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USING OF ACTIV THERMOGRAPHY AND LOCK-IN METHOD WITH ULTRASOUND EXICATION FOR DETECTION OF MATERIAL DEFECTS

Summary. The main purpose of paper is presented an innovative approach in the field of infrared thermal imaging and its integration into the area of engineering applications. Test specimens with different shapes have been chosen from steel material and they have been excitated with ultrasound. For obtain the results was used Lock-in method. Last part of the paper is a description of the results and most appropriate settings of measurement technique for applications with chosen material.
Keywords: infrared radiation, non-destructive testing, lock-in, ultrasound.

ZASTOSOWANIE TERMOGRAFII AKTYWNEJ ORAZ METODY LOCK-IN ZE WZBUDZANIEM ULTRADŹWIĘKOWYM W CELU WYKRYWANIA WAD MATERIAŁU

Streszczenie. Głównym celem niniejszego artykułu jest prezentacja innowacyjnego podejścia w dziedzinie termografii podczerwieni oraz jej wprowadzenia do zastosowań w przemyśle maszynowym. Do badań wybrano próbki różnych kształtów, a jako materiał kontrolny tych próbek została wybrana stal. Próbki poddano działaniu ultradźwięków. Do oceny wyników została zastosowana metoda Lock-in. W ostatniej części artykułu znajduje się opis wyników oraz najkorzystniejszych ustawień aparatury pomiarowej dla wybranego materiału.
Słowa kluczowe: promieniowanie podczerwone, badania nieniszczące, lock-in, ultra-dźwięk.

1. INTRODUCTION

Infrared thermography has developed from a rarely used method to the method growing in popularity among users in recent years. This progress contributed largely by the availability and constantly falling prices of infrared cameras. For this reason, some methods have been developed which make use of infrared thermography in industry [2].

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Pulse thermography was invented for the purpose of non-destructive testing (NDT) of materials and components, hence the "looking under the surface 'bodies. In pulsed thermography is pulsed heat flux generated on the surface typically by means of irradiation with light (e.g. lamp) and then is surface temperature observed in time depending. If inhomogeneity for example: cracks, holes or cavities with different temperature parameters, lies below the surface of the test object, it will have an impact on local dynamic heat flux that passes through the specimen.

As an alternative technique is offered to lock-in thermography, which is also known as heat waves imaging technique, it can be described by the theory of oscillating heat waves. Excitation of the heat occurs periodically with a certain frequency in the body [3, 4, 5, 6]. The advantage of lock-in thermography is that with applying processing of the registered image it may considerably increase its sensitivity compared with the nominal sensitivity of the thermal camera.

2. LOCK-IN THERMOGRAPHY

A prerequisite for the use of this technology is that the excitation signal may be periodically pulsate or in any other way modulated by certain amplitude frequencies, called "lock-in frequency" $f_{lock-in}$. Lock-in thermography is a type of active lock-in method. It means that heat to excite the sample is generated periodically and correlation using the lock-in process is applied to all heat signatures of every single pixel on the image of the observed object.

Digital lock-in process correlation consists of averaging the results of the measured values F_k and system of weighting factors $K_k$to the total number of measured values M:

$$S = \frac{1}{M} \sum_{k=1}^{M} F_k \, K_k, \tag{1}$$

where S is the output signal.

If the excitation is harmonic then the most advantageous correlation function is also harmonic (sine, cosine) function. This kind of lock-in correlation is called sin/cos or narrowband correlation. It can be realized either by narrowing the bandwidth of the detected signal or using the values of harmonic functions for K_k in the equation (1).

The main advantage of the sin/cos correlation is that it enables to user to take into consideration the phase of the signal after the measurement (off-line) when it is used two-channel correlation. Two-channel correlation means that there were used two types of weighting factors, one approximates a sin-function and the second approximates cos-function. Correlation is transferred twice in parallel with both types of weighting factors:

$$K^0(t) = 2\, sin(2\pi f_{lock-in} t) \tag{2}$$

$$K^{\pi/2}(t) = 2\cos(2\pi f_{lock-in} t) \tag{3}$$

Then the first channel measures the component in-phase with the sin-function, and the other channel measures the component in-phase with the cos-function, which is $\pi/2$ phase-shifted to the sin-fuction [1].

If equations (2, 3) are inserted into equation (1) than the result of the two correlations over a complete number periods is:

$$S^0 = \frac{1}{n}\sum_{i=1}^{n} F_i\, K_i^0 \quad (4)$$

$$S^{\frac{\pi}{2}} = \frac{1}{n}\sum_{i=1}^{n} F_i\, K_i^{\frac{\pi}{2}} \quad (5)$$

Where S^0 is called the in-phase signal and $S^{\frac{\pi}{2}}$ is usually called the quasrature signal. Both signals may be either positive or negative [1].

2.1. Ultrasound excitation

Typical set of the lock-in analysis consists of a PC, an infrared camera, an amplifier and generator lock-in frequency. It is precisely the type of generator lock-in frequency will vary different sets, so one can say that it will divided according to the type of excitation.

We decided to use ultrasonic excitation type in other measurements, which is compared with the optical excitation more suitable for steel materials, which have the largest representation in engineering practice yet. Ultrasound lock-in thermography uses the interaction between mechanical and thermal waves to detect material defects. If some damage in components absorbs the excitation of high energy ultrasound waves than it is locally heated. The resulting temperature gradient is captured by an infrared camera on the sample surface and it is subsequently dissipative energy visualized.

This method is suitable for applications in the detection of cracks (as well as open and closed, regardless of its orientation), adhesion testing, rivets and welded joints. As with optical methods as well as ultrasound method, it is possible to detect delamination and impact damage in materials made of composite fibers.

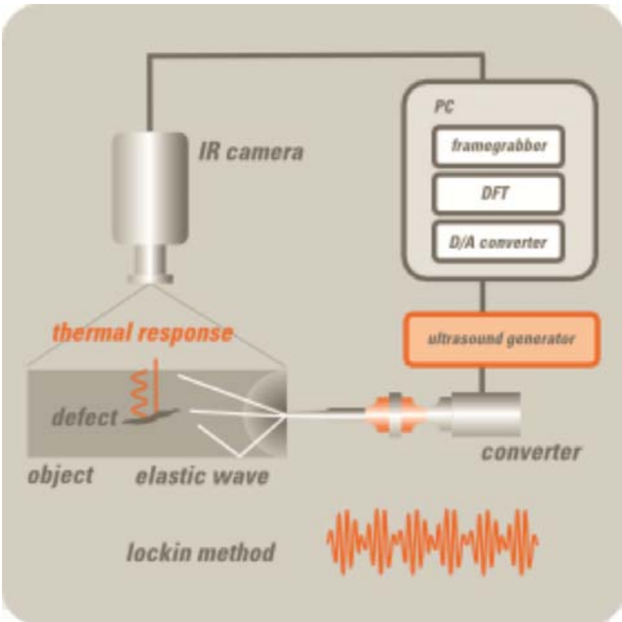

Fig. 1. Schematic representation of the lock-in principle with ultrasonic excitation Utvis
Rys. 1. Schematyczne przedstawienie zasady lock-in ze wzbudzaniem ultradźwiękami Utvis
Source: www.edevis.com

3. MEASUREMENTS

Measurements were made using the system UTvis. It is equipment based on lock-in method with high energy ultrasound excitation. The material of specimens was chosen steel. There were two specimen with different shapes tested (Fig. 2, Fig. 4). These specimens were tested with more setting. It was only the excitation frequency and the frame rate frequency of the camera changed. Parameters like emissivity, integration time number of periods were equally.

Fig. 2. The test sample with this shape before excitation, instead of the expected damage is sprayed by spray of know emissivity
Rys. 2. Próbka przed wzbudzeniem, miejsce przewidywanego uszkodzenia spryskane sprejem ze znaną emisyjnością

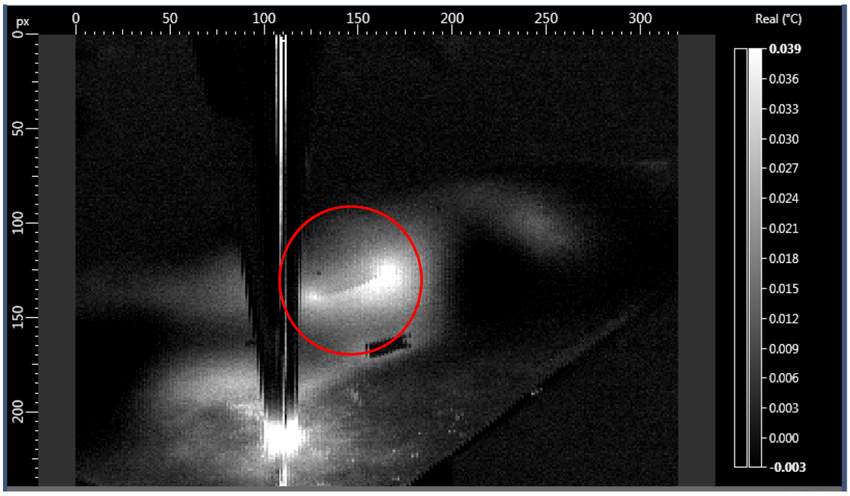

Fig. 3. Specimen after excitation. There is possible to see crack with I shape
Rys. 3. Próbka po wzbudzeniu, na rysunku jest widoczne pęknięcie w kształcie I

The first specimen was formed piece of sheet metal (Fig. 2). There was applied emissivity spray with 0.95 emissivity in instead of the expected damage. After excitation was detected crack with I shape (Fig. 3) in red circle. Crack was detected at a frequency of excitation 0.01 Hz and frame rate frequency of infrared camera was use 50 Hz.

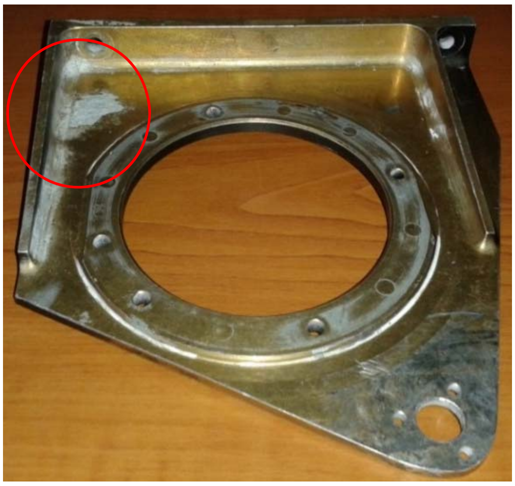

Fig. 4. The test specimen with this shape, the state before excitation
Rys. 4. Próbka, stan przed wzbudzeniem

Fig. 5. Specimen after excitation. There is possible to see inhomogeneity with circular shape in the left top corner
Rys. 5. Próbka po wzbudzeniu, w lewym górnym rogu jest widoczna niehomogeniczność okrągłego kształtu

The second specimen was flange (Fig. 4). After excitation was detected inhomogeneity with circular shape (Fig. 5) also in red circle. Inhomogeneity was detected at a frequency of excitation 0.02 Hz and frame rate frequency of infrared camera was use 10 Hz.

Parameters for infrared camera which are integration time 669 μs and emissivity of material 0.95 were used in the both cases.

Also parameters necessarily to excitation signals were number of periods 3, amplitude 5% and pulse length 0.1 s.

4. CONCLUSION

Each lock-in analysis is specific and it is suitable a different set of excitation signal for its. It was used more sets for excitation frequency and scanning frequency unit l it was detected inhomogeneity. The most appropriate frequency of excitation frequency has proven frequency 0.01 Hz for piece of sheet metal and frequency 0.02 Hz for flange. Therefore the most appropriate frequency of scanning frequency of infrared camera has proved frequency 50 Hz for piece of sheet metal and frequency 10 Hz for flange. Inhomogeneities were detected in display in-phase as a lighter place of temperature field in our case (Fig. 3, Fig. 5). Therefore set of excitation frequency and set of scanning frequency of infrared camera can be also considered sufficient.

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