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HOMOGENEOUS ALLOY AND METHOD OF MAKING SAME

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ABSTRACT OF THE DISCLOSURE

A process of homogenizing alloy material wherein a preselected surface portion of an alloy specimen is melted while the remaining surface is maintained at a substantially constant temperature below the alloy melting point.

It is well known in the science of metallurgy that alloys exhibit certain optimum properties while in a homogeneous condition. Such a condition is a result of the complete diffusion of the solute and solvent elements throughout the solid solution. The completeness of diffusion, however, depends upon a number of variables. Some of these variables are the composition of the alloy, the rate of solidification and the time and temperature available for reheating after solidification.

Alloys in their molten state are known to possess complete homogeniety. This is attributed to the increase mobility of the atoms at elevated temperatures. As the molten alloy is cooled however, nucleation occurs. This causes the formation of crystals which in turn form dendrite arms as growth proceeds. As the dendrite arms are formed, solute elements are rejected from them into the surrounding liquid phase. This results in a solute rich interdendritic region. Unless the solute in these regions is completely diffused the properties for which the solute elements were added will not be optimized.

Diffusion, i.e., homogenization, is facilitated by reheating the solid solution after it has solidified. When the rate of solidification is slow, large dendrites are formed. With these present in the solid solution, long periods of time are required before the solute completely diffuses across the large dendrite arms. The homogenization time is considerably shortened however, when solidification is rapid and fine dentrites are formed.

Two disadvantages result when homogenization is attempted with large dendrites present. The first is the great length of time required at elevated temperatures before homogenization is complete. This requires the utilization of valuable space and equipment for extended periods of time, thus making impractical the commerical production of homogenized alloy material. The second disadvantage lies in the tendency of the solute rich phase to spherodize when subjected to elevated temperatures for prolonged periods of time. This tendency is particularly evident where large dendrities are present in the alloy. Since alloys in commercial ingots freeze slowly, large dendrites of about 1000 microns in size are formed. With these present in the material spherodization is likely to occur well before homogenization is completed.

A method of homogenization which obviates the spherodization problem is that of chill casting and reheating, In chill casting, molten alloy is poured into a mold which is designed to effect a rapid cooling of the liquid alloy. Reheating the resulting casing will cause complete homogenization in a relatively short period of time. Attendant with this process, however, are many problems in mold design, construction and maintenance.

It is because of the aforementioned disadvantages that completely homogeneous alloy ingots are not readily formed. Consequently, the inhomogenieties present in the ingots are carried through into the subsequently rolled products. Thus in commercially available alloy products the ductility of the material is impaired, the strength potential of the alloy is not efficiently developed and mechanical property anistropy is observed.

A principal object of this invention is to develop efficiently the physical and mechanical properties of alloy materials by achieving complete homogeniety in a relatively short period of time.

A fine dendritic structure facilitates rapid and complete homogenization. By fine dendritic structure is meant a structure containing a dendrite arm spacing of less than 30 microns. Since a fine dendritic structure facilitates homogenization and since homogenization aids in the efficient development of the physical and mechanical properties of an alloy, then it follows that the production of a fine dendritic structure is a prerequisite for achieving the rapid and complete homogenization of alloy materials.

Fine dendrites are formed as a result of rapid solidification of a molten alloy. This in turn requires a high rate of heat transfer from the molten mass to some heat sink. The instant invention utilizes the mass of alloy being processed as heat sink.

Reference will be made throughout the specification to a plate-like alloy specimen. It should be noted however that this process is not limited to such specimens but would be equally effective on other configurations such as hollow cylinders.

In order that a plate may be processed it is necessary that it be placed on a supporting structure such as a table. It is preferable if the structure is constructed in such a manner that the transfer of heat from the plate will be facilitated. The desirability of such construction will become more evident later in the specification.

If a high intensity heat source is now brought into contact with the plate a molten pool of alloy will be formed at the surface of the plate. By varying the intensity of the heat source the depth of the molten pool may be controlled. If the heat source is now moved in a plane substantially parallel to the surface of the plate, the pool will form a trough. The molten alloy most remote from the moving heat source will then begin to solidify. The rate of solidification of this molten alloy is dependent to a great extent upon the temperature of the solid alloy material surrounding it. If the surrounding material in the plate is maintained at or below room temperature the rate of solidification is rapid, dendrites are small and homogenization will be rapidly and completely achieved. There would appear to be no lower operating temperature limit, however, for practical purposes the process would not be carried out at temperatures lower than —200° F. If the plate is maintained at temperatures substantially above room temperature and approaching the melting temperature of alloy then dendrites will grow and homogenization will be retarded. For these reasons then, it is essential to the operation of this process that the plate temperature be maintained substantially below the melting temperature of the alloy and in no case higher than ½ the alloy melting temperature, if satisfactory results

are to be achieved. Thus, it can be seen that a supporting structure that facilitates heat transfer from the plate is desirable as an aid in maintaining the plate at a substantially constant temperature.

Since the width of the melted trough will be very narrow in comparison with the area of the plate a large number of passes by the heat source over the surface will be necessary before the whole plate is processed. A fixture supporting a plurality of parallel spaced heat sources would expedite processing. It should be noted here that overlapping of one trough by another on a subsequent pass has not been found to yield detrimental results.

If very thin plates are processed it is desirable to support the plate by means of a "backup" plate. This "backup" plate will support the molten alloy when the sheet is melted through its entire thickness. It should be noted that although this melting would appear to cut the sheet, nevertheless as the heat source is moved along the surface of the sheet the supported molten alloy will solidify without the sheet being severed. After processing, the entire sheet may be stripped from the "backup" plate and homogenized. With thicker plates, it has been found desirable to melt the plate to a depth of about one-half its thickness. By inverting the plate the other one-half may then be melted.

The homogenization process is completed by heating the processed plate to a predetermined temperature for a period of time. Both the time and temperature will depend on a number of variables such as plate thickness and alloy composition, however, one skilled in the art of heat treating may readily be expected to make these determinations.

The effectiveness of the disclosed process may be observed from a perusal of tests results. A plate like specimen of type 7001 aluminum alloy was laid flat on a conventional metal work table in a room having an ambient temperature of 70–80 degrees Fahrenheit. A direct current arc was struck between a nonconsumable tungsten electrode and the surface of the plate, and a pool of molten metal was formed thereby. The electrode was moved at a controlled velocity along the plate surface and the metal melted by the arc froze quickly due to the rapid chilling effect achieved by this arrangement. A bar shaped portion of metal, about ½ inch in diameter, was cut from the plate, homogenized by heat treatment at 900° F. for 3 hours and hot rolled in grooved rolls at 900° F. to form a ¼ inch square shaped bar stock. The resulting shape was solution treated for 4 hours at 900° F., water quenched and aged at 250° F. A comparison between the tensile properties of commercial 7001 alloy and the tensile properties of the alloy specimen which has undergone the disclosed process is made in the following table:

CHEMICAL COMPOSITIONS AND TENSILE PROPERTIES OF COMMERCIAL AND PROCESSED 7001–T6 ALLOYS

	Commercial Alloy	Processed Alloy
Composition (weight percent)		
Zn	7.40	7.90
Mg	3.00	2.70
Cu	2.10	1.60
Cr	0.25	0.16
Tensile Properties		
UTS (K S.i.)	98.0	102.3
YS (K S.i.)	91.0	99.4
RA (percent)	12	19

It can be seen from the data in this table that the processed material has both higher strength and ductility than the commercial material. These increases may be attributed to the higher degree of homogeneity achieved in the processed material. The high strengths and ductilities realized by a high degree of homogenization of fine dendrite spaced material are attractive. However, for metal forming processes and certain military applications, higher ductility even with somewhat lower strengths would be more desirable. Therefore, a leaner solute alloy was made for evaluation. This alloy contained 4.58 Zn, 2.14 Mg, 1.56 Cu, and 0.18 Cr with the balance being aluminum. This material was processed, homogenized for 3 hours and forged to ¼ in. round bar stock. It was found that on re-solution treatment of the forged material, complete homogenization could be achieved by a 10-minute solutionizing time at 900° F., and that a high degree of homogeneity was maintained during the forging operation. The forged material was resolutionized for 3 hours at 900° F., for aging studies' and it was found that hardness, yield strength and ultimate strength increased over the aging range studied (8 to 135 hours) with the highest strengths observed being 65,000 p.s.i. yield strength and 75,000 p.s.i. ultimate tensile strength. These strengths were accompanied by a reduction in area of 51 percent.

Tests conducted on commercially available type 7075 aluminum alloy, which has an Ultimate Tensile Strength (UTS) of 85,000 p.s.i., a Yield Strength of (YS) of 75,000 p.s.i. and undergoes a 20% Reduction in Area (RA) beforce fracture, indicate that the same alloy having a dendrite arm spacing of less than 40–50 microns and which has been completely homogenized, exhibits a 40% RA before fracture. This represents an increase in ductility of 100%.

That for a given ductility an alloy strength may be increased is seen from another comparison. Type 7075 commercial aluminum alloy, whose tensile properties were given above, has the following as its primary solute tolerances: zinc—5.1–6%., magnesium—2.1–2.9%, and copper—1.2–2.0%. An alloy having the same primary solutes in the following perecntages: zinc—17.9, magnesium—12.7, and copper—1.6 was prepared and homogenized by the disclosed method. It underwent a 19% RA, close to that of 7075 commercial alloy, but its UTS and YS were 102,300 p.s.i. and 99,400 p.s.i., respectively. These resutls indicate that a substantial increase in strength is effected with little impairment of ductiilty

The above reference to aluminum alloy is to be construed as illustrative only. The process would be equally effective on magnesium, titanium, copper, iron, cobalt, nickel, and other alloys. It would be particularly effective on those alloys which exhibit high strength properties.

I claim:

1. A process of homogenizing a mass of alloy material up to at least one inch thick comprising the steps of:
   - maintaining an environment for said alloy material selected from the group consisting of aluminum base alloy, magnesium base alloy, titanium base alloy, copper base alloy, iron base alloy, nickel base alloy and cobalt base alloy, at a predetermined temperature below the melting point of said alloy material,
   - heating a surface portion on one side of said alloy material, said heated portion having a sufficient volume to provide a molten pool having a depth at least ½ the thickness of said alloy material by applying means including a heat source adjacent said surface portion for melting said volume,
   - moving said heat source in a plane substantially parallel to said surface portion sufficiently slowly to maintain the depth of said molten pool at least ½ the thickness of said alloy material, and sufficiently rapidly such that the molten pool will freeze to form secondary dendrite arm spacings having distances less than 30 microns therebetween,
   - repeating said moving step until said entire side of said alloy material has been melted and solidified,
   - turning said alloy material over and repeating said moving step until the other side of said alloy material is melted and solidified such that the entire mass of alloy material has been completely melted and solidified, and
   - heat treating the resultant alloy material to produce a homogeneous solid solution.

2. A process as in claim 1, wherein said predetermined temperature is less than one-half the melting temperature of said alloy.

3. A process as in claim 1, wherein said predetermined temperature is room temperature.

4. A process as in claim 1, wherein said predetermined temperature is less than room temperature.

5. A process as described in claim 1, wherein said depth of said molten pool is substantially equal to said alloy material thickness.

6. The process of claim 1, wherein said alloy material includes aluminum base alloy.

7. A 7001–T6 aluminum base alloy made in accordance with claim 1, said alloy having an ultimate tensile strength of about 102,300 p.s.i., a yield strength of about 99,400 p.s.i., and a reduction in area of about 19%, said alloy consisting essentially of about 7.90 weight percent zinc, 2.70 weight percent magnesium, 1.60 weight percent copper, 0.16 weight percent chromium, the balance being substantially aluminum.

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