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Multilayer transducer for impulse eddy current testing system

Abstract. *This paper presents a new electromagnetic Printed Circuit Board (PCB) transducer, which is powered from the Impulse Eddy Current (IEC) system. The PCB transducer has been designed for identification of defects located in the thin test specimen made of Inconel, which is widely used in chemical, nuclear and aerospace industry.*

Streszczenie. *Artykuł prezentuje nowy elektromagnetyczny przetwornik wykonany w postaci obwodów drukowanych (PCB), który jest zasilany z impulsowego systemu wiroprądowego. Przetwornik PCB zaprojektowano w celu identyfikacji wad znajdujących się w cienkich płytach z Inconelu powszechnie stosowanych w przemyśle chemicznym, jądrowym i lotniczym. (**Przetwornik wielowarstwowy przeznaczony do impulsowego systemu wiroprądowego**).*

Keywords: nondestructive testing, eddy currents, multilayer transducer, pulse generation.
Słowa kluczowe: badania nieniszczące, prądy wirowe, przetwornik wielowarstwowy, generowanie impulsu.

Introduction

Eddy current testing is one of the most popular nondestructive testing techniques used for inspection of conducting materials. The new industrial safety demands require substantial improvements of this technique, both in sensitivity and characterization ability. There are basically three types of systems for eddy current nondestructive testing: single frequency instruments, multi-frequency instruments and pulse systems [1]. Accurate assessment of depth or location of defects can be obtained by examining response of the transducer for different excitation frequencies [2]. The same effect can be achieved by analyzing time response of the system in case of the pulse excitation. Such analysis may be carried out in a time and in a frequency domain [3, 4]. Precise identification of the defects can be facilitated if the excitation contains a wide range of frequencies. Therefore, in the proposed system, instead of forcing a rectangular waveform a very short duration impulse is used as the excitation. The short pulses contain many harmonics and it improves performance of the system. The rapidly rising current pulses causes that the transducers used in the system should have a relatively low inductance. On the other hand, the transmitter must have a certain sensitivity and spatial resolution. In order to meet all the goals, a new improved multilayer transducer dedicated for Impulse Eddy Current (IEC) systems is proposed. A precise flaw evaluation was achieved by an analysis of signals obtained from the probe response in the time domain. In this paper an application of the system for evaluation of Inconel planar specimens is described.

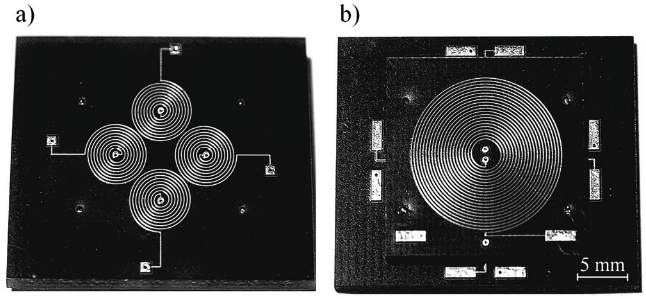

Fig. 1. Photos of the PCB transducer: a) bottom side, b) top side

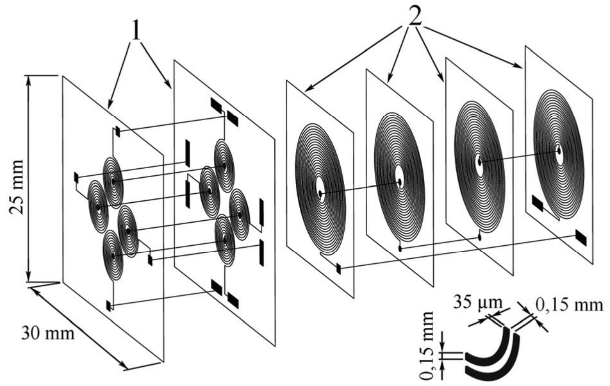

Fig. 2. Schematic view of the PCB transducer (1 - two layers with the detections coils, 2 - four layers with the excitation coil)

Impulse eddy current system

Due to the limited availability of switching power supplies having the required parameters, works have been undertaken aimed at building a specialized current pulse generator [5]. The proposed IEC system enables to carry on tests with very short current impulses. During the tests, generation of a current pulse having amplitude up to 100 A and duration of the pulse from 200 ns was proved.

Differential eddy current transducer

The inductive transducer was fabricated on a FR4 substrate (fiberglass epoxy laminate). The transducer has a total dimension of 30 mm x 25 mm and the thickness of 3 mm. Photos of the transducer are shown in Figure 1. The transducer consists of four detection coils fabricated on two layers and one excitation coil fabricated on four layers of PCB (Fig. 2).

The multilayer coils allow us to achieve greater sensitivity, and maintain high-resolution [6]. The detection coils are connected in a differential manner. Such arrangement of the probe is aimed at its miniaturization and improved spatial resolution. An additional advantage of the transmitter design is a full symmetry and a high precision. In the future, it should simplify identification of the defects.

In cases where the test material is homogeneous, the resultant signal from the measuring coils is close to zero. Any disturbance of the transducer symmetry caused by a defect in the material creates a differential output signal of high amplitude. Changes of the output voltage can be recorded using the oscilloscope with a sampling frequency over 2 GHz. A block diagram of the entire measurement system is shown in Figure 3.

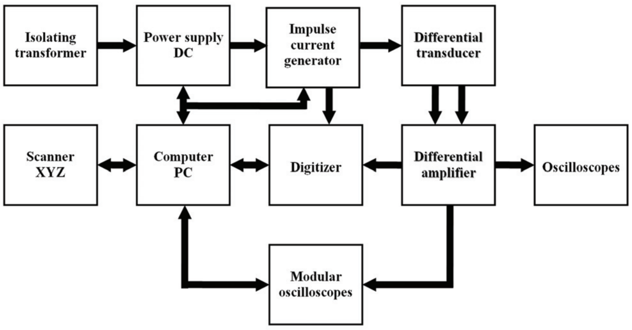

Fig. 3. Block scheme of the IEC NDT system

Measurements

In order to evaluate the effectiveness of the measuring system and the new transducer, a number of test measurements were carried out. During the experiments a 1,3 mm thick Inconel plate (Fig. 4), with artificial defects in the form of EDM (Electric Discharge Method) notches (width 0,2 mm and length 7 mm) was utilized. The defects have relative depth from 40% to 80%. All defects were located on the opposite surface of the examined specimen.

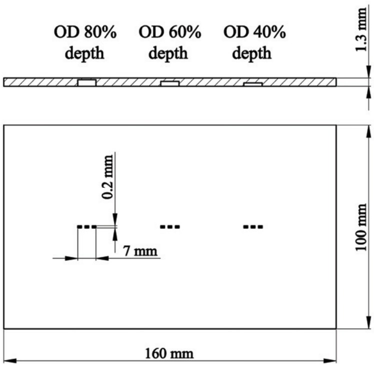

Fig. 4. View of the test specimen made of Inconel (OD-outer defect)

During measurements, the transducer was moved over the flawed area of the specimen with step of 0.2 mm. Figure 5 shows the positions of the transducer, where the highest output respond was observed. The duration of the current impulses was set to 6.75 μs and impulse amplitude was set to 30 A. These parameters were chosen by experiments. A shape of the current pulse which feeds the excitation coil is shown in Figure 6. Signals from detection coils recorded during the measurements at selected locations are presented in Figures 7-9. The measured peak amplitudes at each position of the transducer are plotted in Figure 10. Finally, a relationship between the peak amplitude and the relative depth of defect is shown in Figure 11.

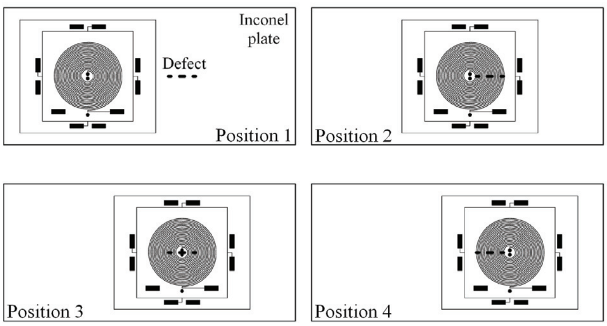

Fig. 5. Selected positions of the transducer during the measurements

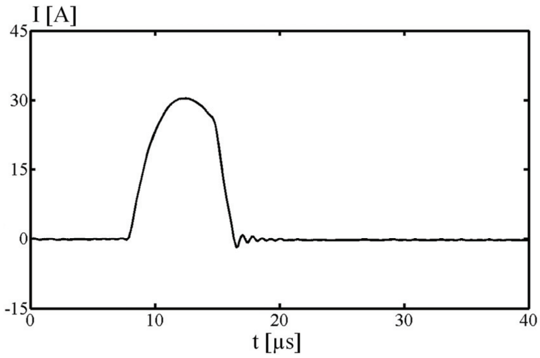

Fig. 6. Waveform of the excitation current pulse

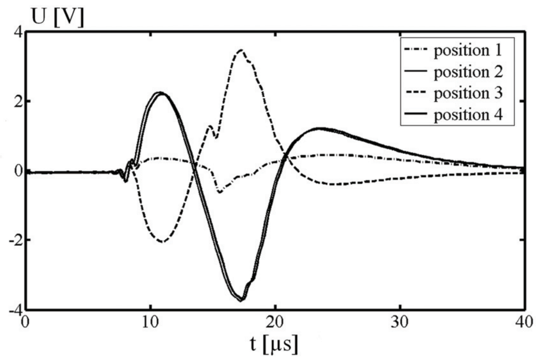

Fig. 7. Signals measured in case of the OD 80% depth

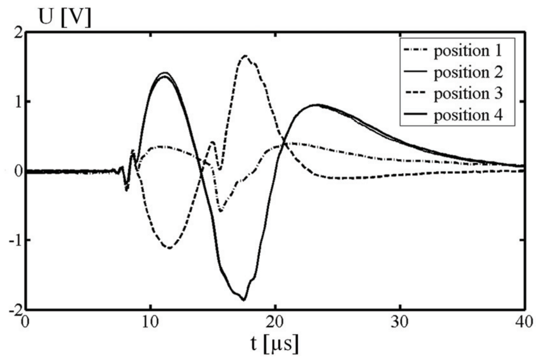

Fig. 8. Signals measured in case of the OD 60% depth

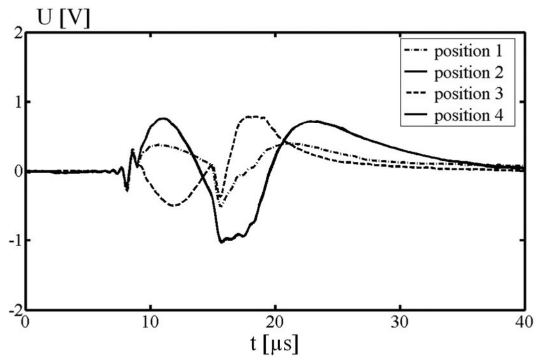

Fig. 9. Signals measured in case of the OD 40% depth

The output signals (Fig. 7-9) measured in case of position 1 and position 4 are nearly identical in case of all the defects. It confirms very good symmetry of the transducer. The symmetry of respond can be also observed in Figure 10, where peak amplitudes were measured for the transducer moving along the defects. The symmetry was achieved thanks to the precise construction of the transducer. As shown in Figure 11 the deepest defects

(60% and 80%) can be detected with a high probability. The 40% defect can be also detected but the amplitude of respond is significantly lower than in case of the other defects. Therefore, it is possible to conclude that the proposed transducer and the system can be utilized mainly to detect surface and subsurface defects. The higher sensitivity for internal defects can be achieved by changes of the excitation current waveform in order to reduce frequency of the main harmonics. Also, additional adjustment carried out in order to reduce output voltage generated for the unflawed specimen can improve the transducer's sensitivity. The other disadvantage of the transducer is non-linear relationship between defect depth and amplitude of the response (Fig. 11).

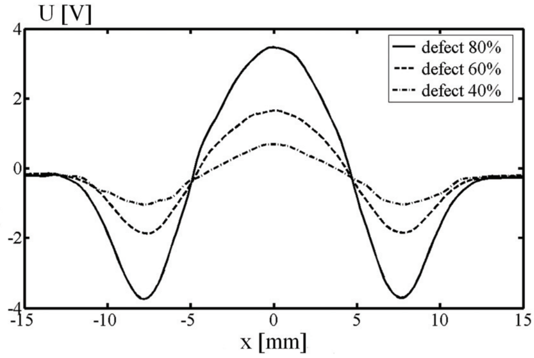

Fig. 10. Peak voltages of signals in case of the OD 80%, OD 60%, OD 40%, measured along the defects

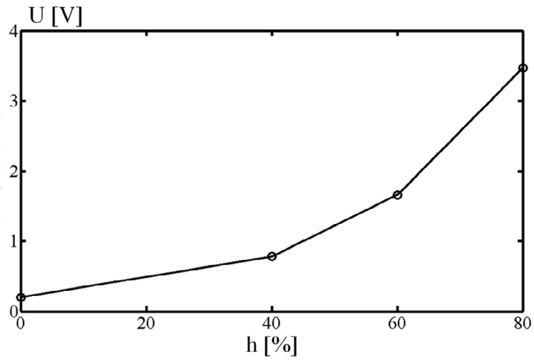

Fig. 11. Peak amplitude as a function of the relative depth of defects

Conclusion

All the tested defects were detected with an appropriate level of signal to noise ratio. The relatively large amplitude variations achieved for defects of different depths allows for their proper identification. Therefore, the presented results allow us to conclude that the proposed system is a promising measurement tool, however further works must be carried out in order to optimize the transducer.

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