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AD-10 Ferromagnetic hysteresis model using fractional derivative resolution developed for the simulation of viscoelastic phenomena.

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Ferromagnetic materials are used in a wide range of electromagnetic applications (energy converters, sensors, inductances ...). Ferromagnetic materials are characterized by a strong answer under the influence of a magnetic field [1]. These properties are of huge advantages in many applications but they are also strongly non-linear and frequency dependent.

In this domain, we observe a growing interest in the development of simulation tools reducing the experimental campaigns and improving the knowledge and the performances. Accurate simulation results can only be obtained by coupling precise electromagnetic equations to the exact material laws (hysteresis, saturation, frequency dependence). Under the influence of an external magnetic excitation, the local magnetic state through the ferromagnetic specimen is ruled by the combination of both the magnetic domain kinetics and the external magnetic field diffusion.

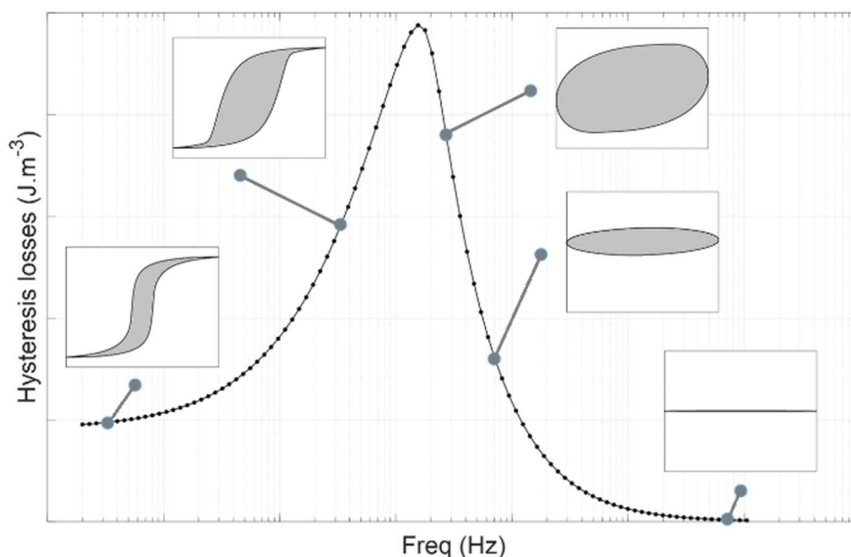


Fig. 1, Illustration of the ferromagnetic hysteresis frequency dependence.

The usual methods for the simulation of the magnetic behavior are all based on the separation of the magnetic contributions, where the microscopic Eddy currents due to the domain wall motions and the macroscopic ones due to the extern magnetic field variations are

considered separately [2]. This separation remains artificial, since practically both losses mechanisms occurs simultaneously and interact on each other.

Alternative solutions for the simulation of these phenomena have already been proposed through the resolution of an anomalous fractional magnetic field diffusion (1, 2 or 3D depending on the experimental situation) [3][4]. The fractional order constitutes an additional degree of freedom in the simulation scheme. It is identified through comparisons to experimental results. By adjusting precisely this order, very accurate local and global simulation results can be obtained on a very broad frequency bandwidth [5]. It allows to predict precisely the dynamic magnetic behavior of classic ferromagnetic components.

Fractional diffusion equation is an interesting method but this is not the only way to take into account the hysteresis frequency dependence using fractional derivative operators. Lump models based on time fractional differential equations is another option [6][7].

In both methods (the fractional diffusion equation and the time fractional differential equation), a numerical resolution of the Riemann-Liouville definition is required. Recent works have demonstrated the effectiveness of using quadrature techniques to approximate the Riemann–Liouville definition for fractional derivatives in the context of nonlinear viscoelastic model [8].

In this manuscript, the quadrature methods are implemented and tested in the case of the ferromagnetic hysteresis. Theoretical results are compared to experimental ones, and conclusions and perspectives are drawn such as possible improvements.

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