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Ultrasonic C-scan imaging for the bone sample

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IIn this paper is presented a nondestructive method to obtain and analyze ultrasound images of bone tissues by C-scan. By applying this method one can obtain bi-dimensional ultrasonic images in which the differences in the image contrast result from the ultrasound-bone tissue interaction. The experimental system consists in an ultrasound pulser-receiver IPR-100, a converter A/D-90 and a 3D transducer-displacement automated system equipped with step-by-step motors (SMC-4) provided by Physical Acoustic Corporation. Pulse-echo technique, in immersion, with a point-focused transducer H10MP15 supplied by Krautkramer Company is used here. Experiments were carried out on 3 human bone tissues samples of different ages. Analysis of C-scan images in amplitude and in TOF results in areal distribution maps of bone density. The number of surfaces and their size with different degrees of bone density are computed and compared.

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1. Introduction

The use of the ultrasound method for characterizing the solid materials regarding the microstructure and associated mechanical parameters, is well known. In a previous paper [1] we have investigated the elastic parameters and their variation with temperature in silicon.

Ultrasonic methods for the investigation of the materials, which constitute the human body, have been successfully used and are yet to be fully exploited. C-scan ultrasonic examination [2, 3] is an important tool for the NDE of bone samples since it allows high resolution imaging of subsurface regions, which would otherwise be inaccessible with the conventional techniques. Other methods for medical imaging either carry known risks of cancer generation (such as X-ray and nuclear medicine), which constrain the achievable image quality, or they are limited in diagnostic scope, or they are expensive and time-consuming. A C-scan image provides a bi-dimensional view of a sample, in which differences in image contrast result from the bone-ultrasound interaction. Data in the form of the return ultrasonic signal amplitude or TOF are collected along a two-dimensional grid, as the transducer is raster-scanned over the bone, in immersion. Pulse-echo technique uses a single transducer both to send and receive an ultrasonic signal. The image that develops depends on the variation in acoustic impedances of the medium of the impinging ultrasound.

The purpose of this image processing is to determine exactly the regions of maximum bone density, hence to estimate accurately the scanned bone surface filled up by calcium and phosphate depositions. The image contrast shows zones with maximum bright intensity that are zones with maximum bone density, and dark regions represent regions filled by air (small bone density) from the bone structure. If one exactly determines zones of maximum bone density of calcium and phosphate depositions, the presence of rickets and osteoporosis can be detected.

2. Experimental

2.1. Sample preparation

Experiments were performed on 3 human bone samples as it follows: a human bone 2000 years old (S1) considered as a reference, a young human bone (S2) and a human bone of medium age (S3).

2.2. Experimental set-up

The experimental measurements were performed in a water tank, made of plastic. The transducer can be driven in three axes under computer control to a spatial resolution of 0.024 mm [4, 5]. The bone sample is set on two plastic holders. The entire experimental set-up is shown in Fig. 1. We used the pulse-echo technique with a single transducer pulser-receiver of type H10MP15, and a point-focused transducer supplied by Krautkramer Company.

The experimental system consists in an ultrasound pulser-receiver IPR-100, a converter A/D-90 and a 3D transducer-displacement automated system equipped with step-by-step motors (SMC-4) provided by Physical Acoustic Corporation.

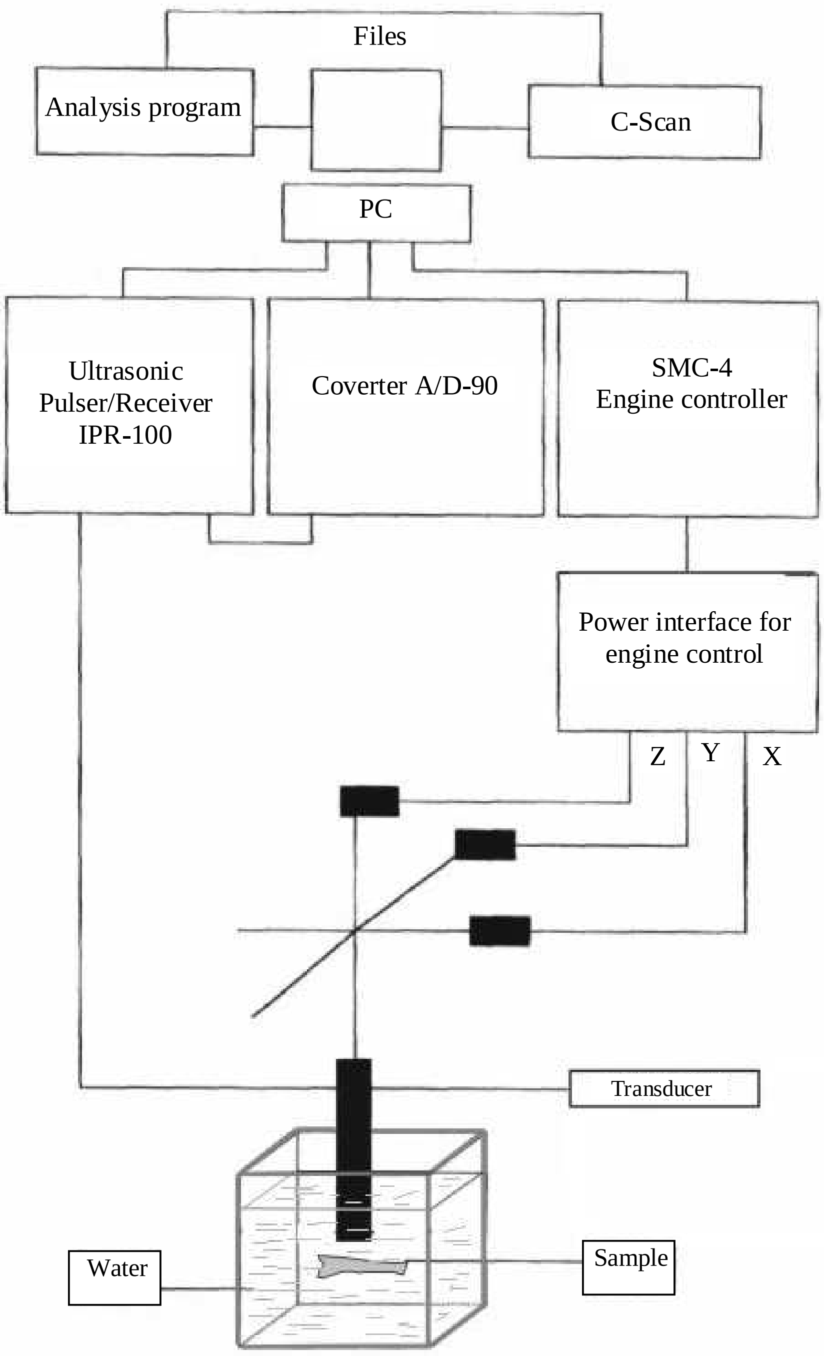

Fig. 1. Experimental system for pulse-echo technique.

3. Results

C-scan images in amplitude and in TOF were recorded for the 3 examined bones (S1, S2, S3). Then, by processing the C-scan in amplitude one obtains a distribution map of the bone density (BD) regions. In this image, large BD regions are mapped to red color, small BD are mapped to green color and between them there are medium BD mapped to blue color.

The obtained information was analyzed with the Analysis program from SOFT-IMAGING, which is an acquisition, analysis and image-processing program.

In order to process the data obtained from the ultrasound scanning, the facilities of the detection Analysis Program were used. For this purpose, a range from the color linear scale from 0 to 256 was selected and the detection was made automatically. These data are saved in files containing information regarding the sample surface, perimeter and diameter and then are statistically analyzed with the Analysis Program.

This program determines the number of surfaces, their size, the total sum, the standard deviation (DS) depending on BD and the percent of BD (large, medium, small) from the entire examined sample. These data were tabulated and the surface was measured in pixels.

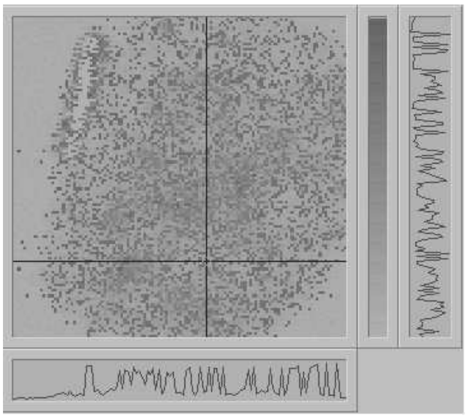

Fig. 2a.

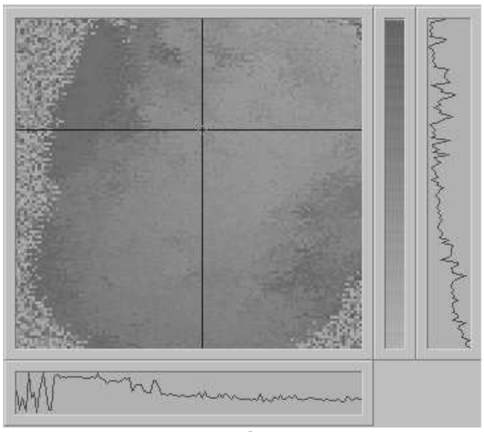

Fig. 2b.

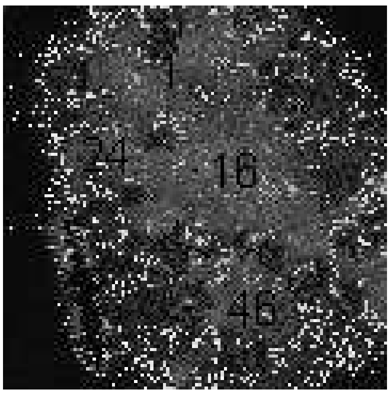

Fig. 2c. C-scan in amplitude (2a), c-scan in TOF(2b), c-scan in a BD zone distribution (2c) for S1 sample.

C-scan ultrasonic image in amplitude and in TOF is shown in Fig. 2a and Fig. 2b, respectively. The image from Fig. 2b represents the result of scanning in TOF showing the geometrical profile of the section. As it is noticed, both from the set and from the analysis of the signal obtained at the two line height, the section it is not perfectly plane. Image processing in amplitude and in TOF results in a BD zone distribution (Fig. 2c) with different colors, from red (high BD) to green (low BD).

Data regarding the number of surfaces, their sizes, the sum and the percent in BD are shown in Table 1.

Table 1. shows the scans in amplitude and in TOF.

	Bone Density (BD)	Surfaces number		Surfaces size		BD%	DS
		__	%	Min	Max		
Sample S_1	Big	16	26.24	10	27	24	5.42
	Medium	38	62.29	10	48	62	9.33
	Small	7	11.47	10	34	14	8.62
Sample S_2	Big	11	5.5	12	153	7	15.71
	Medium	146	73.00	10	221.6	64	13.66
	Small	43	21.5	11	310	29	24.25
Sample S_3	Big	67	46.52	10	584	50	25.03
	Medium	67	46.52	10	118	45	22.71
	Small	10	6.96	10	51	5	12.25

Further, there were analyzed the same images in amplitude and in TOF and the parameters from the table, for the sample 2 (young human bone) and sample 3 (medium age bone).

4. Discussion

Analyzing the table, the scans in amplitude and in TOF one can conclude: sample 1 is considered as a reference in the analysis of the experimental data. Analyzing the data obtained from Fig. 2a, 3a, and 4a and from the Table 1, one can notice that the number of surfaces detected at S1 (reference sample) is smaller then at S2 (61 to 200) because S2 is in continuous growth.

Surfaces of medium BD are the ones having 38 at S1 and 146 at S2 and the maximum size of the surfaces is 222.6 at S2 and 48 at S1.

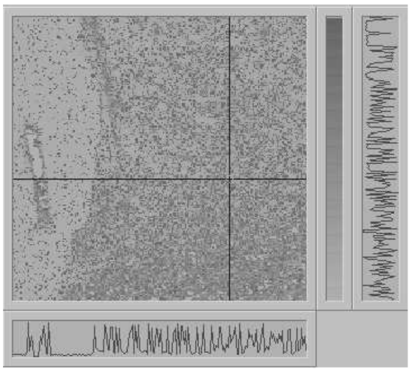

Fig. 3a.

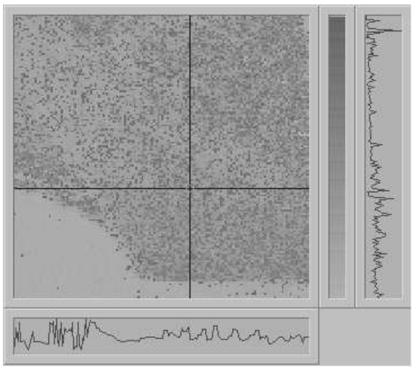

Fig. 3b.

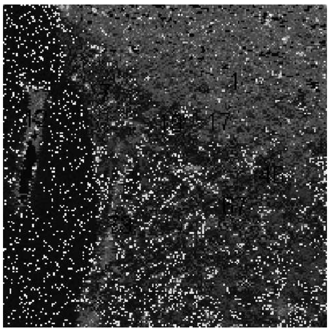

Fig. 3c. C-scan in amplitude (3a), c-scan in TOF(3b), c-scan in a BD zone distribution (3c) for S2 sample.

The growth of the young bone (S2) is also emphasized by the size of the surfaces of small BD: 310 (S2) comparative with 34 (S1). One can conclude that the distribution of the surfaces size is twice bigger at S2 then at S1 for all BD areas. The percentage calculation of BD considering the number of detected surfaces shows stability at medium BD (64%) and a change at small BD: 29% for S2 and 14% for S1, namely twice bigger which shows that S2 is in the process of growth. In the case of S3 (medium age bone) one can notice an increase of the detected medium surfaces (three times) of big BD and a decrease of the ones of small BD that proves that the medium age bone S3 is already mature. The same conclusion is drawn by percentage analysis: 50% (big BD) and 45% (medium BD), namely stability appears in the bony region proved by the 95% percentage.

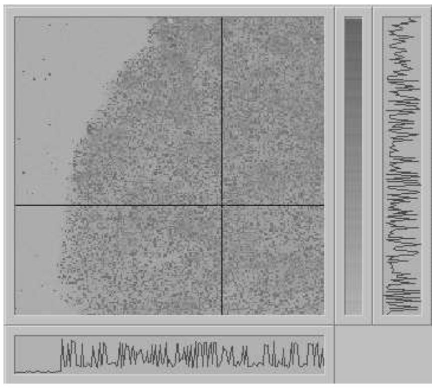

Fig. 4a.

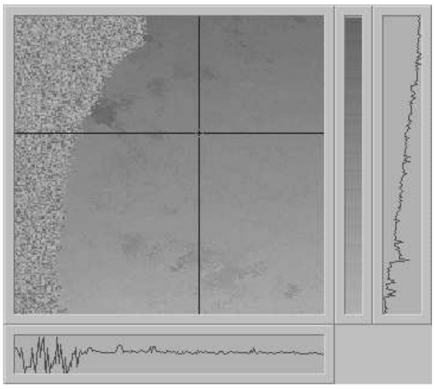

Fig. 4b.

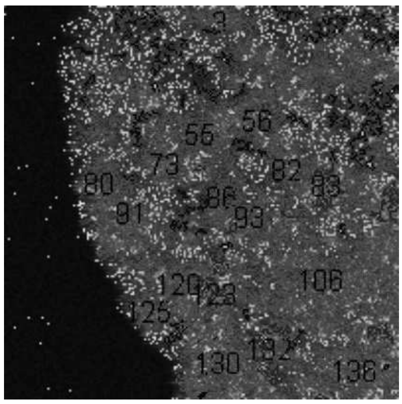

Fig. 4c. C-scan in amplitude (4a), c-scan in TOF(4b), c-scan in a BD zone distribution (4c) for S3 sample.

4. Conclusions

This paper presents an ultrasonic nondestructive method to obtain images from a bone sample by C-scan.

There are examined 3 human bone samples by pulse –echo technique, in immersion. The experimental system is consists of a pulser –receiver IPR-100, a converter A/D-90 and a transducer –displacement automated system equipped with step-by-step motors (SMC-4). The image analysis in amplitude and in TOF leads to the obtaining of areal distribution maps of bone density for the three human bone samples of different ages.

For sample S1 (old human bone) it is noticed that zones of medium bone density (BD) are in higher number than those of higher density, having a higher average value and also a higher standard deviation (SD) 9.33 (comparative with 5.42) that shows an inhomogeneity in the density distribution. At sample S1 prevails the existence of trabeculae (zones of higher and medium density, 86%) comparative with the areale (zones of small density, 14%). At sample S2 (young bone) it is noticed the preponderance of the zones of medium bone density (BD) comparative with those of small bone density. These zones of small BD are in lower number (43) and show a big surface size (310) and a homogeneous density distribution (24.35). Also, at sample S2 it is noticed the existence of trabeculae zones (71%) comparative with areale zones (29%). For sample S3 (medium age bone) it is noticed the same number of surfaces with big and medium (increased) BD. Also, it is noticed the inhomogeneity of surfaces distribution, through the standard deviation that is big enough: 25.03 and 22.71 (the existence of trabeculae zones) comparative with that of “areale” that is more homogeneous: 12.25.

Between samples S1 (old human bone) and S2 (young human bone) there is noticed significant difference in the number of analyzed surfaces, that is lower at S1. Regarding the surface distribution depending on BD, it is noticed that the medium bone density prevails, followed by the big BD and the lower density in the end.

References

[1] P. Petculescu, J. Matei, J. Optoelectron. Adv. Mater. **6**(1), 253 (2004).

[2] G. D. Gordon, S. Canimalla, B. R. Tittman, Ultrasonics **31**(5), 373 (1993).

[3] P. Petculescu, R. Ciocan, Romanian Journal of Physics **44**(3-4), 25 (1999).

[4] J. A. Evans, M. B. Tavakoli, Phys. Med. Biol. **35**(10), 1387 (1990).

[5] P. Petculescu, R. Ciocan, D. Ciobanu “Automated system and automated method for ultrasonic investigation” Patent No. 118612B. OSIM, 2003, Romania.

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