Pulsed Eddy Current Thermography for Defects Detection in Joints of Metal Sheets

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Abstract
In active thermography it is necessary to bring some energy to inspected sample in order to obtain significant temperature differences witnessing the presence of subsurface anomalies. There are different methods of thermal stimulation applied on tested material like heating lamps, laser, ultrasounds or microwaves, and eddy currents are also used for detection of defects in electroconductive materials. In this context the parts to be tested are heated up by an inductively generated current flow and the temperature profile generated thereby on the surface of the component is recorded with a thermographic camera. The anomalies in main material disturb the flow of the current what results in changes of temperature distribution. This changed temperature distribution can be detected thermographically with a very high resolution. The most often applied joining methods of metal sheets are welding, bonding and rivets and screws. Typical damages in these joint are cracks, decreases and corrosion. This paper reports a noncontact inspection method, using pulsed eddy current stimulated thermography, for evaluation of quality of joints of metal sheets.

Keywords: IR thermography, non-destructive testing, eddy current, metal sheet

1. Introduction

In many industrial branches, especially in the production of safety critical components and elements, the quality of applied joints of metal components is of extreme importance. In this context defects occurring in joints are of special importance since they can constitute a starting point for serious damages. The most often applied methods at joining metal sheets are welding, bonding, screws and rivets.
The main defects in welded joints are different types of cracks, incomplete fusions, voids (gas cavity), inclusions (e.g. slag) and improper shapes or gaps.
In bonded joints typical defects are cracks, overheating, pits and blowholes, lack of bonding, inclusions and voids.
In screw joints there are truncation of thread, loose nut, cracks of screw and lack of a screw or nut.
In riveted joints there are worked out and loose rivets, lack of a rivet, crack of rivet and truncation of rivet.
In non-destructive testing the interaction of physical fields with structure of tested material is exploited. Within a relatively short development period of modern nondestructive testing the rich domain of technical means came into being or was developed, making possible utilization of a wide range of physical phenomena. Along with development of data acquisition and processing techniques the possibilities for detailed analysis of information included in signals that corresponds to the interaction between physical fields and the structure of tested material have expanded greatly. IR thermography is one of many methods of nondestructive testing. Thermographic non-destructive testing is not a new concept for assessment of materials. The first tests in this area were performed at the break of fifth and sixth decades of former century [1, 2]. However it was only after the development of capabilities of computer image analysis and appearance of thermal visualization systems of high resolution that the application of non-destructive tests using IR thermography has considerably increased the range and quality of possible tests. The break of last centuries is symbolically represented by 2000 year which is recognized as a very important milestone in IR technology development. The most important event of that time was that IR cameras with cooled focal plane array (FPA) detectors appeared
as commercial products. Now the IR thermal cameras are used as standard devices of NETD below 20 mK and possibilities of their usage in new applications have considerably increased. The eddy current thermography method for testing electroconductive materials is a combination of two existing nondestructive testing methods of the depth sensitive eddy current testing and the fast and contact-free thermography [3, 4].

In order to evaluate the pulsed eddy current thermography on detecting defects in joints of metal sheets it is compared in the paper with a vibrothermography method that uses ultrasonic stimulation.

2. Experimental methods

Eddy current thermography is a NDT-technique for the detection of defects in electroconductive materials. It combines the well-established inspection techniques of eddy current testing and thermography. The advantage of this method is to use the high performance of eddy current testing without knowing the edge conditions. Especially for components of complex geometry this is an important factor which may overcome the high cost of inspection set-up [5].

Pulsed Eddy Current Thermography is technique that uses pulses of eddy-currents induced in conducting media to generate local heating inside the material. The transient diffusion of the heat inside the material, induced by pulsed induction heating, is imaged by measuring the transient temperature profiles on the surface of the material. The presence and characteristics of the defects inside the materials change the surface temperature transients and thus can be used for the nondestructive evaluation (NDE) of conducting materials [6].

The heating stimulation by induction is a very interesting alternative to optical stimulation because the eddy current excites no absorption of light on surface of tested object. Sometimes optical absorption causes useless measurement results and a lot of applications use eddy current as excitation source for avoiding this problem.

The experiments have been fulfilled by means of a FLIR SC 7600 IR imager (image format 320×256, acquisition frequency 5 Hz, up to 1600 images in a sequence). The eddy current stimulation was performed with the frequency from 8 to 30 kHz with the power from 80 to 150 W (maximum allowed power up to 3 kW).

Fig. 1 presents the set-up used for thermographic tests with pulsed eddy current thermography.

The phenomenon of mechanical hysteresis seems to be vanishing in the range of typically used ultrasonic frequencies and electrical powers (from 20 to 40 kHz and up to a few kW respectively) [7, 8], therefore, the parts of not defected composite material remain ‘cold’ during stimulation, while noticeable temperature signals appear in defective areas due to internal friction. The experiments at MIAT have been fulfilled by means of a FLIR SC 7600 IR imager (image format 320×256, acquisition frequency 5 Hz, up to 1600 images in a sequence). Continuous ultrasonic stimulation was performed with a piezoelectric unit at the frequency of 30 kHz with the power from 60 to 100 W (maximum allowed power up to 2 kW). Fig. 2 presents the set-up used for thermographic tests with ultrasonic thermal stimulation.
Fig. 1. Set-up of pulsed eddy current thermography method.

Figure 2. Set-up of vibrothermography method with ultrasonic thermal excitation
Tests have been performed on three samples (Fig. 3-5): both surfaces of the sample (welded joint of steel sheets) is shown in Fig.3, Fig.4 shows riveted joint of steel sheets and Fig.5 presents bonded joint of a rocket missile stabilizer.

Figure 3. The sample – welded joint of steel sheets:
   a) tested side (black painted), b) other side

Figure 4. The sample – riveted joint of steel sheets:
   a) tested side (black painted), b) other side
3. Results

Fig. 6 shows thermograms of the sample with welded joint obtained by pulsed eddy current thermography (Fig. 6a) and vibrothermography with ultrasonic stimulation method, presenting defect of welded joint (gap) on opposite side of the sample (Fig.3b). Obtained results are very similar for both methods.
Figure 7. Thermograms of sample with riveted joint:
   a) pulsed eddy current thermography method,
   b) vibrothermography with ultrasonic stimulation method.

Figure 8. Thermograms of sample with bonded joint:
   a) pulsed eddy current thermography method,
   b) vibrothermography with ultrasonic stimulation method.
In the sample (Fig.4) there are damaged connections in 2 and 3 rivets (Fig. 4a). Rivet 2 is fixed loosely and rivet 3 is very loose comparing to other rivets. Fig.7a presents thermogram of this sample obtained by pulsed eddy current thermography method. Image of rivet 3 (white arrow – Fig. 7a) is a little different than other rivets on this thermogram. Differences between rivet 2 and other rivets are not visible. Different situation is on thermogram obtained by vibrothermography with ultrasonic stimulation method (Fig. 7b). Very good visible is difference between rivet 2 (white arrow) and other rivets. Difference between image of rivet 3 and other rivets are faintly visible.

Damage of the bonded joint of a rocket missile stabilizer is very good visible on thermogram (Fig. 8a – white arrow). This damage is ambiguously visible on thermogram (Fig. 8b – white arrow) obtained by vibrothermography with ultrasonic stimulation method.

4. Conclusions

Results received from eddy current thermal stimulation showed that this method of detection defects in joints of metal sheets is far-reaching. Some defects like bonded joints are better visible than at vibrothermography using ultrasonic stimulation method.

In order to improve detection of defects in different joints of metal sheets in further experiments we would like to focus on the use of eddy currents transducers in different configurations and special techniques of image processing.

References