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The influence of particle morphology on the magneto-mechanical and rheological behaviour of magnetorheological elastomer (MRE)

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This study systematically investigates the influence of particle shape on the rheological, magneto-mechanical, and time-dependent properties of MREs using electrolytic iron particles (EIP) and carbonyl iron particles (CIP). The EIP-based MREs (MRE60) exhibit significantly higher storage modulus (G′) and loss modulus (G″), indicating greater stiffness and energy dissipation. This enhancement is because of the flake-shaped morphology of EIP, which provides a larger surface area, stronger particle-matrix interactions, and improved mechanical interlocking within the elastomer network. Conversely, CIP-based MREs (MRE60S) show lower initial moduli and cross-link density due to their spherical shape, leading to weaker mechanical reinforcement. Temperature-dependent analysis reveals that both G′ and G″ decrease with increasing temperature as a result of matrix softening and reduced interfacial bonding, with a more noticeable effect in EIP-based systems.
In amplitude sweep analysis, MRE60 exhibits a slightly wider linear viscoelastic region (LVER) and a higher G′, indicating better structural stability and a stronger filler network, whereas MRE60S shows earlier network breakdown due to weaker interfacial bonding. The filler effect is more pronounced in MRE60, resulting in enhanced stiffness and load-bearing capacity. In magneto-sweep tests, G′ and G″ increase with an applied magnetic field, as shown in Figure 1a. However, MRE60 has higher absolute moduli and greater energy dissipation, while MRE60S demonstrates a higher relative magnetorheological (MR) effect due to efficient alignment and chain formation of spherical particles. During creep–recovery tests at 1 kPa, 2 kPa, and 3 kPa, both materials exhibit typical viscoelastic behaviour, with creep strain increasing at higher stress levels as shown in Figure 1b. MRE60 shows higher creep strain and residual deformation, indicating more internal rearrangement and damping, whereas MRE60S exhibits comparatively lower creep and more stable recovery. Particle shape plays a crucial role in governing MRE performance. Flake-based systems favour mechanical reinforcement and energy dissipation, while CIP-based systems are more suitable for magnetically tuneable and responsive smart applications.

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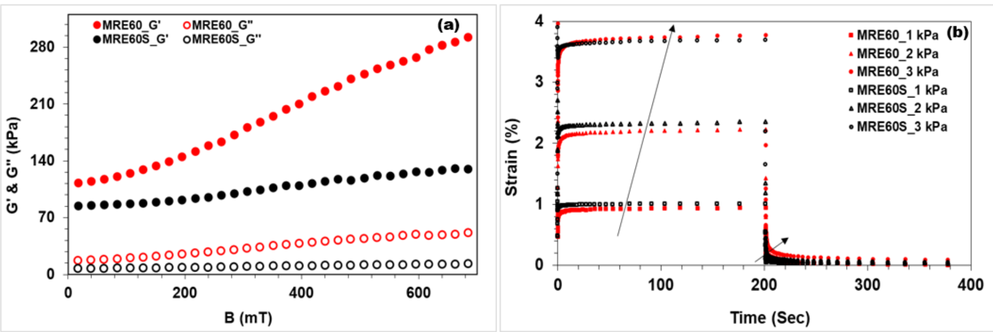

Figure 1: MRE60 & MRE60S graph.

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