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Changes of Working Parameters of a Normal Beam Non-destructive Evaluation Ultrasound Transducer Due to Different Electrical Excitations

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Preliminary note

The electrical excitation dependence of working parameters of a normal beam non-destructive evaluation ultrasound transducer has been investigated. Noteworthy differences between the transducer input electrical impedance and acoustic properties at low excitation voltages (~1V), most often used in electromechanical characterizations by performing frequency sweeps, and at high excitation voltages (~250V), generally used to drive ultrasound transducers in non-destructive evaluation applications, were emphasized. For the purpose of this work, a circular normal beam ultrasound transducer of centre frequency 2 MHz was constructed by using a PZT piezoelectric disk, epoxy-based acoustically passive front matching and backing layers, an electrical impedance matching element, housing and coaxial cable. The transducer was characterized around the thickness extensional vibration mode both by using low and high voltage electrical excitation signals. The characterization of the electromechanical properties was conducted at several different stages of the transducer construction and for several excitation signal waveforms and levels.

Promjene radnih parametara ultrazvučnog pretvarača izlaznog kuta ultrazvučnog snopa 0° za nerazorna ispitivanja uslijed različitih električnih pobuda

Prethodno priopćenje

Svojstva i ponašanje radnih parametara ultrazvučnog pretvarača (izlaznog kuta ultrazvučnog snopa 0°) za kontrolu bez razaranja ispitani su u ovisnosti o vrsti električne pobude. Pokazane su zamjetne razlike između ulazne električne impedancije i akustičnih svojstava pretvarača pri malim električnim pobudnim amplitudama (~1V), koje se u pravilu koriste u elektromehaničkim karakterizacijama mjerenjem frekventne ovisnosti impedancije pretvarača, te pri visokim pobudnim nivoima (~250V), u pravilu korištenih za radnu pobudu ultrazvučnih pretvarača pri obavljanju kontrole bez razaranja. Za ovaj rad konstruiran je osnosimetrični ultrazvučni pretvarač izlaznog kuta ultrazvučnog snopa od 0°, središnje frekvencije 2MHz; u izradi su korišteni akustički aktivan piezoelektrični PZT (olovo-cirkonij-titanat) keramički disk, akustički pasivni prednji i prigušni slojevi na bazi epoksidnih smola, elektronički element za prilagodbu električne impedancije, kućište od nehrđajućeg čelika i koaksijalni kabel. Svojstva pretvarača karakterizirana su oko longitudinalnog ekstenzijskog titrajnog moda korištenjem električnih pobudnih signala i malih i velikih amplituda. Ispitivanje elektromehaničkih svojstava pretvarača napravljeno je pri nekoliko različitih stadija njegove konstrukcije i za nekoliko valnih oblika pobudnih električnih valnih oblika.

1. Introduction

Ultrasound transducers used in non-destructive evaluation (NDE) of materials are typically characterized and modelled by using low-voltage continuous excitation signals of order of magnitude of 1V, in the frequency range centred around resonance frequencies of transducers thickness extensional modes [1-4]. However, for practical NDE applications, these devices are driven by high excitation level spike-shape impulses that have voltage magnitudes that usually go up to several hundred volts and impulse durations up to several hundred nanoseconds. The aim of this work is to discuss differences between these two modes of using the ultrasound transducers through measurements of the input electrical impedance of the constructed device, at the each stage of the construction (from solely the active piezoelectric element up to the whole transducer with a cable and an added inductivity), using low level continuous sweeping voltage magnitude (U_0 = 1V) and high voltage impulses (from 20V up to 200V).

Symbols/Oznake

U_0	- voltage, V - napon	T	- thickness, mm - debljina
D	- diameter, mm - promjer	F	- frequency, Hz - frekvencija

2. Normal beam NDE transducer design and experimental setups

A 2MHz NDE transducer was constructed for this work by using a low-loss PZT APC-851 piezoceramic disc (diameter D = 20mm and thickness T = 1mm) as an acoustically active material [5-6]. The elastic, dielectric and piezoceramic constants of the disc were determined from the input electrical impedance measurements around the series and parallel resonance frequency of its thickness extensional vibration mode [7]. A thick layer of centrifuged tungsten filled epoxy was used as backing, while a thin vacuumed epoxy layer was casted to serve both as a front protective (if the transducer is used for testing on hard structures) and impedance matching (if used in water) layer [8-9]. Additionally, a parallel inductivity was added to match the electrical impedance of the excitation pulses generator. The transducer with a coaxial cable and all the elements used in the construction is shown schematically in Figure 1.

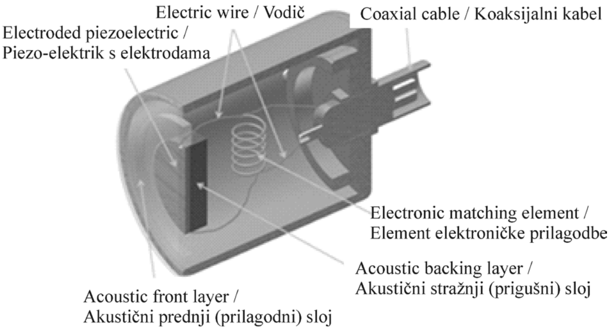

Figure 1. A schematic representation of the NDE ultrasound probe constructed for this work

Slika 1. Shematski prikaz ultrazvučnog pretvarača za kontrolu bez razaranja konstruiranog za ovaj rad

In the experimental part of the work two different measurement setups were used (Figure 2). In the first setup, the input electrical impedance of the device was measured using a *BODE 100* low-voltage impedance analyzer. In the second setup, the ultrasound device was driven at different high voltage magnitude excitation levels using a *TOMOSCAN III* impulse generator. Both measurements sets were performed at the each step of the transducer construction.

3. Results and discussion

The parameters of the piezoceramic were determined from measured input electrical impedance assuming the free resonator model. The input electrical impedance, measured by using continuous voltage sweeping signal, and impulse excitation at different voltage magnitudes, is shown in Figure 3.

One can see that there is no difference in series resonance frequency and the impedance magnitude when the piezoceramic element is driven at different excitation voltage levels. This agrees with previous experimental results at these frequency and voltage ranges which showed a Rayleigh-like behaviour of PZT ceramics [10-11].

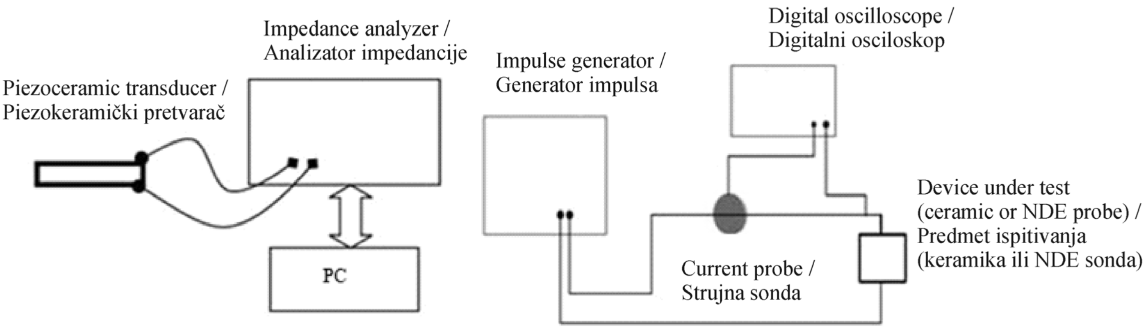

Figure 2. Schematics of the experimental setups used for measurements of the input electrical impedance magnitude and phase by using low-level excitation voltage frequency sweeping signals (left) and high-level excitation impulses (right).

Slika 2. Shematski prikaz eksperimentalnog sustava za mjerenje ulazne električne impedancije (amplituda i faza) koristeći kontinuirane pobudne električne signale malih amplituda (lijevo) i kratke električne impulse velike amplitude (desno).

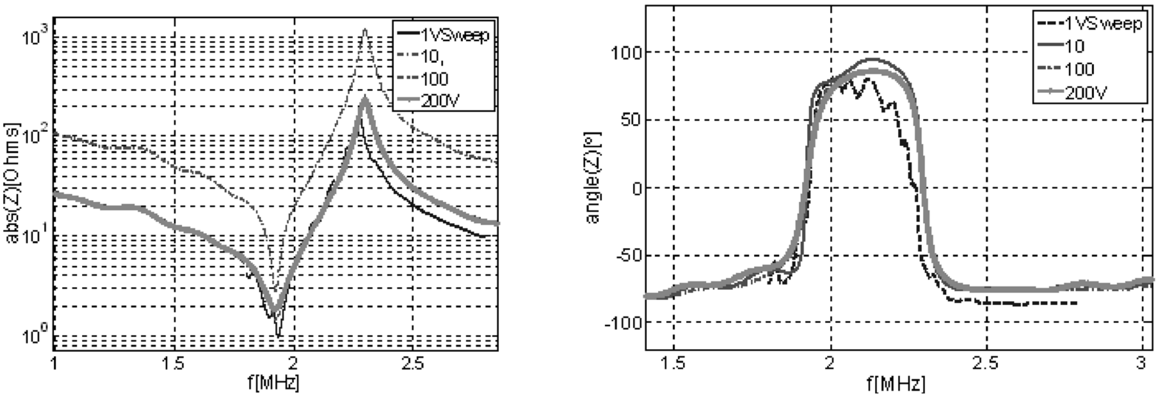

Figure 3. Comparison between electric input impedance and phase measurement results on active piezoceramic element using continuous sweep and impulse excitation

Slika 3. Usporedba rezultata mjerenja amplitude i faze ulazne električne impedancije na akustički aktivnom piezoelektričnom elementu koristeći kontinuiranu promjenu frekvencijske signala male amplitude i kratke električne impulse.

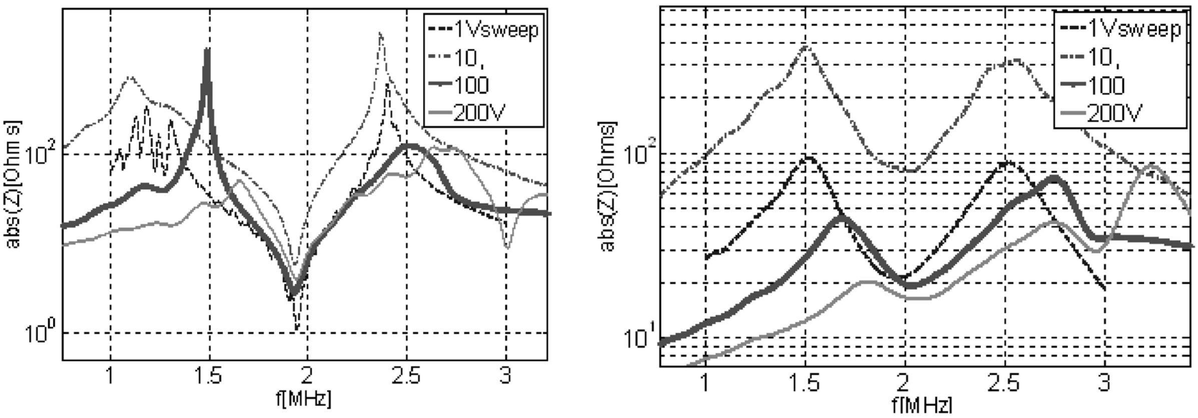

Figure 4. Comparison between measurement results on the assembled PZT piezoceramic disc with inductance and total assembled transducer by using continuous sweep and impulse excitation

Slika 4. Usporedba mjernih rezultata na piezoelektričnom PZT disku s paralelno spojenom zavojnicom te na potpuno složenom pretvaraču, koristeći i kontinuiranu promjenu frekvencijske signala male amplitude i kratke električne pobudne impulse.

In the final stage the whole ultrasound NDE probe has been considered and the procedure of measuring the input electrical impedance at low (1V magnitude sweeping voltage) and higher excitation levels (20V-200V) is done. It is observed that the input electrical impedance magnitude is significantly changed depending on impulse excitation level. The results of measured input electrical impedance magnitude for piezoceramic element with inductance and full assembled NDE transceiver are shown in Figure 4.

If one compares the obtained experimental results with the results, for the same transducer, obtained in the PiezoCAD software [12], that is based on the KLM theory [13-14], one can see that the KLM model agrees well only with low-level signal measurements, which was expected from the model linearity.

4. Conclusion

In this work it was observed that, when a NDE transducer is driven at several excitation levels, a nonlinear behaviour is detected both in the increase of the series resonance frequency and the decrease of the input electrical impedance.

The parameters of the piezoceramic, used as the transducer active element, are also changed at some excitation levels and forms considered in this work. It is then intuitively comprehensible that the models based on the KLM theory are not completely suitable for transducers design.

Acknowledgements

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