Oct. 29, 1968 B. GENTILE 3,408,270

METHOD FOR NON-DESTRUCTIVE TESTING OF MATERIALS

Filed June 25, 1965

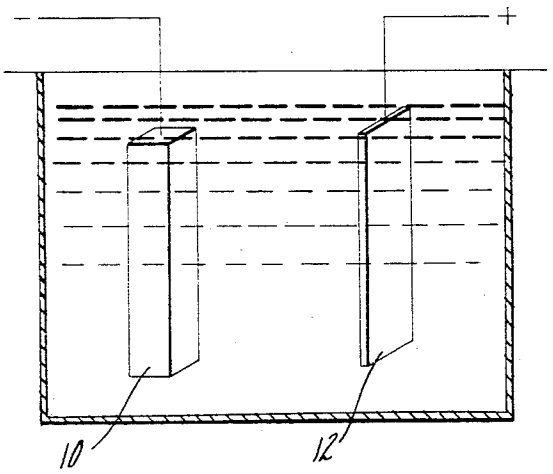


Fig. 1

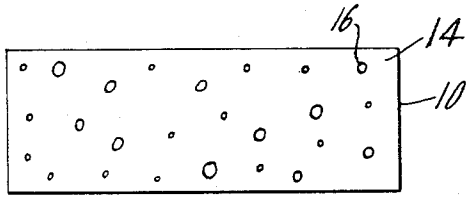


Fig. 2

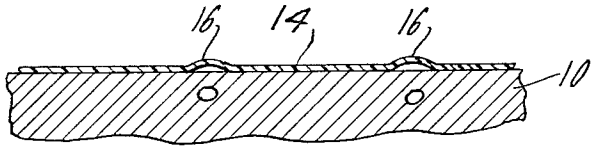


Fig. 3

United States Patent Office 3,408,270 Patented Oct. 29, 1968

3,408,270

METHOD FOR NON-DESTRUCTIVE TESTING OF MATERIALS

Bernard Gentile, Cambridge, Mass., assignor to Anthony J. Gentile, Forestville, Conn.

Filed June 25, 1965, Ser. No. 466,878
6 Claims. (Cl. 204—1)

ABSTRACT OF THE DISCLOSURE

The method of testing a metallic product, particularly one of steel, for stress-raising material inhomogeneities therein, comprising the steps of: providing a low molecular weight nascent gas, such as atomic hydrogen, to said product for absorption in areas surrounding said inhomogeneities; covering the product with a deformable film; and finally treating, as by heating, the product to release the absorbed gas as bubbles in the film adjacent the inhomogeneities.

This invention relates to the non-destructive testing of materials and, more particularly, to a method for locating and determining the probably effect of sub-surface, stress-producing inhomogeneities in a metallic product.

The importance of being able to predict the possible fatigue failure of a crucial component of a high-speed or complex piece of machinery has increased markedly in recent years. Although it is known that the fatigue failure of a metallic product is usually caused by the high internal stresses which develop around inhomogeneities such as porosity, non-metallic inclusions or other surface and sub-surface defects, there has been no known method of non-destructively detecting the presence of failure-producing subsurface inhomogeneities. The techniques which have been developed for locating the surface defects which generally cause torsion or bending fatigue failure utilize some means of increasing the visibility of small surface cracks and are consequently useless in locating sub-surface inhomogeneities.

It is, therefore, a primary object of the present invention to provide an effective non-destructive method for locating sub-surface stress-raising inhomogeneities. Other objects include providing a method of locating these inhomogeneities either before or after a load is applied to the product and without in any way reducing the usefulness of the product.

Generally speaking, the invention concerns a method of non-destructively locating sub-surface, stress-raising inhomogeneities in a metallic product, especially useful with a steel product, comprising the steps of: providing a low molecular weight gas in nascent or atomic condition to the product for diffusion thereinto; generally covering the product with a thin deformable film for capturing any absorbed gas released from the product, and; thereafter treating as by heating the product to release absorbed gas, causing film deformation adjacent any stress-raising inhomogeneities in the product, such deformation usually being in the form of a blister or bubble. The location of these bubbles, which are believed to be caused by the recombination of the absorbed gas into molecular form between the surface of the product and the covering film, indicate the location of stress-raising inhomogeneities.

Other objects, advantages, and features will appear from the following detailed description of a preferred method of practicing the invention, together with the attached drawings in which:

FIG. 1 diagrammatically illustrates one method of presenting a light-weight nascent gas to the product to be tested;

FIG. 2 illustrates results of a test of a product having stress-raising subsurface inhomogeneities, according to the method of the present invention, and

FIG. 3 is an enlarged partial cross-sectional view of the product of FIG. 2.

The portions of a metallic product surrounding an inhomogeneity therein, particularly those surrounding a hard non-metallic inclusion, generally contain high internal stresses. When a load is applied to a product having a number of these highly-stressed internal areas, the stress in each is greatly increased. Eventually, in service, these highly localized, high level stresses cause the initiation of cracks in the product, which cracks propagate and result in the product's failure. I have discovered a method for determining the presence of these stress-raising, inhomogeneities either before or after the product has been subjected to any load.

According to my invention, when a gas, preferably a nascent or atomic, low-molecular weight gas, such as hydrogen, is presented to a metallic product, it will diffuse into the product and collect in the internal areas adjacent the inhomogeneities. When the product, having absorbed a quantity of the gas, is treated by heating it or allowing it to stand at room temperature for a sufficient period of time, the absorbed gas will diffuse outward from the internal areas. When it reaches the surface of the product, the gas recombines into molecular form, simultaneously greatly increasing in both volume and pressure, its released volume being indicative of the inhomogeneity level of the product.

In the practice of the present invention, I utilize the inward and outward diffusion of the gas to determine the number and location of the inhomogeneities in the product. Thus, by covering the metallic product, preferably with a thin, gas-tight, deformable film after a sufficient quantity of gas has been absorbed in the highly-stressed areas, the recombination of the previously absorbed gas at the surface of the product will be captured thereat by the film and will cause film deformation in the form of blisters or bubbles to indicate the location of the inhomogeneities. Since the amount of gas that will be absorbed in the area adjacent an inhomogeneity depends primarily upon the stress-raising effect of the inhomogeneity, the size of the blisters or bubbles in the film is an indication not only of the presence, but also of the size or other characteristics of the inhomogeneity.

When testing a metallic product for inhomogeneities using the method of the present invention, it is desirable to clean all traces of oil, dirt, etc., and to remove any oxide film from the surface of the product before presenting the gas to the product. I have found it convenient to clean dirt from the product either by using a conventional solvent or chemical cleaner, or by electrolytic washing in a hot alkaline solution. The oxide film may be removed by making the product the anode in an electrolytic bath and electrolytically etching it.

The low-molecular weight, nascent or atomic gas preferably used in the practice of the invention may be presented to the surface of the product to be tested by any one of several methods, such as thermal dissociation, pressure, chemical reaction, or electrolysis. When nascent hydrogen is to be used, it can easily be generated, as illustrated in FIG. 1 by making the product to be tested, designated **10**, the cathode in an electrolytic bath, with a conducting plate **12** as an anode. In many cases, this may be the same bath as that used for removing the oxide film in the step previously mentioned. The optimum amperage, voltage, bath temperature, and distance between the cathode and anode, for both the etching and charging operations, depend on the particular product and electrolyte. In most of my experiments I have generated nascent

hydrogen using an electrolytic solution of 4% by volume sulphuric acid, a nickel anode, designated **12** in FIG. 1, and a current density of approximately 6 amps per square inch at 6 volts. When a product made of 52110 steel is being tested, a charging time of approximately 20 minutes will insure sufficient nascent hydrogen penetration to locate inhomogeneities over 0.006 in. below the surface of the product.

After the desired amount of gas has been absorbed by the product, it should be removed from the electrolyte, rinsed, air-dried, and covered with the deformable, gas-tight film **14**, preferably of organic plastic material. It is important to control the covering operation to insure that the layer is not too thick. When the product is covered by coating it with a flexible lacquer, by dipping, spraying or one of several other conventional means, I have found that the optimum layer thickness is preferably about 0.001 inch.

After the coating layer has been allowed to dry, the product may either be placed in an oven or allowed to stand at room temperature to permit the absorbed gas to diffuse outward from the internal stressed areas. It is generally satisfactory to place the product in an 180° F. oven for a period of about one hour. The exact time and temperature will depend on the characteristics of the particular covering material and the amount of gas that was initially diffused into the product.

As previously mentioned, the absorbed gas will recombine into molecular form between the surface of the product and the covering film and cause blisters or bubbles **16** in the film on the surface most nearly adjacent the internal stressed areas in which the gas was initially absorbed. The location of the bubbles in the film indicate the location of the stress-raising material inhomogeneities in the product. If the examination shows that the product does not contain an objectional number of inhomogeneities (and it must be remembered that practically no metallic product will be completely free of inhomogeneities), the covering film may be removed and the product put to its intended use.

FIGS. 2 and 3 illustrate a typical bubble pattern of a product having an illustrative inhomogeneity content.

Other methods of practicing the present invention, within the scope of the following claims, will occur to those skilled in the art.

I claim:

1. The method of testing a metallic product for stress-raising material inhomogeneities comprising the steps of:

providing a low molecular weight nascent gas to said product for absorption in areas surrounding said inhomogeneities,

covering said product with a deformable film; and

treating said product to release said absorbed gas to cause bubbles to form in said film adjacent said inhomogeneities in said product.

2. The method of claim **1** in which said product is of steel.

3. The method of claim **1** in which said product is heated to release said absorbed gas.

4. The method of claim **1** further including the step of chemically cleaning and removing oxides from the surface of said product prior to presenting said gas to said product.

5. The method of testing a metallic product for stress-raising material inhomogeneities comprising the steps of:

electrolytically presenting a low molecular weight nascent gas to said product by making said product the cathode in an electrolytic solution for diffusion into said product and absorption in areas surrounding said inhomogeneities;

covering said product with a deformable film; and

treating said product to cause said absorbed gas to diffuse outwardly from said areas, recombine into molecular form at the surface of the product, and cause bubbles in said film adjacent said areas.

6. The method of testing a metallic product for subsurface, non-metallic inclusions comprising the steps of:

cleaning and removing oxides from the surface of said product;

presenting nascent hydrogen to the surface of said product by making said product the cathode in an electrolytic solution;

rinsing and drying said product;

covering said product with a gas-tight, deformable film; and

heating said product to cause bubbles to form in said film adjacent said non-metallic inclusions in said product.

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HOWARD S. WILLIAMS, *Primary Examiner.*

T. TUNG, *Assistant Examiner.*