United States Patent [19]

Conway et al.

[11] **3,845,658**

[45] **Nov. 5, 1974**

[54] **METHOD OF DETECTING FLAWS IN THE EXTERIOR SURFACES OF HOLLOW WORKPIECES**

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[22] Filed: **June 22, 1973**

[21] Appl. No.: **372,659**

[52] **U.S. Cl.** **73/104,** 117/94, 117/109, 118/418

[51] **Int. Cl.** **G01n 19/08**

[58] **Field of Search** 118/417, 418; 117/109, 117/94; 73/104; 250/302

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[57] **ABSTRACT**

A method for detecting flaws in external surfaces of hollow workpieces employing sized particles carrying a liquid penetrant for transfer thereof to such external surfaces to coat the same with the liquid penetrant for use in the detection of flaws therein, while preventing, because of the size of the transfer particles, any substantial entry of the liquid penetrant into the hollow of such workpiece for collection therein and any subsequent leaking out of the collected penetrant onto the external surfaces to thereby interfere with the detection of flaws therein. The transfer of penetrant to the external surfaces of the workpieces only is facilitated by using an amount of the liquid penetrant insufficient to cause a free flow of penetrant between and around the transfer particles but a sufficient amount of penetrant is employed to coat the external surfaces of the workpieces adequately for the effective detection of any flaws therein.

Suitable apparatus, preferably an open mesh tumbling drum, is provided for effecting such transfer of the liquid, flaw-detecting penetrant to the external surfaces of the hollow workpieces by a combined rubbing, contacting and relative surface movement between said workpieces and said transfer particles. The liquid penetrant and transfer particles as a result of such relative surface movement provide a readily releasable coating of the particles for transfer therefrom of the liquid penetrant to the external surfaces to be tested.

9 Claims, 4 Drawing Figures

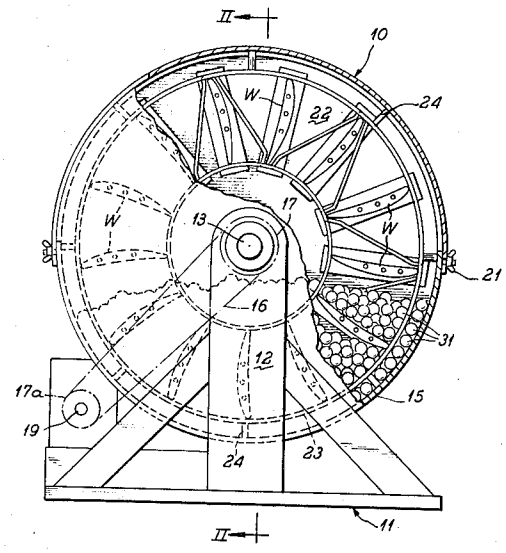


Fig. 1

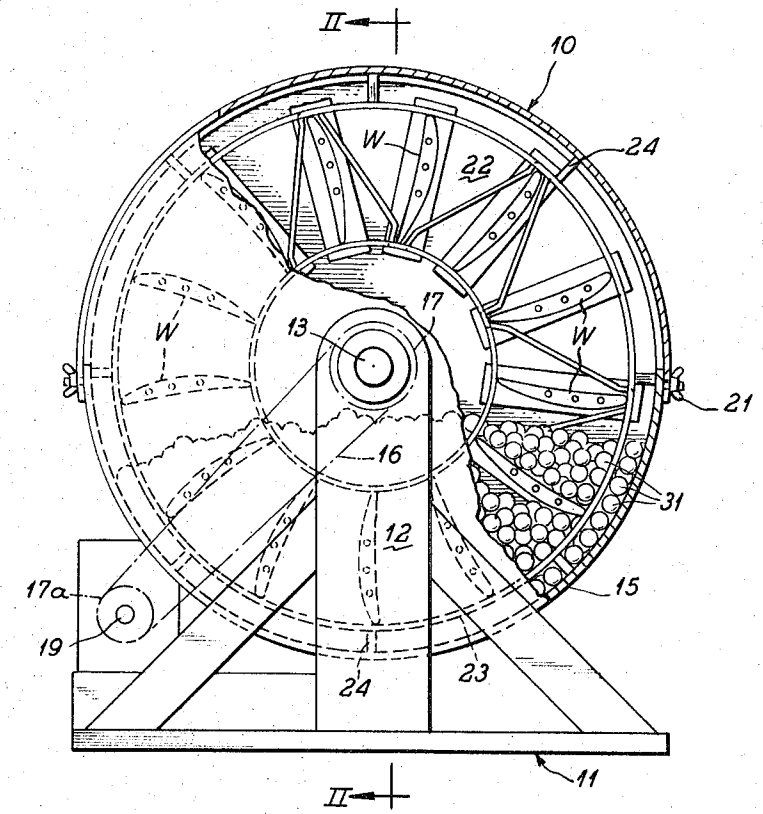
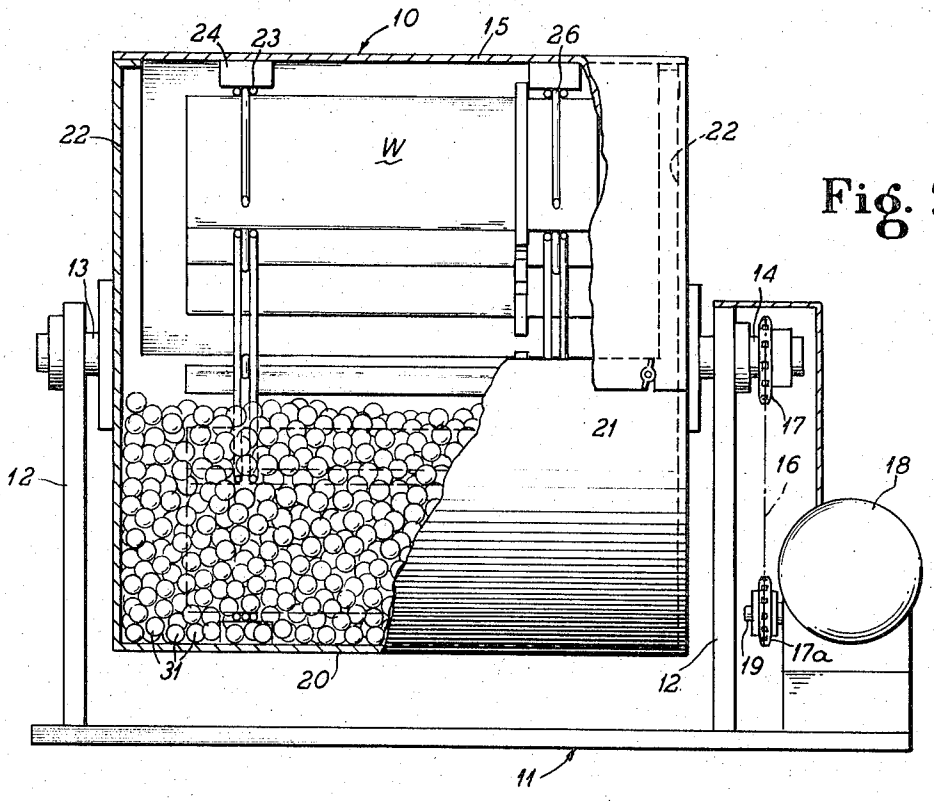

II
10
W
22
24
W
W
17
13
21
16
31
12
17a
15
19
24
23
11
II

Fig. 2


24
23
10
15
26
22
W
22
13
14
21
17
12
16
18
31
20
12
19
17a
11

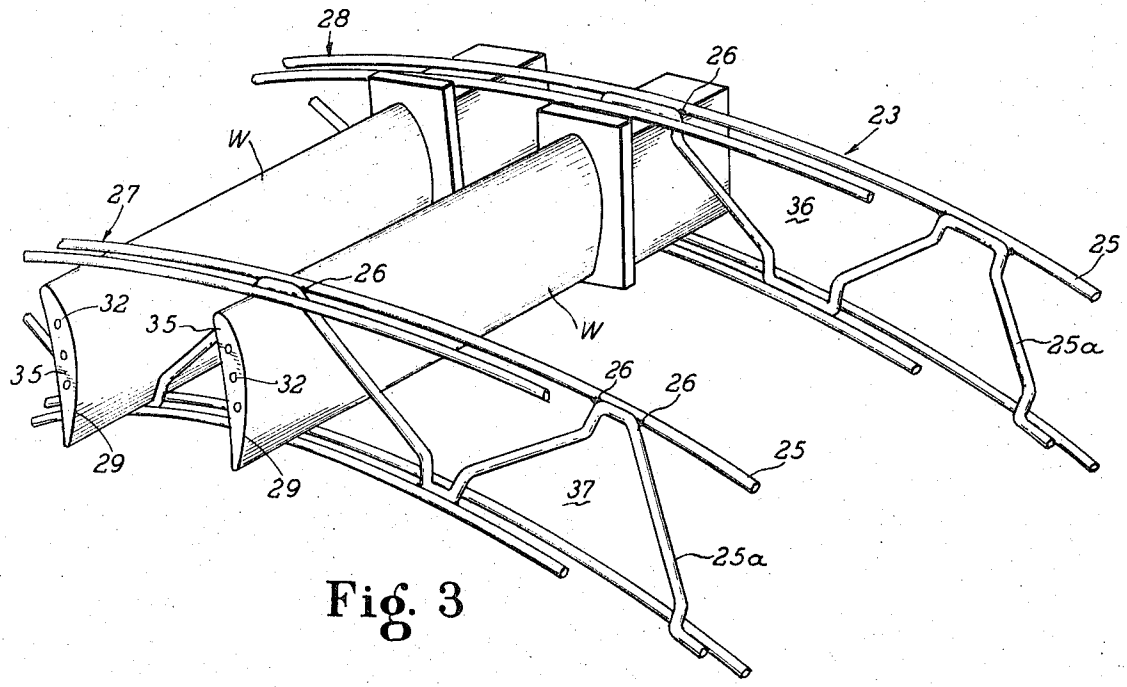

28
26
23
W
27
36
25
26
32
35
W
35
32
26
26
25
29
29
37
25a

Fig. 3

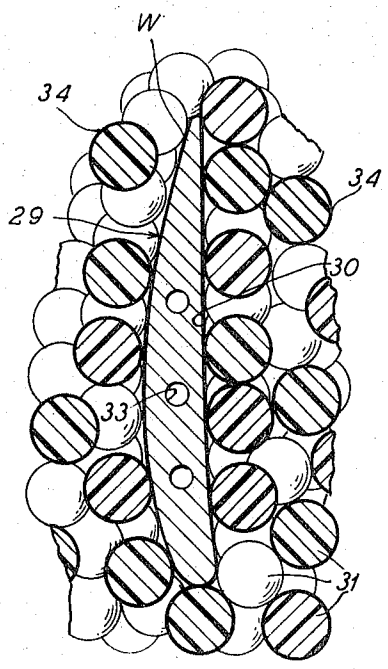

W
34
34
29
30
33
31

Fig. 4

METHOD OF DETECTING FLAWS IN THE EXTERIOR SURFACES OF HOLLOW WORKPIECES

BRIEF SUMMARY OF THE INVENTION

This invention relates to improvements in the known methods for detecting flaws in non-porous, solid surfaces, employing a liquid flaw-detecting penetrant to provide an indication of the existence and location of surface flaws that may be present in the workpiece. In general, the liquid penetrant is colored, by either a visible dye or a fluorescent dye, so as to give flaw indications that are detectable under "white", or visible light, or under fluorescigenous radiation.

The present invention constitutes an improvement whereby the external surfaces of hollow workpieces can be tested for flaws without complications arising because of the presence of openings or passages from the external surface to the hollow of the workpiece and the subsequent escape of any such penetrant from the hollow back to the external surface of the workpiece. In the prior art methods involving immersion of the test piece in the liquid penetrant, or the spraying or flooding of the liquid penetrant over the surface of the test piece, as heretofore practiced, it would have been difficult or impossible to wash out or otherwise eliminate the liquid penetrant from the hollow part and thereby prevent subsequent bleeding out, prior to inspection, of any liquid penetrant that entered the hollow portion of the workpiece. Such bleeding out of the penetrant would make the interpretation of flaw indications difficult if not impossible and, furthermore, would result in an economic loss. It would also increase the likelihood of pollution due to the release of high concentrations of liquid penetrant into the environment at which the testing is being carried out.

Our present invention avoids such difficulties and complications by confining the application of the liquid penetrant to the external surfaces of the hollow parts to be tested for flaws. This result is accomplished through the use of particles that are first releasably coated with liquid penetrant and such coating then transferred to those external surfaces only that are to be inspected for surface flaws. The transfer particles are suitably sized so as to be too large to enter into the hollows or cavities in the workpiece but are capable of readily releasing a sufficient portion of the coating carried by said particles to provide a test coating of the penetrant on and over the external surfaces of the workpieces. In accordance with the usual liquid penetrant technique, any excess of penetrant deposited on the external surfaces is suitably removed while leaving penetrant residues in any flaws that may be present in such external surfaces. The usual examination under appropriate lighting conditions is then carried on to determine the presence, location and significance of any flaw indications found.

It is, therefore, an important object of our invention to provide an improved method for detecting flaws in the external surfaces of hollow parts or workpieces while preventing the ingress of the liquid penetrant into the hollows or cavities thereof and thus avoiding the difficulties and objectionable results that would ensue were the liquid penetrant to find its way into such hollow portions or cavities.

An improved apparatus is provided which is particularly adapted for use in the carrying out of our improved method, whereby only the external surfaces of the workpieces are coated with the flaw-detecting penetrant and entry of the liquid penetrant into any hollow portion of the workpiece is prevented, thereby resulting in a simplification of the overall method and a saving in the use of the flaw-detecting penetrant.

Other objects, features and advantages of our invention will be readily apparent from the following description of certain preferred embodiments thereof, taken in conjunction with the accompanying drawings. Variations and modifications thereof may be effected without departing from the spirit and scope of the novel concepts of the disclosure, and in which the following detailed description of the annexed sheets of drawings by way of preferred example illustrates several embodiments of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is an end elevational view of a preferred embodiment of the apparatus of our invention particularly well adapted for carrying out our method;

FIG. **2** is a longitudinal sectional view taken substantially along the line II—II of FIG. **1** with parts in elevation and partially broken away;

FIG. **3** is a fragmentary detail view in perspective; and

FIG. **4** is an enlarged fragmentary view partly in elevation and partly in section.

DETAILED DESCRIPTION OF DRAWINGS

The reference numeral **10** indicates generally a tumbling drum assembly mounted upon a supporting stand **11** of any suitable construction and shown here as comprising vertical uprights **12** for rotatably supporting stub shafts **13** and **14** extending horizontally from the generally cylindrical rotatable drum **15** of said drum assembly **10.** The drum **15** is rotated by a chain and sprocket driving means, indicated generally by the reference numerals **16, 17** and **17a**, from a motor **18** and its shaft **19.**

The drum **15** comprises a two-part cylindrical shell **20** suitably formed of sheet metal with the two parts thereof held together by clamping means including screws and thumb nuts **21.** Circular plates form closed ends **22** for the drum. As best shown in FIG. **1,** a skeleton type of drum **23** is positioned concentrically within the drum **15** and secured in spaced radial relation thereto by spacers **24.** The drum **23** is made up of a plurality of preformed wires **25** and **25*a*** welded or otherwise secured together, as at **26** (FIG. **3**), to form wire frames **27** and **28** of similar construction and performing together the common function of removably securing hollow workpieces W in proper relative positions and attitudes for receiving a flaw-detection coating on their external surfaces only.

Said workpieces W are here exemplified by corded turbine blades **29** having surfaces **30** that are to be tested for flaws or other surface defects before the workpieces W are put into operational use. As will be explained later in greater detail, the workpieces are tested by the so-called liquid penetrant method, using either a penetrant containing a dye or color visible under "white" light or a fluorescent dye that is best viewed under fluorescigenous radiation.

In conventional practice the liquid penetrant is applied to the surface to be tested by spraying, flooding or the like; any excess of penetrant is removed, as by

water rinsing the surface, while leaving entrapped penetrant or penetrant residue in any flaws that may be present to give indications thereof; and the indications are then observed under appropriate radiation to determine the location, size and significance of such indications in relation to the satisfactory use of the workpiece for its intended purpose.

However, as pointed out earlier herein, our invention eliminates the ingress of the liquid penetrant into the hollow of a hollow workpiece such as constituted by the passages in a corded turbine blade W. Such ingress of liquid penetrant is prevented by the use of transfer particles, such as the particles **31** (FIG. **4**), which can be of any suitable solid materials, such as glass, synthetic plastic, cork, etc., provided the particles are of a minimum size too large to enter the exposed open ends **32** of the cored passages **33.**

In operation, a mass of the transfer particles **31** coated with the liquid penetrant to provide a readily transferable coating **34** is tumbled in the drum **15** along with the workpieces W to effect relative surface movement between said particles **31** and said workpieces W. The result is a transfer of said coating **34** to the external surfaces **30** of said workpieces in an amount sufficient to develop flaw indications for subsequent examination and interpretation.

By properly controlling the amount of liquid penetrant supplied to the transfer particles in the tumbling drum **15,** any large excess of the liquid penetrant is avoided so as to prevent the accumulation of free-flowing liquid in the spaces between the transfer particles with the consequent tendency of the liquid to flow into the open ends **32** of the passages **33.** That problem is not only solved but our method results in a saving in the use of the penetrant and a reduction in the amount of pollution of the environment from the disposal of unused or wasted penetrant. Also, our method makes unecessary the use of open penetrant tanks and spray booths and makes possible minimal use of penetrant with consequently lessening of the amount thereof to be wasted in the rinse water.

Before the start up of the rotary drum assembly **10,** the workpieces W are properly positioned in place in the inner skeleton drum **23.** As best shown in FIG. **3,** each workpiece W is resiliently held at its ends in the wire frames **27** and **28.** This can be accomplished by inserting the end **35** of a turbine blade W through the opening **36** in the wire frame **28** and into a corresponding opening **37** in the wire frame **27.** Due to the resiliency of the wire frames, the wires can easily be displaced slightly during such insertion of the turbine blades to receive the same. After such insertion the resilient contraction holds the turbine blades in the positions shown in FIGS. **1** and **3** during the carrying out of the method of our invention.

OPERATION OF APPARATUS

With the workpieces W in place and the drum **15** open, the drum is partially filled with transfer particles **31.** These particles are pre-coated, as indicated at **34** (FIG. **4**) with the selected flaw-detecting liquid penetrant, using an amount of such penetrant sufficient for the purpose of transferring an adequate amount of penetrant to the external surfaces **30** but insufficient to build up a free-flowing excess of the liquid penetrant over that required for transfer from the coated particles **34** to the external surfaces **30.** If there were such a free-flowing excess of liquid penetrant, it would tend to displace the coated particles **34** into the open ends **32** of the cored passages **33** and permit ingress thereinto of the liquid penetrant. Consequently, such an excess of penetrant over that necessary for coating the transfer particles and through them effecting an adequate test coating of the workpieces is to be avoided.

In the operation of the drum assembly **10,** the liquid penetrant is transferred to the external surfaces **30** of the workpieces W by virtue of the relative surface movement between such surfaces **30** and the surfaces of the coatings **34** on the transfer particles **31.** Such relative surface movement involves a certain amount of rubbing, which limits any large localized build-up of the coating **34** and enhances the rate of transfer of the flaw-detection material from the coating **34** to the surface **30** of the turbine blade.

The transfer particles are considered to be an essential part of the apparatus of our invention and the part that adapts the apparatus to the carrying out of our improved method. For best results the transfer particles are generally rounded in shape such as spheres formed of glass or other vitreous material or of synthetic plastic material having surfaces that are relatively smooth, continuous and non-adhesive toward the flaw detection penetrant that is used. Mixtures of various shaped particles can also be used.

By way of illustration the transfer particles may be glass beads varying from 3 to 6 mm. in diameter provided the openings through the external surface to the hollow interior are at least somewhat smaller than 3 mm. in diameter.

If the penetrant used in water soluble or water miscible the transfer particles can be washed or rinsed with water to remove any excess of the penetrant or the penetrant residue from the surfaces of the transfer particles and also from the surfaces undergoing test for surface flaws. By proper correlation of the surfaces and coatings applied thereto, readily releasable coatings are applied to the transfer particles for transfer to the external surfaces to be tested for flaws.

In these respects our method is basically different from prior methods for the transfer of paint, metal films and adhesive coating materials by a rubbing, brushing or similar operation to provide permanent coatings. In our case the coatings are transient or temporary only and not intended to be permanent.

Our method can be carried out with any known liquid penetrant useful for the detection of surface flaws or defects in nonporous surfaces. The improvement herein disclosed particularly adapts our method specifically to the detection of flaws in the external surfaces of hollow parts, corded workpieces and the like.

While tumbling has been illustrated as one means of effecting transfer of the penetrant, it will be understood that other means such as vibrating tubs, a combination of an oscillating conveyor and a cascading arrangement and the like may also be employed.

We claim as our invention:

1. In a liquid penetrant method of detecting flaws in the external surface of a hollow workpiece; the improvement whereby said liquid penetrant is substantially prevented from entering into the hollow of said workpiece, said improvement comprising

coating relatively large sized particles with an amount of said liquid penetrant insufficient to

cause free-flowing of said penetrant coating off of said particles,

effecting surface contact and relative movement between said coated particles and said workpiece to transfer a portion of said coating to said external surface sufficient to give an indication of flaws therein if present,

the smallest of said particles being too large to enter into the hollow of said workpiece, and

testing said coated external surface for said flaws.

2. The method as defined by claim **1,** wherein said workpiece is hollow by reason of being cored and said coated particles are too large to enter into any core in said workpiece.

3. The method as defined by claim **1,** wherein said relative movement between said coated particles and said workpiece is effected by tumbling.

4. The method as defined by claim **1,** wherein said workpiece is a cored turbine blade.

5. In a liquid penetrant method of detecting flaws in the external surface of workpieces each having a cavity therein accessible by a passage through said external surface, the steps which comprise

applying the liquid penetrant to solid particles too large in size to pass through said passage and carrying an insufficient amount of said penetrant to cause a free flow thereof between and away from said particles,

mixing said workpieces and liquid bearing particles,

effecting relative movement between the resulting liquid penetrant coated particles and said external surfaces to leave a sufficient amount of penetrant on said surface at the site of any flaws that may be present therein to make possible a detection of said flaws, and testing said coated external surfaces for said flaws.

6. The method as defined by claim **5,** wherein said solid particles are rounded in shape and the penetrant is readily transferred by contact with said external surface of said workpiece.

7. The method as defined by claim **6,** wherein said particles are beads.

8. The method as defined by claim **6,** wherein said particles are plastic beads.

9. The method as defined by claim **6,** wherein said particles all have a minimum dimension greater than the maximum cross-sectional dimension of said passage through said external surface.

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