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METHODS FOR IMPROVING HARDNESS AND STRENGTH OF CERAMIC MATERIALS

David A. Thomas, Bethlehem, Pa., and David N. French, Ridgewood, N.J., assignors to Ingersoll-Rand Company, New York, N.Y.

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ABSTRACT OF THE DISCLOSURE

Methods for improving the hardness and strength of frangible or relatively brittle materials, involving surface deformation by mechanical means to establish compressive stresses in the material surface.

This invention pertains to methods for improving the hardness of materials and, in particular, pertains to methods for improving hardness of frangible materials and relatively brittle materials.

It is already known that ductile materials, such as steel and the like, can be surface-hardened by surface deformation caused by mechanical, or other means. However, it has been generally believed that frangible materials, such as glass, and relatively brittle materials, such as those comprising cemented carbides, or magnesium oxides, aluminum oxides, and other ceramic types, and the semiconductor materials, silicon, germanium, etc. and the like, do not lend themselves to surface deformation.

The frangible and the relatively brittle materials have very high compressive strengths, but are weaker in tension or bending. Yet, it is now realized that materials comprising cemented carbides can be hardened by surface deformation, and strengthened as a consequence thereof, as, taking the material tungsten carbide-cobalt, for an example, it is demonstrable that the tungsten carbide particles therein can deform slightly without fracturing.

It is an object of our invention, then, to teach a method of compressively stressing the surface of relatively brittle materials, such as those comprising cemented carbides, e.g., tungsten carbide, or boron carbide, those comprising aluminum oxides, or magnesium oxides, and those comprising semi-conductor materials: silicon, germanium, etc., and the like, to improve the hardness and tensile and bending strength of said materials.

Another object of our invention is to teach a method of compressively stressing the surface of frangible materials, such as those comprising glass, and the like, to improve the hardness and tensile and bending strength of said materials.

A feature of our invention comprises the deforming of the surface of said materials to establish the compressive stresses therein.

Another feature of our invention comprises the deforming of the surface of said materials, in an elevated-temperature environment, to establish compressive stresses therein.

Further objects and features of our invention will become more apparent by reference to the following description taken in conjunction with the accompanying figure, the same being a plot of X-ray diffraction measurements taken on an article novelly hardened and strengthened by the method of our invention.

According to our invention, surface deformation of cemented carbides, and such relatively brittle materials, is introduced by stresses of mechanical origin. The procedures involved are somewhat similar to those practiced in the prior art, in connection with ductile materials.

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Therefore, no detailed discussion of such procedures is warranted here. Briefly though, our method involves deforming the surface of the material by mechanical means to establish compressive stresses therein. Depending upon the type of material involved, our method comprises the steps of confining the material in a temperature-controllable environment, and elevating the environmental temperature to a level in which material flow is accommodated—said temperature being low enough, however, to prohibit the annealing-out of said compressive stresses.

In laboratory experiments undertaken to prove out the feasibility of our invention, shot peening was used as the mechanical deforming means, for example. The shot peening was performed at an Almen intensity of 0.017C. This intensity is very high compared to ordinary shot peening, and is obtained with extra-hard shot. In a cemented carbide specimen (to wit: a tungsten carbide-cobalt specimen) subjected to such peening, the hardness thereof increased from Rockwell A 88.1 before peening to Rockwell A 90.0 after peening. The surface residual stress of the specimen, measured in the tungsten carbide component thereof by X-ray diffraction methods, showed 8,500 p.s.i. in compression before peening, and 130,000 to 220,000 p.s.i. in compression after peening.

By reference to the figure, the meaning of the 130 to 220 thousand p.s.i. spread will become clear. The X-ray diffraction-measured residual stresses were gauged at varying depths below the surface of the specimen. The continuous curve shown in the figure is idealized. Actual measurements were made at particular depths denoted by the dots occurring along the idealized curve. As the figure indicates, the residual compressive stress induced in the specimen, immediately adjacent to the surface, was in the order of 130,000 p.s.i. However, thereafter the stress was gauged at increasing values to a depth of 0.003 inch where the compressive stress was 220,000 p.s.i. Thereafter it proceeded to diminish, yet, even to a depth of 0.0055 inch the compressive stress was measured at approximately 170,000 p.s.i. Observation of the peened surface and of the subsurface region, examined on metallographic section, showed no cracking or damage resulting from the shot peening.

Clearly, our invention is not limited to shot peening of the subject materials at an Almen intensity of 0.017C, any more than it is limited to shot peening as the means of deformation. On the contrary, our invention comprises the compressive stressing of the surface of relatively brittle materials, to improve the hardness and strength of said materials, by mechanically deforming said surface. Shot peening is taught as but one mechanical means, and the Almen intensity of 0.017C is not a prescribed limitation. This intensity was practiced to subject the specimen to a most severe test of damaging, and also to derive clearly evidential compressive stressing. Accordingly, less intense shot peening will effect compressive stressing—although at values and depths varying from those shown in the figure.

The tungsten carbide-cobalt specimen, as explained, had a normally subsisting 8,500 p.s.i. residual compressive stress prior to surface deformation. Of course, specimens will vary, and inherent residual streses therein may range as high as 40,000 p.s.i. So also, a material taken up for compressive stressing which consists of magnesium oxide or aluminum oxide will have no normally subsisting residual compressive stress. But these differences arise from the differing structures of the materials themselves. Our invention remains the first teaching of mechanically deforming such materials to harden and strengthen same, and to derive hardened and strengthened articles of manufacture thereby.

This teaching of our invention is useful in any applications of cemented carbides, such as tungsten carbide-cobalt alloys, where surface failure is expected. Such applications could include the manufacture of rock bit inserts, hardened according to our method to prevent fracture in brazing or during rock drilling, for anvils for high-pressure presses and many other mechanical parts.

From what is known and practiced in the prior art, those skilled therein have considered it futile to attempt surface deformation of other than ductile materials. It has been widely held that cemented carbides, and cermet, or ceramic-type materials are completely brittle, or so relatively brittle as to be given to fracturing when subjected to surface deforming. Accordingly, our teaching sets forth a new avenue in the art of materials hardening and strengthening which henceforth will include these cemented carbides and cermet, or ceramic-type materials. Further, our teaching is applicable to frangible materials, such as those comprising glass, and the like.

It is already known how to strengthen glass; there is a process in the prior art which produces that which is known as "toughened glass" or "tempered glass." To toughen or temper (i.e., strengthen) glass, by creating high compressive stresses in the surface, the known method teaches rapid chilling of the glass surface while the whole glass sheet is still hot—i.e., at a melt temperature. This is a process which can be somewhat complex and expensive to perform requiring, as it does, a heavy refrigerating capacity and is encumbered with heat exchange considerations necessitating meticulous control and a considerable expenditure of time. Our teaching for the production of tempered or strengthened glass is not involved with such limitations. The simplicity of our method remained undiscovered, heretofore, as it has ever been held impractical to contemplate compressive stressing of glass—no less than ceramic-type and like brittle materials—by mechanical deformation.

Glass is frangible at room temperature of course, but it gradually softens at higher temperatures. Specific temperatures at which glass will soften depends on chemical composition, but they are typically above 900 degrees Fahrenheit. Surface deformation by mechanical means, for example—by shot peening, can be carried out on glass, over a limited tempertture range in which the temperature is high enough to allow flow without fracture, but low enough that the compressive stresses built up will not anneal out before cooling back to room temperature. A surface layer is thus kept in a state of compressive stress.

In describing our invention we intend, in no manner, to limit the kinds of relatively brittle materials contemplated for hardening and strengthening. We have cited certain types, only for illustrative purposes; we suggest these—materials comprising tungsten carbide, boron carbide, aluminum oxide, or magnesium oxides—to encompass both the near ceramics and the true ceramics. Further, our invention comprises the hardening and strengthening of those brittle materials known as semi-conductors. In this connection, we point out that the type of material undertaken for treatment will dictate use of either the basic method of our invention, or the temperature-controlled method of our invention. For example, the mechanical deformation of materials comprising tungsten carbide can be carried out at normal room temperatures. Materials comprising aluminum oxide, however, require surface deformation in an elevated-temperature environment. All such refinements of our novel method, including others as will occur to those skilled in the art to which our teachings pertain, are wholly within the spirit of our invention.

The methods of our invention are new and useful in and of themselves, but especially are they useful in that in the practice thereof they yield improved articles of manufacture. It is of little concern whether the article is a hardened and strengthened tungsten-carbide rock bit or a hardened and strengthened glass sheet. The processing of all such articles of manufacture, formed of the frangible materials or the relatively brittle materials, in accordance with our disclosed methods, novelly define greatly hardened and strengthened articles.

Thus, while we have described our invention with reference to specific procedures for the practice thereof, and have done so in connection with given materials, to teach both the methods of hardening and strengthening materials, it is to be clearly understood that this is done only by way of example and not as a limitation to the scope of our invention as set forth in the objects thereof and in the accompanying claims.

We claim:

1. A method of compressively stressing the surface of relatively brittle materials, such as those comprising cemented carbides, magnesium and aluminum oxides, and semi-conductor materials, and the like, to improve the hardness and strength of said materials, comprising the step of:
deforming the surface of said materials to establish said compressive stresses therein; and wherein
said surface deforming step comprises deforming by shot peening.

2. A method, according to claim 1, wherein:
said shot peening is performed at an Almen intensity of not less than 0.017C.

3. A method of compressively stressing the surface of frangible materials, such as those comprising glass, and the like, to improve the hardness and strength of said materials, comprising the step of:
deforming the surface of said materials in an elevated temperature environment; wherein
said surface deforming step comprises deforming by shot peening.

4. A method, according to claim 3, wherein:
said environment contemplates a range of elevated temperatures including temperatures which are high enough to allow flow of said materials, and low enough to avoid the annealing out of said compressive stresses.

5. A method, according to claim 3, wherein:
said surface-deforming step includes the sequential steps of confining said material in a temperature-controllable environment, and
elevating the temperatures of said environment to a value in which material flow is accommodated, to facilitate ready deforming of said surface, and wherein said environmental temperature is low enough to prohibit the annealing-out of said compressive stresses.

6. A method, according to claim 3, wherein:
said shot peening is performed at an Almen intensity of not less than 0.017C.

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ARTHUR D. KELLOGG, Primary Examiner

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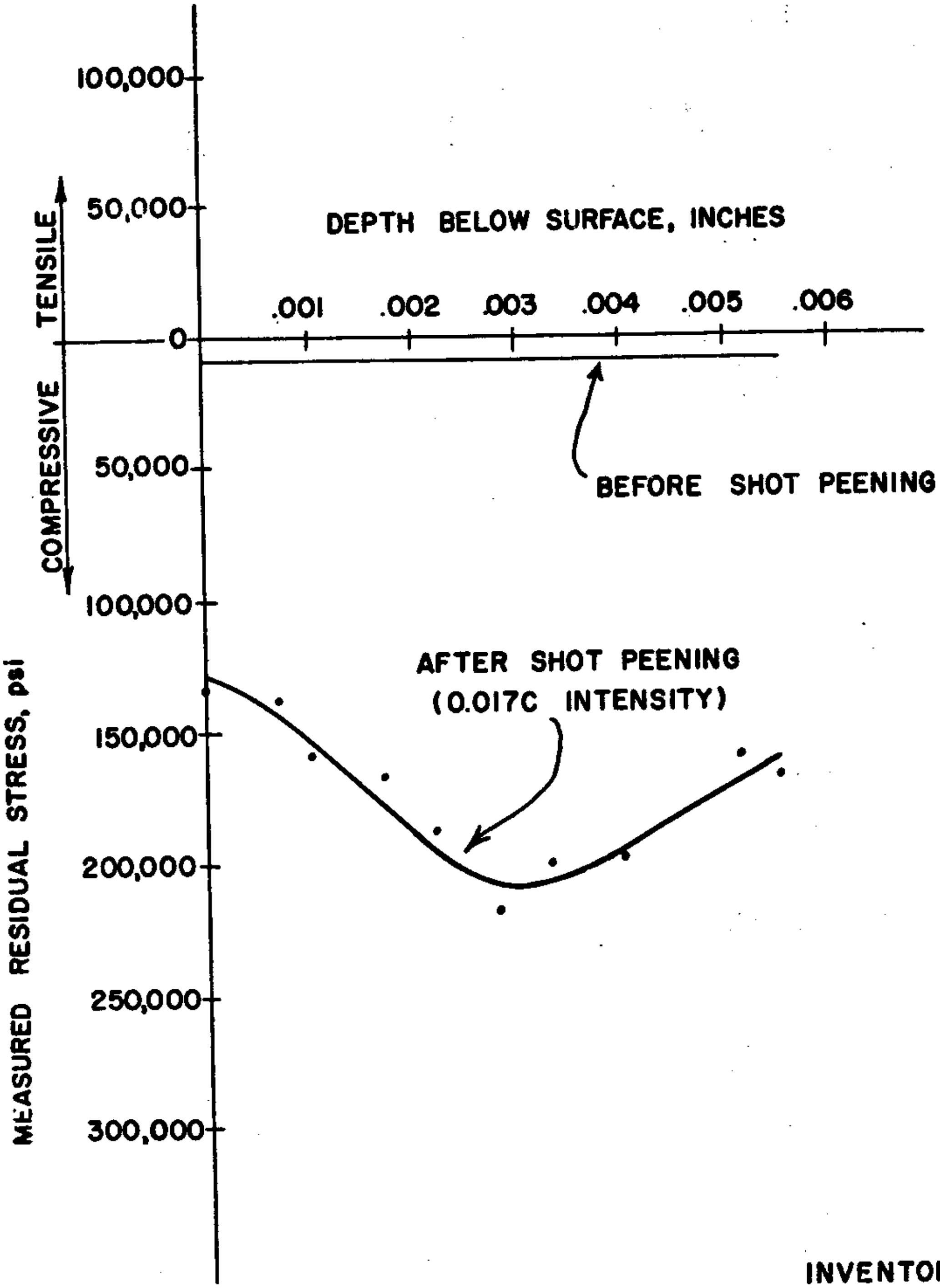

INVENTORS
DAVID A. THOMAS
DAVID N. FRENCH
BY
Bernard J. Murphy
AGENT