Finite Element Simulation of a Magnetic Brake with a Soft Magnetic Solid Iron Rotor

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ABSTRACT

A rotational magnetic brake with a solid iron rotor is excited by a DC current (Fig. 1). The magnetic properties of the rotor are highly nonlinear. Currents are induced in the moving conductive rotor. The magnetic flux is swept along in the direction of the rotation (Fig. 2).

The oscillations appearing in the finite element solutions at high speeds (Fig. 3), have a non-physical nature and are related to the discretisation technique [1]. It is crucial to detect these numerical oscillations and to cope with them. A severe mesh refinement yielding stable results would involve too large meshes. If adaptive mesh refinement is applied, reliable intermediate solutions, even on rough meshes, are required [2]. These are ensured by applying upwinding to the differential problem. The adaptive refinement strategy marks the elements experiencing high velocities or high magnetic energies and cuts them. The combined approach favours transition zones in the moving regions (Fig. 4).

In Fig. 2, the nonlinear model is compared to an equivalent linear one. The dependences of the torque upon the excitation current and the velocity are shown in Fig. 5 and Fig. 6 respectively. As the speed increases (from left to right in Fig. 2), the magnetic flux lines are pushed towards the surface of the solid iron rotor. In the nonlinear model (under in Fig. 2), the flux is redistributed towards the inside of the rotor (Fig. 2e) or at large velocities towards the air gap of the device (Fig. 2f).

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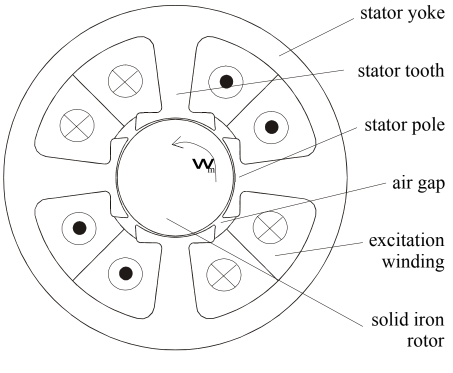

Fig. 1: Rotational magnetic brake.

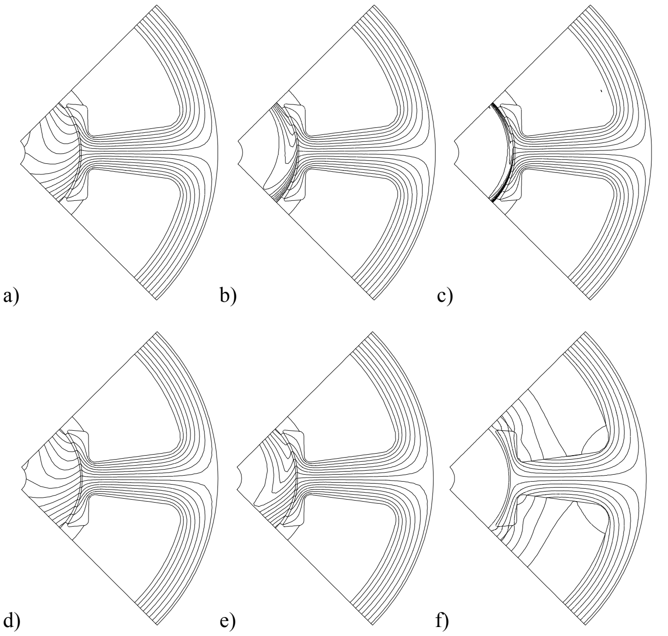

Fig. 2: Magnetic flux lines plots of the linear (a,b,c) and nonlinear (d,e,f) simulations of the magnetic brake with the stator excited by 15 A and the rotor rotating at 1 rad/s (a,d), 10 rad/s (b,e) and 100 rad/s (c,f).

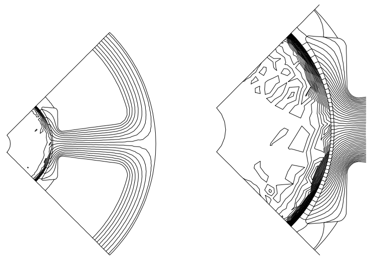

Fig. 3: Finite element solution suffering from numerical oscillations (linear material, angular velocity -100 rad/s).

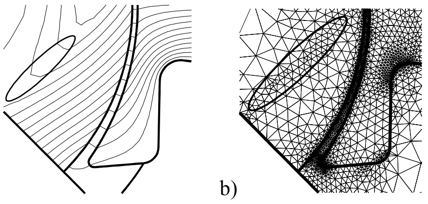

Fig. 4: Detail of a magnetic flux line plot (a) corresponding to a refined mesh (b).

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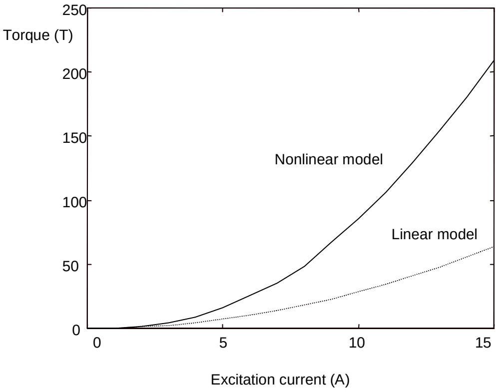

Fig. 5: Current-torque characteristics of the magnetic brake rotating at -50 rad/s in the case of linear rotor iron and in the case of nonlinear rotor iron.

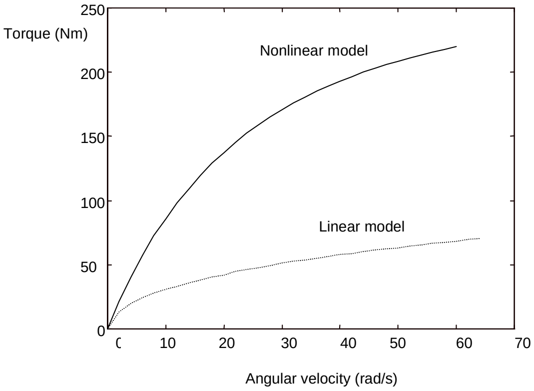

Fig. 6: Speed-torque characteristics of the magnetic brake excited by 15 A in the case of linear rotor iron and in the case of nonlinear rotor iron.