A dual purpose corrosion inhibitor and penetrant composition sensitive to radiography interrogation is provided. The corrosion inhibitor mitigates or eliminates corrosion on the surface of a substrate upon which the corrosion inhibitor is applied. In addition, the corrosion inhibitor provides for the attenuation of a signal used during radiography interrogation thereby providing for detection of anomalies on the surface of the substrate.

7 Claims, 1 Drawing Sheet
DUAL USE CORROSION INHIBITOR AND PENETRANT FOR ANOMALY DETECTION IN NEUTRON/X-RAY RADIOGRAPHY

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH

This invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435, 42 U.S.C. 2457).

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to corrosion inhibition and anomaly detection and, in particular, to a corrosion inhibitor which is sensitive to either neutron radiography interrogation or X-ray interrogation, and acts as a penetrant for anomaly detection.

2. Background of the Invention

Liquid/Vapor Phase Corrosion Inhibitors (LVCI) are used to mitigate or eliminate corrosion on or in non-ferrous aluminum alloys and ferrous alloy metallic structures. Such metallic structures are employed in numerous devices such as in thrust vector control (TVC) frames as part of the Space Shuttle Vehicle (SSV), solid rocket booster (SRB) system. Typically, a paint coating is applied to the surface of TVC frames.

It is advantageous to detect anomalies in the metallic structure such as anomalies due to corrosion or cracks in the metallic surface and/or joint or weld regions. Corrosion to the TVC frame may occur over multiple SRB flight use, exposure to salt air and seawater intrusion during SRB splashdown at sea, and during towback to port for refurbishment. As a result, many TVC frames have been removed from flight use because of corrosion and other surface conditions.

The conventional method to detect corrosion internal to an aluminum alloy TVC frame is through visual inspection and may include the use of a flexible borescope. Anomalous conditions such as cracks or corrosion in a substrate under a previously painted surface will not be observed. Therefore, in many cases, the extent of corrosion and anomalous welds may not be fully determined.

One problem with manual, visual inspection, including borescopic and line-of-sight inspection, is that it is extremely labor intensive. An additional problem with visual inspection is that visual inspection cannot detect corrosion and/or cracks and anomalies under the surface of previously existing coatings such as paint. In order to effectively detect the presence of an anomaly in the substrate under the painted surface, first the paint must be removed. In the case of substrates where a previously painted surface cannot effectively be removed, visual inspection is ineffective in detecting anomalies such as cracks and corrosion present in the substrate under the painted surface. A further disadvantage with borescopic inspection is that it has limited capabilities in evaluating corner areas and areas of severe bends in a metallic structure.

Due to the limitations of visual inspection, further methods have been developed specifically for detecting cracks in the metallic structure which include ultrasonic inspection and dye penetrant detection processes. While both are effective in detecting cracks, neither of these alternative detection processes are effective in detecting corrosion damage.

The anomaly detection systems developed thus far generally fail to determine the extent of corrosion or anomalous weld conditions on the surface of a substrate. Further, these previous detection methods fail to detect corrosion under a coating of paint and in structural weld regions and, in general, cannot be used to accurately inspect corner areas, interferences, and around sharp bends. In addition, the previous detection methods tend to be labor intensive, time consuming, and tedious for the inspector.

BRIEF SUMMARY OF THE INVENTION

In accordance with the present invention, a dual use corrosion inhibitor and neutron ray or X-ray penetrant material allows for the rapid and accurate detection of an anomalous condition by the detection of corrosion by-products and active corrosion while also providing for the detection of discrepant welds and structural and adhesive bonded metal composite failures using a neutron ray process or X-ray process. The corrosion inhibitor acts as a penetrant material for detecting the anomalous condition during neutron radiography (N-ray) or X-ray interrogation. Specifically, the corrosion inhibitor absorbs (i.e., provides attenuation of) a N-ray or X-ray beam. Anomaly detection is provided by first applying the corrosion inhibitor sensitive to radiography interrogation on the surface of a substrate, followed by radiography interrogation. Anomalous conditions such as cracks and corrosion will appear visibly due to the attenuation of the neutron ray or X-ray beam used during radiography interrogation.

According to one aspect of the present invention, a composition is provided for application upon the surface of a substrate. The composition comprises a corrosion inhibitor sensitive to one of neutron radiography interrogation and X-ray interrogation. The corrosion inhibitor acts as a penetrant for anomaly detection on the surface of the substrate.

According to another aspect of the present invention, a method is provided for inhibiting corrosion and detecting an anomalous surface condition of a substrate. The method includes the steps of applying a corrosion inhibitor sensitive to either neutron radiography interrogation or X-ray interrogation and acts as a penetrant for anomaly detection on the substrate.

According to yet another aspect of the present invention, a method is provided for inhibiting corrosion and detecting an anomalous surface condition of a substrate. The method includes the steps of applying a corrosion inhibitor sensitive to either neutron radiography interrogation or X-ray interrogation and in which the corrosion inhibitor acts as a penetrant of the substrate. An anomaly is detected on the substrate using either neutron radiography or X-ray radiography.

A key feature of the present invention is a dual use material which provides both protection of a substrate by mitigating or eliminating active corrosion as well as serving as a penetrant sensitive to radiography interrogation. As a result, significant time is saved from not having to use two processes independently, namely a corrosion inhibitor process and a radiography penetrant material application process. Consequently, an advantage of the dual use material is the associated decrease in costs associated with the reduction in processing steps.

An additional feature of the present invention relates to a corrosion inhibitor sensitive to radiography interrogation which provides for the detection of currently present anomalous conditions such as cracks and corrosion, as well as for detection of future, latent structural defects or anomalies.
which occur in the substrate at some future point after the
application of the corrosion inhibitor. For example, the
present corrosion inhibitor provides for detection of anomalous
conditions immediately after the application of the
corrosion inhibitor to detect any initial anomalous condi-
tions. In addition, the same substrate may be monitored for
corrosion or other anomalous conditions after the substrate
has been used by reexamining the substrate with radiogra-
phy interrogation after the substrate has been subjected to
various operating conditions and stresses.

Yet another feature of the present invention relates to the
detection of anomalous surface conditions of a substrate
present underneath a painted surface. The corrosion inhibi-
tor sensitive to radiography interrogation is first applied to
the surface of the substrate prior to applying a paint coating
over the corrosion inhibitor. After subsequent use, the sub-
strate can be monitored for anomalous conditions by radi-
ography interrogation through the painted substrate surface.

One advantage of detecting an anomalous condition under
a painted surface is the elimination of the need to remove the
paint in order to detect the anomalous condition. Further, the
present detection system provides for detecting anomalous
conditions in areas where the removal of paint is difficult or
impossible.

Additional features and advantages of the present inven-
tion will be set forth in, or apparent from, the detailed
description of preferred embodiments thereof which
follows.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a schematic neutron radiograph of a substrate
without a corrosion inhibitor sensitive to radiography inter-
rogation according to the present invention;

FIG. 2(a) is a schematic of the substrate of FIG. 1 after
the application of the corrosion inhibitor sensitive to radiograph
interrogation;

FIG. 2(b) is a schematic neutron radiograph of the sub-
strate of FIG. 2(a);

FIG. 3(a) is a schematic of a substrate with an anomalous
surface condition occurring in the substrate subsequent to
use; and

FIG. 3(b) is a schematic radiograph of the substrate of
FIG. 3(a).

DETAILED DESCRIPTION OF THE INVENTION

Referring now to FIG. 1, depicted therein is a schematic
neutron radiograph showing a baseline view of a substrate
10 prior to the application of a corrosion inhibitor. Substrate
10 includes substrate portions 10a, 10b with mitered ends
(indicated by broken line 11) joined together at weld 14.
Substrate 10 may include materials such as non-ferrous
metals and alloys including alloys of aluminum, magnesium, copper, zinc, beryllium, or ferrous alloys. In
addition, substrate 10 may include composite structures
composed of organic/metallic materials. As an example,
weld 14 includes a crack 16. In an actual radiograph, the
width 16 will appear indistinguishable from the background
and therefore, crack 16 will be difficult to observe.

Referring now to FIGS. 2(a) and 2(b), corrosion inhibitor
18 is applied to the surface 12 of the substrate 10. The
corrosion inhibitor 18 mitigates and/or eliminates corrosion
on or in non-ferrous alloys and ferrous metallic materials. As
discussed above, corrosion inhibitor 18 also mitigates and/or
eliminates corrosion in composite/metallic combinations. If
the substrate 10 is to be subjected to various stress condi-
tions such as heat and salt water, optimally the corrosion
inhibitor 18 is a liquid/vapor phase corrosion inhibitor
(LVCI). Alternatively, the corrosion inhibitor can be other
liquid polymer forms that also may be part of a composite
resin system with built in corrosion inhibitors, tracers, and/or
dopants.

Corrosion inhibitor 18 is also sensitive to neutron radi-
ography interrogation and serves as a penetrant. The vis-
cosity of corrosion inhibitor is adjusted as necessary to
provide the desired penetration properties. As such, corro-
sion inhibitor 18 penetrates (i.e., fills in) the crack 16.

Referring now specifically to the neutron radiograph of
FIG. 2(b), crack 16 becomes highly visible due to the
presence of the corrosion inhibitor 18 present in crack 16 as
compared with the non filled-in crack 16 depicted in FIG. 1.
Specifically, anomalous conditions, such as crack 16,
appears highly visibly due to the attenuation of the neutron
ray beam used during radiography interrogation.

The neutron radiography process includes adjusting both
the length of film exposure and development time to provide
a maximum contrast for any surface anomaly now filled with
the corrosion inhibitor 18. The corrosion inhibitor disposed
along the substrate surface 12 not visible In the neutron
radiograph due to the optimal exposure settings used to
maximize the detection of surface anomalies such as the crack
16.

The detection of anomalies such as the crack 16 may be
enhanced further by utilizing various additives such as
dopants to the corrosion inhibitor 18 to provide acceptable
neutron-ray attenuation in the desired area. As a result, any
anomaly present will become more visible even if the
anomaly is off-plane from the neutron-ray beam. Thus, the
addition of a dopant provides for maximum anomaly detect-
tion. Further, a wide variety of corrosion inhibitors can be
modified, via dopant addition, to make the various corrosion
inhibitors sensitive to a desired radiography interrogation
process.

Referring now to FIG. 3(a), substrate 30 includes a
substrate surface 32 upon which corrosion inhibitor 38
and a coating of paint 39 are applied. A weld 34 joins the mitered
ends of substrate portions 30a and substrate portion 30b.
Anomaly 36 was formed on surface 3 of the previously
applied coating of paint 39 due to corrosion of the material
comprising substrate 30. Since anomaly 36 is disposed
under the coating of paint 39, the anomaly 36 is not
observable via visual inspection.

Referring now to FIG. 3(b), depicted is a neutron radi-
ograph of the substrate 30. The anomaly 36 is detected on the
radiograph as a gap in the corrosion inhibitor layer 38 as a
result of the erosion of, i.e., the removal of, a portion of the
substrate 30. The length of exposure and development time
of the film are optimized to provide the maximum contrast
for the corrosion inhibitor layer 38 thereby making the
anomaly 36 most readily discernable as a gap in the corro-
sion inhibitor layer 38. As a result, although the anomaly 36
is located underneath the coating of paint 39, the anomaly 36
is detectable by neutron radiography interrogation.

What will now apparent to one of ordinary skill in the art
is that the present invention may be extended to numerous
substrate materials and appropriate corrosion inhibitors sen-
titive to various radiography interrogation techniques. For
example, numerous applications exist for the present inven-
tion in corrosion protection of aircraft, boats, trains,
automobiles, and building structures. The inspection of these
structures can be enhanced through the use of the LVCI/
penetrant inspection material.
While neutron radiography interrogation is described herein, the present invention may be modified for use with X-ray interrogation whereby the corrosion inhibitor is sensitive to X-ray. Further, the corrosion inhibitor may be doped with material which provides further X-ray attenuation.

Alternatively, laser ultrasonics, holography and other non-destructive examination techniques can be used to detect anomalies using an appropriate combination corrosion inhibitor with a respective detector material. As with neutron radiography and X-ray interrogation, the respective detector material amplifies the respective signal of the nondestructive examination technique to assist in locating and identifying anomalous conditions. For example, the respective detector material could be a dopant which amplifies acoustic signals for detection using laser ultrasonics or a material which enhances a thermal energy response during holography.

Although the invention has been described above in relation to preferred embodiments thereof, it should be obvious by those skilled in the art that variations and modifications can be effectuated in these preferred embodiments without departing from the scope and spirit of the invention.

What is claimed is:
1. A method for inhibiting corrosion and for detecting cracks and other anomalous surface conditions of a metallic substrate forming part of a flight structure, said method comprising the steps of:
   - applying a liquid/vapor chase corrosion inhibitor to a surface of the metallic substrate forming part of a flight structure, said corrosion inhibitor being sensitive to one of neutron radiography interrogation and X-ray interrogation and, when applied, penetrating into the substrate;
   - detecting crack or other anomaly on or in the metallic substrate using one of neutron radiography and X-ray radiography.
2. The method of claim 1, wherein said anomaly comprises a corrosion anomaly in the substrate.
3. The method of claim 2, wherein the step of detecting an anomaly comprises detecting corrosion by-products.
4. The method of claim 2, wherein the step of detecting an anomaly comprises detecting active corrosion.
5. The method of claim 1, wherein the substrate comprises a weld region in the flight structure and the step of detecting an anomaly comprises detecting an anomaly in the weld region.
6. The method of claim 1, further comprising:
   - applying a coating layer over the corrosion inhibitor; and
   - wherein the step of detecting an anomaly comprises detecting an anomaly located on the under the coating layer.
7. The method of claim 1, wherein the step of detecting an anomaly comprises irradiating the substrate with a neutron ray off-plane from a plane of the substrate.