Application of the Jiles-Atherton model to iron-based soft magnetic composite materials and interpretation of their magnetic properties in terms of model parameters

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The work presents the application of the Jiles-Atherton model to various iron-based soft magnetic composite materials (SMCs). SMCs one obtains by insulating of ferromagnetic powders with dielectric layers, followed by a compaction to various shapes. This remarkable kind of soft magnetic materials possesses high frequency and DC bias stability of permeability, high saturation magnetic polarization and low dynamic energy loss, so finding wide use in practice as electric motors, generators, inductors, transformers or other electromagnetic components. Their magnetization reversal exhibits several typical features, e.g. the influence of inner demagnetizing fields is significant and has to be considered when modeling magnetization curves or magnetic properties dependencies. Therefore, the SMC samples in the presented study were chosen to be representative - differing in various parameters as the composition, Fe powder size distribution, mean particle size, type of insulation and its volume content, as well as preparation conditions. The consideration of inner demagnetizing fields was implemented to the Jiles-Atherton model, which was so specified for SMCs. Inner demagnetizing fields come from volume and surface magnetic poles at any structural defects, in SMCs mostly on the insulated ferromagnetic particles surfaces. The adapted model fitted the measured anhysteretic magnetization curves, exhibiting very good accuracy and the model parameters were obtained, namely the effective domain density, the interdomain coupling and the average magnetic moment of an effective domain. The model parameters values were interpreted in comparison to selected magnetic properties: the maximum total relative permeability, maximum differential relative permeability, inner demagnetization factor and hysteresis energy loss. It was found that with the decrease of the ferromagnetic filler volume content and the average particle size, the effective domain structure is denser, the interdomain coupling is stronger and the average magnetic moment of an effective domain is lower. Concurrently the inner demagnetizing fields are higher, which leads to the lower numbers of active magnetic objects (movable domain walls), corresponding to the soft magnetic properties degradation (the hysteresis loss is increasing and the permeability is decreasing), as the magnetization reversal is then more difficult and energy consuming. The model parameters and their relation with magnetic properties were found to be specific for a given ferromagnetic material in SMC due to different sizes and pinning tendencies of the domain walls. It was also found that the absolute values of parameters as the effective domain density and the interdomain coupling are remarkably higher than those published in literature for bulk ferromagnets, which pointed at the specificity of magnetization reversal of SMCs.