The Space Congress® Proceedings
1994 (31st) Space Exploration and Utilization for the Good of the World

Apr 26th, 2:00 PM - 5:00 PM

Paper Session I-C - Non-Destructive Detection of Corrosion Under Paint on Critical Surfaces

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NONDESTRUCTIVE DETECTION OF CORROSION UNDER PAINT ON CRITICAL SURFACES

28 February 1994

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ABSTRACT

We describe our proof-of-concept demonstration of the well-known thermal diffusion imaging technique [1,2,3] for detection of corrosion under paint on critical surfaces. Our first application will be the detection and mapping of corrosion on orbiter vehicle wing spars and rudder speed brakes. The technique will also used for the evaluation of doubler plate bond integrity on the rudder speed brakes.

INTRODUCTION

Inspecting orbiter vehicles for surface corrosion under paint is a tedious and time consuming operation. Areas of corrosion are normally detected by the presence of corrosion blisters in the overlying paint layer. Suspect areas are cleaned of paint, repaired if necessary using adhesively bonded doubler plates and repainted. Two areas of particular interest are the forward surfaces of wing spars, and the inner surfaces of rudder speed brakes. Examples of wing spar and speed brake corrosion are shown in Figures 1 and 2. These surfaces are currently inspected for corrosion manually from as much as 1½ feet away.

Our goal in this work is to employ thermal diffusion imaging to improve the efficiency of the current manual corrosion inspection process. To implement thermal diffusion imaging, a brief heat pulse is first applied to the painted surface using a hot air gun or a heat lamp. Following the heat pulse, a thermal infrared camera is used to capture a time sequence of thermal images as the surface cools. The thermal decay characteristics are evaluated for each spatial location in the image and a thermal decay rate map is produced. Since corroded areas generally conduct heat away from the surface more slowly than do uncorroded areas, the decay rate map can be used to locate areas of corrosion and evaluate the relative severity of each area.

The remainder of this paper describes our proof-of-concept test of thermal diffusion imaging for the detection of corrosion under paint as well as our plans for implementing the technology on orbiter vehicles.

TEST RESULTS

We first obtained a test specimen of aluminum plate which measured about 3" x 10" x 1/2". The plate was contaminated with patches of thin surface corrosion. The unmodified test specimen is shown in Figure 3. We then painted a portion of the test specimen with a 0.030" layer of acrylic lacquer, as shown in Figure 4.

The surface of the test specimen was heated about 12°F using a quick pulse from an infrared heat lamp. An Inframetrics Model 600 thermal infrared camera with a computer and modified frame grabber was then used capture a sequence of thermal images as the test specimen cooled. Twenty five images were digitized during the first 1.5 seconds of thermal relaxation.

Figure 5 shows a thermal image of the test specimen 0.2 seconds after the heat pulse was applied. Figure 6 shows a thermal image of the same area 0.3 seconds later. Note that the white (warm) patch near the top center of Figures 5 an 6 appears more persistent than the

Figure 1. *Wing Spar Corrosion*

Figure 2. *Speed Brake Corrosion*

Figure 3. *Corrosion Test Specimen*

Figure 4. *Painted Test Specimen*

surrounding features.

Once the image sequence was digitized, temperature time histories were constructed for each location (picture element) in the image frame. A graph showing the temperature history of two such locations is shown in Figure 7. In areas where the paint is well bonded to the aluminum, the thermal decay curve is exponential and relatively steep. For the corroded areas, the curve has an inflection point, and is rather "Gaussian" in nature. The corroded area exhibited a notably slower decay rate even though the corrosion in question was relatively thin and overlying paint was not blistered.

We created a thermal decay (corrosion) map of the test specimen surface by time-integrating the temperature curve for each pixel of the image and plotting the values of the integrals as a false-color map. It is apparent that the map, which is shown in Figure 8, indicates the position of the corrosion patches on the test specimen.

It should be noted that the corroded areas on the test specimen are all relatively minor compared to the corrosion examples shown in Figures 1 and 2. We conclude that thermal diffusion imaging should be sensitive enough for early detection of corrosion under paint.

INSTRUMENT DEVELOPMENT

We intend to develop a corrosion detection and mapping instrument, based on thermal diffusion, for inspecting critical painted

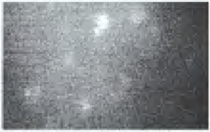

Figure 5. *Thermal Image (t=0.2 sec)*

Figure 6. *Thermal Image (t=0.5 sec)*

surfaces on orbiter vehicles. The device will be initially designed for use on wing spars and speed brakes. Subsequent versions of the instrument will apply the same thermal diffusion technique to verify doubler plate bond integrity.

The instrument will consist of an automated scanner frame to position the thermal imaging system, the thermal imaging system itself, and a heat pulse application system. A PC compatible computer system will provide hardware control, image analysis and a

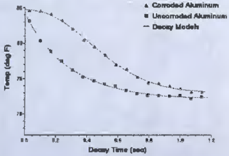

Figure 7. ***Typical Thermal Decay Curves***

Figure 8. ***Thermal Decay Map***

corrosion map archiving system.

The scanner frame will be affixed to work platforms near the test areas. The frame, under computer control, will scan the thermal infrared camera and heat source over the entire test area. Corrosion (thermal decay) maps of the entire area will then be produced using the method described above.

The maps will be registered to visible features on the test surface to facilitate subsequent repair operations. Hard copy maps or "Mylars" of the test area, showing all areas of suspected corrosion will be produced as required. In all cases, a permanent record of the inspection will be maintained by the computer based archiving system.

A Performance Reliability Analysis of the instrument will be performed as part of the design process. This technique, developed as part of our Orbiter Window Defect Scanner System project, uses the methodologies of probabilistic risk assessment to evaluate the probability of detection of the instrument. This analysis is also used to direct the design team to areas where the highest performance to design effort ratio can be realized.

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