Advantage of Double Cage Rotor over Single Cage Rotor Induction Motor

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Abstract
The simulation of double cage induction motor provides the base for the design of the squirrel cage induction motor to prevent desing error and mistakes in its construction and testing so as to obtain maximum efficiency. This paper presents the advantage of double cage rotor over the single cage rotor induction motor. This is achieved through the investigations on the Torque-speed and Stator current-speed characteristics generated through simulation by MATLAB for the purpose of illustration
Keywords: Current versus speed characteristics, Double cage rotor, Induction motor, Single cage rotor, Stator current versus speed characteristics, Torque-speed characteristics

1. Introduction

A three phase induction motor with line voltage of 415V, four poles and supply frequency of 50Hz consisting of outer and inner cage rotor designs is taken as the case study for its Torque-speed and stator current characteristics. The National Electrical Manufactures Association (NEMA) specifies few numbers of designs of squirrel cage induction motors according to the lamination of the rotor [1]. NEMA class A design exhibits rotor bars placed farther from the rotor surface. NEMA class B design has large and deep rotor bars accommodated near the rotor surface. NEMA class C design is the double cage rotor design and NEMA class D design has small bars placed near the rotor surface. The deeper the rotor bars are placed from the rotor surface, the more is the formation of leakage flux and the more is the reactance [2]. The cross sectional area of the upper cage is small leading to its high resistance and high starting torque while the lower cage has large cross sectional area with low resistance and high reactance that gives high efficiency on the load since the copper loss will be low [3]. A squirrel cage induction motor is rugged in construction and reliable in operation because of its minimum maintenance as it lacks commutator or slip rings to service and no brushes to replace. Aluminium bars or copper bars, usually uninsulated are placed inside the rotor core slots near the surface of the rotor which are welded to two end rings made of copper to form shorted windings so that the rotor current depends on the induced voltage and its resistance. The effect of magnetic flux on the rotor current produces rotary field [4]. The conducting bars are not parallel to the shaft but skewed to keep the motor in quiet operation, avoid torque fluctuations, reduce magnetic hum, reduces cogging effect and increase resistance due to its comparatively lengthier conductor thereby reducing the starting current and increasing the starting torque [5]. The stator is excited from an alternating current source and the excitation creates a magnetic field in the form of travelling or rotating wave, which induces currents in the rotor circuits. These currents interact with the rotating wave to produce torque [6].
In this research, we investigate the characteristics of both the double and single cage rotors of induction motor in relation to their starting torque and starting current and to conclude which of these has an advantage over the other. This is achieved by the simulation of motor parameters by MATLAB program.

2. Materials and Methods

The double cage induction motor and its equivalent electrical circuit are shown in Figure 1(a) and 1(b) respectively. R2o and R2i are the resistances of the upper and lower cage respectively while X2o and X2i are the leakage reactance of the outer and inner cage and Xm is the mutual inductance between the cages [7, 8, 9]. RI and X1 are the stator resistance and reactance respectively.
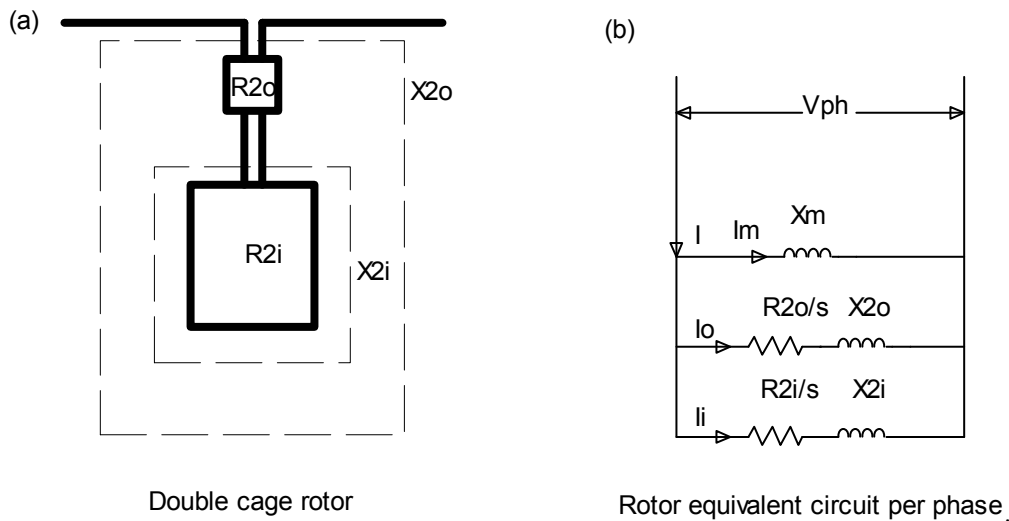
Figure 1. Double cage rotor and the rotor equivalent circuit per phase

Symbol	Quantity	Input values
R1	Stator resistance	0.640 Ω
X1	Stator reactance	0.75Ω
R2	Single cage rotor resistance	0.31Ω
R2i	Inner cage of double cage rotor resistance	0.38Ω
R2o	Outer cage of double cage rotor resistance	3.1Ω
X2	Single cage rotor reactance	0.5Ω
X2i	Inner cage of double cage motor reactance	3.2Ω
X2o	Outer cage of double cage motor reactance	0.5Ω
Xm	Magnetization reactance	26.2Ω
V_L	Line to line voltage	415V
N_{sync}	Synchronous speed in rev/min	1500
ωsync	Synchronous speed in rad/s	157.08

3. Mathematical analysis

The impedance of outer cage is given by:

$$Zo = R2o/s + jX2o \tag{1}$$

The impedance of the inner cage is given by:

$$Zi = R2i/s + jXi \tag{2}$$

The total impedance of the circuit is given by:

$$Zt = \frac{ZoZiXm}{Zo + Zi + Xm} + R1 + jX1 \tag{3}$$

The input current is given by:

$$I = \frac{V_{ph}}{Zt} \tag{4}$$

Results Analysis and Discussion

The output parameters of the single and the double cage rotor induction motor are shown in Table 2

Table 2. Output parameters of single cage and double cage rotor

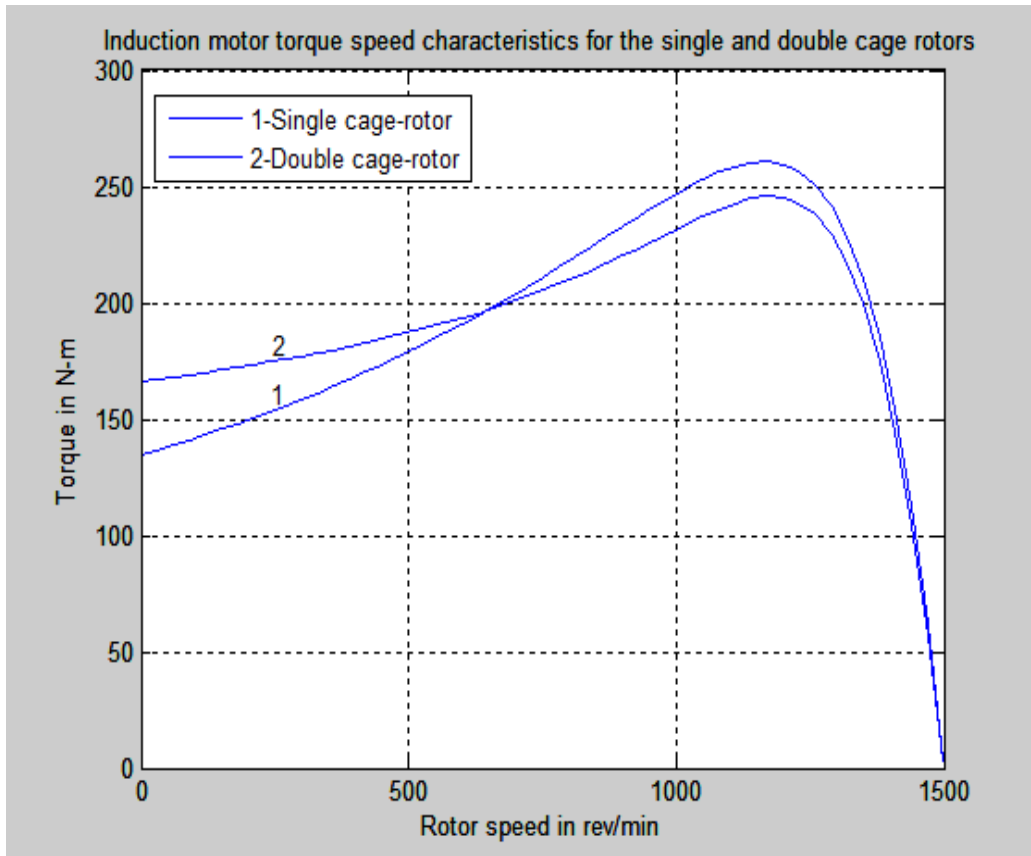| Parameters	Single cage rotor	Double cage rotor
Starting torque, T_{st} (Nm)	134.7	165.99
Full load torque, T_{fld} (Nm)	56.79	56.79
Breakdown torque, T_B (Nm)	260.59	245.798
Starting current, I_{st} (A)	129.76	113.5
Full load current, I_{fld} (A)	16.22	16.22

Figure 2. Torque-speed characteristics of single cage and double cage rotor

Figure 2 shows the torque-speed characteristics of single and double cage rotor. The starting torque of double cage rotor is higher than that of single cage rotor.
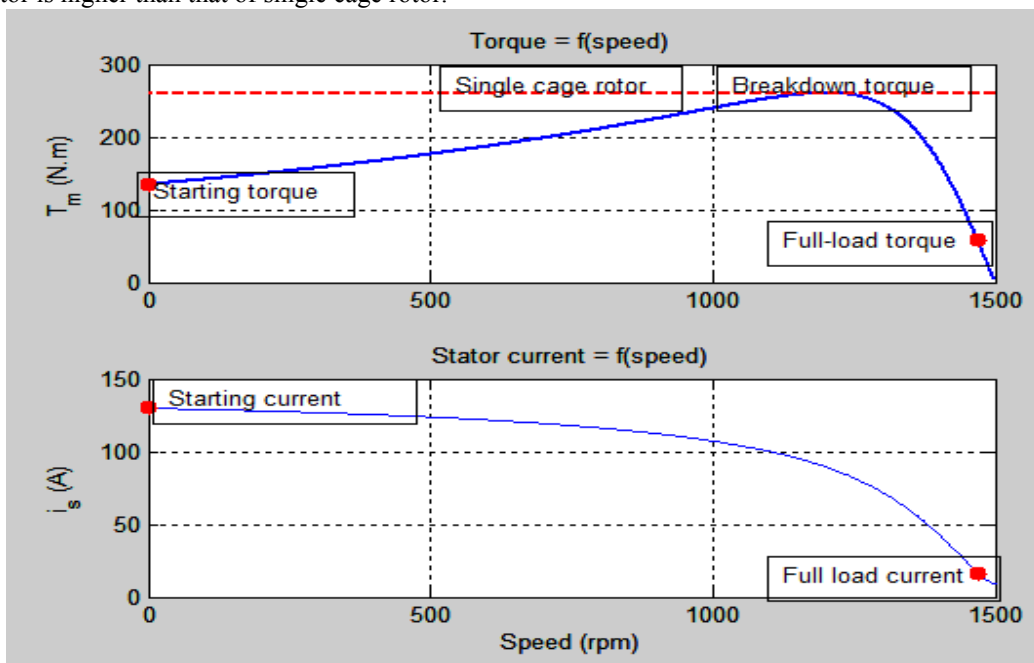

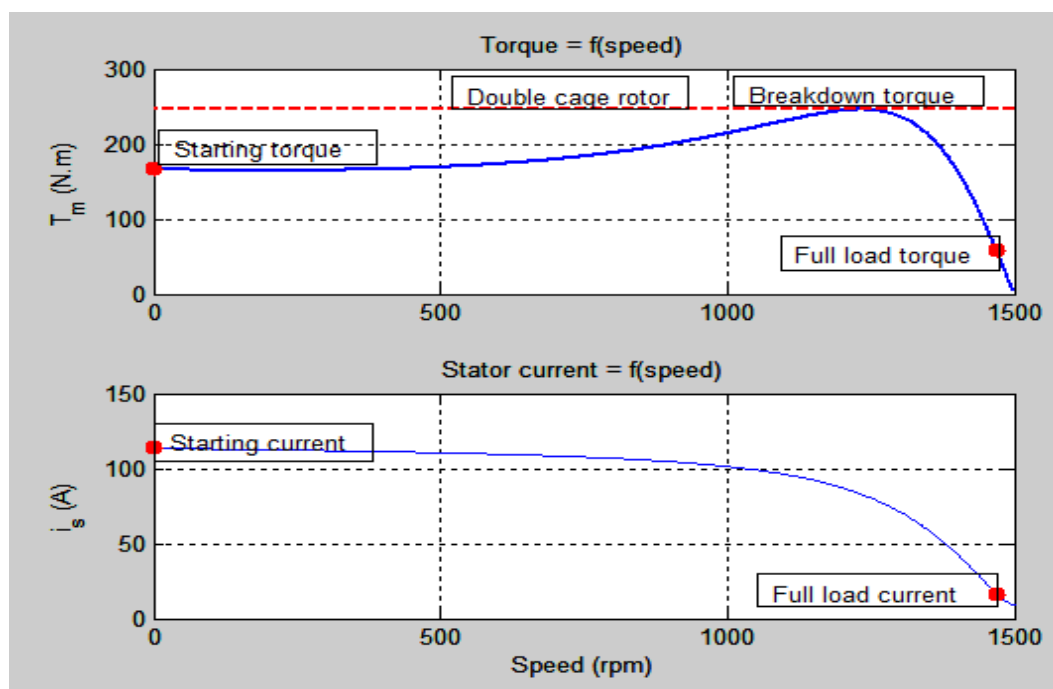*Figure 3. Single cage rotor of induction motor*

Fig.4: Double cage rotor of induction motor

Figure 3 and Figure 4 are the Torque-speed and stator current-speed characteristics of the single cage rotor and the double cage rotor respectively. The stator-current characteristics are similar to stator current speed characteristic. In figure 3, the starting current is eight times the full load current while in Figure 4, the starting current is seven times the full load current which is less than the previous one. The starting current of the motor is considerably reduced in double cage rotor than in a single cage rotor which is the required characteristics since the copper loss is minimized and the efficiency of the motor is increased.

Conclusion

The results obtained show that where starting torque is required, double cage rotor induction motor is preferable since it reduces the starting current and increases the starting torque. With this achievement, tripple cage induction motor is obtainable which would produce more starting torque and lesser starting current than the double cage induction motor. This is beyond the scope of this article but would be investigated in our further research.

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