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Comparison of ceramic and composite transducers

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The acoustic parameters of composite transducers made of PZT ceramic and epoxy resin were calculated using finite element method (FFM) including the homogenization process. In order to compare the composite and plain ceramics ultrasonic transducers the transmitting-receiving transfer functions and reflected pulses were calculated using Mason's equivalent circuit. The transducer back-loading and the acoustical quarter wave matching to medium were taken into account. The results of calculation were confirmed by the experimental measurements.

INTRODUCTION

In this paper the ultrasonic composite transducers (fabricated by Optel, Wroclaw out of PZ 27- Ferroperm and epoxy resin) and plain ceramic transducers were compared.
The back-loading, the quarter wave layer matching of the transducer acoustical impedance to the medium and finally the inductance compensating the transducer clamped capacitance were considered.

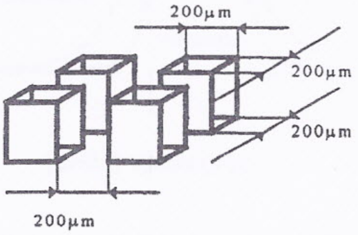

Fig. 1 Piezoelectric matrice

In the previous works [2] the process of asymptotic homogenization of 1-3 composite structures was presented. Using this method the electromechanical coupling coefficient k_t and dielectric constant ε were calculate. It is worth to notice that the

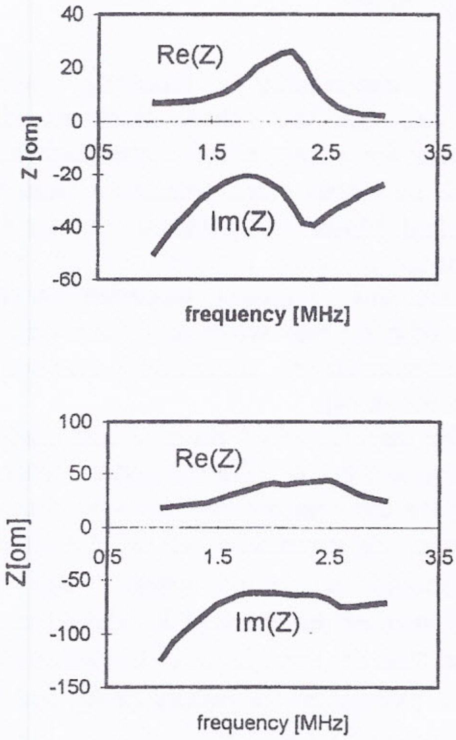

Fig.2 The measured impedance of the of the PZ27 ceramic (top) and composite transducers (bottom) with a back load and the matching layer immersed in water

values of k_t and ε calculated from the measured admittance [1] are the same within 5% accuracy.

Table 1

Transducer type	PZ 27	composite
Coupling coeff. k_t	0.48	0.65
Dielectric const. ε	830	260
Density ρ [kg/m^3]	7700	2830
Velocity c [m/s]	4400	4300
ρc [Mrayl]	34	12.2

Both transducers ceramic and composite ones had the diameter of 20 mm and resonance frequency equal to 2 MHz. The measured impedance of these transducers with a back load and matched to water is shown in Fig.2.

The parameters of composite material were computed applying the homogenization method and the resulting values are presented in Table 1. The acoustical parameters of PZ-27 are given for comparison.

CALCULATIONS OF TRANSFER FUNCTIONS

The transmitting - receiving transfer functions and the echoes from an ideal reflector for a transmitted rectangular pulse of 2 μs length were calculated from the modified Mason's equivalent circuit [3]. Calculations were carried out for plain ceramic and composite unloaded transducers radiating into water and for the back-loaded transducers, acoustically matched to the medium [4].

The impedance of ceramic and composite transducers is different and in order to compare the transmitting-receiving transfer function the impedance of the transmitter R_n should be much smaller and the impedance of the receiver R_O should much higher than the impedance of the transducer. In our calculation the values of R_n and R_O were set to be equal to 0.1 Ω and 1 MΩ, respectively (Figs 3-5).

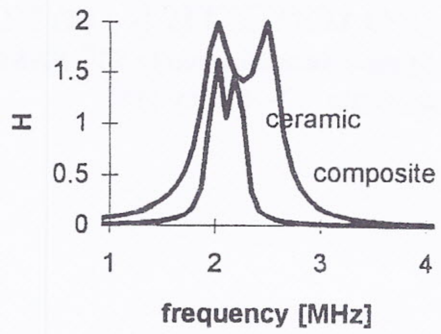

Fig. 3 The calculated transmitting-receiving transfer function of PZ27 ceramic and composite unloaded transducers (R_t = 0.1 Ω, R_r=1 MΩ)

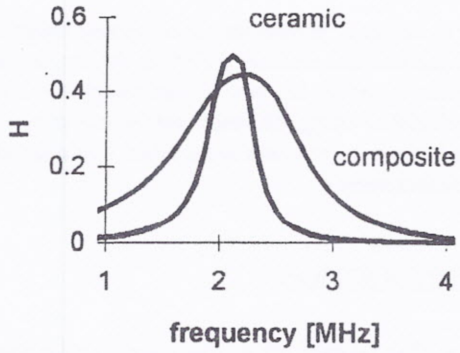

Fig. 4 The calculated transmitting-receiving transfer function of PZ27 ceramic and composite transducers with a back load (R_t = 0.1 Ω, R_r=1 MΩ)

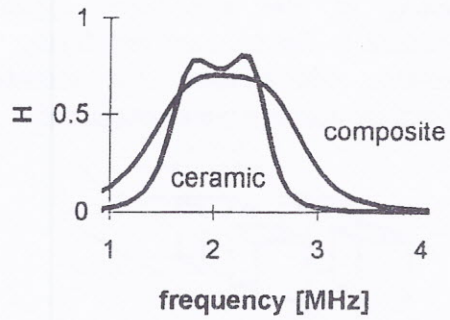

Fig.5 The calculated transmitting-receiving transfer function of PZ27 ceramic and composite transducers with a back load and the matching layer (R_t= 0.1 Ω, R_r=1 MΩ)

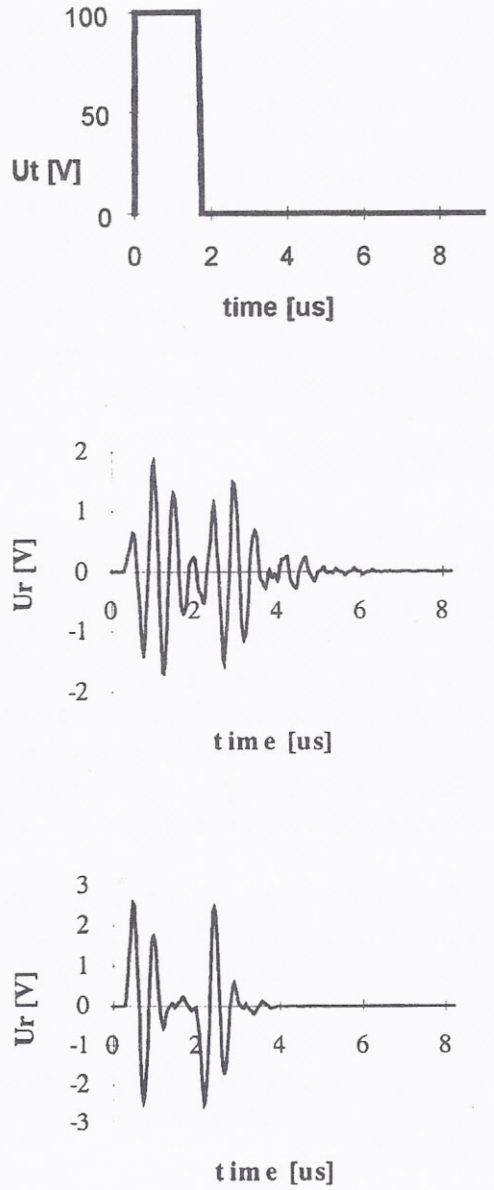

Fig. 6 The calculated reflected pulses for PZ27 ceramic (middle) and composite (bottom) back loaded transducers matched to water for the rectangular driving pulse (top)

The additional resistance of 10 Ω was connected in parallel to the transducer in order to approach the parameters of theoretical models and the actual values of the measurement set-up (Fig.7).

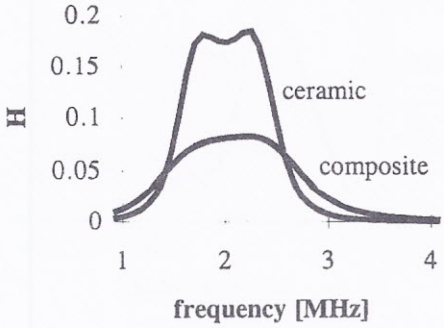

Fig.7 The calculated transmitting-receiving transfer function of PZ27 ceramic and composite transducers with a back load and a matching layer (R_t=R_r=10 Ω)

MEASUREMENTS

The transmitting-receiving transfer function and reflected pulses were measured in the set-up presented in Fig 8.

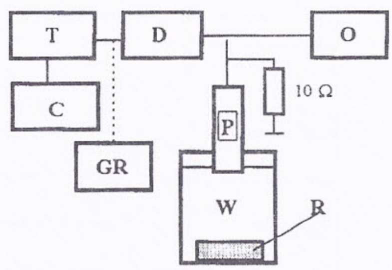

Fig. 8 Measurement system: C - computer PC, T - transmitter RAM 10000-Ritec, D - Diplexer Ritec, O - oscilloscope - LeCroy 9310, P - probe, W - water, R - reflector, GR - square wave pulser SP-801-Ritec

20-period long sinusoidal bursts of 45 V_{p-p} were generated. Next the echoes from the perfect reflector were measured. The transfer function was calculated as a ratio of the amplitude spectra of received echoes and transmitted pulses (Fig.9). To show the advantages of the composite transducer over the ceramic one for short pulse excitation the rectangular pulses (SP-801 and Diplexer) was transmitted (Fig.10).

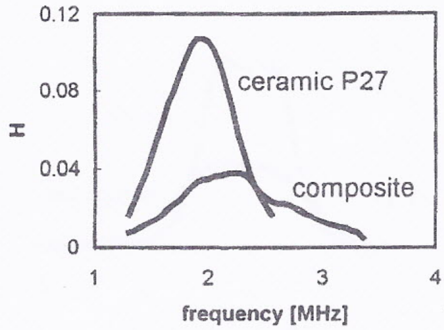

Fig. 9 The measured transmitting-receiving transfer functions of PZ27 ceramic and the composite transducers with the back load and matching layer loaded parallel with 10 Ω resistance

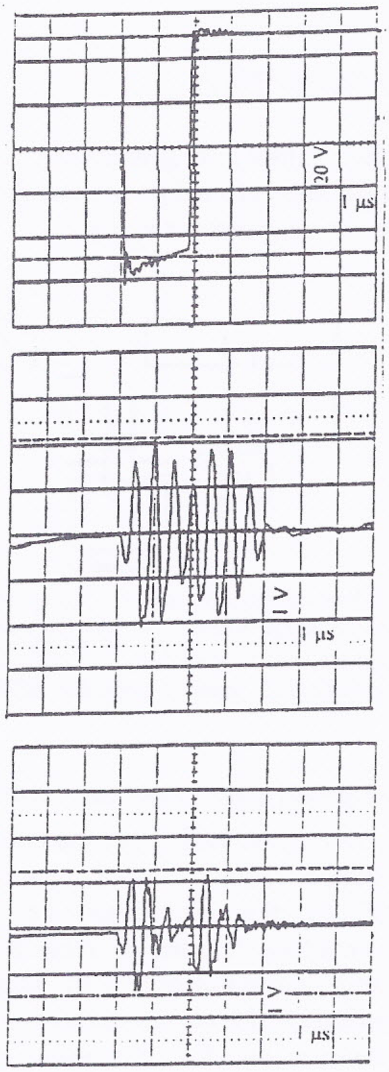

Fig. 10 The measured echoes for PZ27 ceramic (middle) and composite (bottom) transducers with the back load and the matching layer for the rectangular transmitted pulse (top)

CONCLUSIONS

The results of experimental measurements were close to those obtained theoretically proving the possibility of modeling the acousto-electrical properties of composite transducer applying the Mason's equivalent circuit. Small differences were caused by difficulty of defining of the real transmitter and the receiver impedances. The acoustical impedances of the back load material and of the front matching layer were not determined exactly either.

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