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- (54) Title: ENHANCED SURFACE STRUCTURE

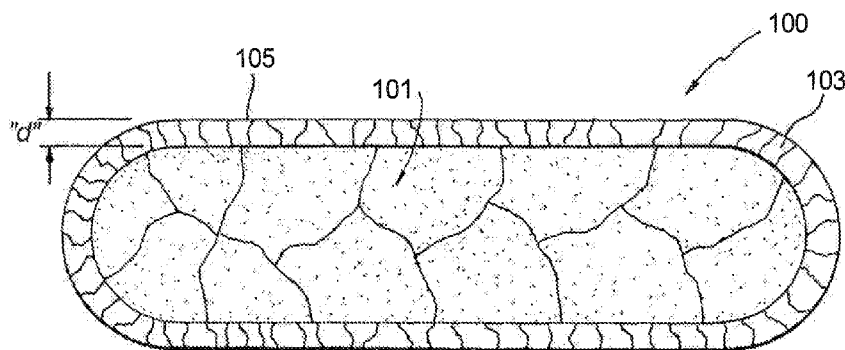


Fig. 1

- (57) Abstract: A formed material can include a composition having a non-recrystallized portion and a recrystallized layer of the composition having predetermined depth, the recrystallized layer forming at least part of a surface of the composition that overlays the non-recrystallized portion. A method of forming a material having an at least partially recrystallized layer can include forming a composition into a predetermined shape having a surface, wherein the forming leaves the surface of the composition in a non-recrystallized state. The method can also include determining a desired depth of at least a portion of a recrystallized layer at the surface and recrystallizing at least a portion of the surface of the composition to form the recrystallized layer to the desired depth.



ENHANCED SURFACE STRUCTURE

RELATED APPLICATIONS

This application claims the benefit of and priority to U.S. Provisional Patent Application No. 61/932,562 filed January 28, 2014, the contents of which are incorporated herein by reference in their entirety.

BACKGROUND

1. Field

The present disclosure relates to material compositions, more particularly to enhanced surface structure material compositions and methods of manufacturing the same.

2. Description of Related Art

Turbomachine components are often made from castings using methods such as a lost-wax cast procedure or other forming methods. After casting, some components may be shot-blasted and/or grit-blasted to remove shell material, oxides, and improve surface finish of the casting. As a consequence of this blasting, an uncontrolled amount of plastic deformation is introduced in to the surface of this material. If the casting is heat treated this surface layer can recrystallize and leave a fine grain region on the surface. However, because the plastic deformation is uncontrolled the depth of the plastic zone is uncontrolled and/or irregular which will lead to an uncontrolled/irregular amount of recrystallization at the surface. The present methods are very chaotic and do not control the depth or quality of recrystallization of the surface layer. Modification of the surface composition can be followed by a phase transformation. Examples include nitriding and carburizing of steels and diffusion coatings in Ni alloys.

Such conventional methods and systems have generally been considered satisfactory for their intended purpose. However, there is still a need in the art for improved techniques of forming materials having a recrystallized surface layer. The present disclosure provides solutions for this need.

SUMMARY

In accordance with at least one aspect of this disclosure, a formed material includes a composition including a base non-recrystallized portion and a recrystallized layer of the composition having predetermined depth, the recrystallized layer forming at least part of a surface of the composition that overlays the non-recrystallized portion. The recrystallized layer can be uniform in depth. The depth of the recrystallized layer can be about 0.005 inches (about 0.127 mm) to about 0.025 inches (about 0.635 mm).

The recrystallized layer can include a smaller grain size than the base non-recrystallized portion of the composition. In some embodiments, the formed material is a turbomachine component.

In at least one aspect of this disclosure, a method of forming a material having an at least partially recrystallized layer includes forming a composition into a predetermined shape having a surface, wherein the forming leaves the surface of the composition in a non-recrystallized state, determining a desired depth of at least a portion of a recrystallized layer and recrystallizing at least a portion of the surface of the composition to form the recrystallized layer to the desired depth.

The recrystallizing step can further include heat treating the composition after a controlled plastic deformation of at least a portion of the surface of the composition to uniformly

form the recrystallized layer. The controlled plastic deformation can include at least one of shot-peening, controlled surface blasting, laser shot-peening, ultrasonic peening, explosion forming, or burnishing.

In some embodiments, the method can further include cleaning the composition by shot-blasting the composition after forming. The method can also further include precipitating at least one phase of the material by heat treating the composition to a desired temperature after forming and/or after or during cleaning. In some embodiments, the forming step can include casting.

In at least one aspect of this disclosure, a method includes casting a material into a cast having predetermined shape, removing the cast from the mold, cleaning the cast by shot-blasting, cold working a surface of the cast to facilitate recrystallization to desired depth, and then heat treating the cast to a suitable temperature to complete uniform recrystallization of the surface of the cast to a smaller grain size than the non-recrystallized portion.

The method can further include heat treating the cast at a suitable temperature to precipitate a phase of the material after removing the cast from the mold and before plastically deforming the surface of the cast to a desired depth.

These and other features of the systems and methods of the subject disclosure will become more readily apparent to those skilled in the art from the following detailed description taken in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

So that those skilled in the art to which the subject disclosure appertains will readily understand how to make and use the devices and methods of the subject disclosure without

undue experimentation, embodiments thereof will be described in detail herein below with reference to certain figures, wherein:

Fig. 1 is a cross-sectional schematic view of a formed composition in accordance with this disclosure, showing a uniform recrystallized layer of a desired depth; and

Fig. 2 is a cross-sectional schematic view of a formed composition in accordance with this disclosure, showing a predetermined recrystallized layer of a desired depth that covers only a portion of the non-recrystallized portion.

DETAILED DESCRIPTION

Reference will now be made to the drawings wherein like reference numerals identify similar structural features or aspects of the subject disclosure. For purposes of explanation and illustration, and not limitation, an embodiment of a formed composition in accordance with the disclosure is shown in Fig. 1 and is designated generally by reference character 100. Another embodiment of a formed composition in accordance with the disclosure, or aspects thereof, is provided in Fig. 2, as will be described. The systems and methods described herein can be used to improve high cycle fatigue life and/or other desirable characteristics of machine components.

In accordance with at least one aspect of this disclosure, a formed material 100 includes a composition including a non-recrystallized portion 101 that is not processed to deliberately affect the crystal structure and/or grain size thereof. The formed material 100 also includes a processed or recrystallized layer 103 of the composition with a predetermined depth “d”.

For purposes of this disclosure, the term “recrystallized” means that the grain size and/or structure and/or other suitable material characteristics of the crystalline structure of the formed material have been modified from an initial formed condition (e.g., from the crystalline structure

of a cast). For example, as shown in the drawings, the recrystallized layer 103 has a smaller grain size than the non-recrystallized portion 101.

The formed material 100 can be a cast, mold, or any other suitable type of manufacture that is formed in any suitable manner. The composition can be any suitable material, including, but not limited to, one or more metals, one or more metal alloys, and/or any other suitable formable composition having a non-processed portion after forming. In some embodiments, the composition can include one or more of nickel, titanium, carbon, iron, steel, IN718, and/or the like.

The recrystallized layer 103 forms at least part of a surface 105 of the composition that overlays the non-recrystallized portion 101. The recrystallized layer 103 can be uniform in depth as shown in Fig. 1. As shown in Fig. 2, in some embodiments, a partial recrystallized layer 207 can form only a portion of the surface of a formed material 200.

The depth of the recrystallized layer 103 can be any suitable depth “d”, including about 0.005 inches (about 0.127 mm) to about 0.025 inches (about 0.635 mm). In some embodiments, the suitable depth “d” is about 0.010 inches (about 0.254 mm). Depth “d” can be about 1 to about 4 times as deep as layers inadvertently formed via known shot-blasting techniques. As disclosed herein, the recrystallized layer 103 can include a smaller grain size than a non-recrystallized portion 101 of the formed material 100. In some embodiments, the formed material can be a turbomachine component such as, but not limited to, compressor rotor blades, stator blades, cases, and/or housings.

In at least one aspect of this disclosure, a method of forming a material having an at least partially recrystallized layer 103 includes forming a composition into a predetermined shape having a surface 105. The forming leaves at least a portion of the surface 105 of the composition

in a non-processed and/or non-recrystallized state. The forming step can be a casting process (e.g. lost-wax casting), a molding process, additive manufacturing, powder bed fusion, or any other suitable manufacturing process.

The method can also include cleaning the formed composition via any suitable method including shot blasting. The method can also include determining a desired depth “d” of at least a portion of a recrystallized layer 103. Certain material characteristics (e.g. high cycle fatigue, low cycle fatigue) are affected by the depth and uniformity of a crystallized surface layer, thus desired material characteristics can be achieved by selecting a desired depth “d” and/or a desired uniformity of a recrystallized layer 103 after forming.

The method can also include precipitation hardening reactions or recrystallizing at least a portion of the recrystallized layer 103 to the desired depth “d”. In some embodiments, the recrystallizing step includes controlling a plastic deformation of the composition at the surface. The plastic deformation can include at least one of shot-peening, controlled surface blasting, laser shot-peening, ultrasonic peening, and/or burnishing such that the depth of plastic deformation is controlled to cause formation of recrystallized layer 103 of a desired depth “d”.

The method can further include heat treating the composition to control intermediate phase reactions such as the precipitation of delta phase in IN718. The heat treating can be done after forming and/or during or after cleaning the formed material via, e.g., shot-blasting, and/or during any other suitable time. The heat treatment can be configured to cause precipitation of desired second phases of material (e.g. δ -phase at about 1550 deg. F, γ' , γ'' , carbide-phases, etc.). Heat treating the composition to precipitate phases of the composition can occur at any suitable temperature and/or series of temperatures to cause precipitation of the desired phases. In some

embodiments, the precipitation of second phases results in less grain size growth and facilitates recrystallization to a smaller grain size.

Hot isostatic pressing can also be performed on the composition to reduce porosity of the composition.

After the formed material 100 is cold worked and/or otherwise plastically deformed at the surface, the method can include heat treating the formed material 100 to facilitate one or more of recrystallization, reduction in grain size, and/or any other suitable material modification to achieve a desired recrystallized layer 103. For example, the formed material 100 may be exposed to a desired consistent and/or varying temperature during the manufacturing process to facilitate recrystallization at a desired depth “d” and/or to a desired grain size.

In at least on aspect of this disclosure, a method includes casting a material into a cast having predetermined shape, removing the cast from the mold, then cleaning the cast by shot-blasting, then cold working a surface of the cast to facilitate recrystallization to desired depth, and then heat treating the cast to a suitable temperature to complete uniform recrystallization of the surface of the cast to a smaller grain size than the non-recrystallized portion. The method can further include heat treating the cast at a suitable temperature to precipitate a phase of the material after removing the cast from the mold and before plastically deforming the surface of the cast to a desired depth.

The methods and systems of the present disclosure, as described above and shown in the drawings, provide for enhanced material properties of certain manufactures. While the apparatus and methods of the subject disclosure have been shown and described with reference to embodiments, those skilled in the art will readily appreciate that changes and/or modifications may be made thereto without departing from the spirit and scope of the subject disclosure.

What is claimed is:

1. A formed material, comprising:
a composition including a non-recrystallized portion; and
a recrystallized layer of the composition having predetermined depth, the recrystallized layer forming at least part of a surface of the composition that overlays the non-recrystallized portion.
2. The formed material of claim 1, wherein the recrystallized layer is uniform in depth.
3. The formed material of claim 1, wherein the depth of the recrystallized layer is about 0.005 inches to about 0.025 inches.
4. The formed material of claim 1, wherein the recrystallized layer includes a smaller grain size than a non-recrystallized portion of the composition.
5. The formed material of claim 1, wherein the formed material is a turbomachine component.
6. A method of forming a material having an at least partially recrystallized layer, comprising:
forming a composition into a predetermined shape having a surface, wherein the forming leaves the surface of the composition in a non-recrystallized state;
determining a desired depth of at least a portion of a recrystallized layer; and

recrystallizing at least a portion of the surface of the composition to form the recrystallized layer to the desired depth.

7. The method of claim 6, wherein the recrystallizing step further includes heat treating the composition after a controlled plastic deformation of at least a portion of the surface of the composition to uniformly form the recrystallized layer.

8. The method of claim 6, wherein the controlled plastic deformation includes at least one of shot-peening, controlled surface blasting, laser shot-peening, ultrasonic peening, explosion forming, or burnishing.

9. The method of claim 6, further comprising cleaning the composition by shot-blasting the composition after forming.

10. The method of claim 6, further including precipitating at least one phase of the material by heat treating the composition to a desired temperature after forming.

11. The method of claim 9, further including precipitating at least one phase of the material by heat treating the composition to at least one suitable temperature that is configured to precipitate the at least one phase after or during cleaning.

12. The method of claim 6, wherein the forming step includes casting.

13. A method, comprising:

casting a material into a cast having predetermined shape;

removing the cast from the mold;

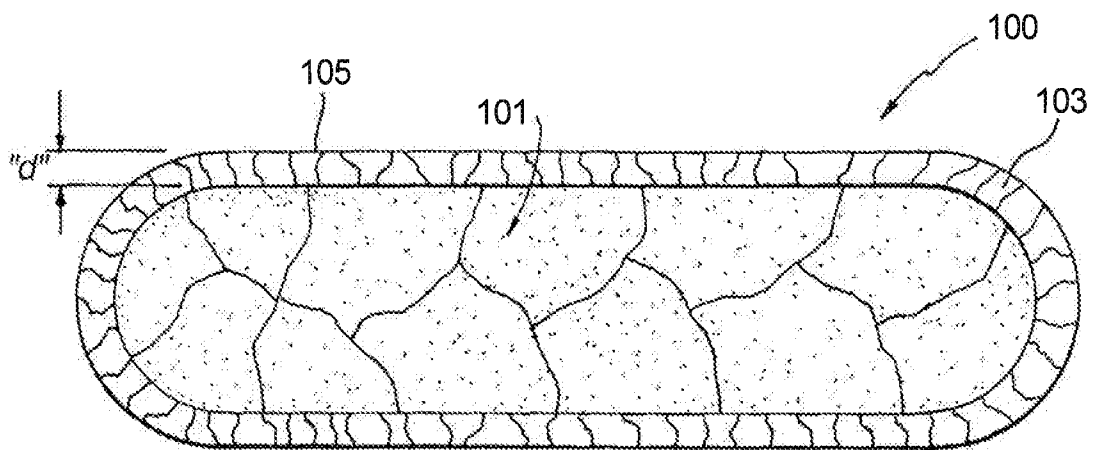
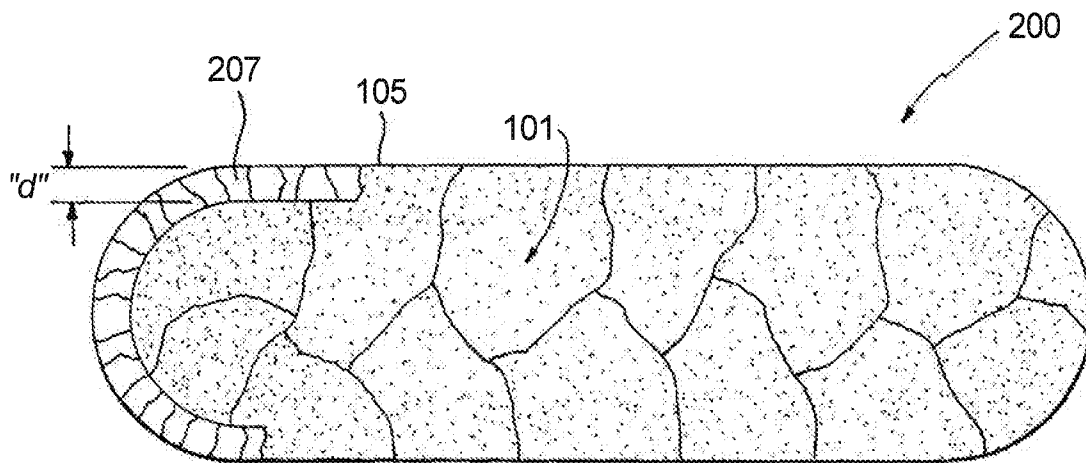
after removing the cast from the mold, cleaning the cast by shot-blasting;

after cleaning the cast by shot blasting, cold working a surface of the cast to facilitate recrystallization to desired depth; and

after cold working the surface of the cast to a desired depth, heat treating the cast to a suitable temperature to complete uniform recrystallization of the surface of the cast to a smaller grain size than the non-recrystallized portion.

14. The method of claim 13, further comprising heat treating the cast at a suitable temperature to precipitate a phase of the material after removing the cast from the mold and before plastically deforming the surface of the cast to a desired depth.

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**Fig. 1****Fig. 2**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/010404**A. CLASSIFICATION OF SUBJECT MATTER****B32B 5/16(2006.01)i, B32B 9/00(2006.01)i**

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B32B 5/16; C22C 14/00; B32B 3/30; C22F 1/10; B23K 20/22; C21D 1/09; H01L 23/48; B32B 9/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords:recrystal, non-recrystal, surface, heat treatment, turbomachine,shot peening, cast

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6521059 B1 (NAZMY, M. et al.) 18 February 2003 See abstract; column 2, lines 12-17, 29-34; column 3, lines 1-21; claims 1, 3, 4; and figures 1-2.	1-14
A	US 4909859 A (NAZMY, M. et al.) 20 March 1990 See entire document.	1-14
A	US 4531981 A (SINGER, R.) 30 July 1985 See entire document.	1-14
A	US 6215191 B1 (BEROZ, M. et al.) 10 April 2001 See entire document.	1-14
A	US 4969593 A (KENNEDY, J. R. et al.) 13 November 1990 See entire document.	1-14



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:

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"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/010404

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US 4969593 A	13/11/1990	None	