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Analysis of the three-phase induction motor with spiral sheet rotor

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ABSTRACT

The improvements obtained on the torque with low currents using rotor with spiral sheets are analyzed in this paper. To have a complete study, several rotors and stators have been built to verify the electromagnetic variations on the three-phase asynchronous motors where they combine different constructive and mechanical characteristics of the related elements: changing inertias, constructive materials, and the geometrical shapes and disposition of the sheets. These different types of motors have been first tested in the laboratory, then, are simulated using computer aided tools (Matlab–Simulink). In particular four stators (1000, 1500, 1500-type A, and 3000 rpm) having the same constructive parameters, have been tested with the following rotors: solid rotor, solid rotor with diamagnetic rings, drag cup, and simple and double squirrel cage rotor. All these results have been compared to those obtained with the seven variants of spiral sheet rotor, presented in this paper.

1. Introduction

The rotors of conventional asynchronous motors are formed by magnetic sheets packed above the shaft of the machine. The rotating magnetic field created by the stator, induces some electromotive forces parallel to the shaft, that is perpendicular to the rotor sheets [1]. Those currents cannot go through if the sheets are electrically isolated between themselves, being necessary the intervention of the conventional squirrel cage bars and rings to close the electric circuits and thus the rotor currents can be circulated.

Typical configurations of three-phase asynchronous motors [2] are shown in Fig. 1 and described in the following points:

- Single cage winding with high resistance and minimal inductance.
- Deep slot cage, with low but progressive resistance and diminishing reactance versus the slip.
- Low resistance and low reactance slot.
- Finally, there are additional configurations of double and triple cage, combining characteristics of the previous dispositions, with different resistance and reactance values for each cage.

In all of these dispositions, currents go through the cage conductors [3], while magnetic field goes through the sheets. The performance of these motors depends on the magnetic field, the current and the distance from the conductor to the shaft.

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2. Prototype description

As an example, the basic mechanical characteristics of some tested rotors are presented in Table 1 [4]. These rotors used have the same dimensions and they are assembled to the stators marked as 1000 rpm, 1500 rpm and 3000 rpm, having all, including the latter one, the same constructive parameters.

3. Three phase asynchronous torque motor

The so called "torque-motor" [5] is a three-phase asynchronous motor with the stator built in a classical way, but its rotor is constructed by a hard sheet iron cylinder (with small hysteresis cycle). With this kind of rotor a higher useful section for flux circulation is obtained, but one of the drawbacks of this motor is the fact that the lines of magnetic fields go through its core reaching considerable depths, inducing an EMF that makes it weaker [6].

A current circulating at higher depth has lower participation in the generation of torque, owing to the following causes:

- Lower distance between the currents and the shaft of the motor.
- The higher reactance results in lower power factor although the losses in the copper were the same also if the currents circulated close to the periphery.

In Fig. 2, this phenomenon is illustrated, showing that the deeper currents are weaker, and have also some delay in the direction of the displacement [7].

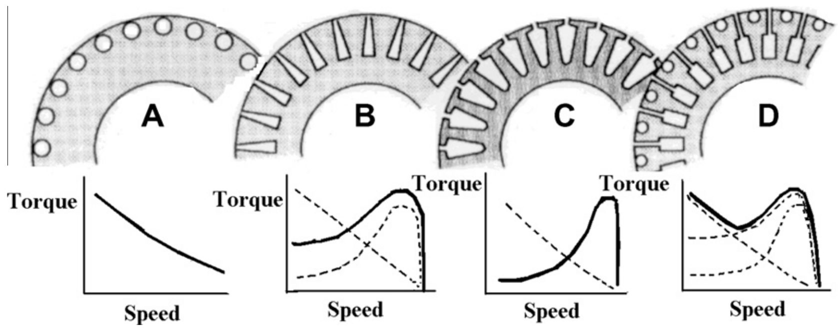

Fig. 1. Typical configurations of three-phase asynchronous motors.

Table 1
Main mechanical characteristics of rotors.

Rotor types	Mass (kg)	Inertia (kg m^2)	Kinetic energy at 1500 rpm (J)	Rotor dimensions (mm)
Squirrel cage	3.440	2.717×10^{-3}	33.519	79.5 × 71
Solid rotor	3.620	2.860×10^{-3}	35.283	79.5 × 71
Solid with ring	3.580	2.828×10^{-3}	34.889	79.5 × 71
Diamagnetic hollow rotor	0.620	4.898×10^{-4}	6.0426	79.5 × 71
Winding rotor	3.120	2.465×10^{-3}	30.411	79.5 × 71
Spiral sheet, A	3.160	2.496×10^{-3}	30.793	79.5 × 71
Spiral sheet, B	3.236	2.556×10^{-3}	31.533	79.5 × 71
Spiral sheet, D	3.040	2.401×10^{-3}	29.621	79.5 × 71
Spiral sheet, Z	3.230	2.625×10^{-3}	32.384	79.5 × 71

4. Motor with spiral sheet rotor

Forming a rotor with spiral shape sheets [8], distributed in a radial disposition around the shaft, it is possible to generate a magnetic field in the rotor periphery, inducing peripheral EMF, and currents along the same sheets, that are only active in their periphery.

The peripheral currents of this rotor have more section to circulate, compared to a normal cage rotor current, as it can be seen in Fig. 3.

Fig. 4 shows a plain representation of the disposition of the sheets [9]. There are two zones: one with active currents going through and the other is used to receive the possible returning currents (a returning currents proposal).

5. Prototype description

Several types of rotor have been constructed; each one is formed by a group of magnetic sheets radically the shaft [10].

When sheets density is constant, in order to eliminate free space that would result of increasing the radial distance, the sheets have been enrolled above the others, as if the rotor would be formed by a group of sheets spinning as it can be seen in Fig. 5.

In this way, the generated flux by the stator winding, that is the rotating magnetic field, falls in an inclined way into the sheets, producing some eddy currents which circulate in the presence of the mentioned flux, generating some antagonistic torques. The outside torque is bigger than the inside one, because the radial distance is much higher, which results in a net torque corresponding to the difference between the mentioned torques (Fig. 6).

6. Magnetic reluctance of the rotor sheets

The relative permeability of the rotor sheets influences several electrical quantities. That is, if the sheets have high permeability, the reluctance of the magnetic circuit will be low, and the magnetic flux flow will be more superficial.

As well as that part, as shown in Fig. 7, with low values of permeability the value of torque grows suddenly, while with high values of permeability the variations in torque are less and in decline.

7. Magnetic field of the stator and the rotor due to parasitic currents

Due to the curve position of the rotor sheets, the revolving magnetic field generated in the stator will be closer to the periphery of the sheets, and it will bring EMFs and currents in their periphery, since it is the active part of the sheets. In this way, the revolving magnetic field generated in the stator windings, have an inclined bearing with respect to the sheets, which in turn produces parasitic currents in the sheets and when circulating with the flow presence

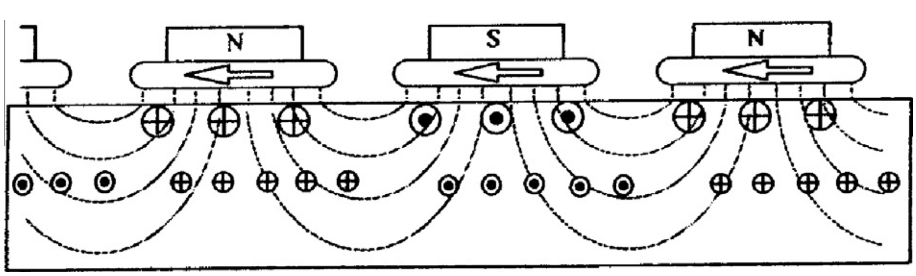

Fig. 2. Section of a "three-phase asynchronous torque-motor".