Magnetic Field and Ferrite Particles Interaction for Membranes with Augmented Shock-Absorption Capability

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Abstract. Managing vibrations, dynamic responses and damping is one of the challenges of engineering design. The aim of this work is to study the use of damping through nanocomposite materials with a main focus on shock-absorption. The new frontiers of research on multifunctional materials are rapidly moving towards the generation of new nanocomposites based on magnetic nanoparticles that play the role of fillers incorporated in a polymeric matrix. In such materials the interaction between the particles during manufacturing and the interaction of the embedded particles with a surrounding magnetic field is of great importance for the improvement of the performance to obtain small size dampers.

Introduction

One of the main problems in engineered devices and structures is vibration damping. In general shock absorbers, convert the kinetic energy into another form of energy. There are two types of active and passive devices [1]. In the active case, piezoelectric materials generate mechanical forces that oppose the vibrations of the source, instead passive devices, are more complex because they require the sensors feedback and command controls. Generally, piezoelectric elements are integrated with an external shunt circuit, which is heavy and bulky. In recent decades, the interest in the use of composite materials has increased greatly. Recent developments in the field of composites involve the application of nanoscale microparticles in a polymer matrix, which bring numerous improvements in mechanical, thermal, acoustic, flame retardant, and vibration damping properties. Magnetic nanocomposites are among the most innovative materials in recent years because they enable a wide range of functions [2]. In general, the fabrication of nanocomposites is challenging because the material properties and performance are greatly affected by slight variations in the distribution of nanoparticles in the matrix. The fabrication process usually consists of several steps. A nanofiller powder is directly sonicated with a polymer solution, or if such a solution is too viscous, it is first sonicated with solvents. Sonication is also crucial because it affects the final distribution of the nanoparticles, which should be very uniform for optimal material properties. For magnetic particles, this step becomes even more complex because these particles are subject to significant mutual interaction due to their dipole moments. In a fully manufactured nanocomposite, the interaction between particles and the magnetic field is influenced by their relative configuration within the polymer chains.

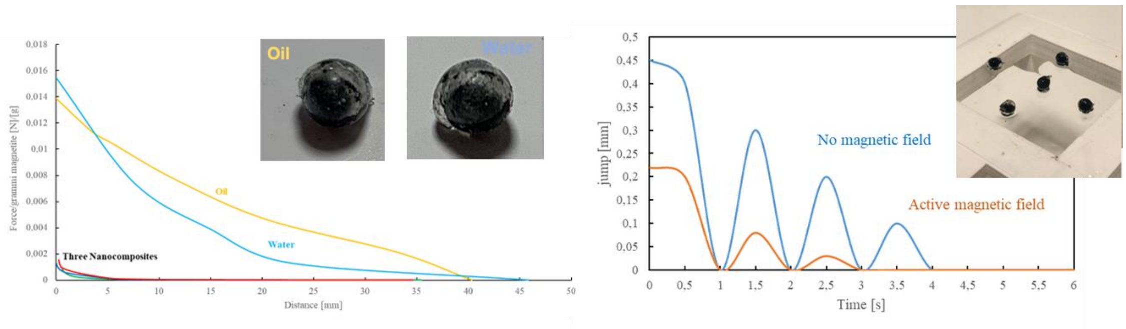

Figure 1: Comparison of the interacting force of various magnetic sphere designs; Damping film with and without a magnetic field.

Objective and results

The goal of this work is a complete understanding of the interaction between individual particles and the interaction of an enclosed group of particles with a magnetic field, combined with the study of shock absorption of ultra-light thin films. This work showed the possibility to improve and modulate, the stiffness and damping coefficient of a silicone membrane, thanks to the inclusion of oil spheres with free magnetite particles. The study, of individual spheres and their interaction with an external magnetic field, allowed to demonstrate that magnetic particles, that are free-to-move inside a shell, have an enhanced interaction with the field than pure nanocomposite spheres. The development of highly performing spheres allowed to create membranes that are greatly able to damp-out vibrations once exposed to a magnetic field also under impulsive actions, leading to the novel concept of an ultra-light membrane that can work as shock absorber.

References

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[2] Kim Y., Yuk H., Zhao R., Chester S. A., Zhao X. (2018) Printing ferromagnetic domain for untethered fast-transforming soft materials. Nature 558: 274-279.