PARALLEL THERMAL WAVE IR VIDEO IMAGING OF POLYMER COATINGS AND ADHESIVE BONDS

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INTRODUCTION

Bonding of materials such as metals, plastics, ceramics, alloys, and composites are extremely important in the manufacturing industry. One of the most commonly used bondings is the adhesive bond. In this paper we describe the use of parallel thermal wave IR video imaging[1,2] for the detection of bonding flaws in plastic and composite samples and also for the inspection of polymer coatings on metal. Using both parallel box-car thermal wave imaging[3] and parallel vector lock-in thermal wave imaging,[4] sub-surface defects have been detected in painted metal panels, and in epoxy and vinyl adhesive bondings of nylon and composite samples.

EXPERIMENTAL

The experimental set-up used for the parallel box-car thermal wave imaging was similar to the one used in Ref. 3, with the exception that in this work experiments were carried out both in the reflection and transmission mode. In the reflection mode the imaging is performed on the illuminated side of the sample, whereas, in the transmission mode, the non-illuminated side of the sample is imaged. In the parallel vector lock-in thermal wave imaging the sample excitation mechanism used in this work was rf induction heating. A block diagram of the rf induction heating is shown in Figure 1. One limitation of this sample excitation method is that the sample must be a conductor, as the sample is basically heated by an induced electric current. The principle of rf induction heating is that when a conductor is subjected to an alternating magnetic field a current is induced in the conductor. In our case , the rf signal sent through the coil is modulated, therefore, modulated heating is induced in the sample. The infrared imaging set-up is composed of an infrared camera, an image processor and a color work station for data acquisition. The Sun work station controls both the heating and data acquisition cycles to assure true parallel vector-lock-in detection video detection. The signal from a conventional IR video camera is processed in real time by a video signal processor (DataCube Inc.) which is also controlled by the work station. The lock-in video detection method involves digitization of the incoming analog signal at 10 MHz and then digitally multiplying the video signal with the sine and cosine functions of the phase. The data are accumulated in separate buffers (each 512 x 512 x 16 bits) and after suitable averaging stored in the computer. The averaging enhances the signal-to-noise ratio. A WSU developed image display tool is used to enhance the display and produce hard copy of the image. A block diagram of the parallel box-car thermal wave IR video imaging in the transmission mode is shown Figure 2. In

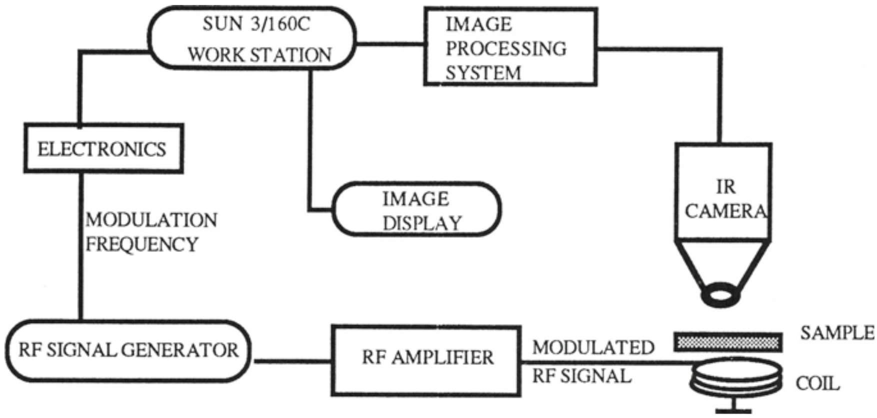

Figure 1. A block diagram of RF induction heating method for thermal wave IR imaging.

this setup a flash lamp with two 250 watts halogen lamps or a industrial grade heat gun is used as the heat source. In the transmission mode heat is applied uniformly to the back surface of the sample. Figure 3 describes the the data acquisition procedure for this method. After the sample is illuminated with the flash, the IR camera records the increased IR radiation from the sample surface. The flash and the frame-grabbing timing are selected so that the frame-grabbing corresponds to the maximum of the surface temperature versus time curve for the particular sample under investigation. This results in maximum contrast between the defect region and the background. The image is averaged over multiple frames and the process is repeated for several (typically 16) flashes and the resulting images are again averaged, thereby, enhancing the signal-to-noise ratio. The resulting images are transferred to the color work station and displayed using a custom colormap.

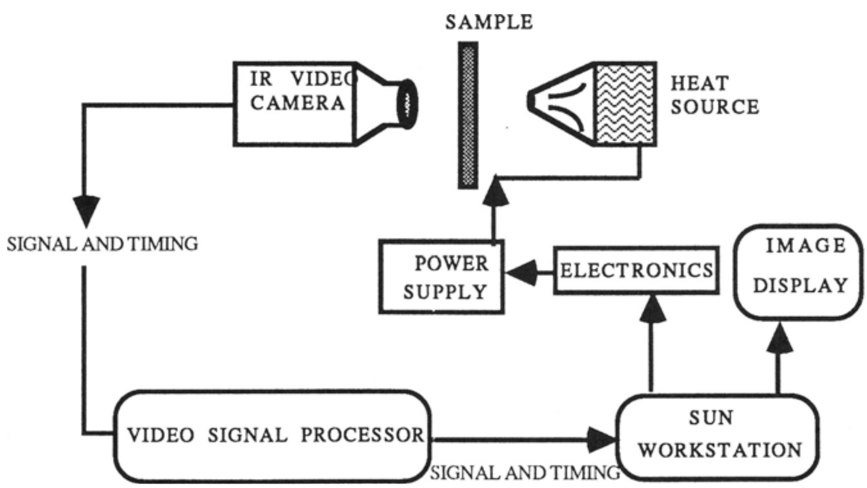

Figure 2. A block diagram of the parallel box-car thermal wave IR video imaging in the transmission mode.

RESULTS AND DISCUSSION

A schematic diagram of the samples used in this study are shown in Figure 4. Primarily two types of samples were (a) adhesively bonded coupons and (b) paint on metal substrate. For adhesive bonding two kinds of adhesives were used, vinyl and epoxy. Samples were prepared with two slabs (4 inches x 1 inch in dimension and 1-2 mm in thickness) of similar material such as nylon or composite, bonded together with epoxy or vinyl with some flaw in the adhesive region.The composite material was thermoset sheet molding compound with glass fibre reinforcing. The flaws were introduced in the adhesive bonds in two ways: to create a bond with a void, a hole was punched in the epoxy tape adhesive prior to bonding, to create a region of poor adhesion, the adherend was treated locally with a silicone-based mold release agent.

For the painted panels, one sample was immeresed in 5% ag. Nacl for 24 hours and was then allowed to age several weeks at ambient temperature and humidity. A second sample, not exposed to Nacl, was used as a control. Figure 5a shows an thermal wave infrared video image of two painted panels side by side, with the untreated sample on the right and the salt treated sample on the left. The left sample shows sub-surface features due to corrosion developing at the paint-steel interface whereas the untreated sample on the right is much more homogeneous and shows no sub-surface features. The paint samples were studied both by the flash method and the RF induction heating method. A video thermal wave image using rf induced heating is shown in Figure 5b. Both the methods were equally effective in detecting sub-surface features although the rf image has better contrast.

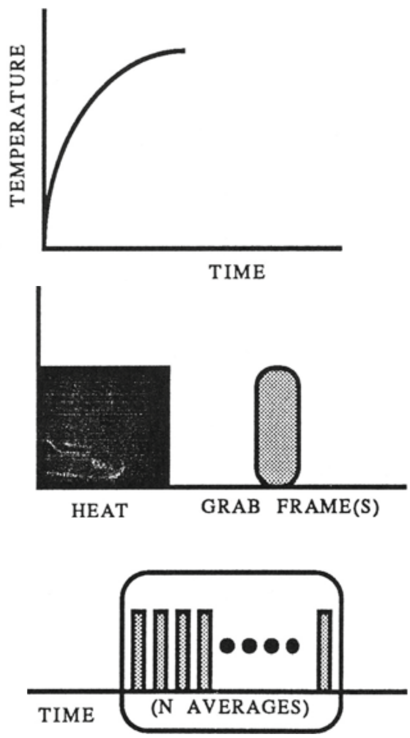

Figure 3. Frame grabbing procedure for parallel box-car thermal wave imaging.

For the nylon and composite samples the parallel box-car thermal wave imaging was used. In Figures 6a and 6b, thermal wave infrared video images of two composite samples are shown. The sample in Figure 6a was bonded with epoxy tape adhesive on a small silicone spot, and the sample in Figure 6b was bonded with vinyl adhesive on a small silicone spot. The bright circular region in the images represent the flaws. Figures 7a and 7b show images of adhesively bonded nylon samples. Figure 7a is an image of edge beads of vinyl adhesive on nylon substrates and Figure 7b is an image of epoxy tape adhesive on nylon with a void in the adhesive.

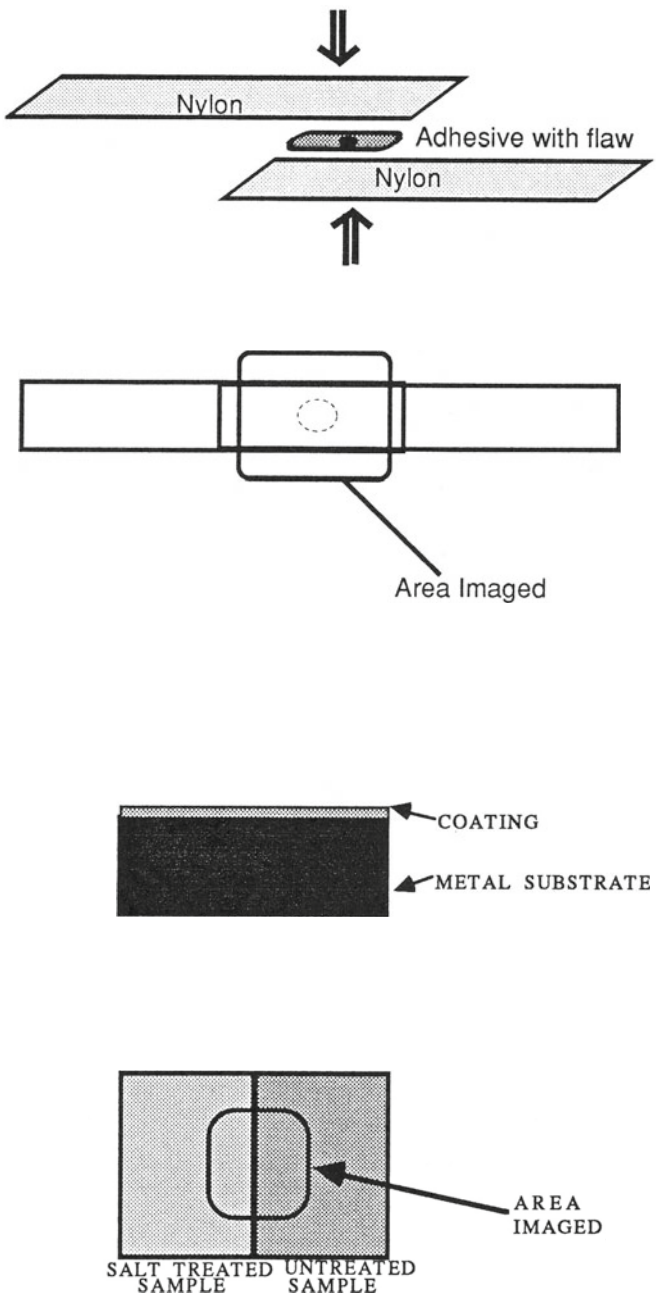

Figure 4. Schematic diagram of the nylon or composite and paint panel samples.

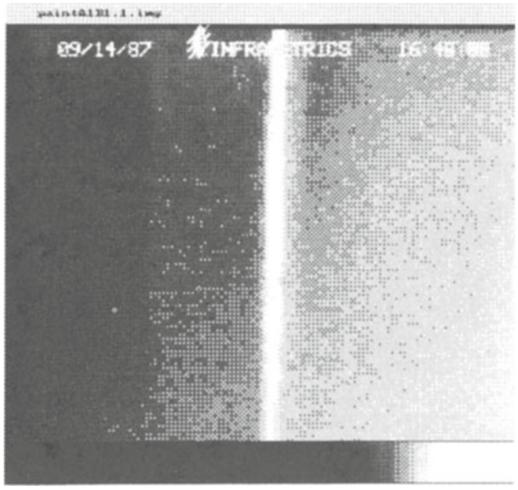

Figure 5a. Thermal wave video image of paint panels. Salt treated panel on left and untreated panel on right.

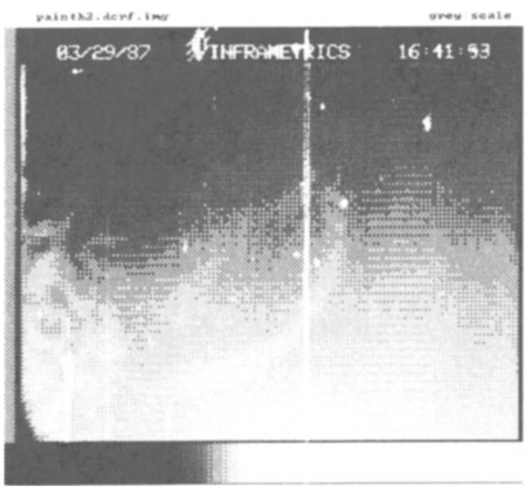

Figure 5b. Thermal wave video image of paint panel using rf induction heating.

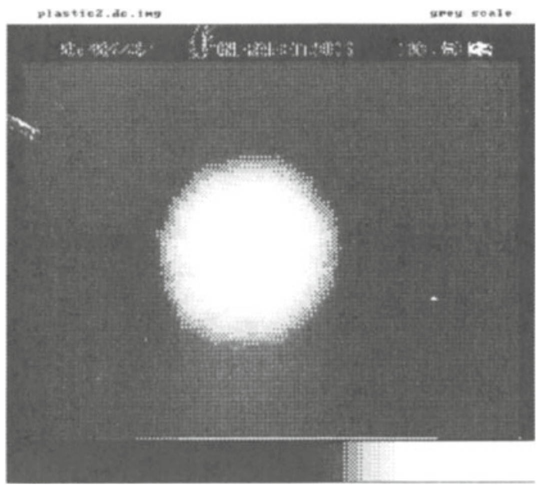

Figure 6a. Thermal wave video image of a composite sample with epoxy tape adhesive on a small silicone spot.

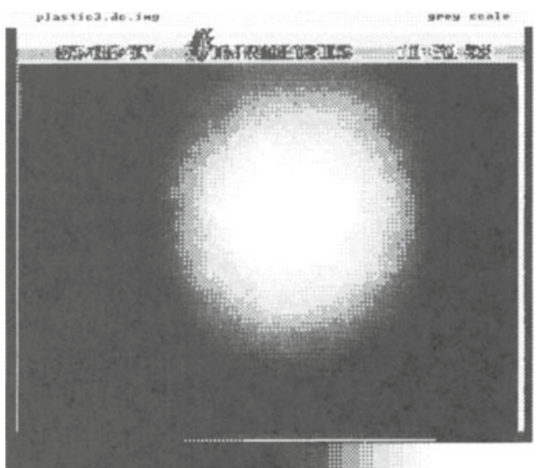

Figure 6b. Thermal wave video image of a composite sample with vinyl adhesive on a small silicone spot.

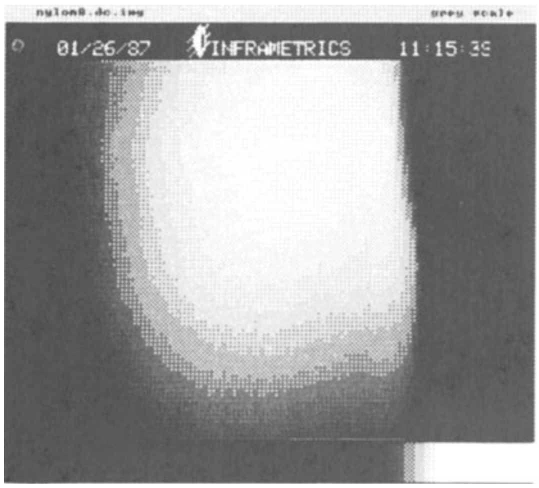

Figure 7a. Thermal wave video images of edge beads of vinyl adhesive on nylon substrates.

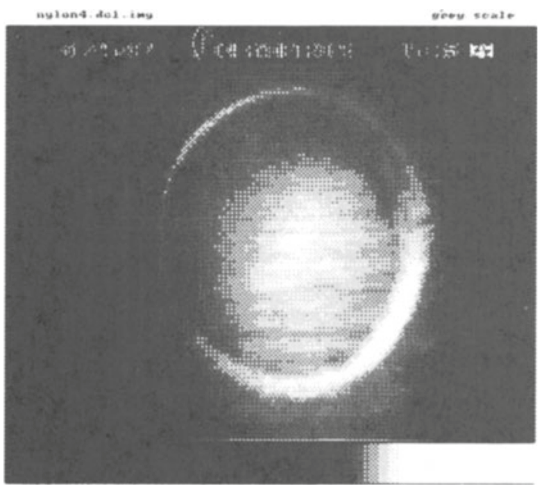

Figure 7b. Thermal wave video images of edge beads of epoxy tape adhesive on nylon with a void in the adhesive.

CONCLUSION

In this work we have used parallel thermal wave IR video imaging to study adhesive bonding in nylon and composite samples and also to image sub-surface features in salt treated paint panels. In addition to the flash method and ac joule heating method of parallel thermal wave IR video imaging as reported in references 3 and 4 we have added the rf induction heating to the parallel thermal wave IR video imaging method. The techniques described in this work can be used as a fast and effective method in detecting subsurface features and evaluating adhesive bonds.

ACKNOWLEDGEMENTS

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3. P.K. Kuo, T. Ahmed, L.D. Favro, H.J. Jin, R.L. Thomas, J. Jaarinen and J. Hartikainen, ibid.
4. T. Ahmed, P.K. Kuo, L.D. Favro, H.J. Jin and R. L. Thomas, ibid.