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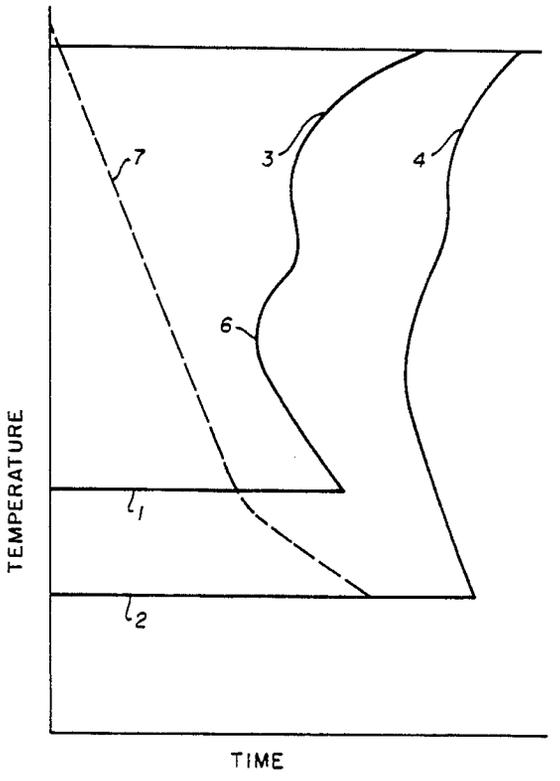
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(54) Process for rapid quenching in a fluidized bed.

(57) A process enabling rapid quenching of articles in a fluidized bed wherein a bed of defined particle type and size is fluidized at a defined flowrate with a high conductivity gas.



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PROCESS FOR RAPID QUENCHING IN A FLUIDIZED BED

Technical Field

This invention relates generally to the quenching of articles in a fluidized bed and is particularly advantageous for the quenching of metal parts in a fluidized bed.

Background Art

Quenching is used extensively in the heat treating of objects in order to rapidly change the temperature of the object. Generally quenching is employed to rapidly reduce the object temperature although quenching may also be used to rapidly raise the object temperature. Often the objects to be quenched are metal parts.

Quenching is conventionally carried out in a number of ways. In spray quenching, a liquid is sprayed onto the object to be quenched. In gas quenching, the object is placed in a flowing stream of a gas or vapor such as air, nitrogen, argon, helium, hydrogen, steam or combustion products. In fog quenching, a gas or vapor stream with entrained liquid droplets is directed onto the surface of the object to be quenched. In immersion quenching, the object is immersed in a liquid bath such as water, brine, oil molten salt, polymer solution, or a liquid cryogen.

Although these conventional quenching methods have been employed satisfactorily, they exhibit a number of disadvantages. For example, liquids such as oil quenchants often leave a layer on the objects which must be cleaned off. Some quenchants, such as molten salts, have disposal problems. Other quenchants, such as polymers and oils, degrade with age and must be replaced. Another disadvantage of some quenchants is the fact that quenching temperatures are often at their boiling temperature thus causing varying heat transfer rates along the surface of the article.

Fluidized beds are known for use in the quenching of objects and serve to overcome these problems. There is little or no cleaning of the object required after a fluidized bed quench. Also the particles used in the fluidized bed are inert and do not degrade. However, fluidized beds have not been used extensively to quench objects such as metal parts because the quench rate has been too low to satisfactorily quench metal parts made of anything other than deep hardening alloys, without forming undesirable softer phases within the metal part.

It is therefore an object of this invention to provide an improved heat treating process wherein metal articles may be quenched in a fluidized bed while avoiding the formation of undesirable softer phases within the metal article.

It is also an object of this invention to provide an improved heat treating process wherein an article may be effectively quenched by use of a fluidized bed.

Summary Of The Invention

The above and other objects, which will become apparent to one skilled in the art upon a reading of this disclosure, are attained by the process of this invention, one aspect of which is:

A process for heat treating steel alloy articles comprising:

(a) providing a steel alloy article at an austenitizing temperature;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fludization flowrate;

(c) immersing the article in said fluidized bed at a bed temperature below the $M_s$temperature of the alloy; and

(d) quenching the article in the bed for a period of time and at a quench rate sufficient to achieve the M_s temperature of the alloy substantially without forming undesirable softer phases within the article while fluidizing the bed with high conductivity gas for at least a portion of the quench period and while maintaining the bed at a temperature below the M_s temperature of the alloy for the entire quench period.

As used herein, the term "quenching" means a rapid change in enthalpy of an object by heat transfer across the boundary of the object, wherein the rate of enthalpy change exceeds that rate when the object is placed in and is surrounded by still atmosphere.

As used herein, the term "quench rate" means the amount of heat transfer per unit time across an object boundary when the object is being quenched.

As used herein, the term "bed" means a defined volume of solid particles.

As used herein, the term "fine solid particles" means porous or non-porous particles having a density within the range of from 0.3 to 20 grams per cubic centimeter and a mean particle diameter within the range of from 30 to 1000 microns.

As used herein, the term "fluidized bed" means a bed through which is passed fluid, such as gas and/or vapor, wherein the fluid drag force of the fluid component causes movement of the solid component from its repose position in a manner that enhances mixing of both components in the bed. The term, fluidized, is derived from the fluid-like characteristics, such as a zero angle of repose, mobility, and a pressure heat equal to the bulk density of the bed, which the bed assumes.

As used herein the term "immersing" means that substantially all of the article to be treated, or if only a portion of the article is to be treated, substantially all of that portion of the article to be treated, is made to be surrounded by the fluidized particles during the quench.

As used herein the term "minimum fluidization flowrate" means the least volumetric flowrate of the fluid component through a bed which is necessary for the bed to attain fluidized bed characteristics under atmospheric pressure.

As used herein, the term "slumped bed" means a bed through which no fluid is passing or through which fluid is passing at less than the minimum fluidization flowrate.

As used herein, the term "high conductivity gas" means a gas, gas mixture, vapor, vapor mixture or gas-vapor mixture having a thermal conductivity greater than or equal to the thermal conductivity of a mixture of 80 percent nitrogen and 20 percent helium at the same temperature and pressure conditions.

As used herein, the term "steel alloy article" means a shaped article comprised, at least in part, of a steel or ferrous alloy.

As used herein the term "austenitizing temperature" means a temperature at which the steel alloy of a steel alloy article is austenite.

As used herein, the term "M_s temperature" means that temperature at which the austenite phase of a steel alloy begins to change to martensite.

As used herein the term "M_f temperature" means that temperature at which substantially all of a steel alloy is converted to martensite.

As used herein, the term "softer phases" means pearlite, ferrite, bainite and the like.

As used herein, the term "nose temperature" means that temperature at which the time required for austenite to start transforming into softer phases is at a minimum.

Brief Description of the Drawing

The sole Figure is a schematic diagram of a steel alloy quench curve superimposed on a schematic steel alloy time, temperature, transformation (TTT) diagram.

Detailed Description

The process of this invention is particularly useful for the heat treating of steel alloy articles and will be described in detail with reference to this type of heat treating.

The process of this invention can be employed to quench effectively an article comprised of any steel alloy. The process is particularly advantageous to quench chromium-molybdenum steels such as AISI types 4130 and 4140, nickel-chromium-molybdenum steels such as AISI 4340, 8620, 8630 and 9860, nickel-molybdenum steels such as AISI 4640, chromium steels such as AISI 5140, series 1100 steels such as AISI 1144, and heat treatable ductile and malleable irons.

The steel alloy article is brought to or is at an austenitizing temperature. The minimum austenitizing temperature for most steel alloys is in the range of from 1500°F to 1700°F. At an austenitizing temperature the structure of the steel alloy is substantially all austenite. The term, austenite, as well as the terms martensite, pearlite, ferrite and bainite, are terms which are well known to those skilled in the art and definitions for these alloy structure terms can be found in many textbooks which relate to heat treating or metallurgy such as Heat Treater's Guide, Standard Practices And Procedures For Steel, Unterweiser et al. ed., ASM, Metals Park, Ohio (1982), Atlas of Isothermal Transformation and Cooling Transformation Diagrams, ASM, Metals Park, Ohio (1977) and Metals Handbook, Vol. 4 Heat Treating, ASM, Metals Park, Ohio (1981).

The bed useful in the process of this invention is comprised of fine solid particles. As examples of the types of bed particles which can be employed with this invention one can name metal oxide powders such as aluminum oxide, chromium oxide, iron oxide and titanium oxide, refractory powders such as silicon dioxide, mullite, magnesite, zirconium oxide and fosterite, and pure elements in the solid state such as iron, copper, nickel and carbon.

The bed particles useful in the process of this invention have a mean particle diameter within the range of from 30 to 1000 microns. Smaller particles are difficult to fluidize and give inadequate heat

transfer while larger particles do not contact heat transfer surfaces with adequate frequency resulting in poor heat transfer and also require a large amount of gas to fluidize the bed.

The bed is fluidized by the passage through the bed of a high conductivity gas. The use of a high conductivity gas is important for the achievement of the advantageous results of the process of this invention because the high conductivity, especially at the austenitizing temperatures, is necessary to achieve quench rates which will enable the attainment of the $M_s$temperature without forming softer phases within the steel alloy. Examples of high conductivity gases include helium, hydrogen and diassociated ammonia. In addition, a mixture of a pure high conductivity gas such as hydrogen or helium with a low conductivity gas may be employed so long as the mixture is consistent with the requirements for a high conductivity gas defined herein.

The bed is fluidized with the high conductivity gas at a gas flowrate which is at least 1.5 times the minimum fluidization flowrate for the specific bed particle type and size employed. Preferably the high conductivity gas flowrate is within the range of from 2 to 7 times the minimum fluidization flowrate. Below the minimum defined flowrate the particle circulation is sluggish resulting in poor heat transfer. At a flowrate above about 15 times the minimum fluidization flowrate, smaller particles may begin to be conveyed out of the bed.

When the bed is fluidized with the high conductivity gas at the requisite gas flowrate the austenite steel alloy article is immersed in the fluidized bed for quenching.

The steel alloy article is kept in the bed for a period of time sufficient to reduce the temperature of the article to or below the $M_s$temperature. This temperature reduction is done at a rapid rate, i.e., the article is quenched. Initially the quenching is always carried out with the bed fluidizing with high conductivity gas. The quenching of the article to the M_s temperature can be carried out entirely with the bed fluidized with high conductivity gas or it can be carried out in part with the bed in a slumped condition and/or fluidized with a low conductivity gas. For purposes of this disclosure any gas which is not a high conductivity gas is a low conductivity gas. However, it is very important that during the quenching step the quench rate of the article be sufficient to enable a reduction in temperature of the article sufficient to reach the M_s temperature without the formation of softer phases within the alloy. In order to successfully carry out the quench, a practitioner may need to vary the fluidizing gas flowrate during the quench period while remaining with the defined limits.

The quench rate is generally measured by a procedure variously known in the art as the Magnetic Test, General Motors Quenchometer Test, or Nickel Ball Test. The procedure comprises heating a 7/8-inch (22 mm) nickel sphere, weighing approximately 1.8 ounces (50 g) to a given high temperature and then quenching the sphere in the quenchant to be evaluated down to give low temperature. The time it takes for the sphere temperature go from the high to the low temperature is a measure of the quench rate. In the process of this invention for the heat treating of steel alloy articles, the initial quench rate as measured by the Nickel Ball Test between the temperatures of 1600°F and 684°F is less than 24 seconds.

In order to more clearly illustrate the process of this invention, reference is made to the Figure which is schematic diagram of a steel alloy quench curve superimposed on a schematic steel alloy time-temperature-transformation diagram. In the Figure, line 1 indicates the M_s temperature and line 2 indicates the M_f temperature. Line 3 indicates the threshold where a steel alloy will begin to form softer phases and line 4 indicates where transformation into softer phases is completed. As can be seen the threshold line 3, which indicates where softer phases will be formed in the steel alloy if the M_s temperature is not first attained, exhibits a distinct leftward bulge or nose 6. The elapsed time for reaching the nose after the start of quenching will vary with the type of alloy and can be obtained from the Atlas which is referenced herein.

Curve 7 illustrates a generalized quenching curve for an article quenched by the process of this invention wherein the entire quenching period, when the temperature of the article goes from the austenitizing temperature to the M_s temperature, is carried out while the bed is fluidized with a high conductivity gas. The quench rate is the absolute value of the slope of quenching curve 7, and as can be seen, the quench rate is sufficient to enable intersection of the M_s temperature at line 1 without crossing threshold line 3.

The bed is operated at a temperature which is less than the M_s temperature, and preferably will be operated at a temperature which is less than the M_f temperature, of the alloy.

As is known to those skilled in the art, a fast quench may not always be desirable because of the possibility of stress creation within the alloy. Therefore, if possible without crossing the softer phase threshold, one can reduce the quenching rate by changing the mode of operation of the bed. After an initial period wherein the bed is fluidized with a high conductivity gas, the process may be carried out with the bed fluidized with a low conductivity gas, or with the bed in a slumped condition. One can alternate between these two modes

of operation and one can, at any time, refluidize the bed with high conductivity gas. A convenient time to change from fluidization with a high conductivity gas to another bed operating mode is when the article temperature has dropped below the nose temperature. As mentioned previously the quenching continues for a period of time and at a quench rate sufficient to achieve the $M_s$temperature of the alloy substantially without forming undesirable softer phases within the part.

Once the M_s temperature is attained one can, if desired, remove the article from the bed. However, it is preferable that the article be kept in the bed and further quenched to the $M_f$temperature. This further quenching, which is also shown schematically in the Figure can be carried out with the bed fluidized with high conductivity gas, but preferably is carried out with the bed slumped or fluidized with a low conductivity gas. One can carry out this further quenching with the bed in either of these three modes of operation and can switch between then, consistent with having a quench rate sufficient to achieve the M_f temperature without crossing softer phase threshold curve 4.

Specialized heat treating techniques, such as, martempering and modified martempering, can be carried out with the process of this invention.

To practice martempering with the process of this invention, one quenches the steel alloy article with the bed fluidized with high conductivity gas until the article temperature has dropped below the nose temperature but is still above the M_s temperature. The bed is then slumped until the article temperature equilibrates, i.e., when the temperature at the center of the article is substantially equal to the temperature at the article surface. Thereafter the bed is refluidized with low conductivity gas and the article is quenched in the bed to the M_f temperature.

In another way to practice martempering with the process of this invention, one quenches the steel alloy article with the bed fluidized with high conductivity gas until the article temperature has dropped below the nose temperature but is still above the M_s temperature. Thereafter the bed is fluidized with low conductivity gas and the article quenched in the bed to the M_f temperature.

To practice modified martempering with the process of this invention one quenches the steel alloy article with the bed fluidized with high conductivity gas until the article temperature has dropped below the M_s temperature but is still above the $M_f$temperature. Thereafter the bed is fluidized with low conductivity gas and the article quenched in the bed to the M_f temperature.

The process of this invention is further illustrated by reference to the following examples which are presented for illustrative purposes and are not intended to be limiting.

Example 1

Steel alloy parts of 4140 steel were heated to an austenitizing temperature of 1625°F. The $M_s$temperature of this steel alloy is 650°F. A bed comprised of 220 mesh aluminum oxide was fluidized with helium at a flowrate of 150 standard cubic feet per hour (scfh) per square foot of bed which is about twice the minimum fluidization flowrate for these bed particles. The nose temperature for this alloy occurs at about 3 seconds after the start of quenching.

The parts were immersed in the fluidized bed and quenched until the part temperature reached 500°F. Thereafter the helium flow was shut off and the bed was slumped for 15 minutes. The bed was the refluidized with nitrogen, a low conductivity gas, until the part temperature reached the $M_f$temperature and then reached the bed temperature of 175°F. The parts were removed from the bed and tested for hardness. The test showed a hardness of 52 Rc (Rockwell Hardness Number on the c scale) at both 1/16 inch and 7/16 inch below the part surface indicating the formation of essentially a complete martensite structure without the formation of softer phases.

Example 2

The procedure of Example 1 was repeated except that the steel alloy parts were comprised of 4340 steel which has an M_s temperature of 550°F. The parts had a hardness value of 52 Rc at both 1/16 inch and 7/16 inch below the surface indicating the essentially complete formation of martensite without the formation of softer phases.

Example 3

Steel alloy parts of 8620 steel, having a 5/8 inch diameter and a 6-inch length, were carburized to 1.0 percent carbon at the surface at a temperature of 1550°F. A bed comprised 220 mesh aluminum oxide was fluidized with helium at a flowrate of 225 scfh which is about three times the minimum fluidization flowrate. The parts were immersed in the fluidized bed and quenched for a time period until the part temperature was below the M_s temperature and was essentially equal to the bed temperature. This time period was about

60 seconds. The parts were removed from the bed and tempered for 1.5 hours at 400°F. A metallurgical sample was prepared by cutting a 1/2-inch section from the end of one of the parts. The surface hardness of the sample was 90 as measured on the 15N scale, and the core, or center, harness was 45 as measured on the Rockwell C scale. The minimum acceptable hardness values for these parts are 80 and 30 for the surface and core, respectively.

For comparative purposes, the procedure of Example 3 was repeated with the exception that the fluidizing gas used was nitrogen. The surface harness of the nitrogen fluid bed quenched sample was 89, but the core hardness was only 22, thus demonstrating the market improvement in part hardness attainable by use of the process of this invention.

One may employ the rapid quenching process of this invention to carry out austempering of a alloy wherein the alloy structure is transformed into bainitic. This procedure may be specially useful in the heat treating of cast iron.

This further aspect of the process of this invention can be defined as follows:

A process for the austempering of steel alloy articles to form a bainitic structure within the alloy comprising:

(a) providing a steel alloy article at an austenitizing temperature;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate, at a temperature within the range of from the M_f temperature to 50°F greater than the M_s temperature of the alloy;

(c) immersing the article in said fluidized bed and quenching the article in the fluidized bed for a period of time until the article temperature has been reduced to that of the fluidized bed at the bed temperature while fluidizing the bed with high conductivity gas for at least a portion of the quench period; and thereafter

(d) stopping the flow of high conductivity gas and maintaining the article in the bed at the bed temperature for a time sufficient to avoid the substantial formation of martensite within the steel alloy.

Step (d) of the austempering treatment can be carried out with the bed slumped or fluidized with a low conductivity gas and one can alternate between these two modes of bed operation.

The rapid quenching process of this invention also can be employed to quench effectively articles comprised of aluminum. Heretofore aluminum and aluminum alloys have been quenched with water or polymer quenchants and these quenchants have enabled quenching rates sufficient to achieve desired metallurgical properties such as high strength after aging and resistance to stress-corrosion cracking. However, especially for relatively thin articles, the conventional quenchants may give rise to a significant amount of distortion which leads to substantial costs associated with straightening operations. The process of this invention can quench aluminum and aluminum alloys at sufficiently high quench rates required for the formation of a uniform distribution of small precipitates within the part. This uniform distribution is necessary for the part to have high strength. However with the process of this invention one can adjust and control the quench rate by operating the bed in a slumped condition or by fluidizing the bed with a low conductivity gas so that one can quench an aluminum article at a quench rate which substantially avoids distortion within the article. The process of this invention as applied to the quenching of aluminum or aluminum alloys can be defined as follows:

A process for heat treating articles comprised of aluminum and/or aluminum alloy comprising:

(a) providing an article comprised of aluminum and/or aluminum alloy at an elevated temperature sufficient to allow hardening of the article by quenching;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate;

(c) immersing the article in said fluidized bed; and

(d) quenching the article in the bed at a quench rate such that a 7/8 inch diameter nickel ball will be cooled from 750 to 550°F in less than 28 seconds, for a time period sufficient to increase the hardness of the article while fluidizing the bed with high conductivity gas for at least a part of the quench period.

Generally the elevated temperature of step (a) is at least 750°F and usually exceeds 800°F. Step (d) can be carried out entirely with the bed fluidized with high conductivity gas, but generally and preferably, is carried out in part with the bed fluidized with low conductivity gas or operated in the slumped mode. Step (d) may be conveniently continued until the article has reached ambient or near ambient temperature.

The rapid quenching process of this invention also can be employed to rapidly lower or to rapidly raise the temperature of an article comprised of any effectively heat treatable material such as metal, glass, ceramic or plastic. The rapid quenching process of this invention as applied to the rapid temperature decrease or increase of an article can be defined as follows:

A process for quenching articles to a desired temperature comprising:

(a) providing an article at an initial temperature;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate;

(c) immersing the article in said fluidized bed; and

(d) quenching the article in the bed for a period of time sufficient to achieve the desired temperature while (i) maintaining the bed at or below the desired temperature if the desired temperature is less than the initial temperature, or (ii) maintaining the bed at or above the desired temperature if the desired temperature is greater than the initial temperature, while fluidizing the bed with high conductivity gas for at least a portion of the quench period.

Step (d) can be carried out entirely with the bed fluidized with high conductivity gas or step (d) can be carried out in part with the bed fluidized with low conductivity gas or operated in the slumped mode.

Now by the use of the process of this invention one can rapidly change the temperature of articles by use of a fluidized bed thus enabling greater control over the temperature change process than is otherwise possible with conventional quenchants. Furthermore the quenching process of this invention is much more convenient and generally is cleaner than conventional quenching processes. The rapid quenching process of this invention is particularly applicable to and advantageous for the heat treating of metal parts to attain a desired internal metal structure.

Claims

1. A process for heat treating steel alloy articles comprising:

(a) providing a steel alloy article at an austenitizing temperature;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate;

(c) immersing the article in said fluidized bed at a bed temperature below the M_s temperature of the alloy; and

(d) quenching the article in the bed for a period of time and at a quench rate sufficient to achieve the M_s temperature of the alloy substantially without forming undesirable softer phases within the article while fluidizing the bed with high conductivity gas for at least a portion of the quench period and while maintaining the bed at a temperature below the M_s temperature of the alloy for the entire quench period.

2. The process of claim 1 wherein the bed is fluidized with high conductivity gas during the entire period of step (d).

3. The process of claim 1 wherein the bed is fluidized with high conductivity gas during only a portion of the period of step (d).

4. The process of claim 3 wherein that portion of step (d) wherein the bed is fluidized with high conductivity gas is the initial portion of the period.

5. The process of claim 3 wherein during at least some of the period of step (d) when the bed is not fluidized with high conductivity gas, the bed is fluidized with low conductivity gas.

6. The process of claim 3 wherein during at least some of the period of step (d) when the bed is not fluidized with high conductivity gas, the bed is operated in a slumped condition.

7. The process of claim 1 wherein the high conductivity gas is helium.

8. The process of claim 1 wherein the high conductivity gas is hydrogen.

9. The process of claim 1 wherein after step (d) the article is kept in the bed for a further period of time and further quenched to the M_f temperature.

10. The process of claim 9 wherein during at least some of the further period, the bed is fluidized with high conductivity gas.

11. The process of claim 9 wherein during at least some of the further period, the bed is fluidized with low conductivity gas.

12. The process of claim 9 wherein during at least some of the further period, the bed is operated in a slumped condition.

13. The process of claim 1 wherein the bed temperature is maintained below the M_f temperature.

14. The process of claim 1 wherein the initial quench rate at the start of step (d) is such that a 7/8 inch diameter nickel ball would be cooled from 1600 to 680°F in less than 24 seconds.

15. The process of claim 9 for martempering steel alloy articles wherein, when the article temperature has dropped below the nose temperature but is still above the M_s temperature, the bed is fluidized with low conductivity gas and the article is quenched in the bed to the $M_f$temperature.

16. The process of claim 9 for martempering steel alloy articles wherein, when the article temperature has dropped below the nose temperature but is still above the M_s temperature, the bed is slumped for a period of time sufficient for the article temperature to equilibrate and thereafter the bed is refluidized with low conductivity gas and the article is quenched in the bed to the $M_f$temperature.

17. The process of claim 9 for modified martempering steel alloy articles wherein, when the article temperature has dropped below the $M_s$temperature but is still above the M_f temperature, the bed is fluidized with low conductivity gas and the article is quenched in the bed to the $M_f$temperature.

18. The process of claim 9 for modified martempering steel alloy articles wherein, when the article temperature has dropped below the $M_s$temperature but is still above the M_f temperature, the bed is slumped for a period of time sufficient for the article temperature to equilibrate and thereafter the bed is refluidized with low conductivity gas and the article is quenched in the bed to the $M_f$temperature.

19. A process for the austempering of steel alloy articles to form a bainitic structure within the the alloy comprising:

(a) providing a steel alloy article at an austenitizing temperature;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate, at a temperature within the range of from the M_s temperature to 50°F greater than the $M_s$temperature of the alloy;

(c) immersing the article in said fluidized bed and quenching the article in the fluidized bed for a period of time until the article temperature has been reduced to that of the fluidized bed while fluidizing the bed with high conductivity gas for at least a portion of the quench period; and thereafter

(d) stopping the flow of high conductivity gas and maintaining the article in the bed at the bed temperature for a time sufficient to avoid the substantial formation of martensite within the steel alloy.

20. The process of claim 19 wherein at least a portion of step (d) is carried out with the bed in a slumped condition.

21. The process of claim 19 wherein at least a portion of step (d) is carried out with the bed fluidized with a low conductivity gas.

22. A process for heat treating articles comprised of aluminum and/or aluminum alloy comprising:

(a) providing an article comprised of aluminum and/or aluminum alloy at an elevated temperature sufficient to allow hardening of the article by quenching;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate;

(c) immersing the article in said fluidized bed; and

(d) quenching the article in the bed at a quench rate such that a 7/8 inch diameter nickel ball will be cooled from 750 to 550°F in less than 28 seconds, for a time period sufficient to increase the hardness of the article while fluidizing the bed with high conductivity gas for at least a part of the quench period.

23. The process of claim 22 wherein said elevated temperature is at least 750°F.

24. A process for quenching articles to a desired temperature comprising:

(a) providing an article at an initial temperature;

(b) fluidizing a bed comprised of fine solid particles with high conductivity gas at a flowrate at least 1.5 times the minimum fluidization flowrate;

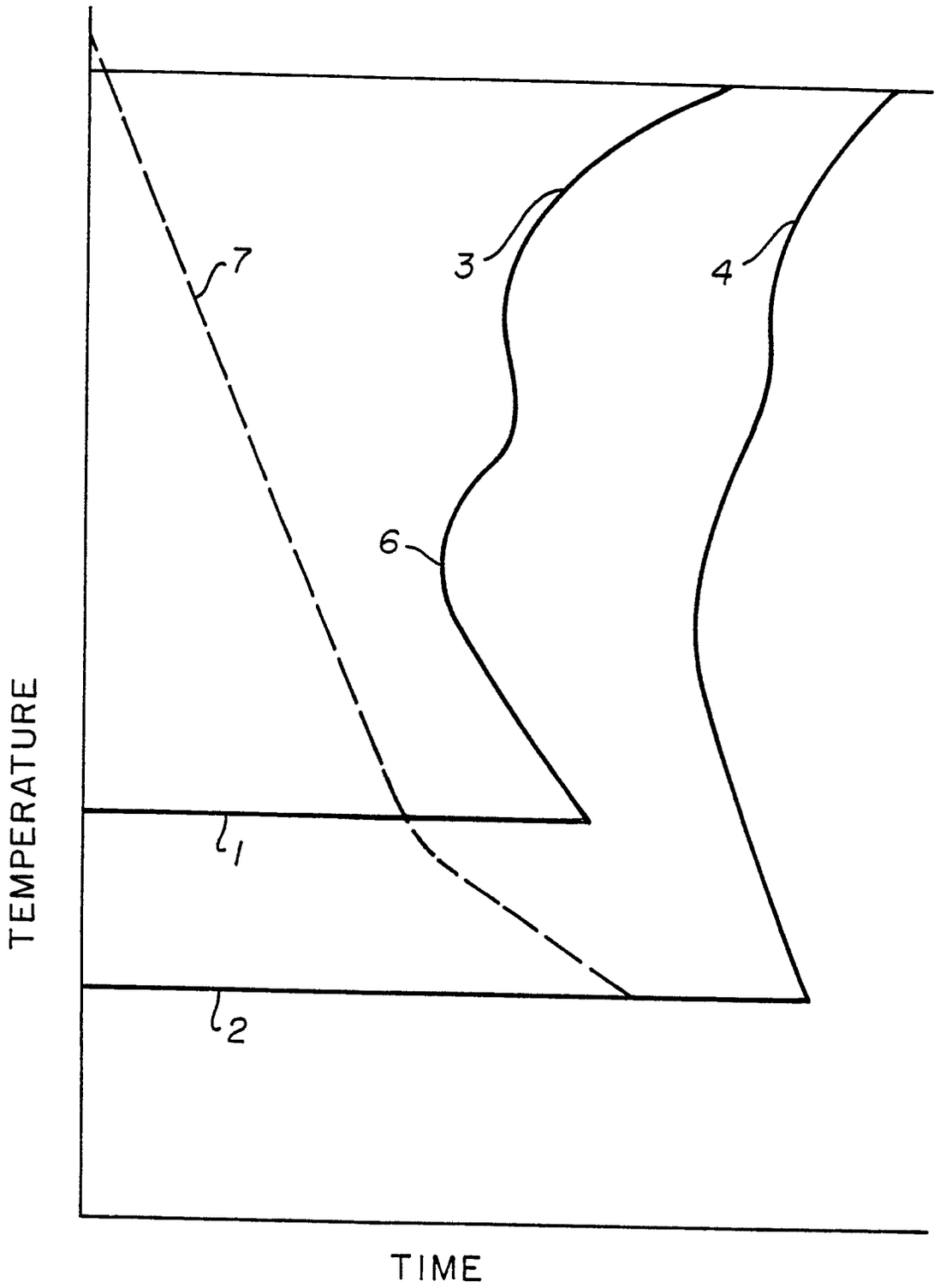
(c) immersing the article in said fluidized bed; and

(d) quenching the article in the bed for a period of time sufficient to achieve the desired temperature while (i) maintaining the bed at or below the desired temperature if the desired temperature is less than the initial temperature, or (ii) maintaining the bed at or above the desired temperature if the desired temperature is greater than the initial temperature, while fluidizing the bed with high conductivity gas for at least a portion of the quench period.

25. The process of claim 22 or 24 wherein step (d) is carried out entirely with the bed fluidized with high conductivity gas.

26. The process of claim 22 or 24 wherein step (d) is carried out in part with the bed fluidized with low conductivity gas.

27. The process of claim 22 or 24 wherein step (d) is carried out in part with the bed in a slumped condition.


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TEMPERATURE
TIME

European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 87 11 0765

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
X	PATENT ABSTRACTS OF JAPAN, vol. 5, no. 54 (C-50)[726], 15th April 1981; & JP - A - 56 5917 (KOMATSU SEISAKUSHO) 22-01-1981	1-7	C 21 D 1/53 C 21 D 1/56
A	EP-A-0 118 836 (ROCKWELL) * claim 1 *	6	
A	FR-A-2 447 968 (CELES) * page 3, lines 25-31 *	8	
A	US-A-3 053 704 (MUNDAY) * column 7, line 60, column 9, lines 44-77 *	8	
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TECHNICAL FIELDS SEARCHED (Int. Cl.4)

C 21 D 1/53
C 21 D 1/56

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
BERLIN	12-10-1987	SUTOR W

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DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl 4)
A	US-A-4 612 065 (KÜHN) * column 4 * -----		

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