MONITORING OF THE PROCESS OF CONSTITUTION OF A PUTTY COATING ON A VEHICLE BODY WITH THE USE OF AN ULTRASONIC METHOD

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Summary

Bonds between surfaces and coatings are widely used in the construction of machines and vehicles. Therefore, it is important to prepare a non-destructive method that will allow monitoring of the process of production of elements containing such bonds. The paper contains a description of the testing procedure, materials and devices used for the realization of the experiment. As a result of the experiment, changes in the longitudinal wave reflection coefficient for three areas of bonding were determined, each of which had the surface prepared in a different way. It has been found that the ultrasonic method utilizing a longitudinal wave allows monitoring of the process of constitution of the bond between the putty coating and the body surface and enables to determine the curing time of adhesive connection and allows detecting defective adhesive bonds and eliminating them in the stage of production.

Keywords: ultrasound, condition monitoring, coating, adhesion

MONITOROWANIE PROCESU KONSTYTUOWANIA POŁĄCZENIA POWŁOKI SZPACHLÓWKOWEJ Z KAROSERIĄ SAMOCHODU METODĄ ULTRADŹWIĘKOWĄ

Streszczenie

Połączenia powłoki z podłożem są powszechnie stosowane w budowie maszyn i pojazdów. W związku z tym, ważne jest, aby opracować nieniszczącą metodę, która pozwoli na monitorowanie procesu wytwarzania elementów zawierających takie połączenia. Artykuł zawiera opis procedur, materiałów i urządzeń wykorzystywanych do realizacji eksperymentu. W wyniku zrealizowanych badań, wyznaczono zmiany modułu ciśnieniowego współczynnika odbicia fali podłużnej dla trzech obszarów nakładania powłoki, z których powierzchnie przygotowano w różny sposób. Stwierdzono, że ultradźwiękowa fala podłużna pozwala na monitorowanie procesu konstytuowania połączenia pomiędzy warstwą szpachlówki i karoserią pojazdu oraz pozwala na określenie czasu utwardzania i wiązania powłoki z podłożem, a także umożliwia wykrywania wadliwych połączeń adhezyjnych i ich eliminacje w fazie produkcji.

Słowa kluczowe: ultradźwięki, diagnostyka, powłoka, adhezja

1. INTRODUCTION

The practice of use of a putty coating for repairs of steel vehicle bodies forces an inspection of the adhesive bond between the putty coating and the body. The inspection is justified by the deviations from the required technological conditions of putty coating. A weak bond between the putty and the metal sheet affects the quality of the repair and the durability of the putty and the automotive lacquer under actual conditions of use determined by dynamic deformation.

The potential inspection methods of the adhesive bonds include vibration, radiographic, thermographic and ultrasonic methods [1–13]. Workshop practice requires simple and easily construed process and the ultrasonic method with its use of a transducer generating longitudinal waves, complies with these requirements. It allows an evaluation of the quality of the bond, discontinuity at the bond boundary and the coating thickness.

The present research relating to adhesive joints is usually conducted with respect to the degradation of these bonds [14–17]. Attention should also be devoted to the period of constitution of the joint, which has not yet been fully studied and the time of constitution under actual conditions, which may differ from the period of time as declared by the manufacturers. Apart from the cognitive aspect, a practical aspect of the research is also important and it allows a preparation of a method of inspection of the joint between the putty and the vehicle body at the stage of constitution of the bond.

The purpose of this work was to determine, by way of experiments, the duration of the period of constitution of an adhesive bond between the putty and the body sheet on the basis of ultrasound parameters representative of the bond quality. The parameter was a longitudinal wave reflection coefficient at the boundary of the bond between the putty and the surface. The reflection coefficient was determined based on the gain of the impulse of the longitudinal wave reflected from the joint boundary as recorded in the screen of an ultrasonic flaw detector.

2. MATERIALS AND METHOD

The research was conducted on a universal putty coating manufactured by Novol. It is a relatively hard putty of low flexibility. The manufacturer does not recommend it for applications on large surfaces [18]. The tests were conducted on a real object, i.e. a vehicle door (Fig. 1).

The period of constitution and quality of the bond (putty - body sheet) depends on the method of preparation of the surface, i.e. the body sheet. Before application of the putty coating, the surface of the tested object was cleaned of the lacquer with the use of 80-grit sandpaper and an eccentric sander. The surface was then cleaned of other contaminations in accordance with the recommendations made by the putty manufacturer.

Fig. 1. The tested object – a vehicle door disassembled from the vehicle, with the coating application area marked

The tests provided for three stages of surface preparation. One part of the surface was prepared in accordance with the recommendations of the putty manufacturer (sand-blasting and degreasing) and the other was prepared against the recommendations. In the first area the authors simulated that the surface had not been cleaned of greasy substances and in the second area – that rust had not been removed from the tested surface.

The prepared surface of the object tested with the use of the three above-mentioned methods of preparation of surface has been presented in Fig. 2.

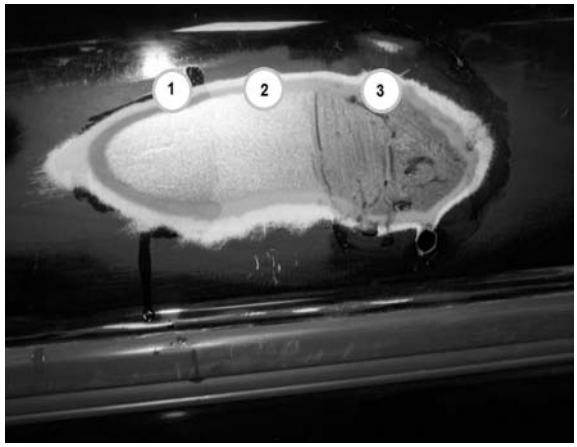

Fig. 2. A fragment of the vehicle door as the tested object – surfaces prepared for application of the putty coating: 1 – non-degreased surface, 2 – surface prepared in accordance with the manufacturer's recommendations, 3 – corroded surface

The tests used an transducer of the frequency of 20 MHz with a water delay generating an ultrasonic wave on the side of the body sheet. The tests also used USLT 2000 flaw detection device manufactured by Krautkramer.

3. EXPERIMENTAL STUDY

The methodology of the tests includes the following activities:

- fixing of the ultrasonic transducer to the body sheet,
- recording of the gain of the ultrasonic wave impulse before applying the coating,
- application of the putty coating onto the body sheet in accordance with the manufacturer's recommendations,
- recording of the gain of the ultrasonic wave impulse after applying the coating,
- recording of the gain of the ultrasonic wave impulse and calculation of the reflection coefficient during the test,
- determination of the course of the reflection coefficient during the period of constitution of the joint.

The transducer with water delay was fixed to the inner side of the tested element (door) through a dedicated handle. The handle was fixed to the body sheet by neodymium magnets. The test system has been presented in Fig. 3.

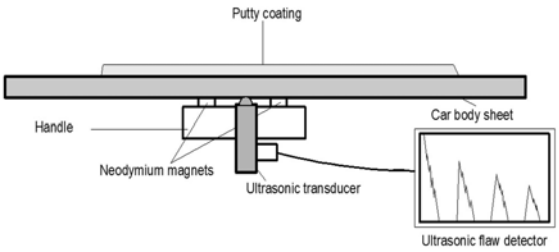

Fig. 3. A diagram showing the fixing of the transducer when monitoring the process of constitution of the putty - steel surface bond

Further gain of the ultrasonic wave impulse were recorded for constant height of the first echo of the multiple echoes sequence on the screen of ultrasonic flow detector – H. The gain was recorded continuously every 10 seconds. An example of the screenshot of the flaw detection device during the tests has been shown in Fig. 4.

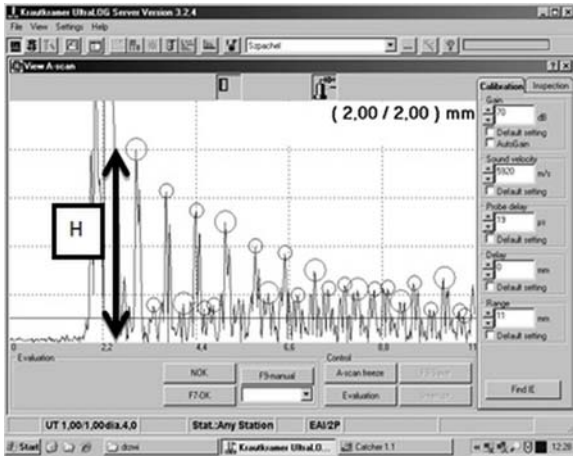

Fig. 4. A screenshot of the flaw detector during determination of the gain of the longitudinal wave impulse

Further, the values were determined of the reflection coefficient – a parameter that is the measure of adherence of the coating to the surface and, consequently, the quality of the adhesive bond. The method of testing was identical for each of the 3 areas of the joint between the putty and the vehicle door surface.

4. RESULTS AND DISCUSSION

The changes of the reflection coefficient of longitudinal wave obtained during the tests have been presented in diagrams (Fig. 5–7).

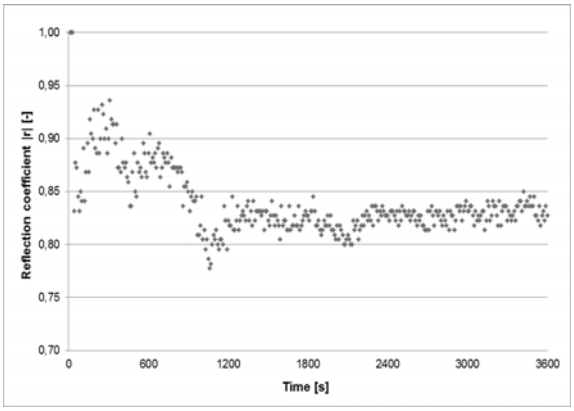

Fig. 5. Changes in the pressure module of the reflection coefficient during constituting of the bond – a sample of the surface prepared in accordance with the manufacturer's recommendations

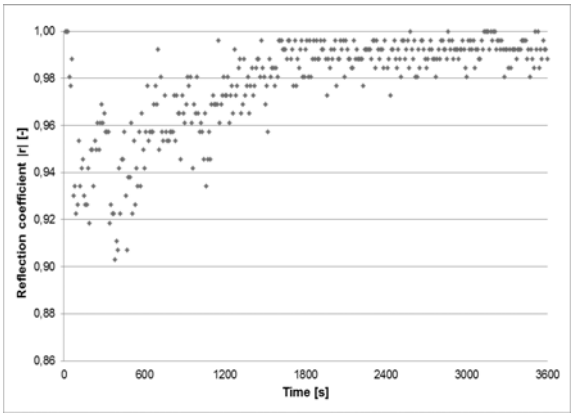

Fig. 6. Changes in the pressure module of the reflection coefficient during constituting of the bond – a sample of a non-degreased surface

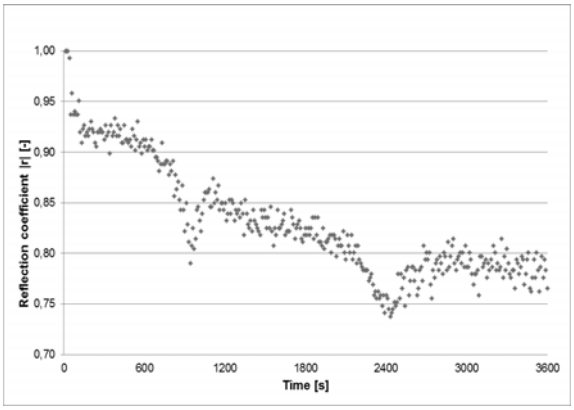

Fig. 7. Changes in the pressure module of the reflection coefficient during constituting of the bond – a sample of a corroded surface

When analyzing the course of the reflection coefficient, as determined during the constitution process, it should be stated that the greatest changes during the experiment occurred for the area with the corroded surface and the smallest changes were found for the non-degreased surface. In the case of

the non-degreased surface, the quality of the bond was the worst. It was confirmed by the values of the reflection coefficient that, upon elapse of approximately 1800 seconds from the commencement of the experiment, ranged between 0.98 and 1.00. The value of 1.00 corresponds to total lack of adherence of the coating to the surface and, therefore, the lower the reflection coefficient value, the better the joint of the coating with body surface.

For the area prepared in accordance with the recommendations made by the manufacturer significant changes in the parameters could be noticed after approximately 25 minutes from the commencement of the tests. The result confirms the manufacturer's data, according to which the hardening and the bonding of the coating with the surface occur in the temperature of 20ºC in the time of 20-30 minutes. The determined value of the pressure module of the reflection coefficient ranges between 0.80 and 0.85.

For the last area with the artificially corroded surface, the value of the pressure module of the reflection coefficient varied throughout the entire period of monitoring. The coefficient value decreases from 1.00 to approximately 0.80.

In the case of the surface prepared in accordance with the manufacturer's recommendations – rough and degreased surface – the decrease in the reflection coefficient value is insignificant. From the value equaling to 1 it decreased to approximately 0.8 (Fig. 5). The high value of the reflection coefficient denotes an absence of a "leakage" of an ultrasonic wave to the unhardened coating. As the coating gets hardened, the penetration of the wave is even greater, which denotes a better bond of the adhesive coating with the surface and easier penetration of the ultrasonic wave through the adhesive joint boundaries.

In the case when the surface is not degreased, an intermediate layer of oil facilitates the flow of the wave from the surface to the freshly applied and unhardened coating. As the coating hardens the oil layer separates it from the surface. This means that the values of the pressure module of the reflection coefficient equal approximately 1, which corresponds to a hardening of the coating and a weak quality of the bond between the coating and the surface.

5. CONCLUSION AND PROSPECTS

On the basis of the performed experiment the following conclusions can be drawn:

- in the case of the surface prepared in accordance with the manufacturer's recommendations, the changes of the reflection coefficient initiated approximately in the middle of the experiment, which can be confirmed by the time of bonding of the coating with the surface as specified by the putty manufacturer,
- changes in the value of the reflection coefficient during the process of constitution of the adhesive connection can be a proof of the process of bonding of the coating and the surface at the boundary of the adhesive joint,
- the ultrasonic method allows monitoring of the process of constitution of the bond such as putty coating and steel surface using ultrasonic wave and the obtained values of the longitudinal wave reflection coefficient can be a proof of the quality of the adhesive bond during its constitution.

In the future, a relation between the values of the reflection coefficient in a given area and the force necessary to detach the coating (and other adhesive coatings) from the surface should be determined.

REFERENCES

[1] Adams R.D., Drinkwater B.W., *Nondestructive testing of adhesively-bonded joints.* NDT&E International. Vol. 30, pp. 93–98, 1997.

[2] Munns I.J., Georgiou G.A., *Non-destructive testing methods for adhesively bonded joint inspection-a review*. Insight. Vol. 37 (12), pp. 941–952, 1995.

[3] Pye C.J., Adams R.D., *Heat emission from damaged composite materials and its use in nondestructive testing.* Journal of Physic. Vol.14, pp. 927–941, 1981.

[4] Baldan A., *Review Adhesively-bonded joints in metallic alloys, polymers and composite materials: Mechanical and environmental durability performance.* Journal of Materials Science. Vol. 34, pp.4729–4797, 2004.

[5] Dixon S., Edwards C., Palmer S.B., Reed J., *Considerations for the Ultrasonic Inspection of Metal-Adhesive Bonds Using EMATs.* Journal of Nondestructive Evaluation. Vol. 19(3), pp. 95–103, 2000.

[6] Hellera K., Jacobsa L.J., Qub J., *Characterization of adhesive bond properties using Lamb waves.* NDT&E International. Vol. 33(8), pp. 555–563, 2000.

[7] Lin L., Shi Y.W., Chen J., Li X.M., Guo G.P., *Ultrasonic testing of the diffusion bonding of titanium alloys.* Insight. Vol. 48(7), pp. 415 - 417, 2006.

[8] Mackiewicz S., Gora G., *Ultrasonic testing of composite structures in the aerospace industry (in Polish).* Eleventh Seminary of Nondestructive Testing of Materials. Zakopane, 8–11 March 2005.

[9] Nelson L.J., Dalton R.P., Birt E.A., *A new low-frequency vibration technique for blind-side inspections.* Insight. Vol. 48(3), pp. 149–154, 2006.

[10] Ravishankar S.R., Murthy C.R.L., *Application of acoustic emission in drilling of composite lamintes.* NDT&E International. Vol. 33(6), pp. 429–235, 2000.

[11] Santos M., Perdiga J., *Leaky Lamb waves for the detection and sizing of defects in bonded aluminium lap joints.* NDT&E International. Vol. 38(8), pp. 561–568, 2005.
[12] Sozanski L., *Ultrasonic inspection of soldered joints (in Polish).* Welding Technology Review. Vol. 8-9, pp. 116–117, 2004.
[13] Wang H., Qian M.L., Liu W., *Laser ultrasonic characterization of adhesive bonds between epoxy coating and aluminum substrate.* Ultrasonics. Vol. 44, pp. 1349–1353, 2006.
[14] Josko M., *Methodological aspects of evaluation of regenerative coatings adherence using an ultrasonic method (in Polish).* Publishing house of Poznań University of Technology. Poznań 2002.
[15] Pilarski A., *Rating the strength of the adhesive layer connections (in Polish).* PhD thesis. Warsaw 1983.
[16] Kwon O.-Y, Kim T.H., Lee K.J., *Monitoring of fatigue damage in adhesively bonded composite-metal joints by acoustic methods.* 15th World Conference of Nondestructive Testing. Rome 2000.
[17] Ulbrich D., Josko M., Manczak R., *An Investigation of degradation of bond between coating and substrate (in Polish).* Journal of Research and Applications in Agricultural Engineering. Vol. 56, pp. 142–146, 2011.
[18] http://professional.novol.pl/karty/tech/LT-01-01_SU.pdf - 28.08.2014, car putty manufacturer website.

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