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(54) FLASH TEMPERING PROCESS AND APPARATUS

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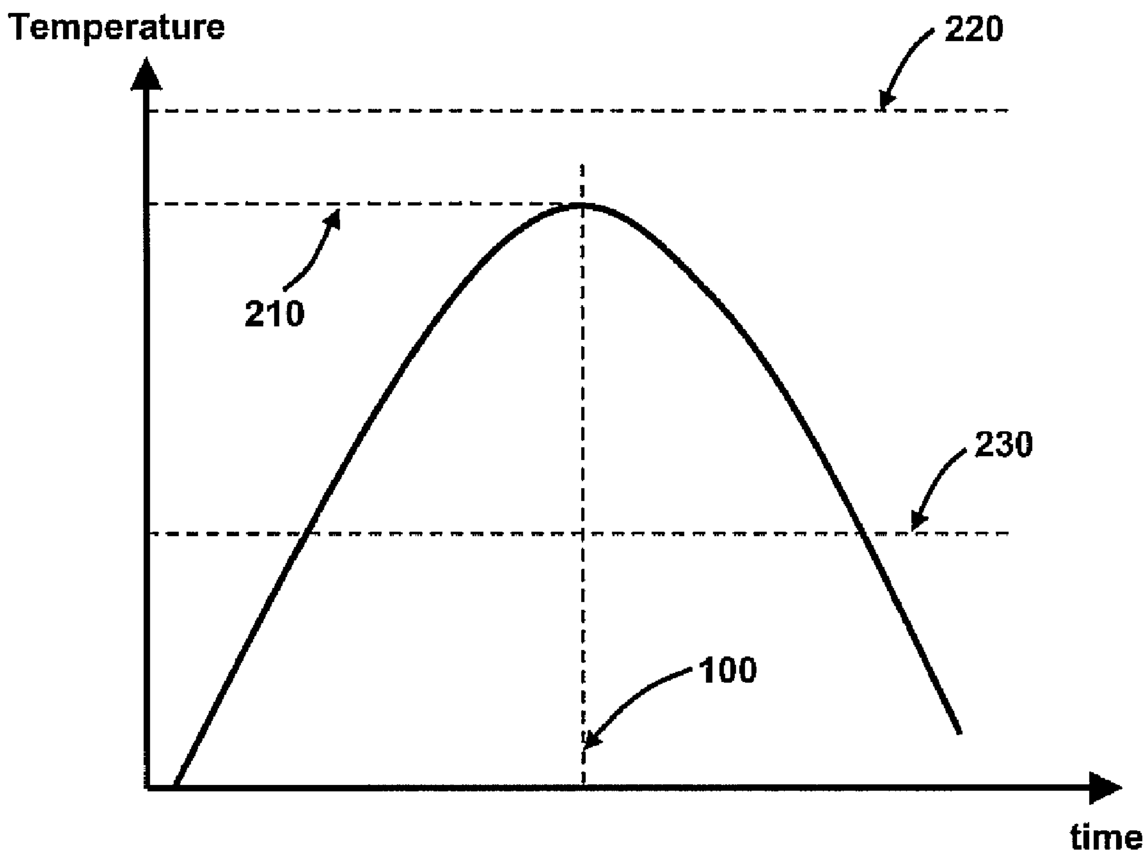
(57) **ABSTRACT**

A method for tempering a workpiece is provided. The method includes providing a ferrous alloy workpiece having a martensite and/or bainite phase therein, heating at least a portion of the workpiece to a preselected temperature and then cooling the workpiece to a lower temperature. The preselected temperature is below the austensizing temperature of the alloy and the heating is accomplished in no more than 60 seconds. One embodiment of the present invention heats the workpiece using resistance heating.



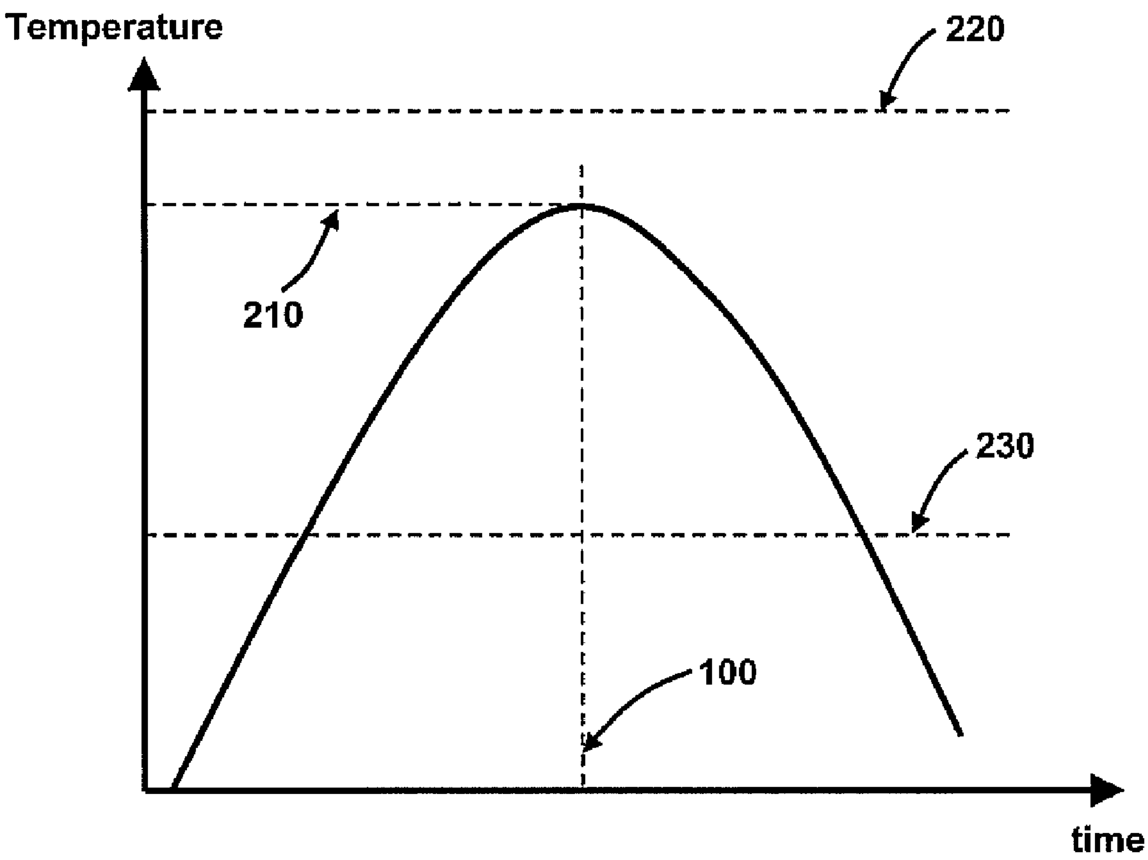



**Figure 1**

# FLASH TEMPERING PROCESS AND APPARATUS

## CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority of U.S. Provisional Patent Application Ser. No. 60/748,473 filed Dec. 8, 2005, which is incorporated herein by reference.

## FIELD OF THE INVENTION

[0002] This invention relates generally to metallurgy. More specifically, the invention relates to a process and method for tempering a ferrous alloy material which includes a martensite phase therein. Most specifically, the invention relates to a method and apparatus for rapidly tempering a ferrous alloy article having a martensite phase therein.

## BACKGROUND OF THE INVENTION

[0003] Various steels and other such ferrous alloys can be hardened by heating these materials to a temperature above their austenizing temperature and then cooling them at an appropriate time/temperature profile so that a martensite phase forms therein. The cooling profile is selected so that the alloy material passes through a first temperature boundary designated the martensite start temperature, and then through a second, lower temperature designated the martensite finish or stop temperature. The specific values and locations of the martensite start and finish boundaries on a time/temperature curve will depend upon the particular alloy being utilized. Steels designated as hardenable generally have values for the martensite start and finish boundaries such that the steels may be easily quenched to form the martensite phase.

[0004] Martensite is any crystal structure formed by displacive transformations, as opposed to slower diffusive transformations. However, martensite is most commonly known as a form of ferrite iron supersaturated with carbon found in very hard steels. Martensite is formed by a rapid cooling of austenite which traps the carbon atoms such that they do not have sufficient time to diffuse out of the austenitic crystal structure and includes grains of ferrite supersaturated with carbon. Martensite is only distinct from ordinary ferrite in that its formation relies on displacive transformation rather than diffusion and nucleation, both of which are relatively slow. The effects of martensite can be easily reduced or eliminated with the application of heat. Therefore, steels that require high strength can be quenched to produce an overabundance of martensite and then tempered to gradually reduce its concentration until the right structure for the intended application is achieved.

[0005] Steels with martensite therein are commonly referred to as martensite steels to those skilled in the art. Martensite steels are hard but brittle. Typical tensile strengths of martensite steels, or in the alternative referred to as martensitic steels, are approximately 220 ksi, their yields are typically 190 ksi, and the percent elongation is approximately 4%. These steels are too brittle for many manufacturing operations, also their high degree of brittleness can limit their utility in particular applications. As such, many applications, including motor vehicle applications, require that martensite steels be tempered so as to improve their elongation characteristics. Tempering involves reheating the alloy material to a temperature which is greater than the martensite start temperature but less than the austenizing temperature, and subsequently cooling the alloy back to ambient temperature. The tempering process reduces the effects of the martensite and/or produces other phases in the alloy which moderate the properties of the martensitic phase. Typical tensile strengths for tempered martensite steels can be as low as approximately 100 ksi, yields approximately 80 ksi, and elongation at least 15%. Tempering can produce various grades of martensite having properties anywhere across this range.

[0006] Bainite is a fine non-lamellar structure that forms in steels when austenite is rapidly cooled below a critical temperature of approximately 723° C. It can be similar in constitution to pearlite, but with the ferrite forming by a displacive mechanism similar to martensite formation. However unlike martensite, the displacive transformation is usually followed by precipitation of carbides from the supersaturated ferrite or austenite. Thus the morphology is typically comprised of aggregates of plates of ferrite separated by cementite, although untransformed austenite and/or martensite can be present between the plates of ferrite. When formed during continuously cooling, the cooling rate to form bainite is higher than that required to form pearlite, but lower than that to form martensite.

[0007] Tempering has heretofore been carried out by reheating the martensite and/or bainite articles in a tempering furnace or oven. This process is fairly time consuming, hardware intensive, and requires a fairly large amount of dedicated manufacturing space. In some instances tempering has been carried out by the use of induction heating coils. These coils are typically swept across the article to create a heated zone. Such induction heating processes are difficult to control, particularly when the article includes irregular features such as openings, protrusions or the like, which can distort the induction field. Generally induction based processes are not capable of precisely controlling the material properties of the articles being treated, and their utility is limited to applications such as stress-relieving hardened articles.

## SUMMARY OF THE INVENTION

[0008] A method for tempering a workpiece is provided. The method includes providing a ferrous alloy workpiece having a martensite and/or bainite phase therein, heating at least a portion of the workpiece to a preselected temperature and then cooling the workpiece to a lower temperature. The preselected temperature is below the austensizing temperature of the alloy and the heating is accomplished in no more than 60 seconds. One embodiment of the present invention heats the workpiece using resistance heating.

## BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 illustrates a time-temperature curve for a flash tempering operation of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0010] In accord with the present invention, it has been found that tempering of martensite and/or bainite articles may be carried out in a rapid process termed herein "flash tempering." According to the method of the present invention and illustrated by the heating curve in FIG. **1**, heat is input into a workpiece over a relatively short period of time **100**, and in an amount sufficient to raise the temperature of the workpiece to a preselected temperature **210** below the austenizing temperature **220**. Preferably the preselected temperature is above the martensite start temperature **230** shown in FIG. **1**, however this is not required for the method to be operable. The temperature selected will depend on the specific nature of the alloy being treated, and the desired properties of the tempered article. The article is then cooled, either under ambient conditions or by contact with a coolant fluid such as a gas or liquid, so as to return the workpiece to a temperature suitable for further processing or handling. This precisely controlled heating and cooling process tempers the martensite phase thereby decreasing the brittleness of the article.

**[0011]** Heating is typically accomplished by a process which can rapidly and precisely input heat energy into an article, One such process comprises resistance heating wherein a flow of electrical current passing through a workpiece causes the heating of that workpiece. Other heating methods may comprise radiant heating wherein a flux of photon energy is directed at the workpiece, plasma heating or flame heating. In some instances, a flux of a hot, inert fluid such as a gas or liquid may be utilized to heat the workpiece.

**[0012]** In one particular embodiment of the present invention, the amount of heat required to heat the portion of the workpiece being tempered is predetermined. This may be done by calculating the required heat energy on the basis of the known or measured characteristics of the workpiece. In other instances, the amount of heat required may be determined empirically by measuring temperature changes in the workpiece when, or while, heat is being input thereto. In any instance, once the amount of heat required for taking the portion of the workpiece being tempered to an appropriate temperature is determined, that amount of heat may be readily and rapidly input into the workpiece, as for example by flowing a current therethrough or by exposing the workpiece to a flux of electromagnetic energy. In one group of embodiments of the present invention, the heat is input into the workpiece over a period of time which is no greater than five seconds. In specific instances, the heat energy is input during a period of no more than one second.

**[0013]** In some instances, the present invention may be used to selectively temper portions of a workpiece so as to provide for varied and controlled properties therethrough. For example, a workpiece having a martensitic phase throughout substantially all of its volume may be selectively tempered so that portions of the workpiece will have reduced brittleness and increased elongation properties. In this manner, energy-absorbing structures such as intrusion beams for motor vehicles and the like may be fabricated.

**[0014]** In some instances, the system may be operative to deliver a "pulse" of thermal energy to all or part of a workpiece in an amount sufficient to cause flash tempering. The magnitude of this pulse may be determined by calculation based upon the properties of the workpiece or by calibration against a standard workpiece. In other instances, the system may be operable in a feedback mode wherein a relatively high flux of energy is input to a workpiece, the temperature of the workpiece is sensed, and the energy input is modulated appropriately so that the workpiece reaches the desired temperature. In some instances, the energy input will be terminated when the sensed temperature of the workpiece is at the determined level, while in other instances it will be terminated at some earlier point to allow for temperature overshoot. In yet other instances, the energy input may be controlled so as to hold the workpiece at a particular temperature for a desired time.

**[0015]** Once the desired temperature is achieved, the workpiece is optionally held at that temperature and cooled back to ambient temperature so as to complete the tempering process. In general, the cooling rate is not critical from a metallurgical point of view. In those instances where the workpiece is relatively thin, cooling may simply be accomplished by contact with the ambient atmosphere. In other instances, the cooling may be enhanced by flowing a gaseous or liquid fluid across the workpiece. In some particular embodiments of the present invention, heating and cooling may be dynamically balanced to achieve the proper heating profile. For example, a heat pulse may be input into the workpiece, and at some point during the active input of heat, flow of a coolant may be initiated. In other instances, coolant flow may commence after input of the heat pulse,

**[0016]** The duration of the heat pulse employed in the present invention will depend upon the temperature to which the article is to be heated, as well as upon the thermal conductivity and dimensions of the article. It is a notable feature of the present invention that relatively short heat pulses may be employed to temper an article This greatly simplifies the tempering process and reduces the hold time required for the tempering process as well as the space which must be dedicated thereto. In a typical tempering process of the present invention, the article is heated to the desired temperature over a period of time which is no more than one minute, and in particular instances no more than five seconds. In particular embodiments, heating is accomplished by a very short pulse of energy which may be electrical energy in the case of resistance heating or electromagnetic energy in the case of inductive heating or radiant heating.

**[0017]** The principles of the present invention are particularly well adapted for tempering relatively thin articles such as frame or body components of motor vehicles or other structural elements both for static and mobile constructions. As such, the present invention has particular advantage for tempering operations carried out on articles having a thickness less than 5 mm and in specific instances less than 2 mm.

**[0018]** The process of the present invention may be integrated into other metalworking and treating processes. For example, metal articles are fabricated by a process wherein resistance heating is utilized to raise the temperature of a workpiece to facilitate forming operations. In such instances, the temperature is typically raised above the austenizing temperature so as to soften the metal. Subsequently, such articles are quenched, typically by contact with a quench fluid so as to form a martensite phase and harden the article. As noted above, such martensite articles are typically very brittle and of limited utility. However, in typical steels used in large volume fabrication processes, it is not possible to directly form a metallurgical phase exhibiting a desired combination of high strength and ductility. Therefore, as previously discussed, such articles need to be separately tempered. In those instances where a rapid heating process such as resistance or inductive heating is utilized, the same apparatus which operates to provide heating for the metalworking and martensite formation can be utilized to temper the article by use of the method of the present invention. In such instances, the system can be programmed to provide an appropriate energy pulse for flash tempering the article. In view of the teaching presented herein, one of skill in the art could readily adapt such apparatus for operation in this mode.

[0019] The foregoing discussion and description is illustrative of specific embodiments of the present invention, but is not meant to be a limitation upon the practice thereof. Numerous modifications and variations thereof will be apparent to one of skill in the art in view of the teaching presented herein. It is the following claims, including all equivalents, which define the scope of the invention.

**1**. A method for tempering a workpiece, said method comprising the steps of:

providing a ferrous alloy workpiece, said workpiece having a martensite and/or bainite phase therein;

heating at least a portion of said workpiece to a preselected temperature which is below the austenizing temperature of said ferrous alloy, wherein said heating is accomplished in no more than 60 seconds; and

cooling said workpiece to a temperature which is below the preselected temperature.

**2**. The method of claim 1, wherein the heating of said workpiece is accomplished in no more than 30 seconds.

**3**. The method of claim 1, wherein said heating is accomplished by resistance heating.

**4**. The method of claim 1, wherein said heating is accomplished by induction heating.

**5**. The method of claim 1, wherein said preselected temperature is above the martensite start temperature for said alloy.

**6**. The method of claim 1, wherein the step of heating is carried out on only a portion of said workpiece whereby said workpiece is selectively tempered.

**7**. The method of claim 1, wherein said workpiece has a thickness which is no greater than 5 mm.

**8**. The method of claim 1, wherein the tempering reduces the initial tensile strength of said workpiece by at least 15%.

**9**. The method of claim 1, wherein said cooling comprises contacting said workpiece with a fluid.

**10**. The method of claim 1, wherein a quenchant fluid contacts said workpiece during at least a part of the time of said heating.

**11**. A method for tempering a workpiece, said method comprising the steps of:

providing a ferrous alloy workpiece, said workpiece having a martensite and/or bainite phase therein;

determining the amount of thermal energy required to heat a preselected volume of said workpiece to a preselected temperature which is below the austenizing temperature of said ferrous alloy;

inputting said amount of thermal energy into said volume of said workpiece; and

cooling said workpiece to a temperature below the preselected temperature.

**12**. The method of claim 11, wherein said preselected volume comprises the entire volume of said workpiece.

**13**. The method of claim 11, wherein said preselected volume comprises a portion of the volume of said workpiece.

**14**. The method of claim 11, wherein inputting said amount of thermal energy into said volume is accomplished in no more than 30 seconds.

**15**. The method of claim 11, wherein the step of inputting said amount of thermal energy comprises resistance heating said preselected volume.

**16**. The method of claim 11, wherein said preselected temperature is above the martensite start temperature for said alloy.

**17**. The method of claim 11, wherein the thickness of said preselected volume of said workpiece is no greater than 5 mm.

**18**. The method of claim 11, wherein the tempering reduces the initial tensile strength of said workpiece by at least 15%.

**19**. An apparatus for tempering a workpiece, said apparatus comprising:

a support for receiving a workpiece of a ferrous alloy material having a martensite and/or bainite phase;

a heater for heating said workpiece; and

a controller for controlling said heater so that said workpiece is heated to a preselected temperature which is below the austenizing temperature of said ferrous alloy, wherein said heating is accomplished in no more than 60 seconds.

**20**. The apparatus of claim 19, further comprising a cooling system, said cooling system operative to said workpiece to a temperature below the preselected temperature.

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