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VIBRODIAGNOSTIC OF WELDED THIN-WALLED PLATES WITH THE USAGE OF LASER SENSORS IN NETWORK INFRASTRUCTURE

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Abstract

The article presents a non-destructive welded joints assessment (vibrodiagnostics) method, in which, with the use of the Internet, computer networking technologies and laser displacement sensors, the quality of welded steel plates may be monitored. The article also describes the possibilities of analysis of received vibrodiagnostics data on the base of diagnostic parameters analysed in function of time and frequency. The method described in the article allows remotely registering, analysing and diagnosing mechanical systems using vibrodiagnostics and information technologies. Modern, computerized methods exhibit efficiency and reliability of results – they are currently the best measuring tools that can be used in automatic monitoring (structural health monitoring - SHM) of marine structures. It is essential to make objective assessment of the results by NDT users, which is tightly connected with the expertise of norms and regulations of NDT. It may be helpful in this respect to monitor responses from a few sensors, arranged in a few measuring points. NDT results quite often trigger further analysis of durability of an object. The NDT of welded joints method as presented in the article allows remotely and in an IT-aided way analysing and diagnosing mechanical systems with the use of vibrodiagnostics method.

Keywords: *non-destructive testing, laser displacement sensors, NDT, vibrodiagnostic, Ethernet, LAN*

1. Introduction

Non-destructive testing aids to obtain feedback about the state, properties and possible defects of the investigated object. It is not interfering with its performance properties; that is by not tampering with its consistency or deteriorating its performance and functional properties; and the structure [1, 2]. Technical objects of non-destructive testing are welded joints, glued joints; pressure welded joints and soldered joints, as well as objects made of composite materials.

The use of NDT is aimed at achieving a relatively high level of both quality and security. The aforementioned tests are conducted in industry and scientific laboratories while new materials are designed and their properties determined. Resigning from NDT or conducting the tests inconsistently with the set out rules may lead to accidents and malfunctions [4]. Growing interest in NDT as well as greater expectations as for the diagnostic information obtained in the course of the tests constitute the main evolutionary factor for developing and advancing NDT. This means that the significance of NDT as a vital element of modern technology [1, 3] is steadily growing.

Modern methods of NDT (still in the phase of research) are presented in Fig. 1 and involve I – acoustic emission, II – thermography, III – vibrothermography, IV – vibration methods as shown in Fig. 2 [6].

In the method, laser displacement sensors constitute the element of a modern vibrodiagnostic system. The sensors themselves as well as the necessary equipment are very expensive and request creating a proper facility. Provided that the cost of the equipment is high, it is vital then to optimize best the test and analytical stands by using full performance of the measuring tools and making them available for possibly biggest group of staff conducting the NDT.

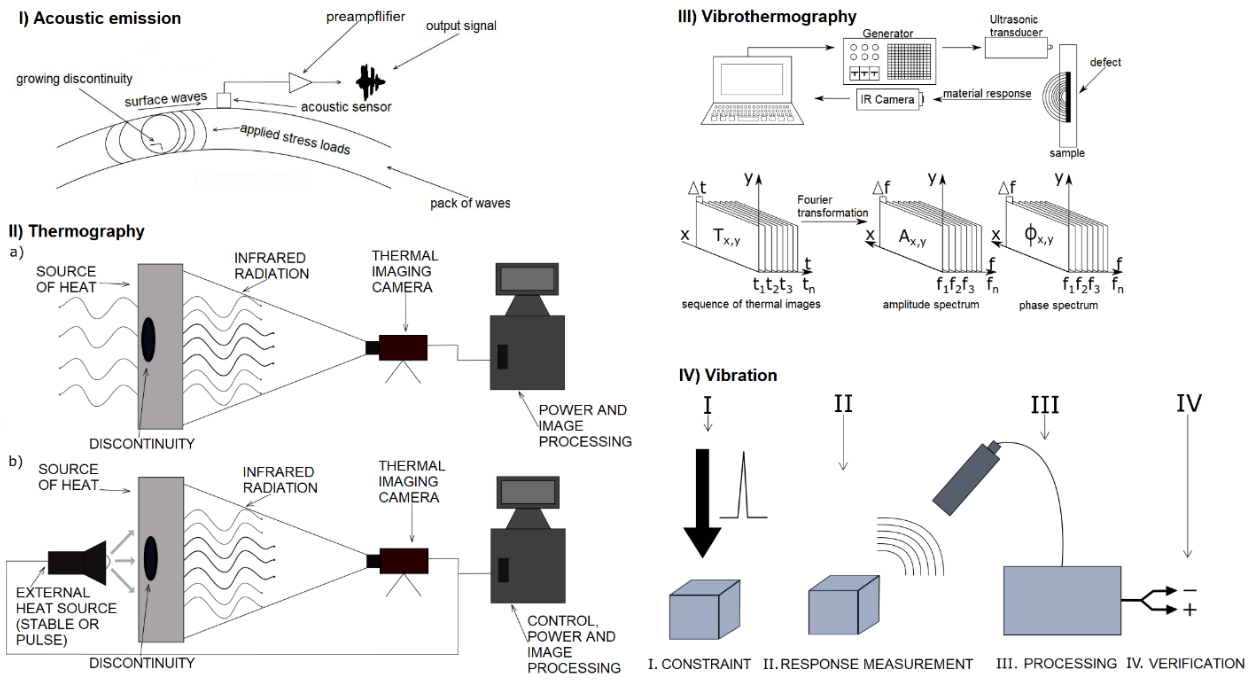

Fig. 1. Modern methods of NDT

2. Stand for conducting NDT of welded joints with LAN

In order to conduct NDT, ILD 2300 Micro - Epsilon laser displacement sensors were used. In the course of the test, vibrations of the plate were forced with the use of modal hammer. Consequently, the vibrations must be recorded; changes of vibrations must be saved and modified in MATLAB, Mathad, MS Excel or other software.

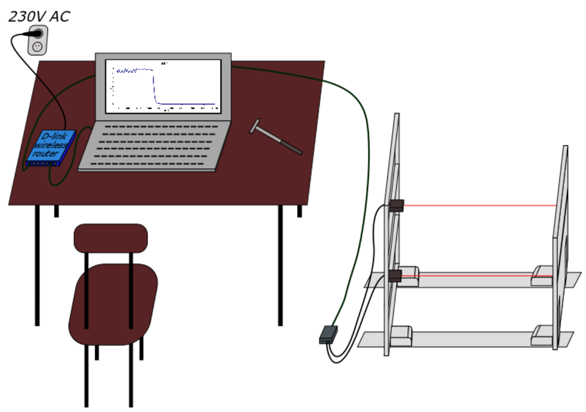

Fig. 2. A test stand for NDT of welded plates with use of laser displacement sensors

The advantages of using laser displacement sensors in testing welded joints are as follows: non-contact measurement, distance from the measured surface, small measurement spot, and fast measure, high precision, almost all kinds of surfaces may be measured.

Laser sensors are used to measure the thickness of various materials in the process of quality control, metal parts processing, in applications connected with registering different surface textures, determining shape of surface of aluminum wheels (after casting alu rims are measured in order to determine various values, such as the deepness of the centre, roundness and cylindricity).

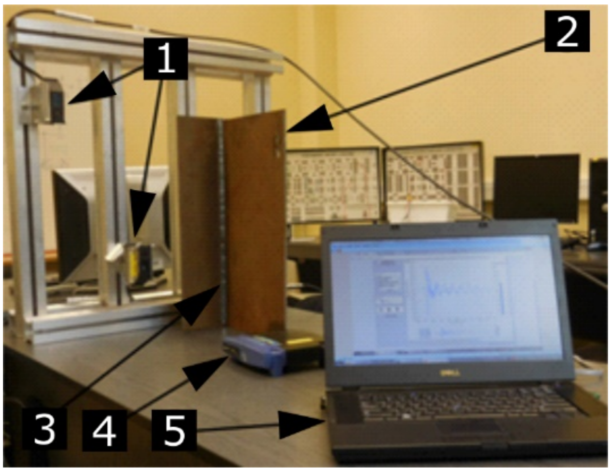

Fig. 3. Photograph of actual test stand for NDT of welded plates with the use of laser displacement sensors in LAN, where: 1 – laser displacement sensors, 2 – welded plate, 3 – weld, 4 – router, computer with web browser

3. The course of welded joints testing with the use of laser displacement sensors in LAN

Before testing, the test stand must be checked in terms of its completeness and proper configuration, especially it must be established whether the computer stand and the router with displacement sensors are linked in the same and properly configurator LAN network [5].

By using, an Ethernet LAN to link the sensors with computers for the test stand enables by means of relatively low costs and time to access a large amount of date for analysing. In the simplest case, in the course of the testing, a web interface may be used, embedded in each sensor. It is also simple to activate the interface as it requests only to type the IP address of laser sensor in the web browser. After doing so, the web browser displays the web site, as the one presented in Fig. 4. Depending on the number of accessible sensors, a few registrations may be performed at the same time.

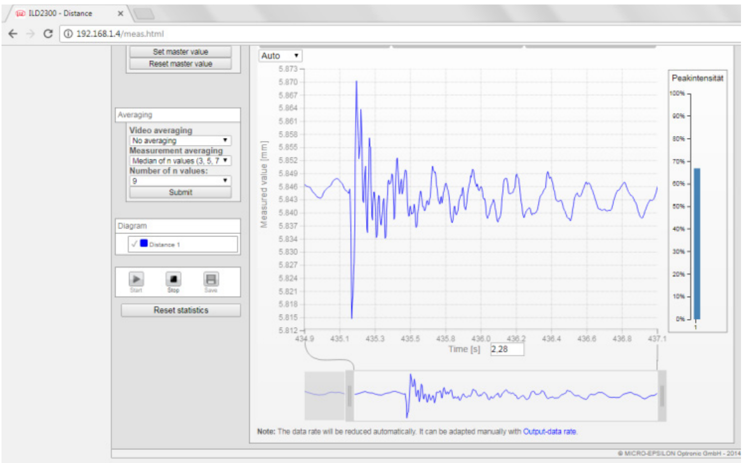

Fig. 4. Web interface of optical displacement sensor

The next stage of testing involves making the analysis of changes in field of time and frequency. In time analysis, responses from displacement sensors for various plates were analysed and compared. In time analysis, formula 1. was applied, which allowed for calculating mean decrement of construction in terms of maximum amplitude.

$$\psi_I = \frac{1}{n} \cdot \ln\left(\frac{A_0}{A_n}\right), \tag{1}$$

where:
ψ – logarithmic decrement,
$A_{0\text{-}n,m}$ – consecutive values of peak value of amplitude,
n, m – consecutive numbers of amplitudes.

The results of calculations were presented in the form of characteristics, where axis x shows numbers of maximums, and axis y shows values of calculated decrement (ψ). By analysing the characteristics, decrement of plate with non-defective weld has been assessed and compared with decrement in plates with defects in welds. Exemplary results have been shown in Fig. 5.

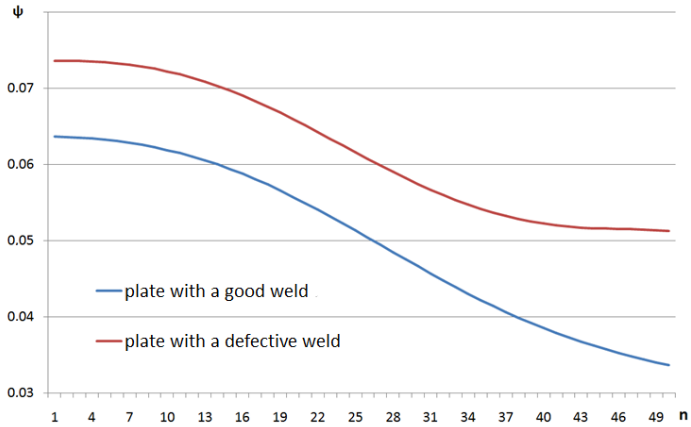

Fig. 5. Characteristics of decrement of a well-welded plate and a plate with defect "lack of side fusion"

At the next stage of testing welded joints with the use of laser displacement sensors, Fourier transform was applied for the responses. For this sake, numerous algorithms may be used, one of which is presented below with the formula 2.

$$F(\omega) = \sum_{0}^{N-1} f(nT)\,\mathrm{e}^{-j\omega nT}\,T\,, \tag{2}$$

where:
N – number of samples in function of time,
n – number of consecutive sample,
T – sampling time.

Results of calculations have been presented in the shape of characteristics, where axis x shows frequencies of each harmonic, and axis y shows modules of amplitude spectre (|X(f)|). By analysing amplitude specters, welds of plates with different defects have been assessed and compared. Exemplary results have been presented in Fig. 6.

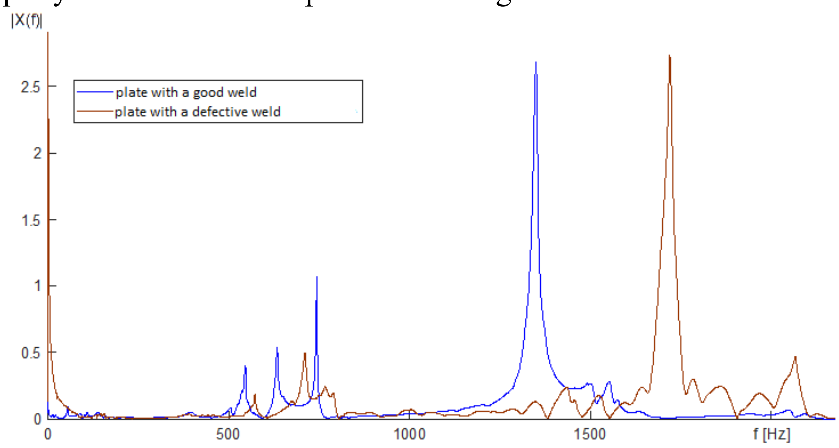

Fig. 6. Amplitude characteristics of a well-welded plate and a plate with defect "lack of side fusion"

4. Conclusion

While conducting NDT it is vital to use modern methods. NDT involves various techniques and hence it is important for the institutions conducting such tests to develop hardware infrastructure, familiarize the research team with new methods of measurement and analysing their results. Using a few methods in testing may contribute to an increased credibility and objectivity of the results of tests. Modern methods of NDT very often take advantage of IT technologies.

Using verified and mature technologies, such as Ethernet LAN network may be crucial to conduct tests with laser displacement sensors in a safe and efficient way. Modern, computerized methods prove to be both efficient and credible in terms of results - they are best measuring tools to be used for automatic monitoring of SHM constructions.

Diagnosing with NDT depends mainly on the very need (the choice of the method of research) and skills as well as the competence of the staff. It is essential to make objective assessment of the results by NDT users, which is tightly connected with the expertise of norms and regulations of NDT. It may be helpful in this respect to monitor responses from a few sensors, arranged in a few measuring points. NDT results quite often trigger further analysis of durability of an object.

The NDT of welded joints method as presented in the article allows remotely and in an IT-aided way analysing and diagnosing mechanical systems with the use of vibrodiagnostic method.

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