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NONDESTRUCTIVE CONTROL AND DIAGNOSING OF TECHNICAL STATE OF MANUFACTURED ARTICLES BY ACOUSTIC EMISSION METHOD

NIENISZCZĄCA KONTROLA I DIAGNOSTYKA STANU TECHNICZNEGO WYTWARZANYCH PRODUKTÓW METODĄ EMISJI AKUSTYCZNEJ

A b s t r a c t

The paper presents some results of practical application of the methods and devices for acoustic emission diagnostics of the technical state of details and constructions developed earlier [1]. The elaborated methods of nondestructive control and strength prognostication can be applied in testing various manufactured articles.

Keywords: *acoustic emission*, *diagnosing strength*, *localizing failure*

S t r e s z c z e n i e

W artykule zaprezentowano rezultaty praktycznego zastosowania metod oraz urządzeń do diagnostyki akustycznej jakości elementów konstrukcji. Opracowane metody niezniszczeniowej kontroli jakości oraz oceny wytrzymałości mogą znaleźć zastosowanie w badaniach wielu wytwarzanych elementów.

Słowa kluczowe: *emisja akustyczna*, *ocena wytrzymałości*, *lokalizacja defektu*

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1. Introduction

Nowadays, the transfer from resource maintenance to technical state maintenance is specifically important. Reliable technical diagnostics allows prolongation of the term of exploitation for a considerable part of machines that have already worked their resource out, which produces a significant saving rate. Unlike the traditional methods of non-destructive control and technical diagnosing, such as ultrasonic crack detection and X-ray radiography, the method of acoustic emission (AE), based on the radiation of material during the change of its inner structure of spring mechanical waves which are caused by the increasing flaws, provides better sensitivity. It also enables one to discover and examine the flaws behaviour and integrality enabling the control of the state of the material without scanning. It is simple for usage in the testing process, manufacture and exploitation, capable of controlling materials not only under the mechanical pressure but also in the process of phase transformations.

The paper introduces the developed methods and means of computer AE control and diagnosing the technical state of details and machine units of varied shape and instances of their practical use.

2. Implementation and results

2.1. Strength diagnosing of welded joints

The investigations which have been earlier carried out by other authors [3–5] show that in the process of joint weld cooling, AE appears without external strain, as a result of heat action which leads to phase transformations in the material, under the action of internal local strains, developing in the joint weld itself and the surrounding area, and due to the irregularity of the material structure. The authors have found that AE method is not effective for controlling the quality of welding circuit plates in the process of flux solidification because of negligible quantity of AE signals and on the contrary – it is highly effective for quality control of welding in the process of joint weld solidification.

With the purpose of working out methods of nondestructive control and diagnosing technical state of joint welds in the process of flux solidification, i.e. even before the weld is in equilibrium, high-quality and defective joint welds of cast iron were investigated. It was stated that the process of flaw formation is characterized by an abrupt quantitative increase of high amplitude AE signals (Fig. 1).

The most informative parameter appeared to be the actual activity of AE signals for the welded joint unit, registered during the temperature change from 200°C to room temperature. The studies resulted in working out a method of detecting welding defects in the process of joint weld formation:

– after burning of arc is over, AE signals are recorded during the time of temperature change from 200°C to room temperature,
– if the maximum actual activity of AE signals during the observations exceeds the permissible level $N = 1$ imp/sec·sm^3 , set according to the results of static processing of the previous experimental data, then the controlled joint weld is subjected to dangerous defect formation.

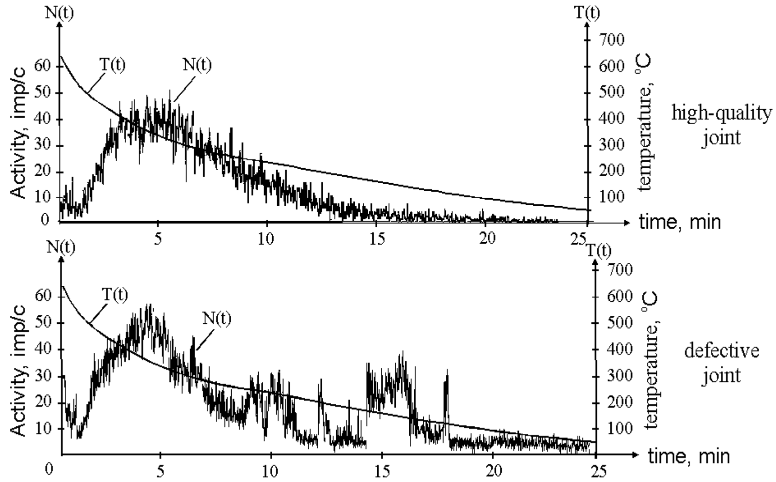

Fig. 1. Comparative acoustograms for high-quality and defective joint welds cooling
Rys. 1. Akustograf porównawczy chłodzonych spoin wysokiej oraz złej jakości

Fig. 2 demonstrates a photo of typical defective welded joint, its formation followed by increased activity of high-amplitude AE signals, shown in the Fig. 1.

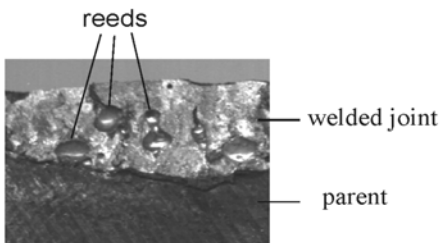

Fig. 2. A fragment of destroyed joint weld
Rys. 2. Fragment zniszczonej spoiny

The elaborated method of diagnosing technical state of welded joints in the process of flux solidification was implemented in Khmelnitsky National University for control of cast iron CH-4 welded joints.

2.2. Diagnosing strength of microassembly frames

Microassembly frames of microwave frequency (Fig. 3), manufactured from aluminum alloy AMg-2, is a permanent connection of base and cover, made with the help of laser welding. These quite critical units are used in modern Ukrainian planes. In the process of operation, i.e. while ascending to a high altitude, internal overpressure emerges in the frames, which may cause the destruction of joint weld and depressurization of the frames. AE method enabled increasing reliability of manufactured frames, making it possible to diagnose, control and prognosticate the strength and hermiticity of frames in manufacturing and operation.

A group of frames was studied, where the junctions of covers and bases are pressurized by means of laser welding, while all the load of external overpressure is taken by either joint weld alone or by joint weld and the product construction.

During the loading process the basic parameters of AE signals were recorded. The program processing of AE signal parameters allowed creation of 2 and 3-dimensional acoustograms, showing the dependence of AE parameters on pressure and linear coordinate between the piezoceramic transducers.

Fig. 3. The microassembly frame of microwave frequency
Rys. 3. Obudowa przetwornika częstotliwości mikrofalowych

The coefficients of predicting depressurization stress, obtained by the data of AE signals activity measurements and registering the internal overpressure of tested frames, can be accordingly used for defining the leak-off pressure in safe loading of frames.

The predictable leak-off pressure is defined by formula

$$P_{\max}^{pr} = P_{pr} K \tag{1}$$

where:

P_{pr} – pressure under which the activity of AE signals reaches the control point (14,9 imp/c).

The values of prognostication coefficients for tested frames, calculated according to formula (5), are within the range of 2–2,53. This dispersion of the obtained values reflects the instability of physical and mechanical characteristics of joint welds and comes from imperfection and weakness of laser welding technology. In this situation, taking into account the particular responsibility of tested frames (the operation on the plane board), we take the minimum value of prognostication coefficient $K_{\min}$ = 2 for predicting the depressurization stress; then a mistake in prognostication is considered a margin of safety.

For arranging nondestructive diagnosing and prognostication of strength and hermiticity of frames for microwave frequency microassemblies a safe level of pressure for frame testing is defined. Using the minimum value of prognostication coefficient, testing pressure is calculated according to formula

$$P_{\text{test}} = \frac{P_{\max(TC)}}{K_{\min}} \tag{2}$$

where:

$P_{\max\,(\mathrm{TC})}$ – the value of internal overpressure which must be withstood by the frame according to technical conditions.

– Nondestructive loading of frame up to P_{test} makes it possible to assess strength and hermiticity of tested frames according to AE signal parameters.

– Consequently, there has been developed a method of nondestructive control, predicting strength and hermiticity of microassembly frames of microwave frequency.
– Diagnosing and predicting strength and hermiticity of microassembly frames of microwave frequency is performed with nondestructive testing of frames by means of internal pressure. Compressed air is directed into the frame until it reaches the testing pressure $P_{\text{test}} = P_{\max(TC)}/K_{\min}$, where $P_{\max\,(TC)}$ is the top possible internal overpressure of the frames according to technical condition, $K_{\min}$ – coefficient of predicting the depressurization sress ($K_{\min}$ = 2). Simultaneous registering of Pressure and AE signal parameters are registered simultaneously during the testing.
– If acoustic emission has appeared with the loading up to P_{test}, and its activity exceeds the reference level (15imp/c), the frame is considered unserviceable in the pressure range identified by technical conditions; if necessary, its depressurization stress is calculated with formula:
– $P_{\max}^{pr} = P_{pred} K_{\min}$, where P_{pr} – the pressure under which AE signals activity has reached the reference level.
– Yet, if AE activity has not exceeded the reference level, the frame is considered suitable for exploitation within the pressure range set by technical conditions.

The authors have also tested microassembly frames of microwave frequency with the help of internal overpressure in dynamic mode in the pulsating cycle.

The AE signals were found to testify to the fact that the process of joint weld destruction starts and develops long before the catastrophic failure (Fig. 4), i.e. depressurization of the frame. What is more, and their use allows exercising control of strength and hermiticity of microassembly frames of microwave frequency in the conditions of loading in the pulsating cycle.

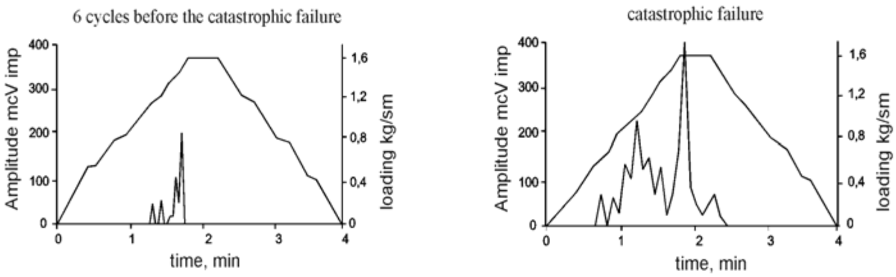

Fig. 4. The starting point of catastrophic destruction of joint weld of microassembly under pulsating
Rys. 4. Punkt startowy zniszczenia spoiny obudowy przetwornika pod obciążeniem pulsacyjnym

Consequently, there has been worked out a method of nondestructive control of strength and prevention of dangerous states in microassembly frames of microwave frequency, operating in the conditions of internal pressure difference in the pulsating cycle. The developed method is intended to exercise nondestructive control strength and hermiticity of frames, operating aboard. The control of frames is done automatically during the flights by means of acoustic emission measuring device, installed on the board of plane. AE sensor, transmitting AE signals to the measuring device, is set in the controlled frame with display panel, informing about the emission of AE signals, in pilot's cabin. If, for some reason, the AE device cannot be installed aboard, the frame control is run by the technician who services the equipment in the plane and tests the frames by internal overpressure every 5 flights and landings. At the same time:

– the phenomenon of Kaiser effect, i.e. the absence of AE signals after the first cycle, i.e. after taking off and landing, proves that the frame is strong and hermetic,
– if AE signals appear at the *n*-cycle, being commensurable with signals emitted during the first cycle, this should be the warning about the process of catastrophic failure that has started, and such a frame is going to depressurize after 6–10 flights and landings.

3. Conclusion

1. A method of detecting defects of welding in the process of joint weld formation has been provided.
2. The method of nondestructive diagnosing and predicting strength and hermiticity of microwave frequency microassembly frames under safe testing by means of internal overpressure in static state.
3. The method of nondestructive strength control and prevention of dangerous states of microwave frequency microassembly frames, installed on the board of aircraft, when as a result of flights and landings frames experience the pressure difference in pulsating cycle and a danger of joint weld failure and depressurization of frame occurs.

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