where ρ is density, $\mathbf{u_r}$ is the radial displacement component, and $\mathbf{c_{11}^{P}}$ is described by the relationship:

$$c_{11}^{p} = \frac{s_{11}^{E}}{\left(s_{11}^{E}\right)^2 - \left(s_{12}^{E}\right)^2} \tag{13}$$

where: s_{ij}^{E}, i and j = 1 or 2 are the PZT compliance coefficients when electrical field E is constant.

Consequently, the vibratory equation solution is:

$$u_r = A \cdot J_1\left(\frac{\omega r}{v^p}\right) e^{j\omega t} \tag{14}$$

where: ω is the applied field frequency, J_1 - Bessel function by first rang and first case, and

$$v^p = \sqrt{\frac{c_{11}^{p}}{\rho}} \tag{15}$$

Electrical admittance Y_e is:

$$Y_e = \frac{j\omega\varepsilon_{33}^{p}\pi a^2}{h} \cdot \left[\frac{2\left(k^p\right)^2}{1 - \sigma_p - \overline{J_1}} - 1\right] \tag{16}$$

and $\overline{J_1}$ is defined by the relationship:

$$\overline{J_1}(z) = z \cdot \frac{J_0(z)}{J_1(z)} \tag{17}$$

where: J_0 is the Bessel function by first rang and zero case, and σ_p the planar Poisson rapport:

$$\sigma_p = -\frac{s_{12}^{E}}{s_{11}^{E}} \tag{18}$$

The k^p coefficient is the planar coupling piezoelectric coefficient for thin discs and it has the relationship:

$$\left(k^p\right)^2 = \frac{\left(e_{31}^{p}\right)^2}{c_{11}^{p} e_{33}^{p}} \tag{19}$$

where: e_{31}^{p} and e_{33}^{p} are the PZT piezoelectric coefficients.

The relation between k^p coefficient and the usual k_p PZT coupling coefficient is the following:

$$\left(k^p\right)^2 = \frac{1+\sigma_p}{2} \cdot \frac{k_p^2}{1-k_p^2} \tag{20}$$

and k_p is related by k_{31} relation:

$$k_p^2 = \frac{2k_{31}^2}{1-\sigma_p} \tag{21}$$

As result of the above relations combination it can be obtain:

$$Y_e = j\omega\varepsilon_{33}^p \frac{\pi a^2}{h}\left(1-k_p^2\right)\cdot\left(\frac{\overline{J}_1 - 1 + \dfrac{\sigma_p + k_p^2}{1-k_p^2}}{\overline{J}_1 - 1 + \sigma_p}\right) \tag{22}$$

The resonance frequencies are the solutions of the transcendental equation (16):

$$\overline{J}_1\left(\frac{\omega a}{v_p}\right) = 1 - \sigma_p \tag{23}$$

and the antiresonance frequencies ($Y_e = 0$) are the solutions of the transcendental equation:

$$\overline{J}_1\left(\frac{\omega a}{v_p}\right) = 1 - \sigma_p - 2\left(k^p\right)^2 \tag{24}$$

4. Discussions

These methods are suitable for non-metallic materials because they have rugged and non-homogeneous structure, high attenuation coefficients for ultrasound propagation waves into materials. Utilizing non-destructive ultrasonic evaluation methods of non-metallic materials it can be determined the main material parameters and material characteristics (elasticity coefficients, density, propagation velocity, ultrasound attenuation, etc.).

The pulse-echo method is suitable for flaw detection into material structure, locating voids, honeycombing, delaminating, depth of surface opening cracks, thickness measurement, etc. The model of piezoceramic disc is used to modeling the transducer (emitter or sensor).

Conclusions

Signal graphic representation analysis determines the propagation time and attenuation coefficients of pulses propagated into material. Also, could be the signal processing, in order to determine the propagation velocity into material.

As result, this pulse-echo method is suitable for non-metallic materials with rugged and non-homogeneous structures, such as the asphalt layer. Also, it is a non-destructive method at low frequencies, proper to construction materials with high attenuation coefficients of ultrasound signals. The ultrasonic pulse wave analysis has the ability of being a quick and simple test with the added bonus of being a true non-destructive test, appropriate as quality control and assurance in road constructions and can yield certain benefits, such as the road thickness measurement [9], [10].

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