

Lumped Parameter and Circuit Models of Electromechanical Switching Device Electromagnets

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Abstract—Forced DC electromagnets are widely used in modern electromechanical switching devices. In cases, where the total costs of simulation of high-fidelity electromagnetic field’s 3D and even 2D models are unacceptably high, alternative techniques based on lumped parameters and magnetic circuit models of switching device electromagnets can be used. The paper presents a technique for calculating the dynamics of forced DC electromagnets using the Maple code as an example of simulation of the magnetic circuit of an electromagnet used in vacuum contactors.

Index Terms—Electromagnet, lumped parameters, magnetic circuit, switching device.

I. INTRODUCTION AND PROBLEM DEFINITION

Forced DC electromagnets are widely used in modern electromechanical switching devices, in particular in vacuum contactors, to reduce their size, power consumption and increase their speed [1]. At the stage of development and design of such switching devices, it is necessary to analyze the distribution of the transient electromagnetic field of an electromagnet during operation of the device, taking into account the force control circuit.

A mathematically rigorous calculation of the transient electromagnetic field can be performed by the solution of a system of nonlinear partial differential equations in various formulations, for example, in terms of the magnetic vector potential A [2]. However, at the design stage, when the total cost of simulation of 3D and 2D models is unacceptably high, alternative methods may be required. Such an effective technique, based on models of magnetic circuits with lumped parameters, is proposed in this paper.

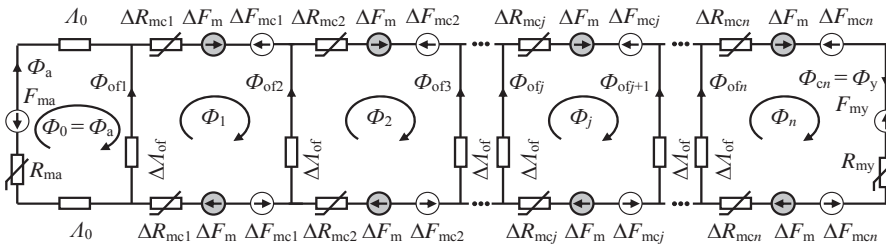


Figure 1: Substitution circuit of the magnetic circuit of a double-rod electromagnet taking into account the effect of eddy currents in cores, armature and yoke

Figure 1 shows the equivalent circuit of the magnetic circuit of a double-rod electromagnet of the vacuum contactor. Unlike the well-known circuit [1], in this circuit at each section of the core, "eddy" MMFs are introduced that occur during transients and are indicated in the circuit as $\ominus \Delta F_m$ unlike MMFs of the coil shown in the circuit by the symbol \oplus . "Eddy" MMFs also appear in the branches of the equivalent circuit corresponding to the sections of the armature and yoke.

In Fig. 1 the following notation is used: Φ are the magnetic fluxes; R_m , ΔR_m are the magnetic resistances of the sections of the magnetic circuit; ΔA_{of} are the magnetic conductivities of outflow.

The values of magnetic resistances are determined taking into account the magnetization curve of the material of the magnetic circuit and are nonlinear functions of the magnetic flux.

II. A TECHNIQUE PROPOSED AND RESULTS OBTAINED

A technique for calculating the dynamics of forced DC electromagnets in the Maple computing environment by coupled solution of the nonlinear system of partial differential equations using the described equivalent circuit of the magnetic circuit and the equations of the electrical circuit which includes capacitive, inductive and resistive lumped parameters (taking into account the peculiarities of the control circuit for the forced switching on the electromagnet coils) and the mechanical circuit is developed.

The results obtained are analyzed and compared with experimental data. Good agreement between the calculated and experimental data is shown.

REFERENCES

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