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EVALUATION OF TWO ULTRASONIC SYSTEMS FOR ANALYSIS OF POROSITY IN CERAMIC

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ABSTRACT

The Ultrasound Laboratory of the Nuclear Engineering Institute (LABUS / IEN) has developed an ultrasonic technique to measure porosity in nuclear fuel pellets (UO_2). By difficulties related to the handling of UO_2 pellets, Alumina (Al_2O_3) pellets have been used in preliminary tests, until a methodology for tests with pellets of UO_2 could be defined. In a previous work, in which a contact ultrasonic technique was used, good results were obtained to measure the porosity of Alumina pellets. In the current studies, it was found that the frequency spectrum of an ultrasonic pulse is very sensitive to the porosity of the medium in which it propagates. In order to define the most appropriate experimental apparatus for using immersion technique in future tests, two ultrasonic systems, available in LABUS, which permit to work with the ultrasonic pulse in the frequency domain were evaluated . One system was the Explorer II (Matec INSTRUMENTS) and the other the ultrasonic pulse generator Epoch 4 Plus (Panametrics) coupled with an oscilloscope TDS 3032B (Tektronix). For this evaluation, several frequency spectra were obtained with the two equipment, by the passage of the ultrasonic wave in the same pellet of Alumina. This procedure was performed on four different days, on each day 12 ultrasonic signals were acquired, one signal every 10 minutes, with each apparatus. The results were compared and analyzed as regard the repeatability of the frequency spectra obtained.

1. INTRODUCTION

The porosity of ceramic nuclear fuel pellets (UO_2), which are widely used as nuclear fuel in Pressurized Water Reactors (PWR), should be well controlled so that the reactor functions perfectly and efficiently [1]. Porosity is not only a key factor to guarantee the mechanical properties [2] but also a determinant factor to thermal conductivity once it is related to the structural integrity of the fuel.

Therefore, the ultrasound laboratory of the nuclear engineering institute (LABUS/IEN) has developed several researches using nonconventional ultrasonic techniques applied to the characterization of porosity in ceramic materials. Among the processes of measurement of porosity, researches that use ultrasonic techniques to create correlations between ultrasonic wave velocity and the porosity of the respective material, analyzing the ultrasonic pulse of time domain can be highlighted [3, 4]. However, a recent technique that was developed in LABUS analyzes ultrasonic pulse in frequency domain [5] instead of time domain, which is commonly used. In frequency domain, ultrasonic pulse interacts with the internal structure of the analyzed material, altering the initial shape of the signal due to the interactions. After passing through the material, the signal is deformed to each type of internal structure. Thus, the frequency spectrum of the ultrasonic pulse provides data that can be applied to characterize the analyzed pellet, functioning as the “signature” of the material.

During analyses, when observed in frequency domain, the ultrasonic wave showed to be sensitive to the porosity variations of the propagation medium. With this technique, it was possible to detect variations of 0,01% porosity in Alumina pellets [6]. Moreover, it was possible to improve precision, leading to conclude that the coupling between the transducer and the body sample, and the equipment used to spectrum measurement are the main sources of imprecision in the measurements.

It is important to note that this work does not intend to analyze how the ultrasonic signal interacts with different porosities. It wants to determine just what equipment provides frequency spectra with lower amplitude oscillations, so it was used only one pellet.

Aiming at defining the most appropriate equipment to be used in further tests, it was carried out an evaluation of two ultrasonic systems, available at LABUS, which allow researchers to deal with the ultrasonic pulse in frequency domain. One of the systems analyzed is composed of the pulse generator Epoch 4 Plus (Panametrics) coupled with an oscilloscope TDS 3032B (Tektronix) and the other is Explorer II (Matec INSTRUMENTS).

These systems were analyzed with regard to repeatability of the measurements, in which several frequency spectra were obtained from the two pieces of equipment through the passage of the ultrasonic wave in the same Alumina pellet, repeating this procedure on four different days.

2. MATERIALS AND METHODS

2.1. Materials

Based on previous studies, [3,5], one Alumina (Al_2O_3) ceramic pellet was randomly selected to be used as the unique body sample in which spectrum measurements were done. This pellet was synthesized at 1150 ºC and pressed at 10 MPa, obtaining a 37,1% porosity. It is, then, a 25x25x5 mm quadrate shaped pellet, as shown in Fig. 1.

Figure 1. 5MHz longitudinal wave transducer, coupled to the pellet used in this study.

2.2. Ultrasonic System 1 (SU1) – Generator Epoch 4 Plus and digital oscilloscope TDS3032B

The system formed by the Panametrics pulse generator Epoch 4 Plus (on the left) and the Tektronix digital oscilloscope TDS3032B (on the right) is shown in Fig. 2. In the same figure, it is possible to see an amplitude filter used to attenuate the analyzed signal, protecting the oscilloscope input from destructive voltage.

The apparatus assembly scheme is illustrated in Fig. 3. A computer was added to store and analyze the spectra.

In this system, the pulse generator emits a high voltage signal, which passes through the filter and is directed to the transducer. The transducer converts the signal into an ultrasonic pulse, executing the emission and reception of the signal. When the signal returns to the transducer, the ultrasonic pulse is once more converted into a high voltage pulse, whose voltage is attenuated when it passes through the amplitude filter. From the amplitude filter, the signal is emitted to the input of the oscilloscope. Then, the oscilloscope carries out the Fourier Fast Transformed (FFT) in real time and promptly emits these spectra to the computer, in which all the analyses are done.

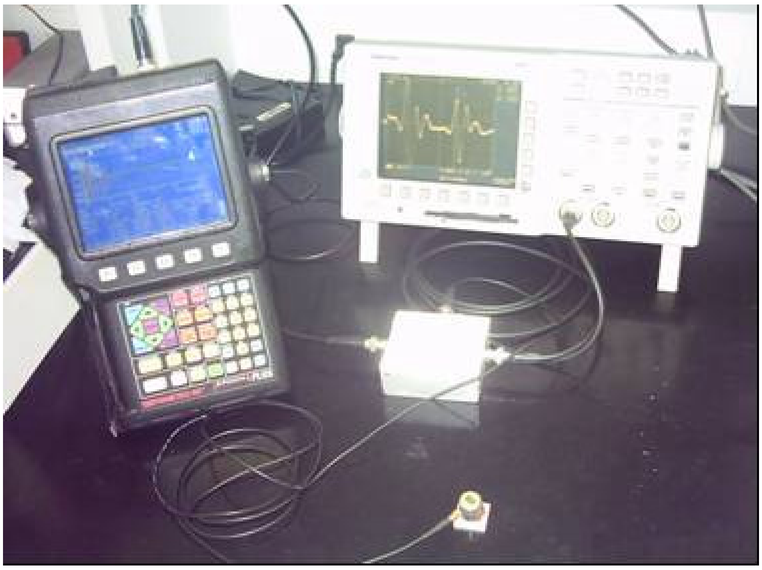


Figure 2. Generator Epoch 4 Plus and TDS 3032B oscilloscope.

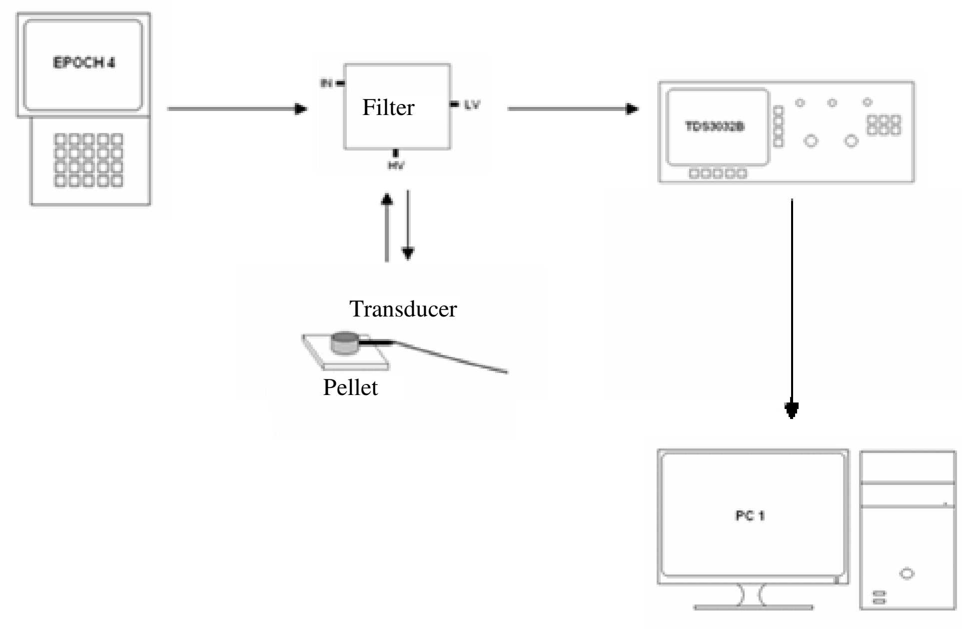


Figure 3. Schematic drawing of the experimental setup by using the generator and the oscilloscope.

2.3. Ultrasonic system 2 (SU2) - Explorer II

Internally, Explorer II (Fig. 4) is a conventional computer (motherboard, processor, memory, etc). It works with a 233 MHz Intel Pentium II processor and a 64 Mb RAM memory. Its operational system is *Windows 95* and the software used for data collection is MUIS 32 – Matec Instruments. This computer has two boards: TB1000 - *MATEC Instruments,* which is responsible for the ultrasonic signal generation and the other, STR8100D – *SONIX*, responsible for signal acquisition.

Figure 4. Explorer II.

In Fig. 5, one can see the simple schematic drawing of the experimental setup; in its assembly, little equipment is involved. EXPLORER II is responsible for generating ultrasonic pulse as well as acquiring the signal and executing FFT. Like SU1, spectra storage and analysis are carried out by the computer.

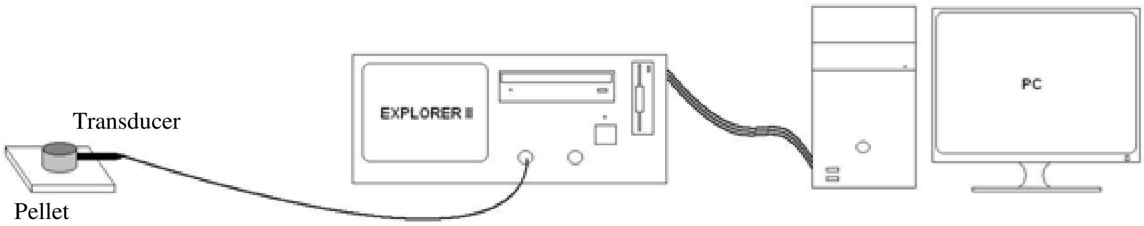


Figure 5. Schematic drawing of the experimental setup by using Explorer II.

2.4. Experimental Procedure

For four days, both systems were tested and several spectra were acquired using a 5 MHz longitudinal wave transducer (Panametrics). Liquid vaseline was used as the coupling agent between the transducer and the pellet.

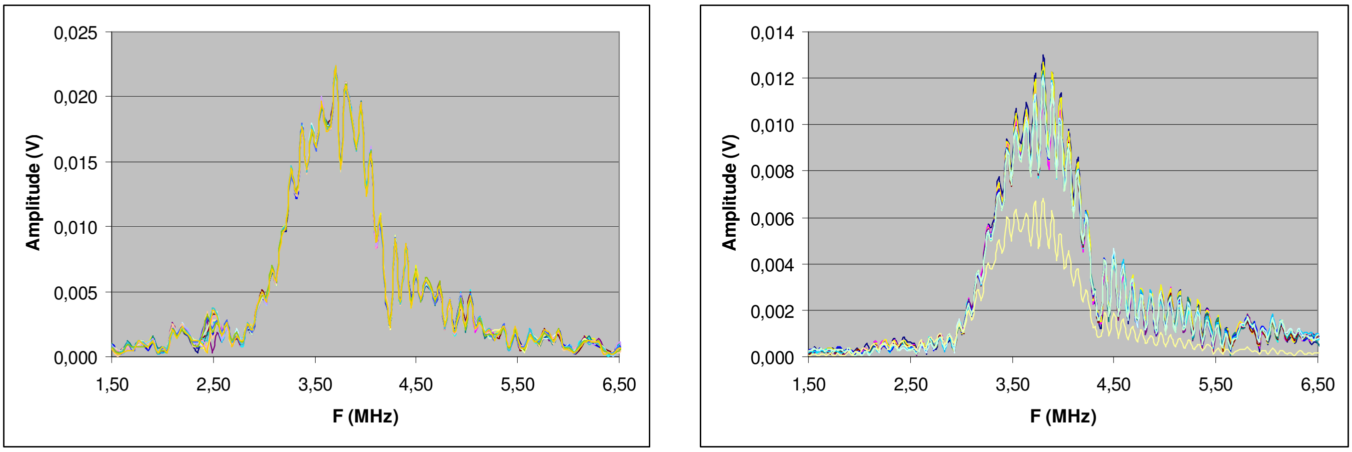
On each day, 12 spectra measurements were executed in each system by using the same ceramic pellet as the reference sample. The spectrum measurements were done at 10 minute intervals, with a total time of approximately four hours (two hours for each system) per day.

Although the systems do not have the same options of configuration, they were adjusted so as to present results as similar as possible. Nevertheless, as previously said, this study aims to test the repeatability of the results (not the similarities) in each system to determine which system is the most reliable to acquire frequency spectra and in which systems the measurements present the lowest fluctuations.

The spectra measured in these systems will be further analyzed; then, based on this analysis, the system that presents the best measurement repeatability may be determined through spectra measurements.

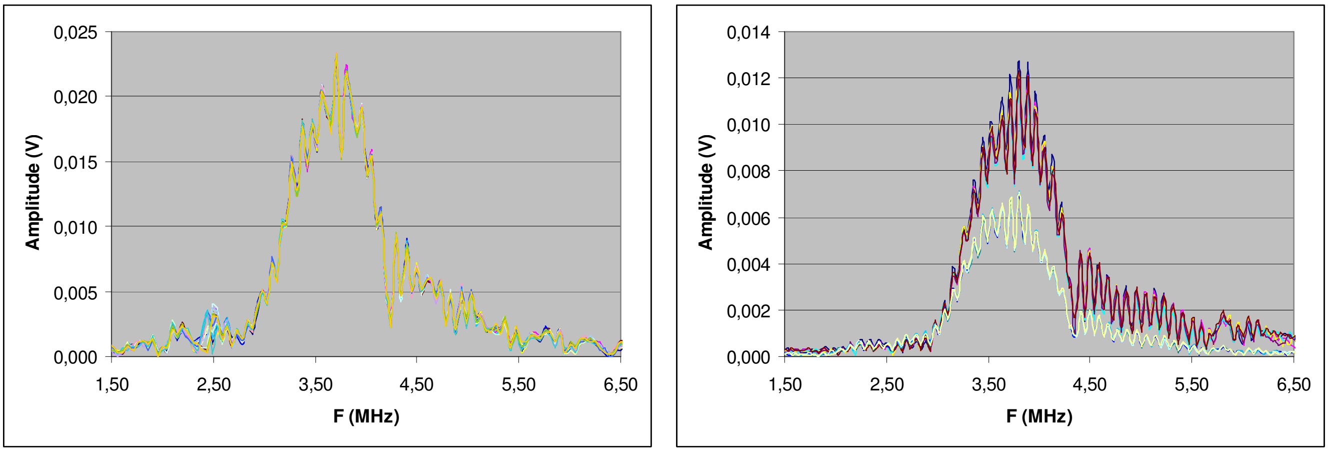
3. RESULTS AND DISCUSSIONS

The measurement oscillations can be visualized by analyzing the spectra measured on each day. The spectra measured with SU1 are shown in Fig. 6(a) to 9(a) and the ones measured with SU2 are shown in Fig. 6(b) to 9(b).



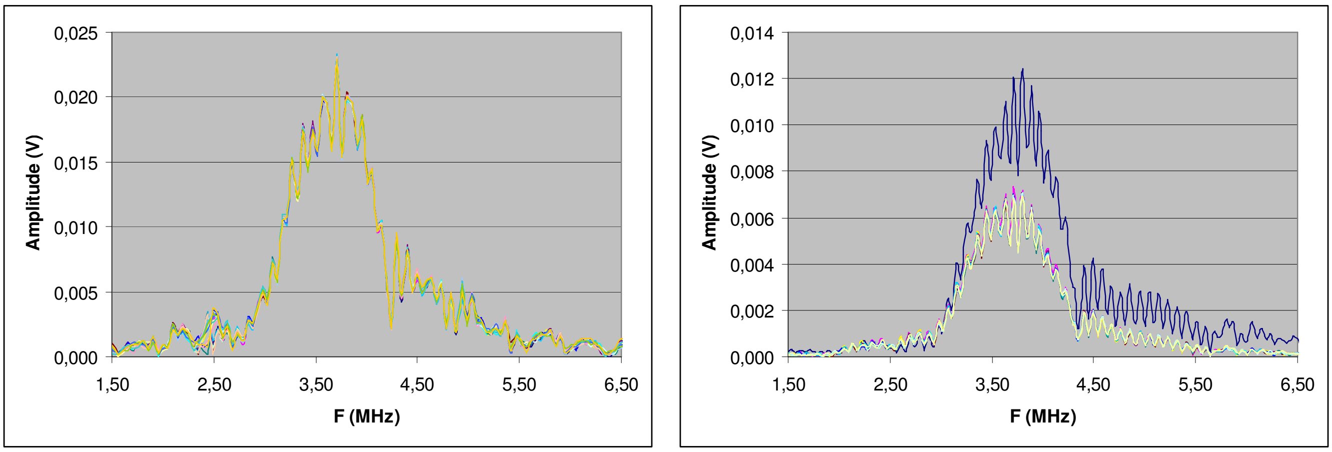
a) b)

Figure 6. First-day spectra measured with SU1 (a) and SU2 (b).



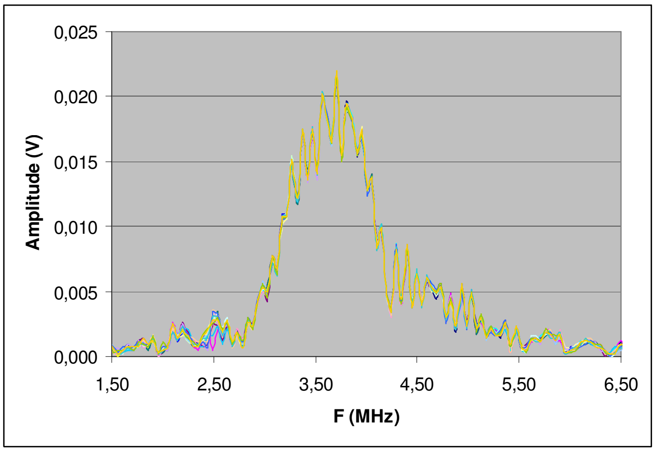
a) b)

Figure 7. Second-day spectra measured with SU1 (a) and SU2 (b).

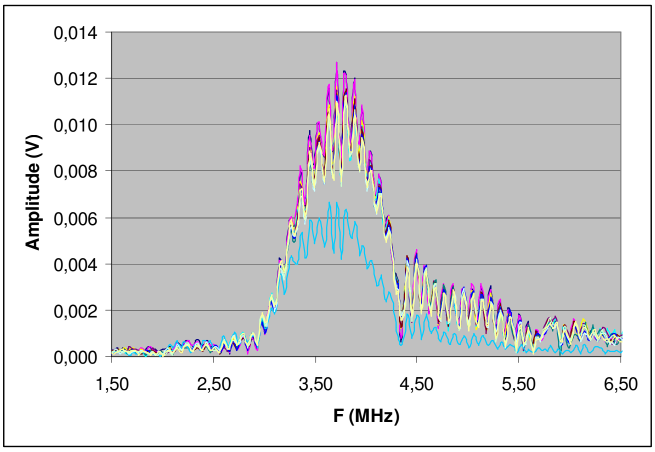


a) b)

Figure 8. Third-day spectra measured with SU1(a) and SU2 (b).



a)



b)

Figure 9. Fourth -day spectra measured with SU1 (a) and SU2 (b).

The result of the maximum amplitude analysis of all spectra measured over a four day test is illustrated in Fig. 10. In this figure, it is possible to observe that each analyzed system presents an average amplitude value in accordance with the configuration of each system. By utilizing Explorer II, it is possible to observe that there is a higher oscillation of these values.

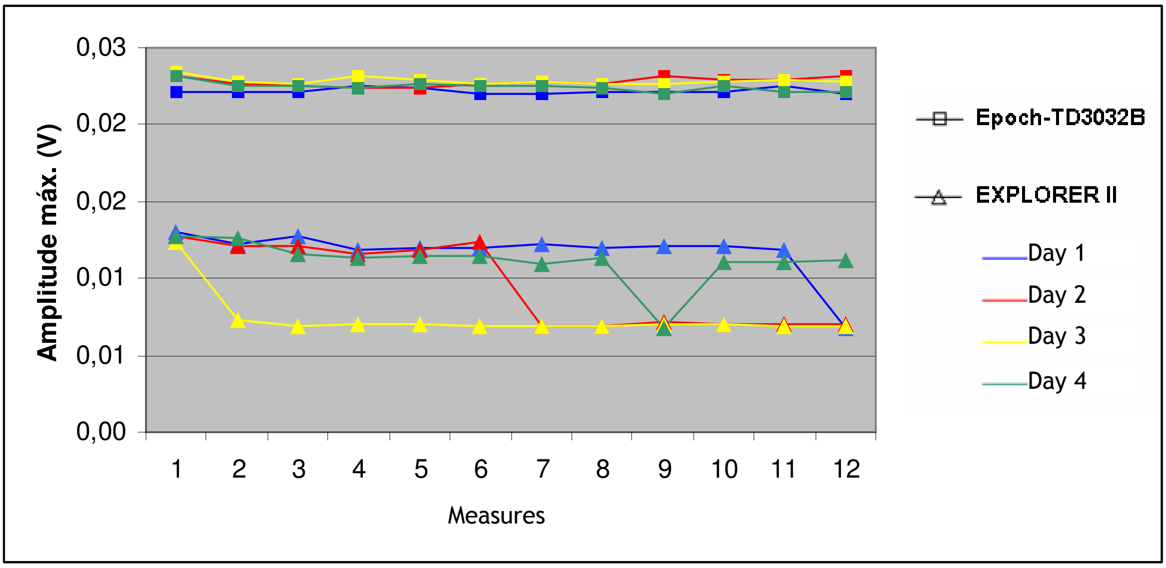


Figure 10. Amplitude oscillations in the spectra over four day test.

4. CONCLUSIONS

According to the results, SU1 (Generator Epoch 4 Plus and digital oscilloscope TDS3032B) presents a better performance when compared to SU2 (Explorer II). Concerning reliability of the measurements (repeatability), SU1 is the most reliable system once it provided low oscillation spectra. Therefore, it is possible to conclude that SU1 will be the system utilized in further tests in order to proceed in developing a porosity measurement method through ultrasonic techniques.

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