United States Patent Office 3,348,290 Patented Oct. 24, 1967

3,348,290

METHOD OF FABRICATING A HEAT EXCHANGER FROM A SINGLE CAST INGOT BY ROLLING HEAT TREATING AND BONDING

Irwin Broverman, Cheshire, and George Jagaciak, Milford, Conn., assignors to Olin Mathieson Chemical Corporation, a corporation of Virginia

No Drawing. Original application Oct. 23, 1963, Ser. No. 318,158. Divided and this application July 15, 1966, Ser. No. 574,853

1 Claim. (Cl. 29—157.3)

This application is a division of co-pending application Ser. No. 318,158, filed Oct. 23, 1963, now abandoned.

This invention relates generally to improvements in sheet metal panels having component layers thereof of dissimilar hardness and ductility, and to a method of fabricating these panels.

More particularly, it relates to an improvement over the invention disclosed in co-pending application S.N. 160,282, filed Dec. 18, 1961, in the names of Irwin Broverman and Michael J. Pryor, now U.S. Patent 3,196,528.

As fully detailed in that application, sheet metal panels having component layers of different hardness and ductility are desirable in the heat exchange art, and particularly in the field of refrigerator evaporators which are subject to so called "ice pick" damage. These evaporators are formed of sheet metal panels having interior passageways disposed between bulged out or distended portions of opposed thicknesses of the panel. Frequently, severe damage is caused to the panel passageway 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 refrigerator freezing compartment.

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

The fabrication of the panel is greatly facilitated by achieving a combination of characteristics between the hard and soft layers of the panel in which an aluminum-chromium alloy has substantially the same hardness in the cold worked condition as does pure aluminum, has a marked thermal stability in the recovery range, and has a substantially equivalent final recrystallization temperature as that of pure aluminum. This combination of characteristics of the aluminum-chromium alloy and the pure aluminum is necessary in order to achieve an equivalent resistance to deformation on hot and cold rolling which results in equal reduction and extension upon such rolling, thereby permitting the use of sheets of equal length and thickness. Also, these characteristics are necessary to permit the development of a strength differential between the aluminum-chromium alloy and the pure aluminum upon subsequent critical partial annealing.

More particularly, in order to use components of dimensional equivalence, which is both more efficient and economical than sheets which are dimensionally dissimilar, the aluminum-chromium alloy and the pure aluminum must have an identity of physical properties during hot and cold rolling; thus the aluminum-chromium alloy must have substantially the same recrystallization temperature as that of pure aluminum to achieve equal reduction and extension on hot rolling, and it must have substantially the same degree of work hardening for the same amount of cold work as is applied to pure aluminum. Finally, it must have a thermal stability in the recovery range coupled with substantially the same final recrystallization temperature as that of pure aluminum in order to achieve a differential in strength after partial annealing.

Accordingly, it is an object of this invention to provide a unified sheet of metal uniquely adapted to the fabrication of a one-side-flat bi-alloy sheet metal article having hollow portions or passageways internally disposed therein.

It is another object of this invention to provide a unified sheet metal article having component layers thereof of different hardness and ductility.

It is another object of this invention to provide novel aluminum alloy compositions having desirable combinations of properties such as combined strength and ductility.

It is yet another object of this invention to provide a method of fabricating the article of this invention.

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

The foregoing objects of this invention are achieved to a surprising extent by providing a composite article of aluminum base metal which comprises a first component sheet or layer of a commercial purity grade aluminum which contains from 0.15% to 0.45% chromium distributed throughout the base metal in the form of a very finely divided uniform dispersion of chromium-aluminum precipitate, and a second component sheet or layer of the same commercial purity grade aluminum integrally united with the first component sheet, the second sheet being substantially free of the chromium aluminide ($CrAl_7$) precipitate.

In accordance with our invention, the above article is fabricated generally by selecting an aluminum alloy from among the commercial purity grade alloys which contain about 99.00% to 99.75% aluminum. These alloys have been found to possess physical properties which yield the desirable similarity of metallurgical characteristics during initial phase of processing and dissimilar metallurgical characteristics during later stages of the processing.

To achieve the ultimate high strength component of the composite article, which constitutes the novel alloy of this invention, the commercial purity grade aluminum is alloyed with chromium ranging from 0.15% to 0.45%, with an optimum at about 0.35%. The molten mass is then cast by the DC casting process, entering the DC casting mold at a temperature within the range of 1300° to 1375° F. Care should be exercised to avoid having the molten composition enter the mold at a temperature below 1300° F.

Lower temperatures than this stated limit are preferably avoided, particularly where higher concentrations of chromium of the order of 0.45% are to be included in the ingot, because of the tendency of the chromium to precipitate from the liquid alloy composition in the form of primary coarse crystals of $CrAl_7$. Such precipitated coarse crystals cannot be converted to a finely divided and uniformly dispersed particulate form. A more finely divided or microscopic particle size precipitate is required to achieve the desired thermal stability of the alloy, as is more fully pointed out below. The use of melt temperatures such that the metal entering the mold falls between the range of 1300° to 1375° F. permits casting of the ingots containing up to 0.45% chromium with substantially all of the precipitated $CrAl_7$ in the desirable finely divided form.

The cast ingot contains chromium in solid solution and $CrAl_7$ dispersed in an extremely fine form of microscopic and submicroscopic particles. In order to induce the precipitation of the dissolved chromium into the desired extremely fine form, the ingot is subjected to a preheat

practice consisting of a soak of the ingot within the temperature range of 850° to 1025° F., preferably at a temperature between 950° and 975° F. for a period of between 10 and 24 hours. The time interval specified is the time during which the alloy is within the stated temperature range.

Where chromium concentrations are higher for example approaching 0.45%, longer soak periods, up to about 24 hours, are used to make possible production of the best mechanical properties after cold work. For lower concentrations, in the preferred range of 0.32% to 0.38%, a lower upper limit on the soak period of about 16 hours permits maximum physical properties to be obtained.

Also in general, for best mechanical properties, it is preferred to precipitate as much as possible of the chromium as $CrAl_7$ particles of very fine or microscopic size. By microscopic size or microscopic particles, as used herein, is meant particles of a size the larger of which is clearly resolvable by metallographic microscope techniques only at higher magnifications of 500× and above.

Regarding the lower limit of the soak period, although some precipitation occurs from use of soak periods below 10 hours, the use of a soak period of at least this duration is necessary for attainment, of optimum anodizing properties in the sheet surface. Where less than a 10 hour soak is employed with a commercial purity grade aluminum containing at least 0.15% chromium, some of the unprecipitated chromium will come out of solution during hot rolling, and will produce a surface which shows undesirable streaking and/or discoloration from the anodizing treatment.

It has been found that this preheat treatment is essential in ensuring the presence of a maximum amount of the chromium in the form of a very fine or microscopic dispersion of $CrAl_7$ uniformly distributed throughout the process ingot. Only through the formation of this dispersion is the reduction of chromium in solid solution assured; and this is necessary due to the fact that an optimum response is obtained in a subsequent partial annealing following cold working, and the development of large differences in yield strength between the components of a composite sheet, where a maximum amount of the chromium is present in the very finely divided, uniformly dispersed form.

The process ingot is then hot rolled at any temperature below 950° F. to the gage required for forming the composite product. Alternatively, the ingot can be hot rolled to some intermediate gage and then cold rolled to final gage where this cold rolling is followed by an anneal.

Regarding this upper limit, it should be kept in mind that the alloy compositions have distinctly improved properties only when that portion of the chromium additive, present in the microscopically subdivided and uniformly distributed form, is at a concentration effective to inhibit the recovery of the alloy after cold work when subjected to a partial anneal. Maximum effectiveness of the chromium additive is achieved when substantially all of the additive is present in the microscopically subdivided and uniformly distributed form.

In this connection, the temperature at which the composite blank, i.e., a pressure welded but uninflated composite sheet product, one layer of which is composed of the chromium alloy of the invention, is heated in preparation for rolling, or the temperature at which the chromium alloy sheet is rolled prior to preparation of the blank, may vary and may range for short periods of time up to about 975° F. without apparent deleterious effects in the finished sheet. The temperature of the material containing chromium, however, should not normally be allowed to exceed 1025° F. during primary metal processing, i.e., up to the formation of the primary metal stock, as this may lead to partial redissolution of the $CrAl_7$. Redissolution of the $CrAl_7$ from the uniformly distributed microscopically subdivided form detracts from the effective contribution of the chromium bearing phase to the desired combination of properties following cold working and partial annealing, particularly where the redissolution is followed by hot rolling because the $CrAl_7$ is caused to be precipitated by such rolling in an anisotropic form. Such precipitation causes non-uniform dispersions of the $CrAl_7$ and results in accentuated textural streaking and/or discoloration on anodizing.

Accordingly, the upper limit of 1025° F. for soaking or subsequent primary heat treatment of the alloy is necessary because above this temperature the chromium may be coalesced and may also be redissolved which can lead to coarsening or subsequent reprecipitation of the $CrAl_7$ respectively in the less desirable larger particle form.

A piece taken from this starting stock containing chromium is prepared for assembly with a dimensionally corresponding sample of commercial purity grade aluminum free of chromium. The faces of the components to be confronted in the assembly are cleaned by conventional steps such as brushing, organic solvent degreasing, etching in acid solutions, or similar conventional steps.

After such cleaning a pattern of stop weld is applied to one of the surfaces to be confronted. The assembly is then tack welded at its corners to preserve alignment during subsequent processing.

As part of the secondary metal processing, the assembly is then heated to a temperature between 800° and 1000° F., and preferably within the range of 900° and 950° F., and is pressure welded by hot rolling with a reduction in thickness of 60% to 65%. This hot rolling reduction is followed, after cooling, with a cold reduction by rolling in the nature of 30% to 35%. Excellent metallurgical pressure welding is produced by this combination of steps.

Following the hot and cold rolling, a large differential in yield strength is developed between the two alloys by subjecting the blank to a critical partial annealing practice. This anneal is carried out in a temperature range in which the unalloyed commercial purity aluminum undergoes considerable loss of strength by recovery or recrystallization, while the chromium-aluminum component undergoes only slight loss of strength by recovery, thereby developing a differential in yield strength between the two components. To obtain the larger differences in yield strength the partial annealing is desirably carried out between a temperature of 550° and 600° F. for a period of 10 to 60 minutes.

To illustrate the development of this differential in yield strength after critical partial annealing, the yield strength of commercial purity aluminum alloy 1100 containing chromuim after annealing at 575° F. for 60 minutes is 17,000 p.s.i., while that of commercially available annealed aluminum alloy 1100 is 5,900 p.s.i. For a composite of aluminum alloy 1100 and 1100 containing chromium, a partial annealing results in the alloy 1100 having a yield strength ranging from 9,500 p.s.i. to 5,500 p.s.i. after 30 to 60 minutes annealing at 550° F., respectively, and is almost constant at 4,000 p.s.i. to 5,000 p.s.i. after 30 minutes annealing at 600° F. By contrast, the aluminum alloy 1100 containing 0.35% chromium has yield strength values of about 20,000 p.s.i. to 17,500 p.s.i. after annealing at temperatures of 550° and 600° F. respectively, almost independent of annealing times between 30 and 60 minutes. The preferred partial annealing cycle is a heating at 550° F. for about 60 minutes to develop the higher yield strength differential without any significant sacrifice of the tensile properties.

The partial annealing is followed by inflation of the partially annealed blank using the differential pressure inflation procedure employing a cavity die to expand the softer aluminum component layer while the component layer containing chromium remains in a smooth flat configuration.

Alternatively the inflation of the partially annealed blank between platens as taught in the patent art pertinent to inflation methods although the same degree of smoothness and flatness of one side is not achieved by this inflation.

The following is an example of this invention, and is to be construed as illustrative and not all inclusive.

Example

A molten mass of aluminum alloy 1100 was alloyed with 0.35% chromium and cast by the DC casting process at a temperature of 1350° F. The ingot was then subjected to a preheat or homogenization procedure consisting of a soak of the ingot at a temperature of 950° F. for 10 hours, after which the ingot was hot rolled to .230" gage strip at a temperature of 850° F. and was then cold rolled to .125" thickness and annealed at 650° F. for 4 hours. A blank was prepared by placing a sample of this strip adjacent a correspondingly dimensioned sample of aluminum alloy 1100 strip, with a pattern of stop weld between the confronting surfaces, after which the blank was hot rolled at 950° F. to a 65% reduction in thickness, cold rolled to a 30% reduction, and subjected to a critical partial annealing at 575° F. for 60 minutes. Tests on this blank following inflation showed a differential in yield strength of 13,000 p.s.i. resulting from yield strengths of 18,000 p.s.i. and 5,000 p.s.i. in the chromium-aluminum component and the aluminum 1100 component respectively.

It will be apparent from the foregoing description that there has been provided an article and method for making same 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 claim.

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

A process for fabricating sheet metal panel comprising the steps of:

(A) casting a molten mass of aluminum having from 0.15% to 0.45% chromium therein into an ingot at a temperature in excess of 1300° F.,

(B) precipitating said chromium into a uniform dispersion of microscopically sized particles of chromium aluminide in said ingot,

(C) and rolling said ingot to at least two sheets,

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

(E) heating said blank to a temperature within the range of 800° to 1,000° F.,

(F) pressure welding said sheets together in the area not covered by said weld inhibiting material,

(G) cooling and cold working said blank to develop a high strength level in said sheets,

(H) partially annealing said blank in the temperature range of 550° to 600° F. for a period of about 10 to 60 minutes,

(I) and inflating the blank in the unwelded areas by the application of fluid pressure therein.

No references cited.

JOHN F. CAMPBELL, *Primary Examiner.*

P. M. COHEN, *Assistant Examiner.*