Exploring the Impact of Different Milling Parameters of Fe/SiO2 Composites on Their Magnetic Properties

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Abstract. In modern times, our reliance on electronic devices is steadily growing. From sensors to computers, electromotors to inductors, and electromagnetic circuits, these gadgets are ubiquitous. They rely on diverse magnetic materials, each needing optimal properties with minimal cost. This drives global research into creating new alloy compositions or innovative composites, where even the preparation process can profoundly affect their magnetic characteristics. Magnetic materials are pivotal across industries, spanning materials engineering, automotive, power generation, electronics, electromechanical equipment, and beyond.

Soft magnetic composites (SMCs) are a rapidly expanding subset of soft magnetic materials that demand relatively modest investments for their production. Typically, these materials are crafted from ferromagnetic powders, which undergo milling in various types of mills, adjustable under different conditions, often by altering the ball-to-powder ratio (BPR). The milled powders may also be coated with organic, inorganic, or hybrid organic-inorganic coatings to mitigate eddy current loss.

We have focused on investigating the influence of the conditions of mechanical milling of iron powder particles and its subsequent treatment by smoothing surface irregularities. The powders prepared by milling in a planetary mill at the parameters BPR 3:1, 6:1, 9:1 for 120 minutes was covered with an electro-insulating layer of SiO2 by the Stöber method. This “wet” method of insulation can create a consistent layer of insulation on the powder particle surface by chemical reaction made during mixing isopropyl alcohol (320 ml), dis-tilled water (64 ml), tetraethyl orthosilicate (TEOS, 98 %, 32 ml) and ammonia (8 ml) for coating of 10 g of iron powder. The powder obtained this way were pressed at a uniaxial pressure of 700 MPa for 3 minutes at a temperature of 400 ˚C in a vacuum.

We have found out that compacted sample prepared from powder milled at a ball-to-powder ratio (BPR) of 3:1 exhibited the lowest coercive field and losses compared to other samples. This occurred because the particles of the powder sustained minimal damage during milling. Milling reduces particle size and introduces defects that hinder domain wall displacements, thereby increasing the coercive field and total losses. Smaller particle sizes offer the potential for higher composite density within a certain limit. Among the prepared samples, the one compacted from powder milled in a planetary mill at BPR 3:1 demonstrated the best magnetic properties, with a coercive field of 330 $A.m^{-1}$ and total loss of 93 $J.m^{-3}$ at a frequency of 500 Hz and maximum induction of 0.1 T.

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