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DOI: http://dx.doi.org/10.26628/wtr.v90i12.983

PRZEGLĄD SPAWALNICTWA Welding TECHNOLOGY REVIEW

Evaluation of adhesive joint coating and substrate with ultrasound method

Abstract

Adhesive joints are widely used in the construction of modern automotive vehicles. These are not only adhesive joints, but also, connection between coating and steel substrate. The paper presents the results of tests of adhesion of the putty coating to the steel substrate using the ultrasonic method. A reflection coefficient |r| of longitudinal wave was used as a measure of adhesion in the area of the adhesive joint. The tests were performed for joints of car body sheet and a putty coating. In order to obtain different quality adhesive joints, the surface preparation of the steel sample was varied. The obtained results show that it is possible to estimate the adhesion of the adhesive coating to the steel substrate based on ultrasonic measurements. The smaller is the value of the reflection coefficient |r| the greater the mechanical adhesion of the coating to the substrate.

Keywords:
ultrasonic testing;
automotive vehicles;
car body;
adhesion;
coating

Introduction

Adhesive coatings are widely used in the construction of modern machines, including motor vehicles. Both protective and decorative coatings are used. Preventive or regenerative coatings that are applied to obtain or reproduce specific properties can also be found. In the construction of modern vehicles, adhesive coatings are encountered at the stage of their manufacture – paint coatings – as well as renovations or repairs. The main factor affecting the durability of connection of the coating with the substrate is the adhesion phenomenon [1]. It is a phenomenon of attracting the particles of two bodies whose outer layers have been joined together. Adhesion, along with the thickness and tightness of the coating, are the basic features that affect the durability of the connection and ensure the fulfilment of certain required functions [2]. Adhesion of the coating to the substrate can be determined by destructive methods (e.g. the scratch method) and non-destructive methods (e.g. the ultrasound method) [3÷7]. In the case of ultrasonic tests, a module of reflection coefficient |r| of the longitudinal wave in the area of the adhesive joint is used as a non-destructive measure of adhesion.

The main purpose of the research presented in this article is to assess the adhesion of the coating to the substrate for various surface preparation of the car body sheet, based on changes in the reflection coefficient |r| module.

Conduct of the study

The tests were carried out on samples prepared from car body sheet, on which a putty coating was applied, which is very often used in the repair of motor vehicle body. Ultrasonic testing was carried out at designated points, both before and after applying the coating to the substrate. The recorded values of the height of the first ultrasonic wave in the area of the connection allowed to estimate the reflection coefficient |r|. A view of a sample with a putty coating applied is shown in Figure 1.

The substrate for the applied coating was prepared in three different ways using abrasive paper with P40, P120 and P240 designations. It should be noted that the manufacturer of the putty coating recommends the use of P80-P120 abrasive paper and the manual surface treatment of the substrate. The use of different abrasive papers has led to differentiated surface preparation, which should translate into different values of the reflection coefficient |r| and adhesion of the coating to the substrate. In each area, 12 measurement points were applied, thanks to which it was possible to assess the adhesion distribution in a given area. Thanks to the determination of the coefficient of variation, it was determined that 10 ultrasound measurements should be made at one measurement point. The thickness of the putty, which was approx. 4 mm, did not have a significant impact

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on the results of ultrasonic measurements. Ultrasonic high-frequency wave (20 MHz), due to its properties, will not penetrate through the putty layer, but will bounce off from the interface between the coating and the substrate, and some of the wave energy that penetrates into the coating material will be damped. Part of the ultrasonic wave energy that will return to the transducer provides information on the quality of the adhesive joint. The research used a modern ultrasonic flaw detector USM35XS and a transducer that allows point measurements.

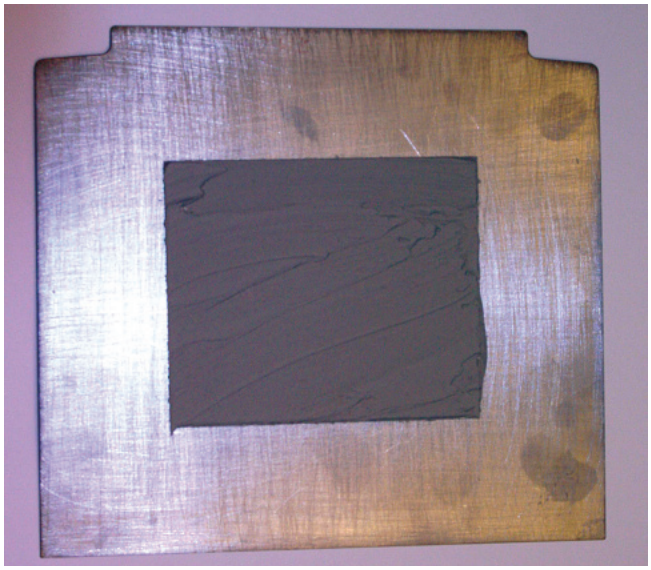

Fig. 1. View of the sample with the car putty coating

On the basis of ultrasonic measurements (the height of the first wave impulse), the reflection coefficient was determined:

$$|r| = 10^{\frac{-\Delta W}{20}} \quad (1)$$

$$\Delta W = 20 \cdot \log\frac{H_1}{h_1} \quad (2)$$

where:

$|r|$ – reflection coefficient;

ΔW – drop in border impulses in dB;

H_1 – height of the first (highest) pulse during the measurement in the first stage;

h_1 – height of the first pulse (the highest) during the measurement in the second stage.

The exemplary results depicted on the flaw detector screen during ultrasonic tests before and after the application of the coating are shown in Figures 2 and 3.

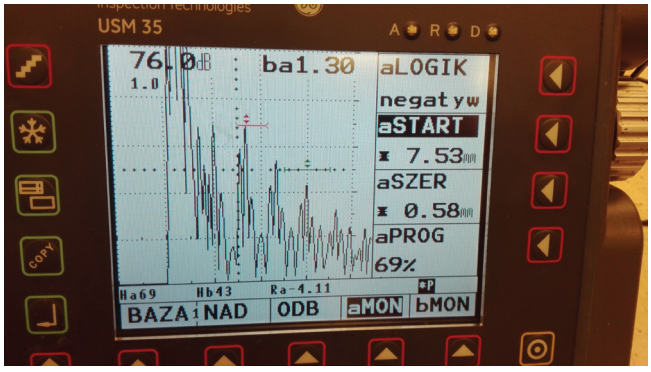

Fig. 2. The view of ultrasonic flaw detector screen before the car putty coating was applied

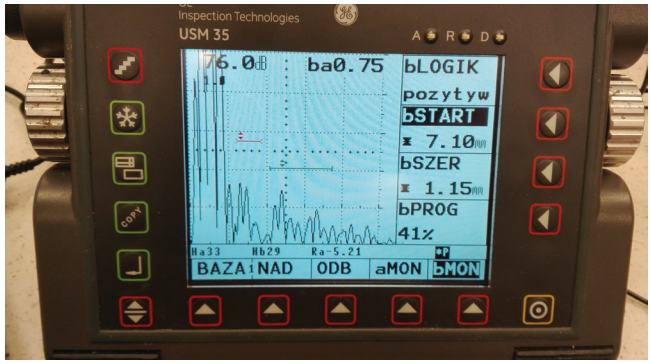

Fig. 3. The view of ultrasonic flaw detector screen after the car putty coating was applied

Research results

The reflection coefficient of longitudinal wave takes values from 0 to 1. The value 0 means the best adhesion of the coating to the substrate, in real conditions unachievable. The value 1 is equal to the total lack of adhesion of the coating to the substrate. From the above it follows that the lower is the value of the reflection coefficient |r|, the higher the value of mechanical adhesion. The obtained values of the reflection coefficient for three areas are shown in Figures 4, 5 and 6.

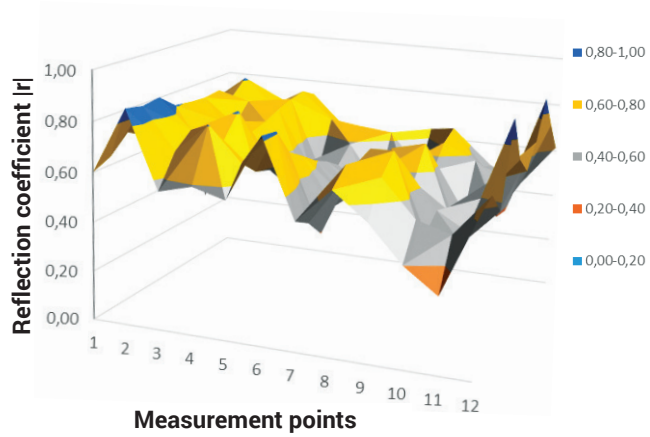

Fig. 4. The values of the reflection coefficient for the surface prepared with paper P 40

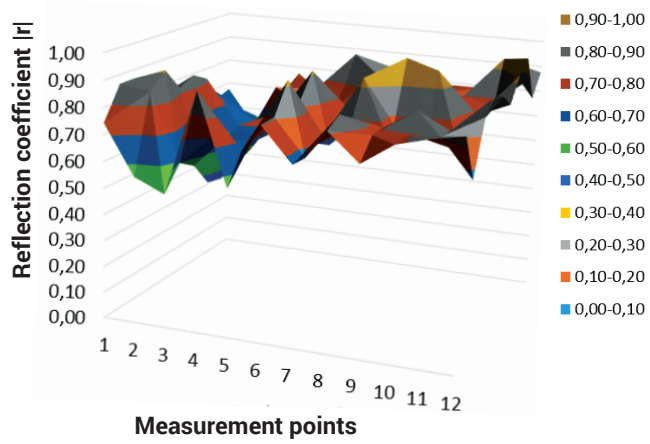

Fig. 5. The values of the reflection coefficient for the surface prepared with paper P 120

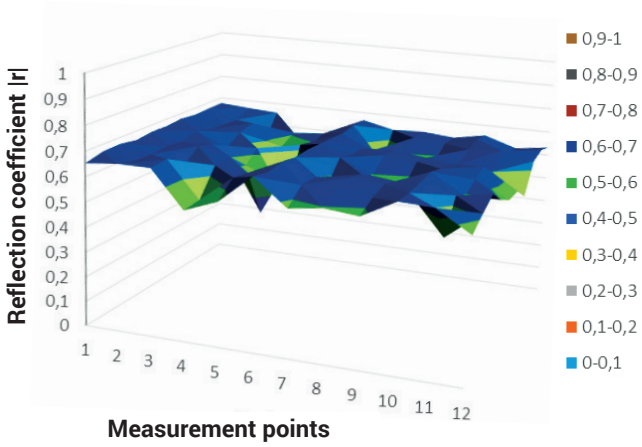

Fig. 6. The values of the reflection coefficient for the surface prepared with paper P 240

Based on the ultrasonic measurements made, it should be noted that the most even values distribution of the reflection coefficient |r| were obtained for the surface prepared with P240 paper. The module values for this area are in the range of 0.5÷0.7. In the case of the other two samples, a larger dispersion of the module's values is visible. This may be due to the process of shaping of the surface, which consisted of manual sanding of the car body sheet.

Summary

Taking into account the research and the conclusions obtained, the following statements can be drawn:

- Ultrasonic method allows to estimate the adhesion of the adhesive coating to the steel substrate, based on the value of the reflection coefficient |r| of longitudinal wave in the area of the adhesive joint.
- The obtained values of the reflection coefficient |r| for samples prepared using various abrasive papers range from 0.2 to 0.9, with the dominant values of the module at the level of 0.5÷0.7.
- Manual sanding of the substrate surface with P40 and P120 paper causes that for the applied putty coating on the car body sheet, an even distribution of the reflection coefficient was not obtained.

In the next step of the research, the results of ultrasonic tests and the values of the reflection coefficient should be linked with the mechanical adhesion of the coating to the steel substrate.

Badania zostały wykonane w ramach działalności statutowej WMRiT Politechniki Poznańskiej, projekt DSMK/3530

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