



# Modification of the ultrasonic properties of elastomers loaded with magnetic particles by applying magnetic fields during curing

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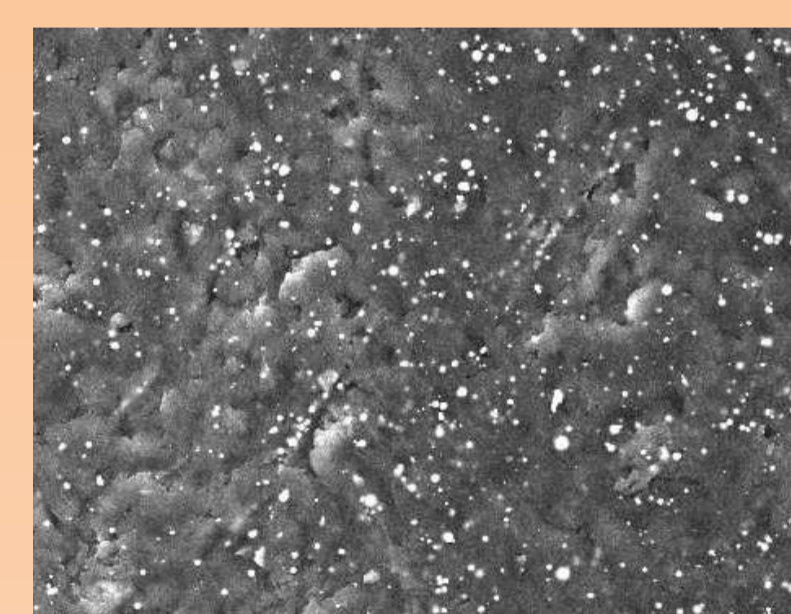
## Introduction

- Magnetorheological elastomers (MRE) consist on magnetic particles embedded in a polymeric matrix and are considered smart materials due to the variation of the properties when an external magnetic field is applied [1]; a particular case of (0-3) connectivity composite material.
- The particle concentration varies the ultrasonic properties of the polymers loaded with non magnetic particles [2].
- Isotropic MRE: samples cured without the influence of the external magnetic field [1-3].
- Anisotropic MRE: particles are aligned in the direction of the applied external magnetic field during the pre-structure process [4].
- The aim of the work is to determine and analyze the influence of the particle concentration and the pre-structure process on the ultrasonic properties of the MRE.

## Synthesis

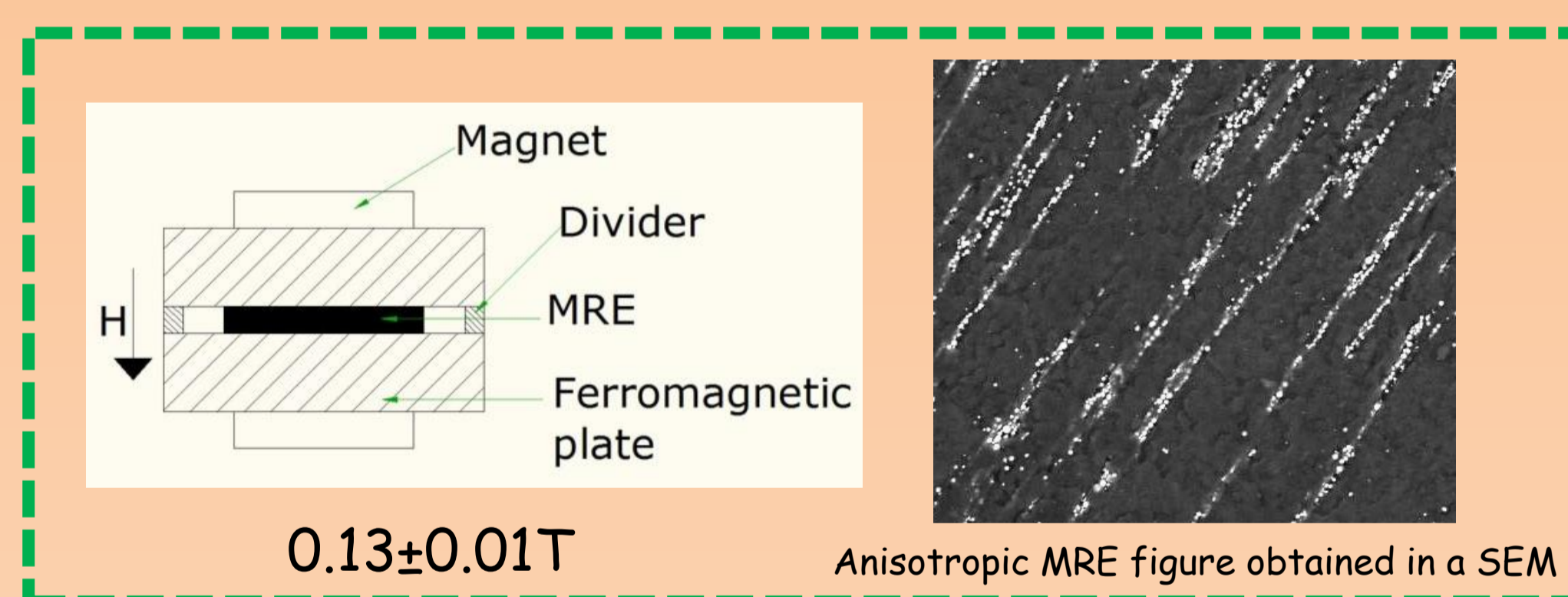
- The synthesized MRE has three components: the silicone WACKER Elastosil® M 4644 A, the vulcanizer WACKER Elastosil® M 4644 B and Carbonyl iron powder particles are embedded in the matrix with an average particle size of  $1.25 \pm 0.55 \mu\text{m}$  and spherical shape.
- Particle volumetric concentrations: 0%, 5%, 10%, 15%, 20%, 25% and 30%.

### ISOTROPIC



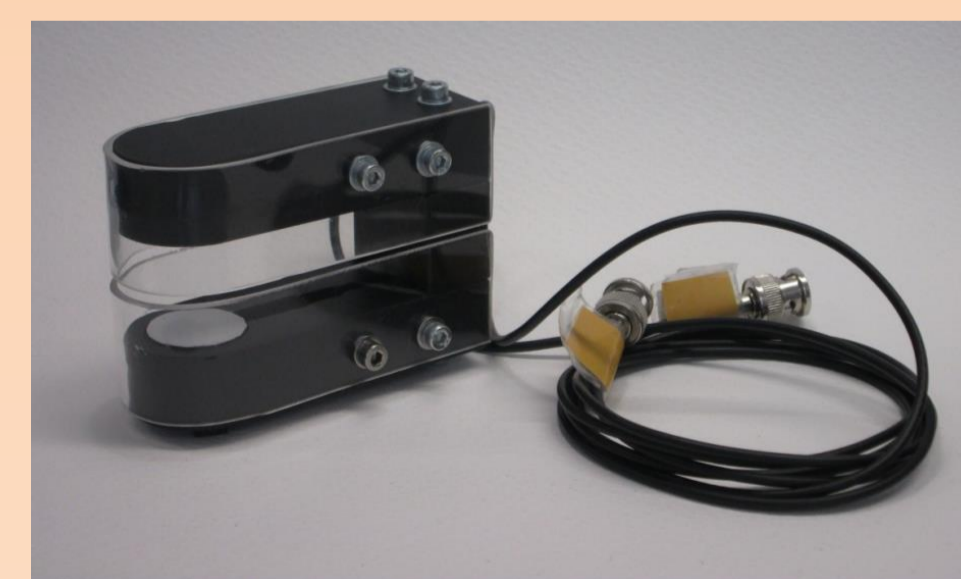
Isotropic MRE figure obtained in a SEM

### ANISOTROPIC

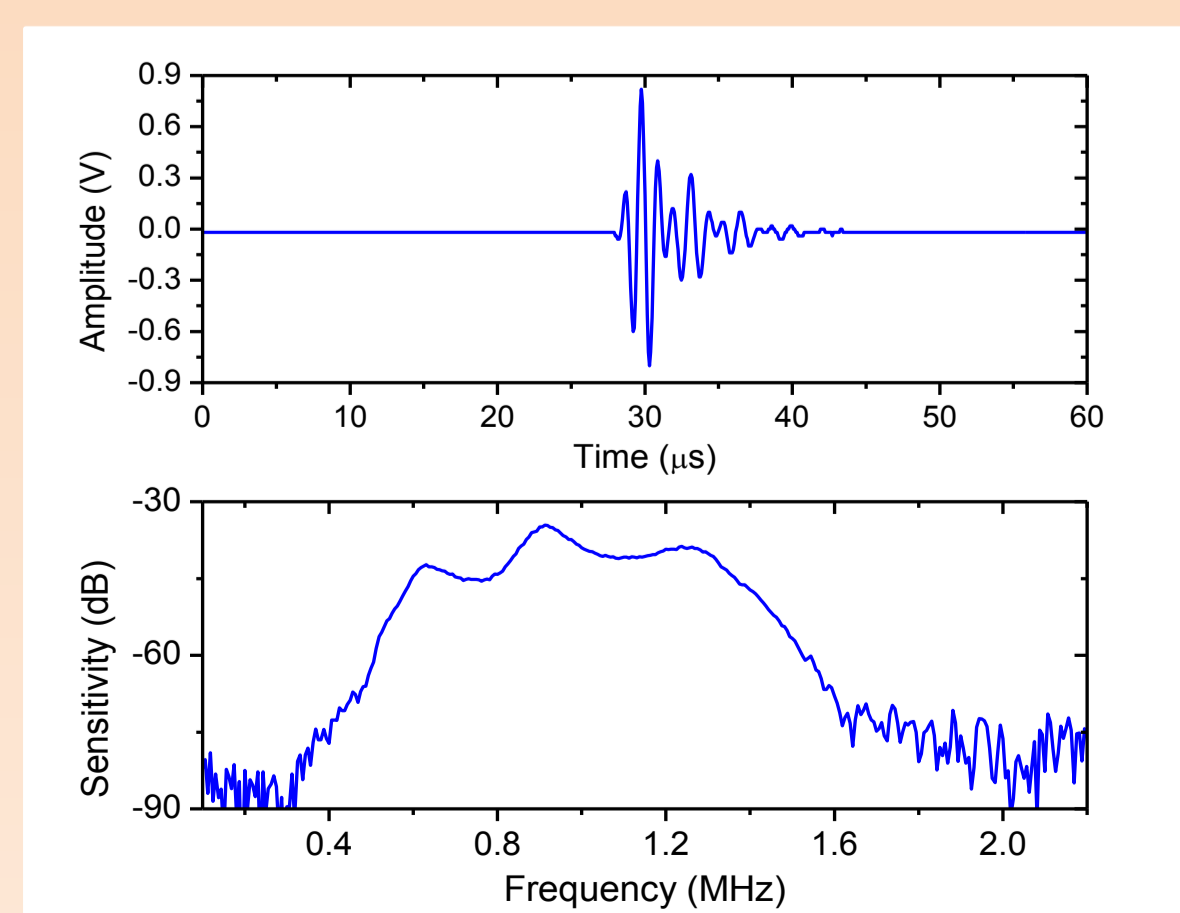


## Characterization

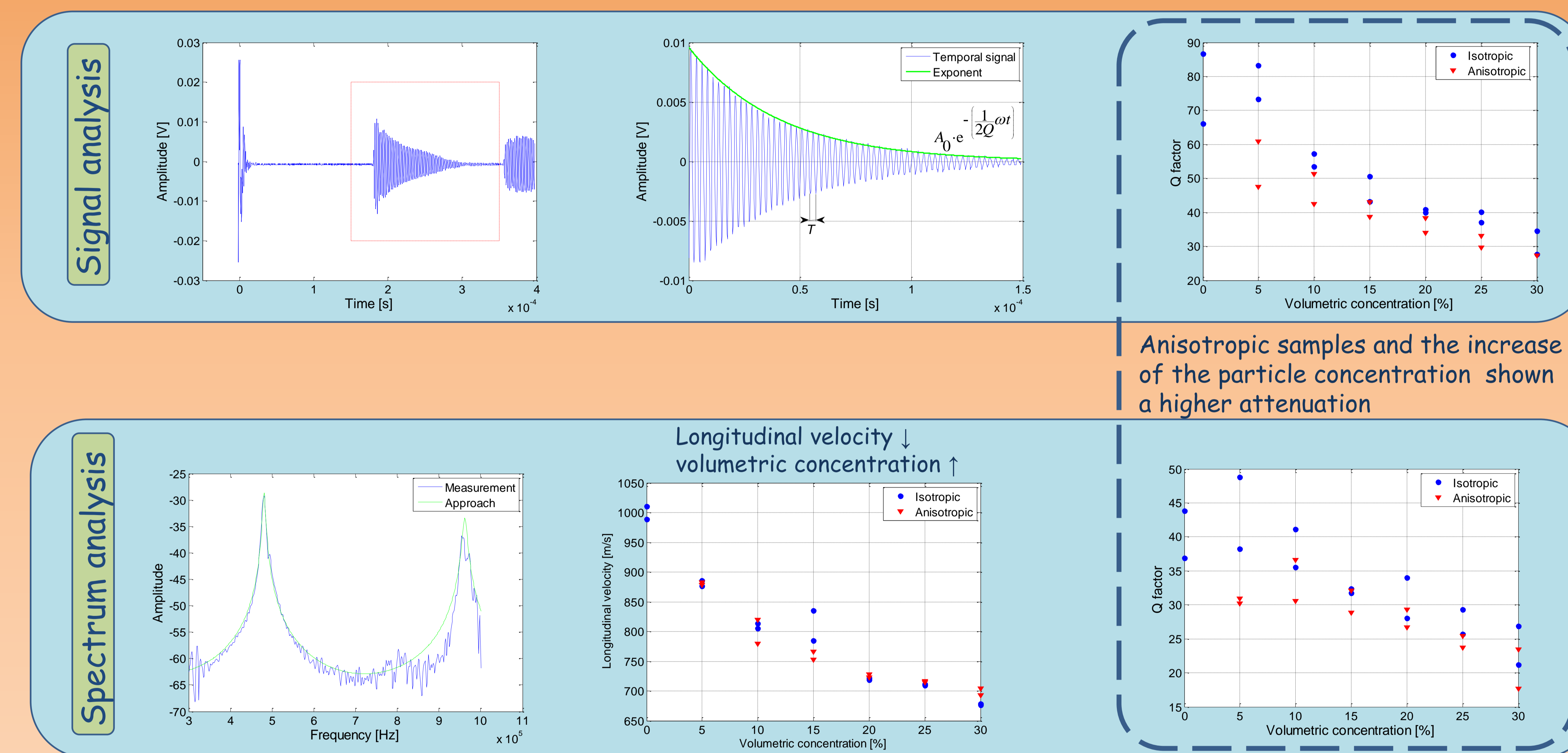
- The magnitude and the phase spectra of the transmission coefficient of a plate-shaped sample are measured at normal incidence and in a ultrasonic frequency band.
- The measurements were performed using a pair of air-coupled wide-band transducers fabricated at us-biomat research group (ITEFI, CSIC) [5-6], and the air-coupled technique is preferred because it offers a better possibility to study changes in materials properties upon the application of a magnetic field [7].



- Transmitter transducer were driven by a 200 V amplitude semicycle of square wave, provided by a conventional pulser (Panametrics 4077), the received signal was analogically amplified (30 dB), with the reception function of the Panametrics 5077 and then digitized by a Tektronix scope (TDS5052).



## Results



## Conclusions

- The increase of the particle concentration from 0 to 30% reduces the longitudinal velocity from 1000 to 700 m/s.
- Quality factor increases when the particle concentration increases, which means that the attenuation is higher, due to the scattering losses introduced by the particles.
- No effect of the pre-structure, obtained with a magnetic field, has been observed on the ultrasonic velocity.
- The quality factor depends on the pre-structure process: the anisotropic samples present a higher attenuation than the isotropic samples.

## Acknowledgment

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## References

- [1] Lokander, M. and Stenberg, B., "Performance of isotropic magnetorheological rubber materials," *Polym. Test.*, vol. 22, pp. 245-51, 2003.
- [2] T. E. Gómez Álvarez-Arenas, A. Mulholland, G. Hayward, J. Gomatam, "Wave propagation in 0-3/3-3 connectivity composites with complex microstructure," *Ultrasonics*, 38(9), pp. 897-907, 2000.
- [3] Varga, Z., Filipcsei, G. and Zrinyi, M., "Magnetic field sensitive functional elastomers with tuneable elastic modulus," *Polymer*, vol. 47, pp. 227-233, 2006.
- [4] Li, J., Gong, X., Xu, Z. and Jiang, W., "The effect of pre-structure process on magnetorheological elastomer performance," *International Journal of Materials Research*, vol. 99, pp. 1358-64, 12, 2008.
- [5] T. E. Gómez Álvarez-Arenas, "Acoustic impedance matching of piezoelectric transducers to the air," *IEEE transactions on ultrasonics, ferroelectrics, and frequency control*, 51(5), pp. 624-33, 2004.
- [6] T. E. Gómez Álvarez-Arenas, T. R. Shrout, S. J. Zhang and H. J. Lee, "Air-Coupled Transducers Based on 1-3 Connectivity Single Crystal Piezocomposites," 2012 IEEE International Ultrasonics Symposium Proceedings, pp. 2230-2233, 2012.
- [7] T. E. Gómez Álvarez-Arenas, "Simultaneous determination of the ultrasound velocity and the thickness of solid plates from the analysis of thickness resonances using air-coupled ultrasound," *Ultrasonics*, vol. 50(2), pp. 104-109, 2010.