United States Patent [19]

Alburger

[11] **3,791,198**

[45] **Feb. 12, 1974**

[54] **TESTING PANEL FOR INSPECTION PENETRANTS HAVING CRACKS OF CONTROLLED DEPTH AND WIDTH**

[76] Inventor: **James R. Alburger,** 5007 Hillard Ave., La Canada, Calif. 91011

[22] Filed: **Nov. 27, 1972**

[21] Appl. No.: **309,690**

[52] **U.S. Cl.** **73/53,** 73/104

[51] **Int. Cl.** **G01n 11/00,** G01n 19/08

[58] **Field of Search** 73/53, 104

[56] **References Cited**

UNITED STATES PATENTS

2,186,014	1/1940	Ellis	73/104
3,164,006	1/1965	Alburger	73/53

Primary Examiner—Donald O. Woodiel

Assistant Examiner—John P. Beauchamp

[57] **ABSTRACT**

A test panel which may be used for evaluating inspection penetrant crack detection performance, comprising essentially a soft, malleable metal substrate coated with a brittle surface layer of controlled thickness within the range of from about 5 microns to 50 microns, said brittle layer having a pattern of craze cracks which are generated by a mechanical stretching of the panel to a point where the average crack width falls within the range of values from about 0.5 micron to 20 microns.

5 Claims, No Drawings

TESTING PANEL FOR INSPECTION PENETRANTS HAVING CRACKS OF CONTROLLED DEPTH AND WIDTH

RELATED PATENTS AND PATENT APPLICATIONS

U.S. Pat. No. 3,164,006, "Evaluation Performance of Liquid Penetrant Tracer Materials."

Appln. Ser. No. 237,984, filed Mar. 24, 1972, for "Test Panel for Evaluating Inspection Penetrant Performance. "

This invention relates to a test panel for evaluating the flaw detection performance of inspection penetrants. More particularly, the invention relates to a craze-crack panel in which both the depth and width of surface cracks are controlled and adjusted so as to fall within a desired dimensional range.

Test panels having surface cracks of known dimensional magnitude are important for use in the design, qualification, and acceptance testing of inspection penetrant materials. They are not often used to make side-by-side comparisons of test penetrants and reference materials, but there is a continuing need for test panel structures which will permit photoelectric measurements and the determination of performance characteristics on penetrants without the need for comparison with a reference material.

Various kinds of test panels have been devised in the past for the purpose of evaluating flaw detection performance of inspection penetrants. An early type of test panel was the so-called heat-fractured aluminum block, in which fracture cracks are produced by sudden chilling, in ice water, of an aluminum plate which has been heated almost to its softening point. This type of test panel has cracks which may be as deep as one quarter inch or more. The cracks are random in size, depth, width, and distribution. This type test panel has proved to be unsatisfactory for evaluation of high-sensitivity inspection penetrants due to the excessive depth of the cracks, which acts to provide large reservoirs of penetrant liquid.

Another type of test panel was developed by Ohio State University, and further refined by Monsanto Laboratory, under Air Force development contracts. This panel consists of a sheet of copper or brass which is burnished to a mirror finish and then plated with layers of nickel and chromium to carefully controlled thicknesses. The chrome layer is brittle, so that when the panel is bent over a curved form, a pattern of cracks appears in the chrome layer. This so-called cracked-chrome-plate panel is accurately controlled with respect to crack depth (thickness of the chrome layer), but it is not controlled or adjusted with respect to the width of the cracks. In fact, when the bent panel is straightened, the cracks tend to close up to an average width of 0.1 micron or less. The only thing which prevents the cracks from closing up to zero width is the random distortions and displacements of the metallic crystal configuration which take place in the process of bending and straightening.

A third type of test panel is the so-called cracked anodic-film test panel which may be constructed in accordance with the teachings of my U.S. Pat. No. 3,164,006, for "Evaluation Performance of Liquid Penetrant Tracer Materials." The preferred procedure for making a cracked-anodic-film panel is to anodize a

sheet of aluminum to an accurately controlled thickness of the anodic coating. A sulfuric acid anodizing procedure, the so-called 215-R1 anodize, provides a suitable anodic film about 0.0008 inch thick, and which is brittle and capable of being easily cracked by bending the panel. A large number of closely spaced cracks may be generated in the anodic coating, merely by bending the anodized panel over a curved form. Although the depth of the cracks (i.e., coating thickness) is controlled in this test panel, the crack width has not heretofore been controlled or adjusted. When the bent panel is straightened, the cracks tend to close up to an average width of 0.1 micron or less.

I have devised an improvement in the structure of the cracked-anodic-film test panel, as set forth by the teachings of my copending application, Ser. No. 237,984, filed Mar. 24, 1972, for "Test Panel for Evaluating Inspection Penetrant Performance." This improvement comprises a method and material for sealing small surface porosities in the anodic coating, so as to provide a glassy-smooth transparent anodic layer which exhibits only the crack pattern without any substantial amount of background porosity.

Other types of cracked test panels have been constructed in the past, including a panel made by plating a soft metal plate, such as copper, with brittle iron. In all cases, where cracks are generated in a brittle surface coating, the cracks are generated by bending the panel over a curved form, and then straightening the panel. In all cases, the process of straightening or flattening the cracked panel serves to close up the cracks, so that the width of such cracks normally falls in the range of about 0.1 micron or less.

I have discovered that the widths of the cracks which appear in the above-described cracked-brittle-layer panels are much too small to provide a desired level of fluorescence response of penetrant entrapments. This is because all of the presently available inspection penetrants exhibit very small fluorescence response at liquid film thickness values in the range of 0.5 micron or less.

All inspection penetrant materials comprise essentially solutions of indicator dyes, visible-color or fluorescent, and they all exhibit a feature of "Beer's Law Transition of Fluorescence or Color Response," such that as the thickness of a liquid layer of the penetrant is reduced, a critical dimension is reached where the color of fluorescence response becomes rapidly reduced toward zero. I have discovered that the fluorescence response, for example, of the most sensitive known penetrant diminishes to less than 50 percent of its maximum value at liquid film thicknesses smaller than about 0.5 micron. In a typical low-sensitivity visible-color or fluorescent penetrant, the point of 50 percent reduction of response occurs at liquid film thickness values in the range of 6 to 10 microns.

Thus, a surface crack in a test part, in which either the depth or width is smaller than about 0.5 micron, cannot contain an entrapment of penetrant which exhibits an effective film thickness greater than the 0.5 micron value, and such entrapments will, therefore, provide excessively low levels of fluorescence or color response.

Thus, I have discovered, in order to evaluate properly the flaw detection performance capability of an inspection penetrant material by means of a cracked test panel, it is necessary that the cracks in the panel shall

be standardized with respect to width as well as depth, and both of these dimensional magnitudes must be greater than about 0.5 micron.

The principal object of this invention, therefore, is to provide a test panel for use with inspection penetrants in which there is generated a pattern of surface cracks having controlled and adjusted depths and widths.

Other and incidental objects of the invention will in part be obvious and will in part become apparent from the following description thereof.

I have discovered that any of the existing cracked-brittle-film test panels may be treated and mechanically deformed in such a way as to provide controlled depth and width of surface cracks. The conventional procedure of bending the panel over a curved form acts to stretch the convex surface, while compressing the concave surface. A pattern of elongation-stress cracks normally appears in the convex surface, and in the case of a test panel having a thickness of about 0.050, bent over a curved form with a radius of about 3, the cracks which appear are distributed across the curved surface at a frequency of from about 10 to 50 cracks per inch. As already stated, when the thus-bent-and-cracked panel is straightened, the cracks tend to close up by compression forces, so that the typical width of a given crack is in the range of 0.1 micron.

I have discovered that it is possible to generate a novel and useful crack pattern by mechanically stretching the panel instead of bending it. The stretching operation is carried out by gripping an approximately square sheet of panel material along opposite edges, and applying sufficient stretching force to elongate the panel beyond its elastic limit. The following example illustrates a preferred panel structure and technique of crack width control.

EXAMPLE 1

A large sheet, 3′ × 8′, of 1100-0 aluminum, 0.100 inch thick, was anodized in a sulfuric acid bath in accordance with the well-known 215-R1 procedure, yielding an anodic coating thickness of about 0.0008 inch, or 20 microns. The large sheet was then cut up into small pieces about 4.75 inches square, and the squares were checked as to the anodic coating thickness using an eddy-current thickness gauge.

Several of the panels were treated in accordance with the teachings of my copending application, Ser. No. 237,984, filed Mar. 24, 1972, For "Test Panel for Evaluating Inspection Penetrant Performance." The panels were dipped in a solution of sodium silicate, drained, dried, and baked in an oven to provide a glassy, smooth sealant coating covering the natural fine surface porosity of the anodic layer.

A surface-sealed panel was mounted in a stretching fixture in such a way that opposite edges of the panel were gripped uniformly so as to provide an even stretching tension. The distance between the gripper bars of the stretching fixture was about 4 inches. Force was applied to stretch the panel, and a dial indicator was employed to measure the displacement between the gripper bars.

It was observed that as the panel was stretched to a relatively small displacement between the gripper bars, a pattern of craze cracks quickly appeared over the entire surface of the panel. The cracks in this pattern were perpendicular to the direction of stretching, and were present at a frequency of about 15 to 20 cracks per millimeter. It was also observed that once the pattern of cracks was formed, additional stretching did not generate more cracks, but acted only to widen the existing cracks.

The panel was stretched to a final displacement between gripper bars of about 0.375 to 0.40 inch, representing a linear stretching of the panel of about 9 to 10 percent. In this way, cracks were obtained having an average width of about 0.0002 inch, or 5 microns.

A series of tests, using different degrees of stretching and different panel thicknesses, showed that crack width could be accurately controlled from about 1 micron up to as much as 15 or 20 microns. An excessive degree of stretching resulted in rupture of the test panel; however, it was found that the optimum crack width of from about 4 to 8 microns could be readily obtained. It was observed that the presence of the anodic coating acted, at least in part, to stabilize the panel against localized failure by excessive elongation, so that relatively large percentages of elongation may be obtained, providing uniform stretching across the surface of the panel.

Several of the stretch-cracked panels were reinserted in the stretching fixture, being turned at an angle of 90°. Again, the panels were stretched, yielding an additional crack pattern at right angles to the first crack pattern. It was observed that the number of cracks in the anodic coating was thereby almost doubled. Due to the effect of work-hardening of the aluminum, greater stretching force was required for the second step of stretch-cracking, the frequency of the cracks was slightly less, and the average crack width was slightly greater than in the first crack pattern.

The stretched-cracked panels were trimmed to a size of about 3.75 inches square, by shearing off the wrinkled and deformed portions around the edges, and the finished panels were then used in testing fluorescent penetrants of various sensitivity levels.

A few drops of a water-washable penetrant were applied to the surface of a craze-cracked panel. Excess penetrant was wiped off with paper towelling, and the panel surface was polished by rubbing with cleansing tissue. Examination under a microscope showed that the surface area between cracks was substantially free of penetrant residue.

The thus-prepared panel was placed in a washing fixture having a glass window to permit irradiation of the panel by ultraviolet light and measurement of fluorescent response by means of a photomultiplier photocell. Instantaneous relative values of fluorescent brightness, as a function of washing time, were recorded on a strip-chart recorder. It was found that strip-chart recordings of indication depletion could be easily made and reproduced with good repeatability, thus providing a reliable measure of "Indication Depletion Time Constant" for the penetrant under test.

A similar test, using an anodic test panel cracked by means of the conventional bending technique, failed to provide useful measurement data. The density or frequency of cracks on the panel surface was not sufficient to provide a satisfactory photocell response, and the fluorescent response of entrapments in cracks which did exist was excessively weak due to the narrow crack width. The result was that Indication Depletion Time Constant values could not be accurately or reliably determined.

EXAMPLE 2

A procedure was carried out similar to that of Example 1, except that in this case the anodic coating was dyed with a black dye (the so-called black anodize), resulting in a relatively opaque brittle anodic coating. The anodic surface was sealed by application of the sodium silicate coating, and panels were stretched to provide controlled crack widths in the range of from 1 to 20 microns.

A thus-prepared craze-cracked black anodized panel, having a crack width of about 5 microns, was used for testing the performance capabilities of inspection penetrant developers. In this case, penetrant was applied to the panel, the surface was cleaned and polished to a point where a relatively low level of indication brightness was obtained. This level of brightness was measured, a developer was applied, and the "developed" brightness was measured. The enhancement in brightness thus provided a measure of developer performance.

A similar test, using a black anodized test panel cracked by means of the conventional bending technique, failed to provide useful measurement data. The frequency of cracks in the crack pattern was insufficient, and the cracks were too narrow to permit the formation of adequate penetrant entrapments. The result was that measures of developer performance could not be accurately or reliably determined.

EXAMPLE 3

A plate of burnished copper, about 5 inches square and 0.100 inch thick, was plated with a thin coating of nickel, followed by a coating of chrome, providing a thickness of the chrome-plate layer controlled to a value of about 20 microns. The plated panel was mounted in a stretching fixture, and a stretching operation was carried out similar to that of Example 1. Again, it was found that a mass of craze cracks was produced, and it was found possible to calculate the average width of the cracks by counting the cracks and measuring the amount of stretching, or displacement between gripper bars in the stretching fixture.

The thus-produced craze-cracked panel was observed to have an opaque surface suitable for use in evaluating developer action by a technique similar to that of Example 2. Comparison of the thus-produced test panel with a similar panel cracked by means of the conventional bending technique showed that the stretch-cracked panel yielded reliable and repeatable measurement results, whereas the conventional bend-cracked panel failed to provide useful results which could be read out by means of a photomultiplier photocell.

It will be understood that the test panels of the invention may be constructed using any one of a variety of base metal substrates. Also, a variety of brittle surface coatings may be utilized. The substrate metal must be relatively soft and maleable, so that it may be stretched to a degree sufficient to provide a desired average crack width. The preferred base metal is a soft aluminum, such as the 1100-0 material.

Although opaque brittle surface coatings, such as chrome-plate or brittle iron, may be used to provide a controlled crack width test panel, these are suitable mainly for measurements of developer action, and they are not readily adaptable to measurements of Indication Depletion Time Constants. Thus, the preferred type of brittle coating is a transparent anodic layer, such as is produced by the commonly known 215-R1 anodizing procedure on aluminum. Similar transparent anodic coatings may be produced on magnesium, beryllium, titanium, zirconium, and other metals. However, aluminum is preferred as a base metal.

Although a black dye is preferred for staining the anodic layer in cases where an opaque brittle anodic coating is wanted, it is also possible to utilize colors such as red, blue, brown, etc. I, therefore, do not restrict myself to the use of any particular color dye for the purpose of staining the anodic layer. It will be understood that additional opacity may be achieved by incorporating a suitable dye in the sodium silicate solution which is used to seal the surface porosity of the anodic layer. It will also be understood that the sodium silicate sealer coating may be omitted if desired.

I have found that the optimum width of cracks produced by the stretching method of the invention is about 5 to 8 microns. For certain specialized purposes, as for evaluation of developer performance, it may be found desirable to utilize a test panel having crack depths in the range of 5 to 10 microns and crack widths in the range of 1 to 3 microns, while for evaluating the performance of extremely low sensitivity penetrants, it may be desired to utilize a test panel having crack depths in the range of 30 to 50 microns and crack widths in the range of 15 to 20 microns.

In practice, it is quite difficult to produce an anodic coating thicker than about 20 microns, since as the anodic layer becomes thicker, the electrical resistance increases, thus slowing down the anodic reaction. However, by modifying the normal 215-R1 procedure, and by greatly prolonging the time of treatment, it is possible to achieve anodic film thicknesses approaching 50 microns. Chrome-plating procedures, and similar plating operations, do not suffer from such limitations, so it is relatively easy to adjust the thickness of the brittle coating to any desired value from a few microns up to 100 microns or more.

It will be understood that the useful range of brittle coating thicknesses in the test panel of the invention is from about 5 microns to 50 microns, with a preferred range of from about 10 microns to 30 microns. Also, it will be understood that the useful range of crack width, as produced by the stretching process of the invention, is from about 1 micron to 20 microns, with a preferred range of from about 4 microns to 8 microns when the panel is to be used for general-purpose evaluation of penetrant and developer performance. When the panel is to be used for certain special purposes, as described, other ranges of crack width may be preferred.

It will be understood that the test panels of the invention may be coated, prior to stretch-cracking, with a thin layer of sodium silicate so as to minimize the effects of background porosity. It will also be understood that the sodium silicate coating, if used. may contain a visible-color (preferably black) dye, so as to render it partially opaque. In some cases, where so desired, the visible-color dye may be omitted from the anodic coating and included only in the sodium silicate coating.

I claim:

1. In a test panel for evaluating inspection penetrant performance consisting essentially of a maleable metal sheet coated with a brittle surface layer capable of pro-

ducing craze cracks under stress, the improvement wherein said brittle coating is controlled and adjusted to a thickness within the range of from about 5 microns to 50 microns, and said panel is mechanically stretched beyond the elastic limit of said maleable metal, whereby craze cracks are produced in said brittle layer, and controlled and adjusted to a width within the range of from about 1 micron to 20 microns.

2. A test panel in accordance with claim **1,** in which said maleable metal sheet is aluminum, and said brittle surface layer is an anodic coating.

3. A test panel in accordance with claim **2,** in which said anodic coating is stained with a visible-color dye.

4. A test panel in accordance with claim **2,** in which said anodic coating is coated with a thin layer of sodium silicate.

5. A test panel in accordance with claim **4,** in which said layer of sodium silicate contains a visible-color dye.

* * * * *