(NASA-Case-MFS-28496-1) GRADIENT TEMPERING PROCESS Patent Application (NASA) 11 p

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NASA CASE NO. MFS-28496-1
PRINT FIG. #3

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Serial Number 07/929,553
Filing Date Aug. 14, 1992
NASA/MSFC

TECHNICAL ABSTRACT NASA CASE NO. MFS-28496-1

GRADIENT TEMPERING PROCESS

A process for tempering a product made from a metal alloy that produces varying degrees of toughness throughout a cross section of the product.

The process consists of exposing a surface of a product made from a hardened metal alloy to an intense energy source of sufficient magnitude and for a time period sufficient to cause enhanced tempering of the surface without causing austenization.

The novelty of this invention lies in the fact that, up to now, tempering was a process that was only utilized to produce uniform characteristics throughout a cross section made from a metal alloy.

Inventor: Richard A. Parr

Employer: NASA/MSFC

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NASA Case No. MFS-28496-1 PATENT

GRADIENT TEMPERING PROCESS

The invention described in this patent was made by employees of the United States Government and may be manufactured and used by or for the Government for governmental purposes without the payment of any royalties.

BACKGROUND OF THE INVENTION

Field of the Invention: This invention is a treatment process for a product made from a hardened metal alloy that improves the alloy's resistance to fractures (i.e., fracture toughness) and resistance to stress corrosion cracking (SCC) in specified areas while maintaining hardness and strength characteristics in other areas. More specifically, the present invention is a treatment process for treating the inside bore diameter of an annular bearing race to improve its (1) fracture toughness against tensile stresses resulting from bearing installation and/or operation and (2) resistance to SCC, while maintaining necessary hardness and strength characteristics on the exterior race diameter.

Background Information: Desired characteristics for products made from metal alloys are not always achieved simultaneously and, at times, are at odds with one another. For example, to produce a high strength metal alloy, a sacrifice in material toughness may be necessary. Similarly, to achieve a high degree of toughness, some sacrifice in strength may be necessary. Thus, in an effort to achieve desired characteristics, either over-design or compromise has been necessary.

Sometimes, localized treatments processes, such as surface treatments, will meet the desired characteristics without over-design or compromise, but such processes usually have drawbacks, which may or may not be important. For example, some surface treatments designed to increase surface hardness actually decrease the corrosion resistance of the surface.

Another way to achieve desired characteristics that are at odds with one another is to use composite materials (i.e., two or more materials bonded together to act as a unit). However, such materials are very expensive to manufacture.

SUMMARY OF THE INVENTION

The present invention involves a process for tempering a product made from a metal alloy on a gradient. The process of gradient tempering comprises a localized application of energy from an intense source for a short period of time to a portion of a surface where increased toughness is desired.

An object of the present invention is to achieve different mechanical properties in a product made from a metal alloy throughout a given cross section in order to meet differing design requirements at different places in the cross section.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGURE 1 shows the general relationship between martensite and austenite for a given period of time at a given temperature.

FIGURE 2 shows the general relationship of surface temper depth as a function of time period and energy applied to the surface.

FIGURE 3 shows hardness as a function of depth below the surface for a product that has been gradiently tempered in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

A preferred embodiment of the present invention consists of exposing a surface of a product made from a hardened metal alloy to an intense energy source of sufficient magnitude and for a time period sufficient to cause enhanced tempering of the surface without causing austenization. The intensity may vary depending on the alloy involved and the desired effect, but the intensity is generally related to the temperature needed to achieve the desired toughening of the surface without causing austenization of the surface. The general relationship between martensite and austenite for a given period of time at a given temperature is shown in Figure 1. The period of exposure to the energy source may also vary depending on the alloy and the desired effect, but the length of exposure is generally related to depth of toughening below the surface that is desired, with longer times being associated with a greater degree of toughening. The general relationship of surface temper depth as a function of time period and energy is shown in Figure 2. The end result is a product that has been tempered on a gradient. In other words, toughness of the alloy will vary with distance below the surface to a depth where the mechanical properties of the alloy will be virtually unchanged.

The invention was demonstrated on a cylindrical test piece of a through-hardened, through-tempered alloy identified by the American Iron and Steel Institute (AISI) as 440C. The test piece had a diameter of 24 mm (0.945 inch) and a length of 20 mm (0.787 inch). The initial through-hardness and through-temper were obtained with the following treatment process:

(1) Austenitize at 1975^{O}F +/-15^{O}F and cool to produce an untempered martensitic grain structure.

(2) From room temperature, cool at a rate that does not exceed 10°F per minute until a final temperature of at least -120°F is reached. Then, cold treat at -120°F or lower for 30 minutes.

(3) Temper at 400°F +/-15°F for 2 hours and cool to room temperature.

(4) Temper again at 400°F +/-15°F for 2 hours to produce a tempered martensitic grain structure.

The test piece did not have a Vickers hardness No. less than 675 (Rockwell C-scale hardness No. 59). In addition, the average grain size of the test piece, in accordance with American Society of Testing and Materials (ASTM) E112 entitled "Estimating the Average Grain Size of Metals," was rated as a 7. (The forgoing procedure is not part of the present invention and is provided only to make this example of the invention complete.)

To demonstrate the invention, the surface of the test piece was heated with an electromagnetic induction heating apparatus by translating the test piece through an electromagnetic coil of the apparatus. The test piece was exposed to the electromagnetic field of the coil, which was produced with 16 kilowatts (360 volts) of power at a frequency of 10 kilohertz, for approximately 1.4 seconds. The result was a gradiently tempered test piece. As shown in Figure 3, the

Vickers hardness No. was lowered to 450 at the surface while remaining at 675 at a depth of 3.0 mm below the surface.

The heating from the electromagnetic field occurred by translating the test piece into and out of the coil. To account for localized variations in the electromagnetic field within the coil, the test piece was also rotated during its translation through the electromagnetic field. Generally, the geometry of a product will dictate the manner in which a high-intensity, low-duration heat source is applied. For example, in order to gradiently temper an annular bearing race from the surface of the inside bore diameter to the surface of the outside race diameter, an electromagnetic coil would be inserted into the annular race. In addition, the intense energy source used for heating could possibly be a laser or some other device rather than an electromagnetic induction heating apparatus.

ABSTRACT

A process for tempering a product made from a metal alloy that produces varying degrees of toughness throughout a cross section of the product.

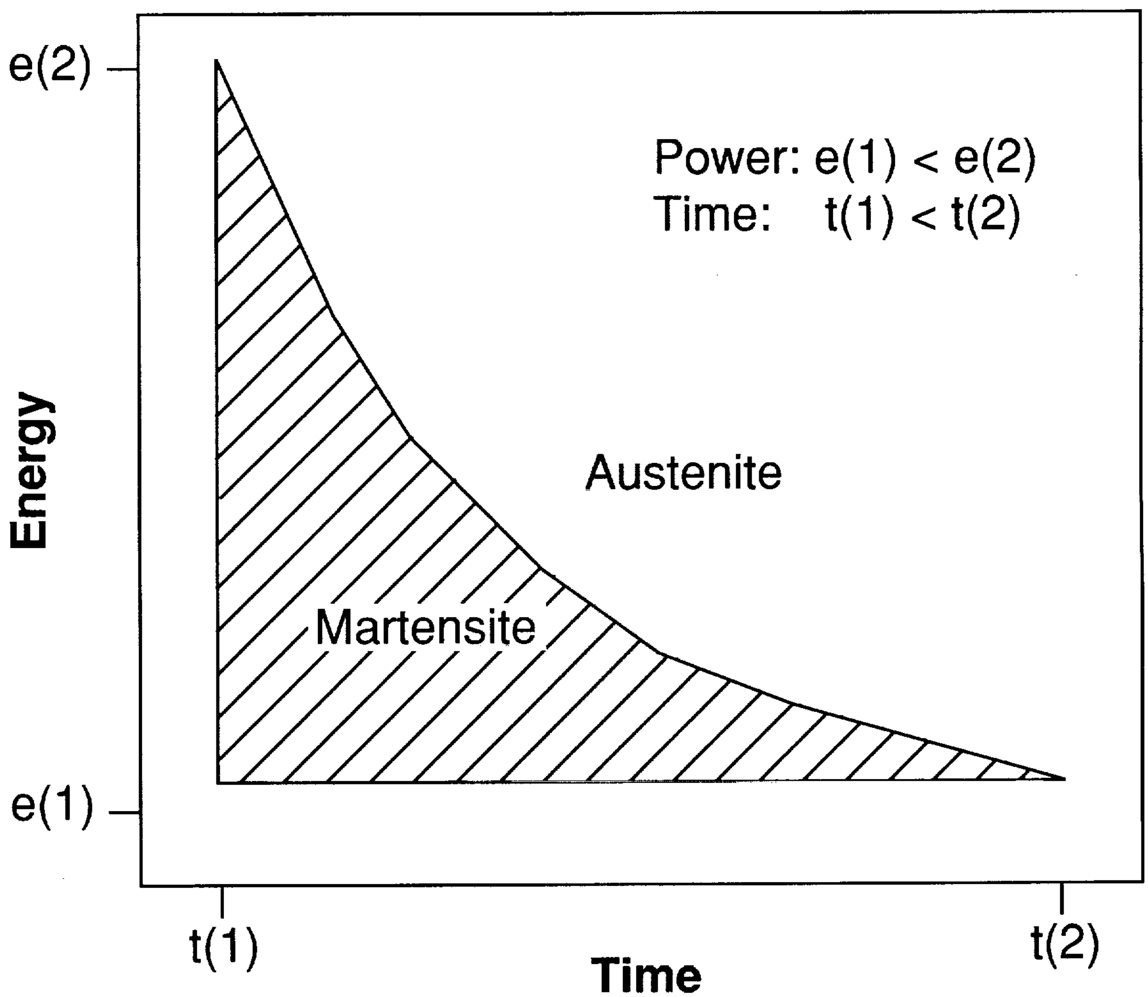
e(2)
e(1)
Energy
Power: e(1) < e(2)
Time: t(1) < t(2)
Austenite
Martensite
t(1)
t(2)
Time

FIGURE 1

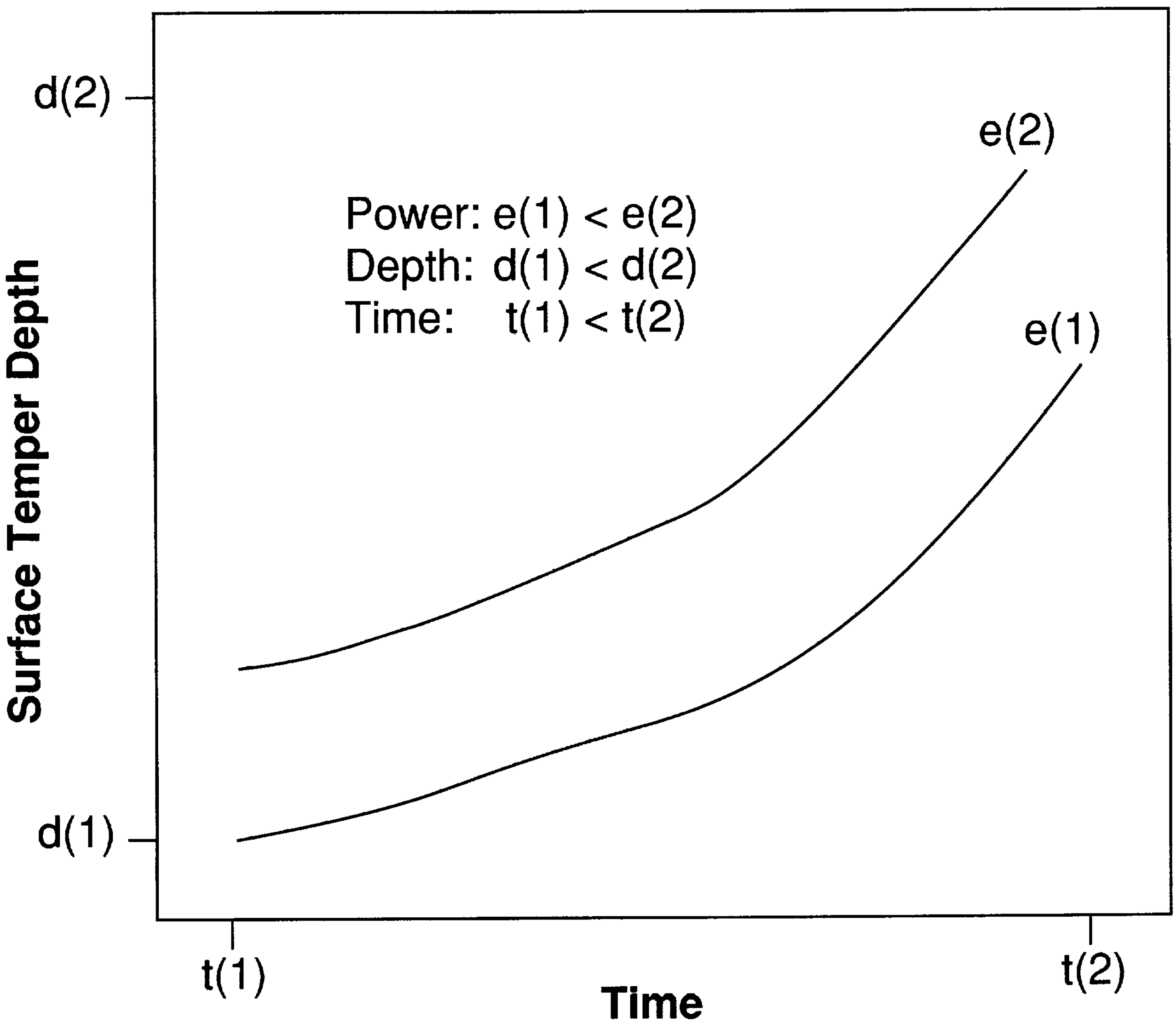
d(2)
d(1)
Surface Temper Depth
e(2)
e(1)
Power: e(1) < e(2)
Depth: d(1) < d(2)
Time: t(1) < t(2)
t(1)
t(2)
Time

FIGURE 2

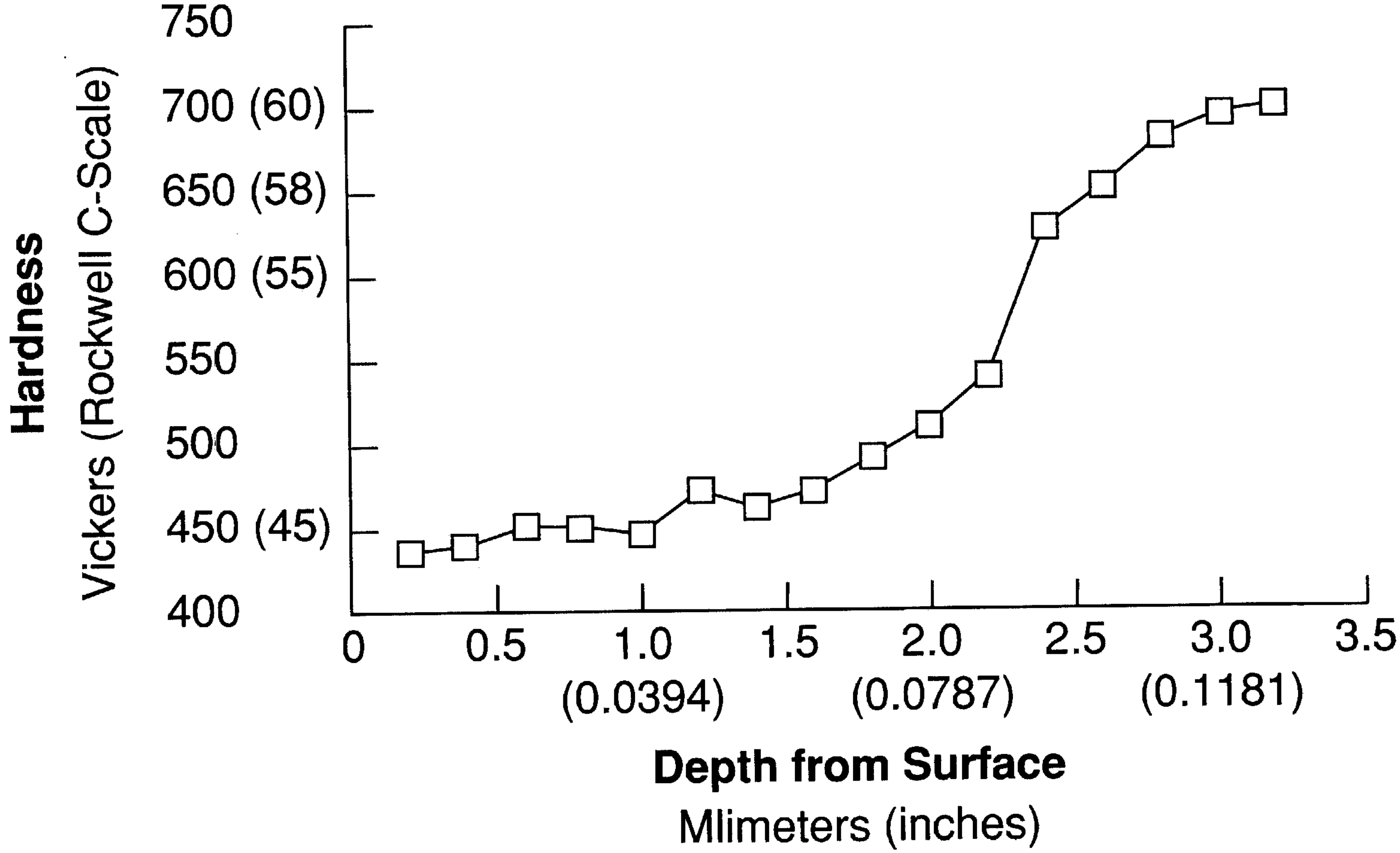
Hardness
Vickers (Rockwell C-Scale)
750
700 (60)
650 (58)
600 (55)
550
500
450 (45)
400
0
0.5
1.0
(0.0394)
1.5
2.0
(0.0787)
2.5
3.0
(0.1181)
3.5
Depth from Surface
Mlimeters (inches)

FIGURE 3