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Influence of Starting Cage Material upon Dynamic Behaviour of Reluctance Synchronous Motors

In this paper there is studied the dynamic regime behaviour of a reluctance synchronous motor fitted out with a starting cage. There are analyzed two concrete situations: cage made of aluminium and cage made of copper. There are presented the mathematical model of the motor, the simulation program and the simulations carried out for the two situations. For the case of cage made of aluminium there have been performed experimental tests for direct-on-line no-load starting, tests that confirm the simulations carried out. The paper ends with conclusions regarding the influence of the cage material upon the time-dependent variation of the main electrical and mechanical quantities of the motor.

Keywords: reluctance synchronous motor, mathematical model, simulations, experimental tests

1. Introduction

Dynamic regime behaviour of reluctance synchronous motors is a present problem, fact confirmed by several papers published in different international scientific manifestations [4], [5], [6], [7] etc.

The starting of these motors is, in the most cases, a direct-on-line one. This starting is possible owing to a short-circuited cage assembled on the rotor.

This paper aims at analyzing the dynamic regime mentioned before from the view point of the material which the starting cage is made of.

There will be considered two concrete situations: cage made of aluminium, respectively of copper.

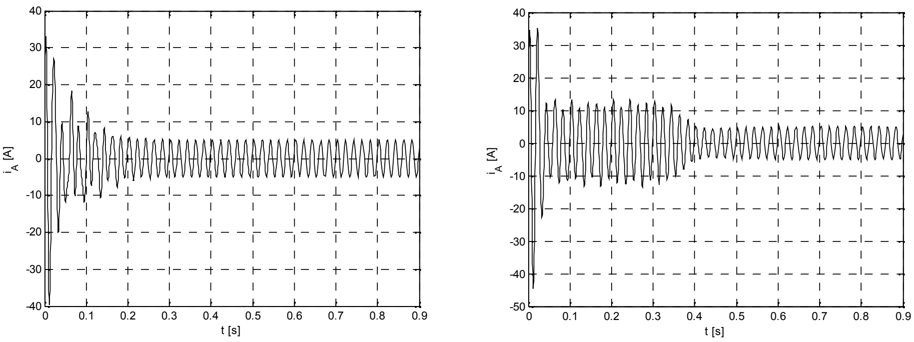
2. Simulations

Using the mathematical model of reluctance synchronous motor detailed in [2] and the Matlab-Simulink program, presented in [3], there have been obtained the graphics from figures 1-11.

There are presented two categories of characteristics corresponding to the two types of cages (a – cage made of aluminium, b – cage made of copper).

In order to carry out this analysis, there has been assessed a reluctance synchronous motor having a cage made of aluminium and the following parameters: R_s = 3,77 Ω; R_D = 1,5 Ω; R_Q = 4,5 Ω; $L_{s\sigma}$ = 0,0081 H; $L_{D\sigma}$ = 0,0059 H; $L_{Q\sigma}$ = 0,0067 H; L_d=0,281 H; L_q=0,081 H; J = 0,005 kgm^2; p = 2. The motor is supplied by a phase voltage of 220 V and operates in rated load (M_r=7,6 Nm).

For the case of cage made of copper it has been considered that the cage geometrical dimensions are the same. As a consequence, the rotor resistances are the only values which are modified. The new values for which simulations have been carried out are: R_D=1,05 Ω and R_Q=2,6 Ω.



a) b)

Figure 1. Characteristics i_A=f(t) for: a – cage made of aluminium, b - copper.

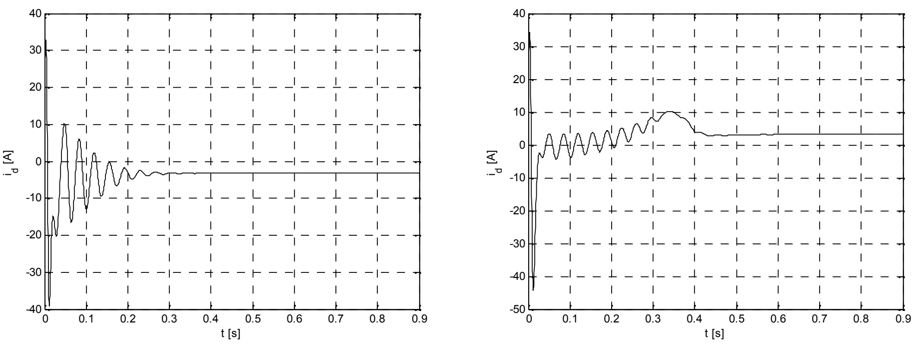


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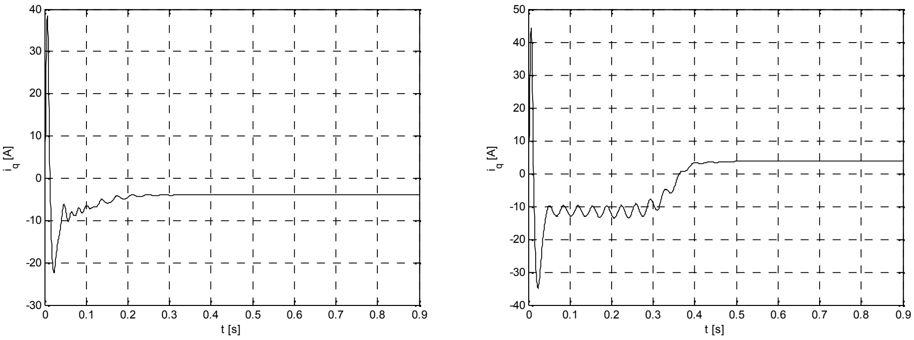
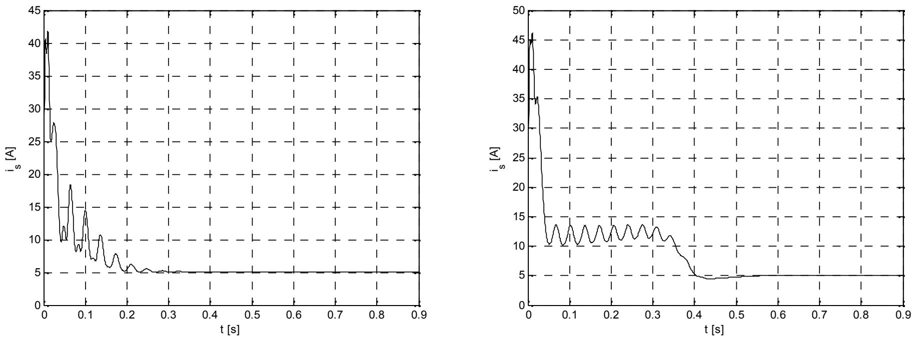
Figure 2. Characteristics i_d=f(t) obtained for the case of asynchronous starting.



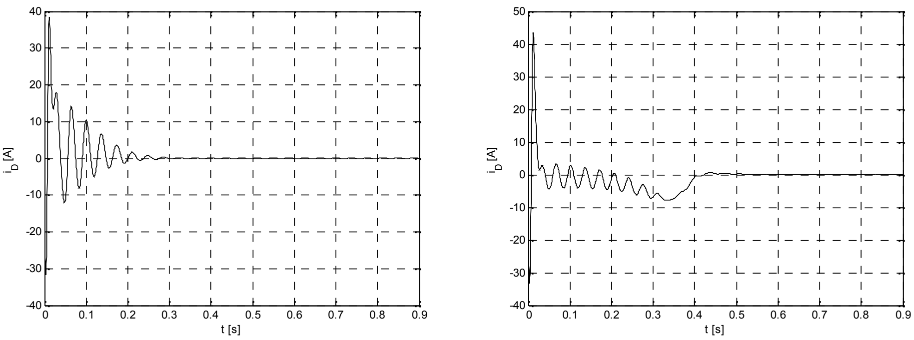
a) b)

Figure 3. Characteristics i_q=f(t).



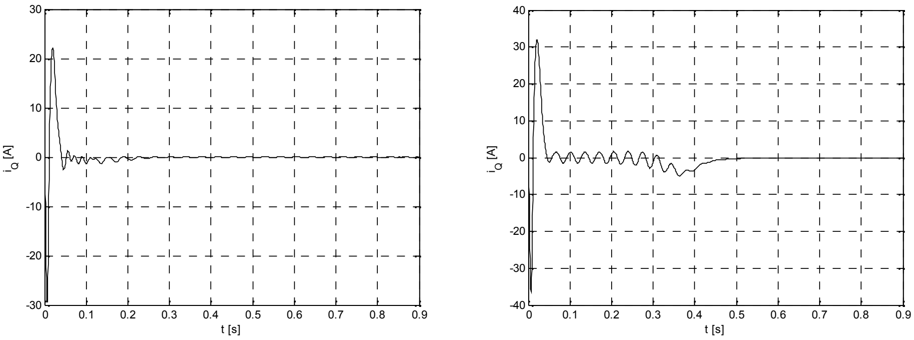
a) b)

Figure 4. Characteristics i_s=f(t) corresponding to the two cases.



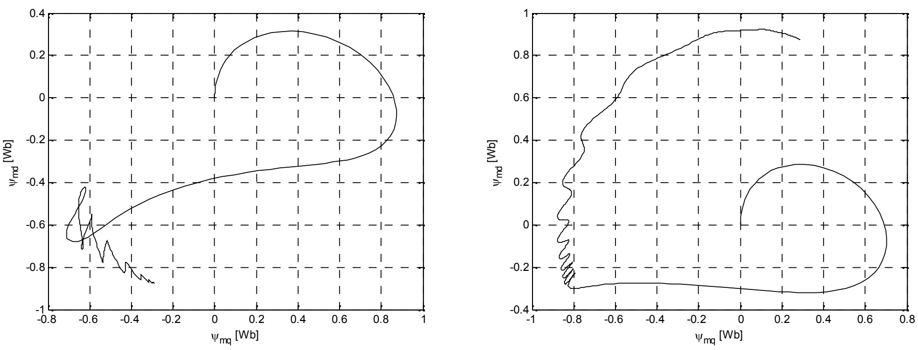
a) b)

Figure 5. Characteristics i_D=f(t) corresponding to the two cases.



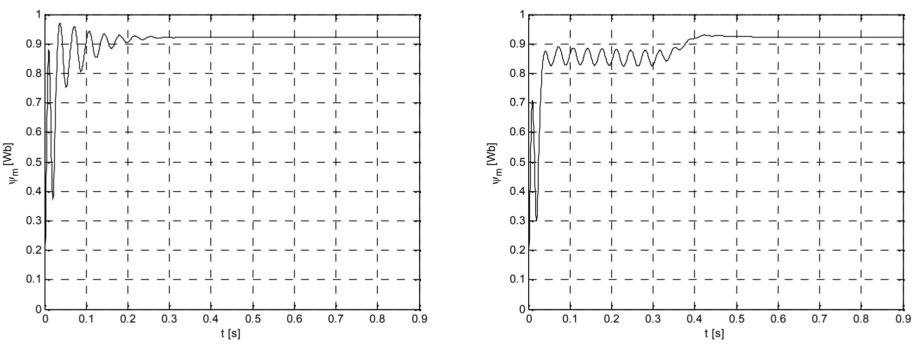
a) b)

Figure 6. Characteristics $i_Q=f(t)$ obtained for the case of asynchronous starting.



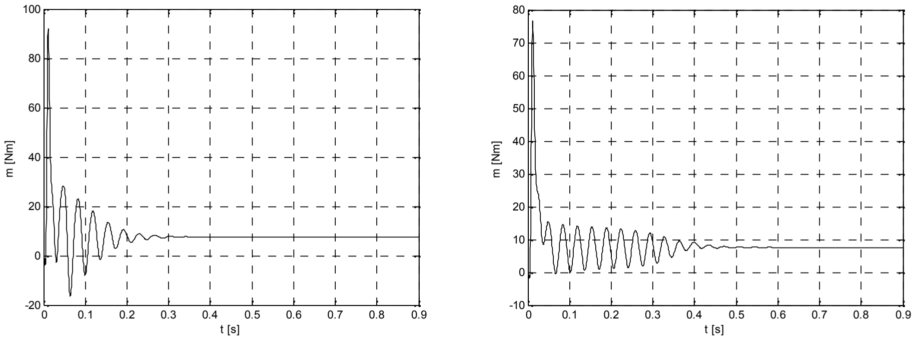
a) b)

Figure 7. Dependences $\Psi_{md}=f(\Psi_{mq})$.



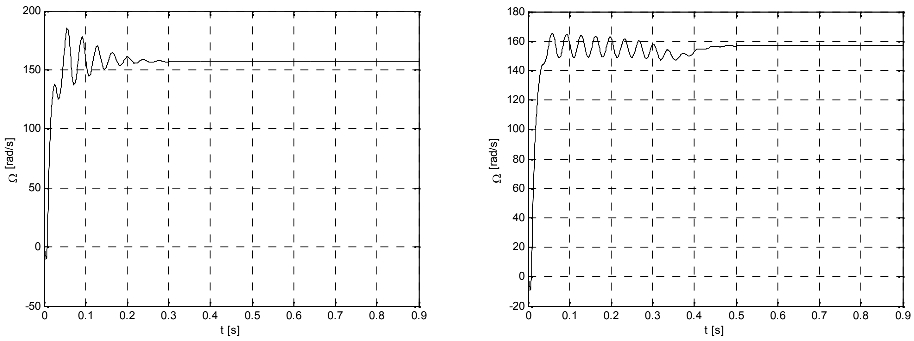
a) b)

Figure 8. Characteristics $\Psi_m=f(t)$ corresponding to the two cases.



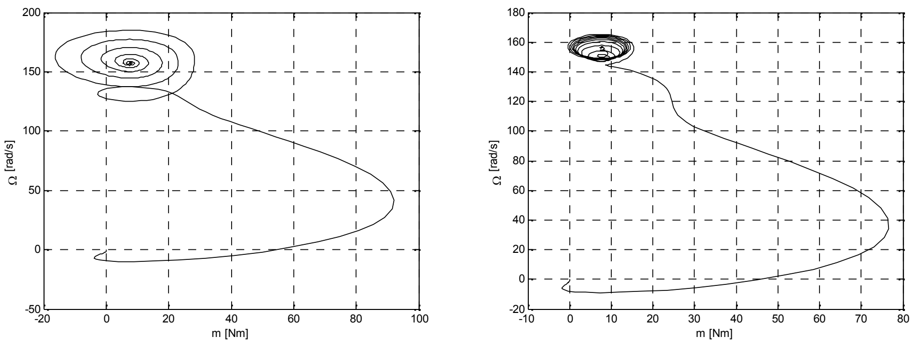
a) b)

Figure 9. Characteristics m=f(t) obtained for the case of asynchronous starting.



a) b)

Figure 10. Characteristics Ω=f(t) corresponding to the two cases.



a) b)

Figure 11. Characteristics Ω=f(m).

3. Experimental results

In order to carry out experimental tests there has been used the scheme presented in figure 12.

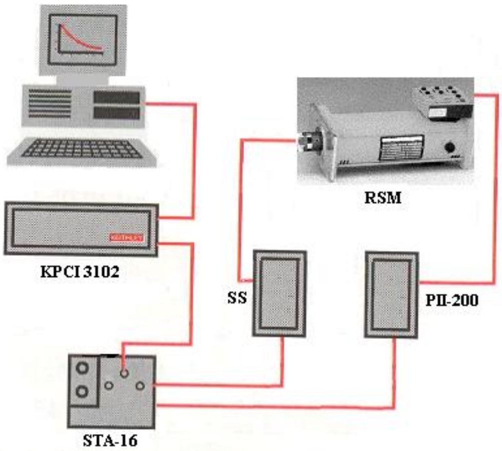


Figure 12. Block scheme of the experimental circuit.

The notations used are:

KPCI 3102 – data acquisition board [8];

STA 16 – connections block;

PII 200 – current transformer;

SS – speed sensor;

RSM – reluctance synchronous motor rated at 1,5 kW (starting cage made of aluminium).

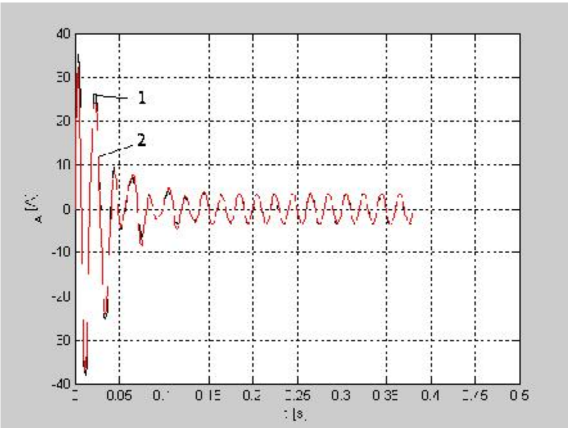


Figure 13. Characteristics of the experimental current (1) and simulated (2).

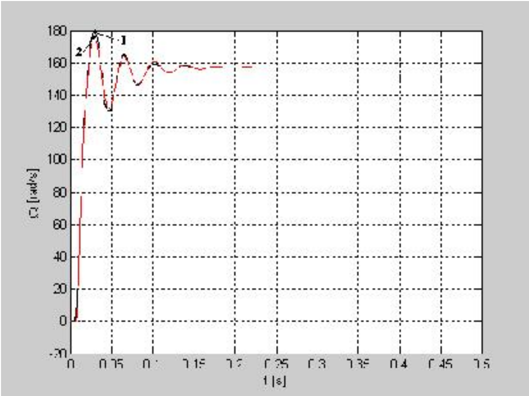


Figure 14. Characteristics of the experimental speed (1) and simulated (2).

With the help of the experimental circuit has been monitored the no-load starting in case of direct-on-line starting. The time-dependent evolutions of the A phase current (Figure 13) and of the speed (Figure 14) is presented in comparison with its evolution obtained by simulation.

As it may be noticed, the two characteristics (experimental and simulated) are almost overlapped (little differences concerning the maximal currents are caused by the magnetic saturation phenomenon of the core).

In conclusion, the figures 13 and 14 confirm the simulations carried out (for the cage made of aluminium).

The experimental confirmation for the case of the copper cage is not necessary. The purpose of the paper is to asses the behaviour of such a motor before building it practically and to answer the question: "Is it worth or not to build such a motor?".

4. Conclusions

The following conclusions emerge from the analysis of the figures 1-11:

- the duration of the currents transient regimes increases in case of cage made of copper (Figure 1-Figure 6);
- the magnetic flux modifies in larger limits in case of cage made of aluminium (Figure 8);
- the maximum torque obtained in case of cage made of aluminium is with approximately 15 Nm higher than the maximum torque obtained in case of cage made of copper (Figure 9);
- in case of cage made of aluminium the speed has higher transient values than in case of cage made of copper (Figure 10).

Acknowledgment

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