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STUDYING THE EFFECT OF PRIMER COATINGS AND SURFACE ACTIVATIONS ON ADHESION IN ADHESIVELY BONDED PLASTIC PLATES USING ULTRASONIC TESTING

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ABSTRACT

Bonded structures are found in several applications such as automotive, aviation and transportation industries. The quality of adhesive bond is very important for structural integrity. Over the years, there have been several attempts at understanding bond integrity using Nondestructive techniques. The present work investigates the bond quality and integrity when two plastic plates are bonded by an epoxy based adhesive. Specifically, the work focuses on the influence or effect of surface treatment on the adhesion quality. This includes effect of spray-on primer, and surface activations which are expected to improve the bond quality. Surface activation specifically is to help the plastic receive the primer. A comparative study utilizing contact based ultrasonic testing methods is conducted to Nondestructively study the same.

For this study, the Reflection Coefficient Theory (RCT) was used to characterize the bond between the plastic and adhesive. The changes in the reflection coefficients due to the effect of surface treatments were studied. This enabled the establishment of a range of acceptable reflection coefficient values that was used to characterize bonding quality.

Keywords: Adhesion, Reinforced Plastics, Ultrasonic Testing, primer, surface treatment

1. INTRODUCTION

It has been shown in the previous studies conducted that bonding strength can be improved by altering the surface preparation by surface treatments such as primer coatings, etching, laser treatment and plasma treatment [1, 2, 3]. Many adhesives generally possess poor wetting characteristics and due to their high viscosity during the bonding process, primers are used to pretreat high surface energy substrates prior to adhesion bonding to improve the performance of the bonded component [4]. Furthermore, primers offer improvements to environmental resistance and thermal stability, thereby establishing strong moisture resistant interfacial bonds and protecting surface from hydration and corrosion [5]. In this study we explore the effect of a spray-on primer coating.

Surface Activation is generally used to clean and activate the surface of the adherend to improve adhesion with the adhesive. It also rids the adherend of any surface contamination. It is highly used in the industry due to its flexibility and lower cost, and is more environment friendly compared to other methods [1]. There are several studies which explore the effect of these surface treatments, but were destructive in nature. [6]. This has created the need to determine the adhesion quality and bond integrity using non-destructive methods to incorporate it in the global industry as a whole.

2. MATERIALS AND METHODS

2.1 Materials

The sample consists of the two plastic plates bonded by an epoxy based adhesive. Figure 1 shows the general cross section of a sample. The plastic plates used in this study are olefin based reinforced plastics with different types of reinforcements

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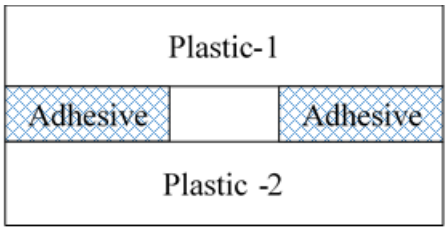

FIGURE 1: Cross section of a typical sample.

Table 1 lists the different types of samples that were used in this study. The samples that were surface activated and primer coated are referred to as the reference samples as they have been reported to have better adhesion characteristics [6]. Industrial applications often utilize painted plastics and hence few samples with a layer of paint on one of the plastic plates have been included in the study. Individual plastic plates were also studied to simulate the no bonding scenario.

TABLE 1: Table of different type of samples used in this study

Code	Type of Sample
TP-U	Unpainted Plastic
TP-B	Plastic+Paint-1
TP-G	Plastic+Paint-2
TP-UPP	Unpainted:Primer+Surface Activation on Plastic
TP-UPr	Unpainted: Primer only on Plastic
TP-UPl	Unpainted: Surface Activation only on Plastic
TP-PB	Painted: No Primer/No Surface Activation on Plastic

2.2 Method

Adhesion is an interfacial property [7]. The need to characterize adhesion requires a parameter that varies for different interfacial conditions. Reflection coefficient perfectly encapsulates this as it gives a measure of the acoustical impedance difference between the two surfaces on either side of the interface. A good bond would correspond to a very small reflection coefficient as there is maximum energy transfer, and a bad bond would correspond to a relatively higher reflection coefficient. Each of the cases to be studied would result in different interfacial characteristics which can be quantitatively measured in terms of the reflection coefficients to evaluate the bond integrity. It has been shown that, knowing the properties of the constituent layers individually, the reflection coefficients can be directly related to the ratio of the amplitudes of the first interface echo (B1) to the front wall echo (F) i.e B1/F [8]. Figure (2) explains the concerned reflected echoes. This relation utilized to experimentally evaluate the desired situations in this study. We further discuss the results of this study in terms of the ratios as they have lesser computationally complexity.

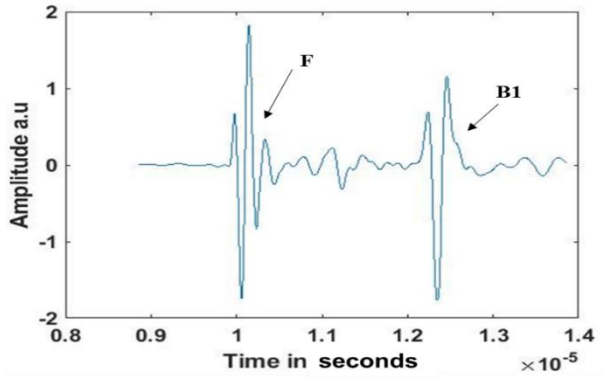

FIGURE 2: A-scan of a typical Contact UT measurement highlighting the front-wall (F) and interface (B1) echoes for an individual plastic plate.

The experimental procedure is as follows:

1. Establish B1/F ratios i.e reflection coefficient for the 5 reference samples. The experiments were conducted over 5 samples to get a good statistical average of the values.
2. Establish the B1/F ratio for individual plastic i.e., this constitutes the no bonding scenario.
3. Establish ratios for all situations i.e., only primer, only surface activation, surface activation and primer and no primer nor any surface activation.
4. Create a range with the lower limit arising from reference sample and upper bound from the individual plastic.

The experiments were done using the contact based pulse echo method with 25 tests per sample to establish a good statistical average of the ratio for a sample. Since, there is a requirement to characterize the entire sample and not just discrete points, an immersion based ultrasonic C-scan is carried out for the all the samples.

The experimental setup for contact Ultrasonic Testing consisted of a Panametrics pulser/receiver, a digital oscilloscope, a computer to process data and 5 MHz delay line longitudinal probe. For the immersion testing, C-scans were obtained using the UTWin software and a 5 MHz planar immersion transducer was used.

3. RESULTS AND DISCUSSION

In order to create a range of ratios that relate to the Rc's, the lower and upper limit of the range has to be established. The upper limit of the range pertains to the case with no adhesion or disbond. This would be equivalent to the B1/F ratio of individual plastic plate (no adhesive cured). Figure 3 shows the scatter plot for individual plastic plates with different surface conditions.

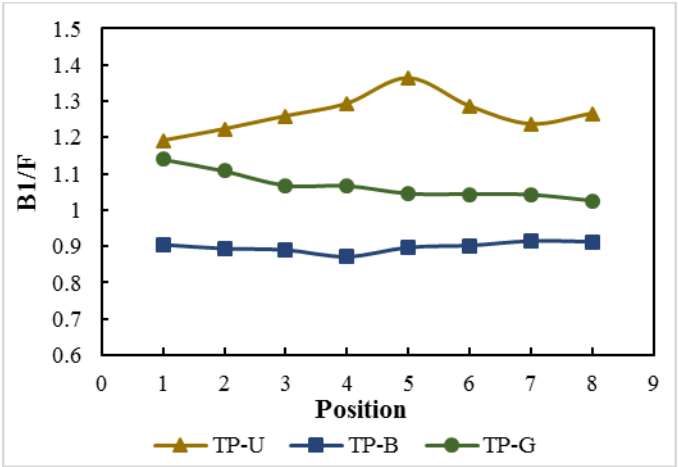

FIGURE 3: Scatter plot for the variation of B1/F ratios spatially for individual plastic plate. The statistical average of all measurements for that sample are indicated

From figure 3, we can see the ratios vary depending on the presence or absence of paint on the plastic. It is also seen that unpainted plastic plate has a much higher ratio. The reason for this might be because of the different acoustical impedances of the paint compared to the plastic itself.

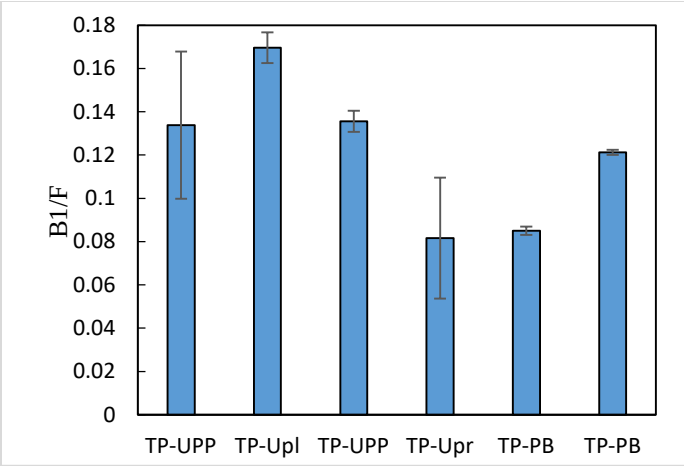

FIGURE 4: Statistical average of all measurements for the samples described in section 2.1

Figure 4 meanwhile gives the statistical averages of all measurements for each type of sample.

4. CONCLUSION

The ratios show a variation ranging from 3% to 53% spatially across different samples and this might be due to surface defects during the manufacturing process. The variability across the samples are mitigated by taking multiple measurements across the sample. Also, the preliminary results show that the ratios vary considerably for different conditions. It is seen that ratios for the unpainted and non-surface activated scenario has a ratio lesser than that of the reference sample which is against the expected outcome. This might be due to the difference in the stiffness's for the surface treated plastic and adhesive near the bond-line. In summary, spray on primer coatings and surface activations is expected to improve bonding. Although preliminary results show that absence of primer coatings or surface activations does weaken the integrity of the bond, further studies on more samples would need to be done to completely validate and verify the same.

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