Nondestructive Testing for AmericaOne

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"Well, there's nothing like a healthy dose of reality to begin the day. This morning we all showed up for work and, for a second, it felt like the normal situation, but the cruel reality that we were no longer racing settled over the compound. Everyone is handling it well and making the best of it. Coz cranked up the stereo and soon the yard was humming along as the crew began to break down the boats and get things ready for storage."

Bob Billingham CEO AmericaOne

ABSTRACT

Infrared imaging techniques have been developed, primarily in the aerospace industry, for evaluating composite materials and bonded structures. This is done by applying uniform heat to the surface of the material and monitoring the changes in the temperature distribution for a short period of time. When a structure is free of disbonds or delaminations, the temperature distribution will change as the surface heats and cools, but will remain uniform. Disbonded and delaminated areas will warm up relative to the near by, well-bonded, areas. This is due to the lack of thermal conductance into the underlying areas.

Ford Motor Company is one of the primary sponsors of the "AmericaOne" team. Our contributions consist of both money and technical assistance.

This paper will cover the nondestructive testing that was performed in Auckland New Zealand during the Challenger's Round and the Louis Vuitton Series. Cases showing delamination of deck surfaces and cracking around cockpit area will be discussed.

Keywords: IR nondestructive testing, marine structures, disbonds, delaminations

1. INTRODUCTION

This was not the ordinary assignment that we are use to receiving at Ford Motor Company. No plant to visit, no automobile to scan, not even a tire near by. So, what is Ford Motor Company doing in the America's Cup, sponsoring a sailboat? The materials that are used in the construction of an Americas Cup yacht are comparable to that of a CART or F1 racecar. This is the material of the future in the automobile industry.

Nondestructive testing was performed on the two AmericaOne yachts during round robin three and the semifinals of the America's Cup, in Auckland, New Zealand. This paper will cover the techniques, testing methods and some of the results from this work

2. TECHNIQUES AND METHODS

The techniques for inspecting the composite material come, primarily from the aerospace industry, where it is used to inspect bonded structures, coatings and composite materials. This is done using a heat source to apply a uniform pulse to the material surface and using an thermal imager to monitor the changes in the temperature distribution over a period of time. Where all the substructures are uniform and free of delaminations or disbonds, the temperature will change as the surface heats and cools, but will remain uniform. Disbonds and delaminations will remain warmer due to the lack of thermal conductance into the underlying material. These areas will show up lighter in the thermal image, compared to the darker, well bonded, area. There are many choices one can select for the inspection technique. The technique used depends on the flaw size that is acceptable, the type of flaw and the thermal properties of the material and the optical properties of the material being inspected. The heat source selection is based on portability, power consumption, safety and availability.

The hulls of the boats to be inspected are made of composite sandwich structures of graphite-epoxy face sheets reinforced with aluminum honeycomb. This material is well suited for infrared inspection. A hot air gun was selected as the heat source,

due to the size constraints of working inside the hulls. Two infrared imagers were used. Inframetrics 760 scanner and a Thermacam SC1000. Both of these instruments are capable of video output and image capture.

The type of defects that were expected to be found were: bond line between graphite/epoxy face sheets and honeycomb cores, graphite/epoxy face sheets and Nomex honeycomb cores and graphite/epoxy face sheets and balsa cores. Also, graphite/epoxy face sheets were inspected for delaminations.

3. INSPECTING THE BOATS

Americas Cup boats are designated by their sail number. The two AmericaOne boats are USA49 and USA61. USA 49 was the first boat constructed (Sept 98') and USA 61 followed a few months later (Feb 99'). The technology team that Ford was providing was not in place at this time. Therefore, not enough inspection was done during the construction period. This proved to be a hindrance at a later date. US49 was made to be a heavy weather boat and US61 a light air boat. US49 was sailed during the earlier part of the campaign with US61 being used in the semi finals.

1. USA49

This boat was involved in a collision in the early rounds with Stars and Stripes (Dennis Conner). The rear scoop was struck and removed. This boat was repaired in less than 24 hours and racing again the next day. It was found at a later date that we, in fact, had taken on a lot of water into the aluminum honeycomb as a result of the collision. Infrared inspection was used to map out the water incursion. Holes were drilled and water was allowed to drain. The water needed to be removed in a timely manner due to the salt water' effect on the aluminum honeycomb.

Daily inspections:

The Runner Bulkhead. The bulkhead is rear of the cockpit and forms a vertical wall at the forward end of the scoop. The bulkhead is highly loaded and must withstand the loads introduced from the backstays, which support the mast from the rear of the boat. Failure of this structure could cause major damage to the hull and a possible demasting. Four defects were found in the first inspection made in Auckland New Zealand. They are symmetrically located along the centerline of the boat, and appear to be the result of the fabrication process. These were deemed not serious. This conclusion was drawn due to the near surface location of the voids.

Cockpit/foredeck. This is the area around the front of the cockpit and the foredeck just in front of the cockpit. This area is under a lot of stress due to the location of the mast and the keel. The boat is under stress to "fold in half". Some cracks were found in this area along with water that had seeped in between the deck skin and the composite. The deck skin was ground away and was repaired by inserting a piece of foam and adding four layers of graphite fabric in a wet lay-up patch.

Rudders. This was inspected every couple of races, mainly where the composite was attached to the metal through hull fitting. Not too many failures occur in this area, but a failure here and your race day is over. A few small delaminations were found in non-critical areas.

USA61

This hull was inspected during construction in Costa Mesa California. This provided a good base line for the inspection work that was done in Auckland.

Daily inspections:

The Runner Bulkhead. Some delaminations were found during the fabrication of this boat and were repaired on site. These critical areas were inspected in Auckland on a daily basis and were deemed to be in a sound condition.

Cockpit/Foredeck. Vertical cracks were found in the two for corners of the cockpit. Through further inspection it was determined that these were splits in the deck skin and did not go any further down into the graphite plys.

Rudders. A couple of small delaminations were found near the top of the rudder and were deemed not serious. These were monitored on a daily inspection.

Booms. A section of the boom from USA61 was repaired in Costa Mesa. This patch was about four feet long and the full height of the boom (Approximately 20 inches).

Spinnaker Poles. These were inspected daily due to the abuse they see during racing and practice.

Other forms of NDE were used along with infrared inspection. Most metallic hardware was either x-rayed or dye penetrate was used on site. Some ultra sound was used on solid graphite parts involved with the mast.

4. ILLUSTRATIONS OF FINDINGS

Fig. 1 is a photograph of the port side cockpit on US49. This was originally thought to be a separation between the deck skin and the composite. It was found through infrared inspection that there was a delamination in the composite below the deck skin. Fig. 2 is the corresponding thermogram

Figure 1. Photograph of a defect on the port side cockpit on US49

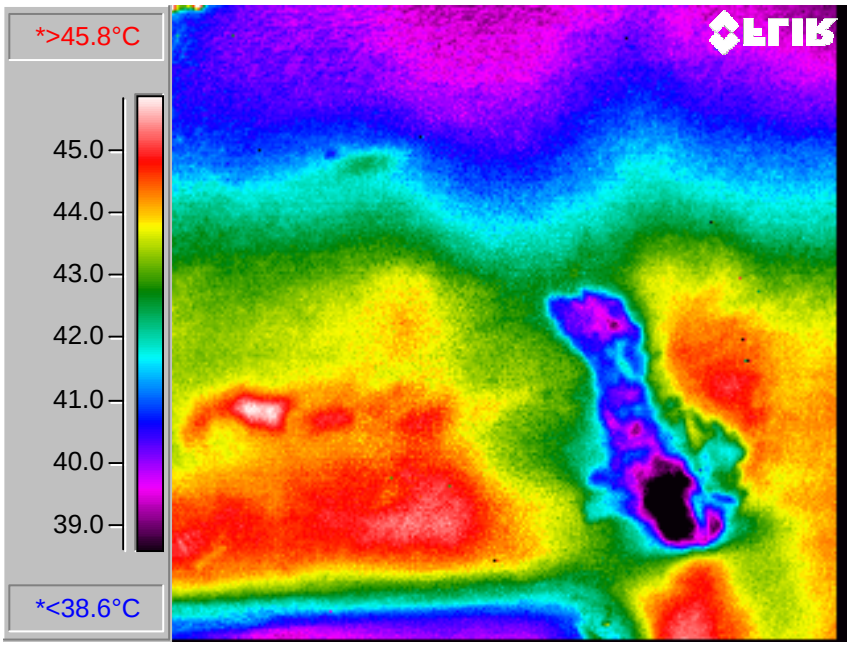

Figure 2. Thermogram of the defect illustrated in figure 1

Fig. 3 is a photograph of a defect on the fore deck of US61. This was a delamination that was found in a critical area. Fig. 4 is a thermogram of the defect.

Figure 3. Photograph of a defect on the foredeck of US61

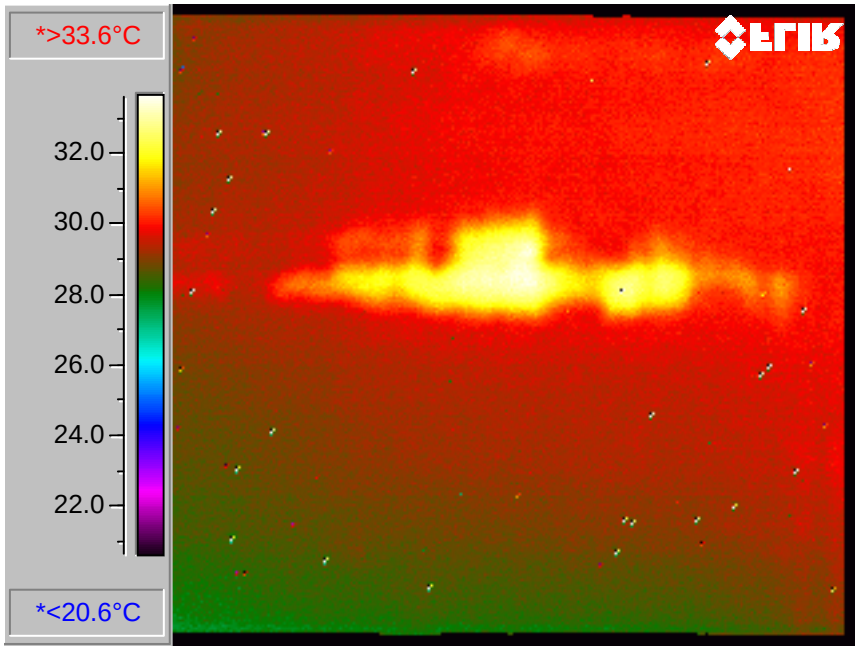

Figure 4. Thermogram of the defect shown in figure 3

5. SUMMARY - LESSONS LEARNED AND RESULTS

- The ability of infrared to find defects in structures of AmericaOne was demonstrated and proved to be a fast and effected method of NDE.
- Other forms of NDE were needed to complete the inspection process.
- A number of defects were found and repaired, thus saving a crisis while sailing.
- The daily inspections monitored any minor disbonds and delaminations. None showed any growth.
- As the next challenge for the cup arrives and Ford becomes involved, we are going to be there from the start. Base line data will be taken as construction of the first boat begins.