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THE INFLUENCE OF THE ADHESIVE PATH WIDTH ON SELECTED PARAMETERS OF AMPLITUDE-FREQUENCY SPECTRUM OF ULTRASONIC SURFACE WAVE

Summary

During exploitation motor vehicles require a number of maintenance, repair and diagnostic activities. Among all road vehicles, buses deserve special attention. These vehicles are designed to transport more than 9 people with the driver. Contemporary buses are characterized by a significant number of inseparable - adhesive joints. At the production stage the assessment of the quality of adhesive joints can be carried out using destructive and non-destructive methods. The assessment of the quality of adhesive joints of new vehicles can only be carried out using non-destructive methods. Adhesive joints of steel profile-plywood used in modern buses, is a combination difficult to test joints. Such combination can not be examined using classical control techniques. The article proposes not only the use of a surface ultrasonic wave, but also the possibility of analysis of the obtained signals in the frequency domain using the Fast Fourier Transform (FFT). The tests confirmed that within a certain range, this approach allows the assessment of the width of the adhesive path in adhesive joint.
***Key words**: adhesion, ultrasound, ultrasonic wave spectrum, FFT*

WPŁYW SZEROKOŚCI ŚCIEŻKI KLEJU NA WYBRANE PARAMETRY WIDMA AMPLITUDOWO-CZĘSTOTLIWOŚCIOWEGO ULTRADŹWIEKOWEJ FALI POWIERZCHNIOWEJ

Streszczenie

Eksploatowane pojazdy samochodowe wymagają szeregu czynności obsługowych, naprawczych i diagnostycznych. Spośród wszystkich pojazdów drogowych, na szczególną uwagę zasługują autobusy, czyli pojazdy, które są przeznaczone do przewozu więcej niż 9 osób wraz z kierowcą. Współcześnie produkowane autobusy cechują się znaczną liczbą połączeń nierozłącznych – klejowych. Na etapie produkcji, ocena jakości połączeń klejowych może być prowadzona z wykorzystaniem metod niszczących oraz nieniszczących. Ocena jakości połączeń klejowych pojazdów eksploatowanych może być prowadzona jedynie przy wykorzystaniu metod nieniszczących. Połączenie klejowe profil stalowy – sklejka, stosowane w we współczesnych autobusach, to połączenie o niskiej podatności defektoskopowe. Połączenia takiego nie można badać z wykorzystaniem klasycznych technik kontrolnych. W pracy zaproponowano nie tylko wykorzystanie powierzchniowej fali ultradźwiękowej, ale również zaproponowane przeprowadzenie analizy uzyskanych sygnałów w dziedzinie częstotliwości z wykorzystaniem szybkiej transformaty Fouriera (FFT). Przeprowadzone badania potwierdziły, że w określonym zakresie, takie podejście umożliwia ocenę szerokości ścieżki kleju w połączeniu.
***Słowa kluczowe**: klejenie, ultradźwięki, widmo fali ultradźwiękowej, FFT*

1. Introduction

Innovative technologies in the field of vehicles construction use newer materials. Previously metal was the most used material but now plastics, rubber or glass are increasingly used. Growing interest in the range of new materials causes demand for different way of conventional joining techniques such as threaded, welded or riveted joints. Welding joint techniques have been replaced by adhesives. The general division of adhesives divides them into natural and synthetic ones. Natural are of animal or vegetable origin [9, 16]. Synthetic is distinguished due to the chemical base, the form of adhesive, the binding method or the field of application. In order to achieve the desired effect, the adhesive formulation is adapted to the materials to be joined. This technique of joining elements and parts is characterized by high reliability, durability of the joint, as well as resistance to loads [12]. Comparing riveted joints with adhesive joints, it can be seen that the elements joined by adhesive show better resistance to bending and vibrations. Bonding technology is used not only for joining metal elements but also allows a wider use of plastic materials on the car body vehicle. This is especially important because in contrast for metal components for plastics other joining techniques are not used interchangeably. The next function of adhesive joints, apart from joining elements and machine parts, consists in sealing [6, 8]. The adhesive, due to the consistency, seals well and additionally provides corrosion protection. The adhesive technique also has disadvantages. During bonding process stresses on the entire adhesive surface are generated [14]. That may cause damage to the connected parts or zinc coating which protects against corrosion. Another important issue is the difficulty in disassembling of the adhesive joint as well as the low resistance to high temperatures (250º) [7].

Taking into account vehicle and machine safety joined parts should be evaluated. The adhesive joints can be checked using destructive tests and non-destructive examinations [3]. Tests are carried out in laboratory conditions as well as in production conditions [8]. Such tests allow to assess not only the strength of the adhesive, but also the technique of bonding, surface preparation, methods of adhesive application, spreading and hardening the adhesive.

In the previously conducted tests of adhesion joints, a reflection coefficient for longitudinal ultrasonic wave propagating in the joint area was used [1, 4, 11, 13]. This parameter is used to estimate adhesion of the adhesive layer to the substrate, but only on one side of the joints. In addition, it does not allow to determine the width of the adhesive path in joint. A part of the research also lead to the location of defects in adhesive joints such as kissing bond [2, 4, 15]. This allows detection of poor quality joints already at the manufacturing stage. Research is also conducted in the field of the frequency domain of the wave propagating in the area of the adhesive joint [5, 10]. However, frequency studies are usually only a small complement to the main studies that are carried out in the time domain of ultrasonic wave.

2. Experimental research

The research was carried out in two stages: the first stage was preliminary research, the second stage was the main research. The main goal of the preliminary tests was to assess the possibility of obtaining ultrasonic signals useful for the tests and to determine measurement errors of the test stand. The main goal of the second stage presented in this article is to assess the possibility of using the ultrasound method to assess the quality of adhesive joints used in the construction of mass transport vehicles using surface waves and the analysis of pulses in the frequency domain.

Ultrasonic testing was performed on a sample made of steel and closed profile with dimensions 120x40x3 mm and 1510 mm long. Such profiles are used to make frames in buses - especially on their chassis. On the closed profile after cleaning and degreasing, adhesive CX80 Hybricx Premium was applied (Fig. 1). The thickness of the applied adhesives was 3mm. The width of the glue was from 4 to 79 mm.

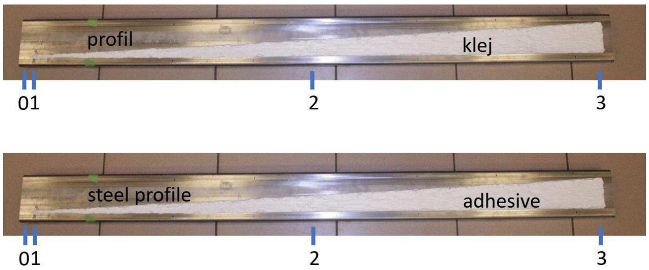

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Fig. 1. View of the sample used during the test: 0 - area without adhesive, 1 - area in which the width of the adhesive path was 4 mm, 2 - the area in which the width of the adhesive path was 49 mm, 3 - the area in which the width of the adhesive path was 79 mm

Rys. 1. Widok próbki wykorzystywanej w badaniach: 0 – obszar pozbawiony kleju, 1 – obszar, w którym szerokość ścieżki kleju wynosiła 4 mm, 2 – obszar, w którym szerokość ścieżki kleju wynosiła 49 mm, 3 – obszar, w którym szerokość ścieżki kleju wynosiła 79 mm

Two ultrasound transducers (MWB90-4) of the surface wave were used for testing which were placed opposite each other. A coupling gel was used on the contact surface of the probes. A sample with attached ultrasonic transducer is shown in Fig. 2 and 3.

To perform the ultrasonic tests a stationary computer with a UMT15 flaw detector equipped with software enabling the reading of parameters for a selected area of the ultrasonic surface wave pulse was used. The frequency and the area under the envelope for the given frequency ranges, marked P1 ... P12, presented in Fig. 4, are the basic parameters of the FFT spectrum envelope that were recorded.

Source: own elaboration / Źródło: opracowanie własne

Fig. 2. Location of ultrasonic transducers during tests

Rys. 2. Rozmieszczenie głowic ultradźwiękowych podczas badań

Source: own elaboration / Źródło: opracowanie własne

Fig. 3. Ultrasound transducer mounted on a steel profile

Rys. 3. Głowica ultradźwiękowa zamocowana na profilu stalowym

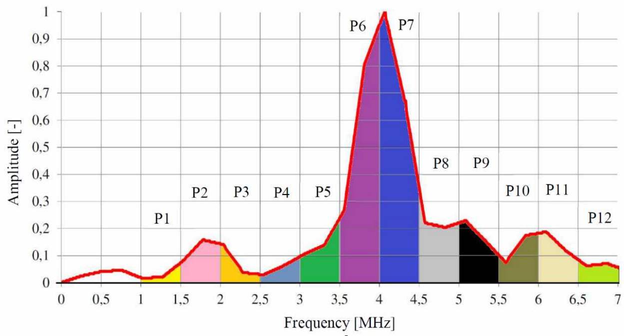

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Fig. 4. View of the envelope of the ultrasonic surface wave pulse with the selection of ultrasonic quality measures - surface area (P1 to P12)

Rys 4. Widok obwiedni impulsu ultradźwiękowej fali powierzchniowej z zaznaczeniem ultradźwiękowych miar jakości – pola powierzchni (P1 do P12)

During the first stage of experiment 30 measurements were performed in three areas where adhesive was applied and in one place where no adhesive was applied. Measurements were made in areas where width of applied adhesive was: 4mm, 37 mm, 79 mm. Each measurement was carried out in the same marked place detaching the ultrasound transducer from the lateral surface of the sample and then again being applied to the same place.

In the second (main) stage of research, measurements were performed by moving the ultrasound heads along the test sample (the same that in the first stage), registering selected parameters of ultrasonic pulses in the frequency domain every 10 mm of the length of the sample. Changing the position of the transducer and receiver of ultrasonic waves the Fourier transform of signal of the ultrasonic pulse was obtained and recorded. The signal was presented in two forms as an ultrasonic pulse as a function of frequency and a momentary amplitude value.

The correct setting of the transducers was considered the one for which the maximum amplitude frequency was located during the measurement by manipulating the transducer position. After several measurements, it was necessary to change the gain of ultrasonic pulse. It was selected in such a way that the maximum amplitude of the signal graph was at least 0.7 units of height amplitude. The research was carried out in the widest place of the adhesive path - 79 mm.

3. Test results

As the main measures of the width of the adhesive path, the transmitted frequency band and surface area under the frequency-amplitude characteristic were assumed. In preliminary studies four areas were selected for which the results are presented in Table 1.

After completing the preliminary research results, basic tests were carried out. During this study the presented pulse parameters were recorded for different adhesive path widths. Due to the large number of measurements, the results of the research are presented in graphical form in the Fig. 5 and 6.

Based on the results presented in the Fig. 5 and 6, it should be stated that for surface area P8 above 0.85 it was found that the width of the adhesive path is up to 5 mm and it is possible to measure its width. For surface area P3 with a value above 0.26 it is about 28 millimeters. For P3 greater than 0.03 the width of the adhesive path was about 25 mm, for P8 - 0.95 means no adhesive while the value from 0.8 to 0.9 means the width of the adhesive path to 5 mm. For the remaining results no unequivocal interpretable values were obtained (for the same values of width of the adhesive path different values of the area under the envelope of the amplitude spectrum were obtained). This may be due to defects occurring in the joint area and the spread of the quality of adhesive joints. Further research is planned in which the use of surface ultrasonic waves will be associated with the use of longitudinal wave parameters.

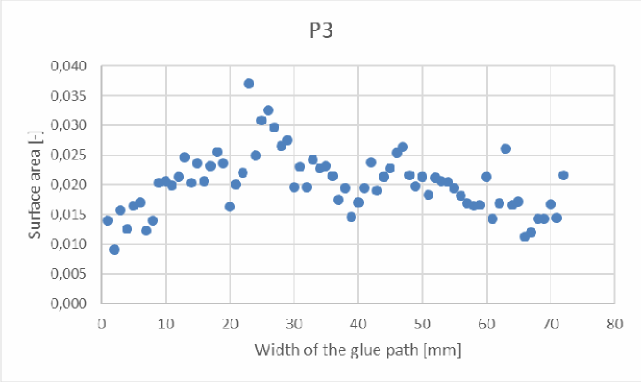

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Fig. 5. Dependence of the surface area P3 on the width of the adhesive path

Rys. 5. Zależność pola powierzchni P3 od szerokości ścieżki kleju

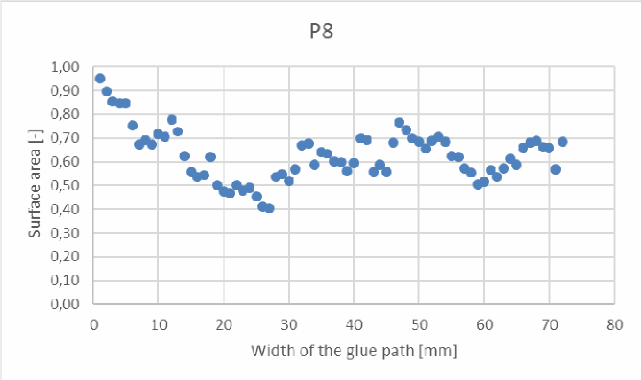

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Fig. 6. Dependence of the surface area P8 on the width of the adhesive path

Rys. 6. Zależność pola powierzchni P8 od szerokości ścieżki kleju

Table 1. The results of preliminary tests

Tab. 1. Wyniki badań wstępnych

	No adhesive		The width of the adhesive path – 4 mm		The width of the adhesive path – 37 mm		The width of the adhesive path – 79 mm	
	Result	Measurement error	Result	Measurement error	Result	Measurement error	Result	Measurement error
Surface area	1.060	0.008	1.190	0.006	0.790	0.038	0.660	0.013
P1	0.021	0.006	0.020	0.006	0.020	0.026	0.020	0.010
P2	0.020	0.007	0.020	0.006	0.021	0.020	0.011	0.008
P3	0.015	0.006	0.015	0.007	0.018	0.019	0.007	0.006
P4	0.019	0.006	0.017	0.006	0.015	0.020	0.005	0.004
P5	0.017	0.009	0.018	0.006	0.017	0.018	0.003	0.004
P6	0.017	0.008	0.015	0.007	0.016	0.013	0.003	0.003
P7	0.014	0.008	0.012	0.007	0.005	0.013	0.002	0.003
P8	0.016	0.009	0.013	0.006	0.014	0.017	0.002	0.004
P9	0.018	0.009	0.017	0.006	0.011	0.019	0.003	0.004
P10	0.020	0.009	0.017	0.008	0.020	0.018	0.004	0.004
P11	0.021	0.007	0.019	0.005	0.013	0.016	0.005	0.004
P12	0.019	0.018	0.018	0.016	0.017	0.024	0.004	0.011

Source: own elaboration / Źródło: opracowanie własne

4. Conclusion

Taking into account the tests and obtained results the following conclusions can be made:

- It is possible to obtain pulses on the flaw detector screen while testing the adhesive joint between the steel profile and the plywood and to conduct their analysis in the frequency domain using FFT.
- The width of the adhesive path influenced selected parameters of the pulse spectrum in a limited range.
- Ultrasonic measures of adhesive joint quality such as transmitted frequency band and area under the graph of the pulse spectrum have been proposed. It was found that for the surface areas obtained during the research errors are small and for the frequency response the error was so small that it was assumed to be close to zero.

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