casting, homogenization and initial breakdown hot rolling. It is, of course, vital to the practice of the invention that the intermetallic compounds precipitate either as a coarse particle size dispersion with large interparticle distance or as a fine particle size dispersion with small interparticle distance depending on the nature of primary fabrication treatment. As more fully developed hereinafter, the former type dispersion favors maximum softening rates by recovery upon critical partial annealing after cold working, while the latter type dispersion its effective in retarding the recovery process upon subsequent fabrication treatment.

In general, due to economic and other considerations, moderate strength, common heat treatable aluminum alloys are selected as the material for both component layers of the composite. These alloys are those having aluminum ranging from 95.00% to 99.75% and obtain their strength through strain hardening, of which alloys 1100 and 3003 are typical examples respectively of an aluminum iron silicon group and an aluminum manganese group, both highly suited to the practice of this invention.

In preparing the selected alloys for processing in accordance with the principles of this invention, two individual masses of the same alloy are cast in accordance with conventional casting practice for these alloys. During solidification in the casting procedure iron or iron plus manganese may come out of solid solution, depending upon the alloy composition selected, as the appropriate eutectic, while other metallic constituents often remain in solid solution.

Following casting, scalping according to conventional practice, one of the ingots is subjected to a homogenization treatment consisting of a soak of the ingot at a temperature within the range of 900° and 1150° F. for a period of 4 to 72 hours, preferably at an optimum temperature and period within these ranges determined by the alloy selected, for example, 950°–1000° F. for about 10 hours for alloy 1100 and 1000°–1050° F. for about 24 hours for alloy 3003. During this homogenization treatment, the iron eutectic, if formed, is transformed to iron aluminide ($FeAl_3$) in the AlFeSi group which then reacts with the silicon to form an insoluble αAlFeSi intermetallic compound which is produced in the homogenized ingot as a coarse particulate dispersion having large particle size and large interparticle distance, and which is essentially stable during subsequent hot rolling. In the aluminum manganese group, a similar coarse particulate dispersion of $MnAl_6$ is formed which is also stable during subsequent hot rolling. This form of dispersion favors maximum softening rates upon partial annealing after cold working.

The other of the two ingots is not subjected to the aforementioned homogenization treatment and therefore does not contain the coarse particulate dispersion when the ingot is ready for initial breakdown hot rolling. During the subsequent hot rolling, however, αAlFeSi forms in the AlFeSi group and $MnAl_6$ forms in the AlMn group under the conjoint action of deformation and temperature. Here multisite fine dispersions with small interparticle distance are formed which will remain stable in subsequent thermal mechanical treatment under 1000° F.

The two ingots can now be processed in an identical fashion down to Rolls-Bond starting stock. In accordance with this practice, the ingots are hot rolled to approximately .250" gage strip, entering the rolls at a temperature between 800° and 1000° F., preferably at about 850° F., and then cold rolled to .125" thickness and interannealed at about 650° to 700° F. for 4 hours, or they may be initially hot rolled down to the .125" gage. During the breakdown hot rolling, the intermetallic compound for the selected alloy is still formed in the sheet from the unhomogenized ingot. However, due to the lower temperature range of the breakdown hot rolling step (800° to 1000° F.) compared to that of the homogenization range to which the other ingot was subjected, and due to the fact that the precipitation occurs under the combined influence of lower temperature and deformation, the intermetallic compound is produced as a fine particle size dispersion which prevents softening by recovery in the low annealing temperature range to which the composite is subjected following pressure welding. In other words, this fine form of the dispersion favors minimum softening rates upon annealing after cold working.

As used in this specification, the terms "fine" and "coarse" in reference to the particle size of the intermetallic compound dispersion have reference to those particles which are clearly resolvable or are not resolvable by metallographic microscope techniques at magnifications of approximately 50×.

In the production of a composite blank formed from the two alloys, a sheet is taken from each of the two starting stocks and is prepared for assembly by first cleaning each of the confronting faces of the components by conventional steps such as wire brushing, organic solvent, degreasing, etching in acid solutions, or similar conventional steps.

After such cleaning, a pattern of stop weld material is applied to one or both of the confronting faces of the component by conventional means, the pattern of stop weld material being a foreshortened version in the direction of rolling of the final pattern configuration desired. The components are then assembled together and the assembly is tack welded at its corners to preserve alignment of the sheets during subsequent processing.

Prior to pressure rolling, the assembly is heated to a temperature within the range of 700° to 950° F., preferably to about 930° F., and then pressure rolled to about a 65% to firmly weld the two component sheets together in the areas not covered by the stop weld material. The hot rolling is followed, after cooling, by a cold rolling reduction of about 30% to achieve the final blank gage and to produce high strength by cold working.

After cold rolling, a large differential in yield strength of the component sheets can be developed by proper partial annealing of the blank. The anneal is carried out in a temperature range in which the component sheet fabricated from the homogenized ingot containing the coarse particulate dispersion of insoluble constituents undergoes considebale loss of strength by recovery, but in which the component sheet fabricated from the unhomogenized ingot containing the fine particulate dispersion of insoluble constituents formed during initial hot breakdown rolling undergoes only slight loss of strength by recovery. To obtain the desired high differential in yield strength, this anneal is desirably carried out within the temperature range of 500° to 620° F. for a period of 5 minutes to 10 hours and preferably at a temperature of 585° F. for about 15 minutes for alloy 1100. For alloy 3003, the temperature range for partial annealing is 570° to 655° F. for a similar period of time, with an optimum of 620° for about 15 minutes.

To illustrate the development of this differential in yield strength it has been found that with this type of partial

annealing, fully homogenized 1100 will soften to yield strength values of around 5,000 p.s.i. minimum, whereas the unhomogenized 1100 can retain strength of up to about 13,000 p.s.i. maximum, thus achieving a differential in yield strength of about 8,000 p.s.i. between the components of the composite. With respect to 3003, a sheet from the fully homogenized ingot will soften to yield strength values of around 7,000 p.s.i. minimum, whereas unhomogenized 3003 can retain strength of up to about 24,000 p.s.i. maximum, thus achieving a differential in yield strength of about 17,000 p.s.i.

To complete the final article, the composite blank is inflated by the cavity die inflation technique to provide a one side flat combination where the unhomogenized component becomes the flat member and will resist deformation at internal working pressures even with large tube widths, or in the alternative by conventional inflation techniques between the faces of flat platens to achieve a partial one side flat composite.

The following are examples of the practice of the invention and are to be considered as illustrative and not all inclusive.

Example I

Tow individual masses of aluminum alloy 1100 containing 0.57% iron and 0.16% silicon, together with other impurities normal for this alloy, were cast by the DC casting process. After casting the ingots were scalped and one of them was subjected to a homogenization treatment by heating within the temperature range of 950° to 1000° F. for 16 hours. The other ingot was not homogenized but was directly subjected to subsequent fabrication treatment identical to that performed on the homogenized ingot. This treatment consisted of hot rolling the ingots at about 850° F. from 16" to a thickness of 0.22", after which the sheets were cold rolled from 0.22" to 0.125" and annealed at a temperature between 650° and 700° F. for 4 hours.

Subsequently, a sample was taken from each starting stock, and a pattern of stop weld material was interposed between the confronting faces of the sheets, after which they were assembled together, heated to a temperature of between 930° and 950° for 20 minutes and hot rolled to a reduction of 65% at this temperature, after which they were cold rolled by a reduction of about 30%. The unified sheet was then partially annealed at a temperature of about 585° for 15 minutes. It was found that the component from the homogenized ingot softened to a yield strength of about 5,500 p.s.i. while the component formed from the unhomogenized ingot retained a yield strength after annealing of about 11,000 p.s.i., thereby achieving a strength differential of 5,500 p.s.i.

Example II

Two individual masses of aluminum alloy 3003 containing 1.07% manganese, 0.63% iron and 0.23% silicon, together with other impurities normal for this alloy, were cast by the DC casting process. After casting the ingots were scalped and one of them was subjected to a homogenization treatment by heating within the temperature range of 1125° to 1150° F. for 16 hours. The other ingot was not homogenized but was directly subjected to subsequent fabrication treatment identical to that performed on the homogenized ingot. This treatment consisted of hot rolling the ingots at about 850° F. from 16" to a thickness of 0.22", after which the sheets were cold rolled from 0.22" to 0.125" and annealed at a temperature between 650° and 700° F. for 4 hours.

Subsequently, a sample was taken from each starting stock, and a pattern of stop weld material was interposed between the confronting faces of the sheets, after which they were assembled together, heated to a temperature of between 930° and 950° for 20 minutes and hot rolled to a reduction of 65% at this temperature, after which they were cold rolled by a reduction of about 30%. The unified sheet was then partially annealed at a temperature of about 585° for 15 minutes. It was found that the component from the homogenized ingot softened to a yield strength of about 20,800 p.s.i. while the component formed from the unhomogenized ingot retained a yield strength after annealing of about 23,500 p.s.i., thereby achieving a strength differential of 2,700 p.s.i.

It will be apparent from the foregoing description that there has been provided a method for making a composite metal article and the article formed thereby which is believed to provide a solution to the foregoing problems and achieve the aforementioned objects. It is to be understood that the invention is not limited to the examples described herein which are deemed to be merely illustrative of the best modes of carrying out the invention, but rather is intended to encompass all such modifications as are within the spirit and scope of the invention as set forth in the appended claims.

What I claim and desire to secure by Letters Patent is:

1. A process of fabricating an aluminum sheet metal panel having a relatively smooth hard component layer and having distensions raised from an opposite integrally unified softer component layer, both said layers being formed of substantially the same composition, said process comprising the steps of:

(A) providing a pair of aluminum alloy ingots having substantially identical composition,

(B) subjecting one of said ingots to a homogenization treatment to form a coarse particle size dispersion of insoluble constituents therein, said treatment consisting of a soak of the ingot at a temperature within the range of 900° to 1150° F. for a period of from 4 to 72 hours,

(C) rolling said ingots to sheets within the temperature range of from 800° to 1000° F. in which said coarse particle size dispersion is unaffected and in which a fine particle size dispersion of insoluble constituents is formed in the sheet from the other of said ingots,

(D) forming a panel blank by positioning said sheets adjacent one another, one of said sheets having applied to a confronting surface thereof a pattern of stop weld material,

(E) hot rolling said blank to integrally unify said sheets together as a composite panel in the areas not covered by said stop weld material,

(F) cold rolling said composite panel to develop maximum strength in said sheets by work hardening,

(G) partially annealing said panel within the critical temperature range of from 500° to 655° F. for a period of from 5 minutes to 10 hours in which said sheet having said coarse particle size dispersion undergoes considerable loss of strength by recovery but in which said sheet having said fine particle size dispersion undergoes only slight loss of strength by recovery thereby developing a differential in yield strength between said sheets, and

(H) inflating said composite panel in said unjoined portions by the application therein of a fluid under pressure.

2. A process of fabricating an aluminum sheet metal panel having a relatively smooth hard component layer and having distensions raised from an opposite integrally unified softer component layer, both said layers being formed of substantially the same composition, said process comprising the steps of:

(A) providing a pair of aluminum ingots, each of said ingots containing Fe+Si 1.0% maximum and Al 99.00% to 99.75%,

(B) heating one of said ingots to a temperature within the range of 950° to 1000° F. for a period of about 10 hours,

(C) rolling said ingots to sheet within a temperature range of 800° to 1000° F.,

(D) forming a panel blank by positioning said sheets adjacent one another, one of said sheets having ap-

plied to a confronting surface thereof a pattern of stop weld material,

(E) pressure rolling said blank within the temperature range of 700° to 950° F. to form a composite panel,

(F) cold rolling said panel,

(G) partially annealing said panel at a temperature within the range of 500° to 620° F. for a period of 5 minutes to 10 hours, and

(H) inflating said composite panel in the unjoined portions defined by said pattern of stop weld material by the application therein of a fluid under pressure.

3. A process as set forth in claim **2** wherein said partial annealing is carried out at a temperature of about 585° F. for a period of about 15 minutes.

4. A process of fabricating an aluminum sheet metal panel having a relatively smooth hard component layer and having distensions raised from an opposite integrally unified softer component layer, both said layers being formed of substantially the same composition, said process comprising the steps of:

(A) providing a pair of aluminum ingots, each of said ingots containing Mn 1.5% maximum and Al 95.00% to 99.00%,

(B) heating one of said ingots to a temperature within the range of 1000° to 1050° F. for a period of about 24 hours,

(C) rolling said ingots to sheet within a temperature

range of 800° to 1000° F.,

(D) forming a panel blank by positioning said sheets adjacent one another, one of said sheets having applied to a confronting surface thereof a pattern of stop weld material,

(E) pressure rolling said blank within the temperature range of 700° to 950° F. to form a composite panel,

(F) cold rolling said panel,

(G) partially annealing said panel at a temperature within the range of 570° to 655° F. for a period of 5 minutes to 10 hours, and

(H) inflating said composite panel in the unjoined portions defined by said pattern of stop weld material by the application therein of a fluid under pressure.

5. A process as set forth in claim **4** wherein said partial annealing is carried out at a temperature of about 585° F. for period of about 15 minutes.

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