A COMPARATIVE STUDY AND INVESTIGATION OF DIFFERENT ROTOR DESIGNS OF INDUCTION MOTOR FOR URBAN USE ELECTRIC VEHICLE

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Abstract—Because of environmental effects of fossil fuels and shortage problems of reserves, the researchers focus more and more to electric vehicles (EV). But it has a range problem because of insufficient battery technology. It looks that EV's are more useful for urban usage for today. In this paper, we designed an induction motor(IM) for urban usage Electric Vehicle (EV)by considering urban traffic limitations such as unsteady velocity and stop-go options. We optimized take-off torque recover urban traffic limitations by comparingsingle cage and double cage rotor design performances.

Index Terms—Electric Vehicle, Induction Motor, Motor Design, Rotor Design.

I. INTRODUCTION

In last decades, energy needs are increasing rapidly, as environmental problems because of fossil fuels. Eco-friendly, highly efficient and facilitating human life products are more attractive in the market and researches as well. Electrical vehicles (EV) and bicycles can be mentioned as best examples for this process, because of being more popular, against exhausting risks of petroleum in near future, however most of vehicles are designed to be able to consume only petroleum [1-4].

Growing EV is correlated with improvement of battery tech¬nology and Electric motor (EM) designs. An efficient meeting point of that improvements will offer us a new traffic habit with silent, without emission and eco-friendly. EM is most important part of vehicle for movement and vari¬ous designs are used for EV technology. On the EV's, mostly In¬duction Motors (IM) and Synchronous Motors (SM) (both per¬manent magnet and salient pole types), sometimes DC mo¬tors and Switched Reluctance Motor (SRM) are used for traction. Improvement of magnet technology let to increase efficiencies of PM motors. But high prices of magnetic ma¬ter¬ials and demagnetization risks are still disadvantages of per¬ma¬nent magnet motors. Using DC motors for EV is limi¬ted because of having commutators and brushes, in spite of having a linear diagram of velocity-torque [5-7]. SRM is limi¬ted because of fluctuation of output torque [8]. Most com¬mon used motor on EV's is known as IM with simple and stable design, higher ability to control and lower cost [9-10]. Many studies focused on comparisons of various EM on EV with the criteria such as efficiency, weight, fault tolerance, se¬cu-rity and durability. And IM is accepted most reliable de¬sign against SM, SRM and PM [11 -14].

We proposed an IM for urban usage EV, not to be effected in¬suf¬ficient battery problem. We optimized take-off torque, which is important for urban style EV is driven unsteady velo¬city changes and stop-go. We com¬pa-red single cage and double cage rotor design performances.

II. MAIN DESIGN EQUATIONS AND PROPOSED MOTOR

The relation, between output of EM, core size, velocity and specific magnetic and electrical loads, is called as output equation and represented with . While designing an EM the power on armature Q can be calculated with Eq. 1., where is phase current and is the voltage inducted on armature. can be found by Eq. 2., where is as winding factor and is frequency.

$$Q = 3.V_{ph} I_{ph} \times 10^{-3} \ kVA \quad (1)$$

$$V_{ph} = 4.44 k_w . f \phi_1 N_{ph} \quad (2)$$

Eq. 1. can be revised to Eq. 5., with calculation electrical load, which is seen on Eq. 3. and magnetic load, which is seen on Eq. 4. is obtained with Eq. 6 [15,16].

$$ac = \frac{I_z Z}{\pi D} \quad (3)$$

$$B_{ort} = \frac{p\phi}{\pi D L} \quad (4)$$

$$Q = C_0 D^2 L n_s \quad (5)$$

$$C_0 = 1.11\pi^2 B_{ort}\, ac\, K_w \times 10^{-3} \quad (6)$$

The initial 3D model of the three phase, 7.5 kW, 400 V, 2-pole, induction motor whose design and analysis are given in Fig. 1. With respect to all parameters calculated by using analytical method, are given in Table I. and detailed design parameters are shown in Table II. and Table III.

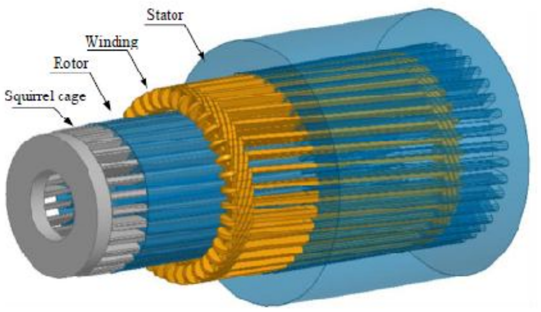
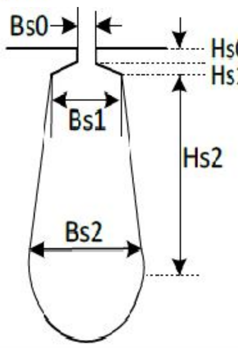


Fig. 1. Designed Motor for EV.

Table I.Basic design parameters

Description	Details of parameter
Motor type	3 phase, squirrelcage
Outputpower	7.5 kW
Ratedfrequency	50 Hz
Number of poles	2
Ratedspeed	2949 rpm
Efficiency	86.66 %
No- loadphasecurrent	3.55 A
Rated stator phasecurrent	8.40 A
Slotfillfactor	53.52 %

Table II.Stator design details.

Description	Value
Stator outerdiameter	200 mm
Stator innerdiameter	110 mm
Length	140 mm
Number of slots	36
Skewwidth	0
Number of conductorsperslot	28
StackingFactor of Stator Core	0.95
Type of Steel	M530-50A
Coilpitch	16
	$H_s0 = 0.7\,mm$
	$H_s1 = 1.8\,mm$
	$H_s2 = 13.4\,mm$
	$B_s0 = 2.8\,mm$
	$B_s1 = 5.64\,mm$
	$B_s2 = 7.98\,mm$

III. SINGLE CAGE VS DOUBLE CAGE ROTORS

The performance of EM is effected by various parameters, such as groove number, which changes magnetic field [17,18]. So, we have some prerequisites about groove number of stator as being integer, which must be an exact number of phase number, and support balanced winding. And groove number of rotor must not equal to stator one nor exact number of each other. We determined it as 36 concerning reference EM producer companies [19,20].

To get a real comparison result, we did not change neither groove numbers of rotors nor dimensions of motor. The comparison of single cage and double cage designed motor analysis are summarized on Table IV., which shows that efficiencies are same in different rotor designs approximately. Torque – velocity and efficiency characteristics are seen on Fig. 2., which shows that however efficiency is nearly equal, take-off torque is obtained for double cage higher than single one.

Table III.Rotor design details.

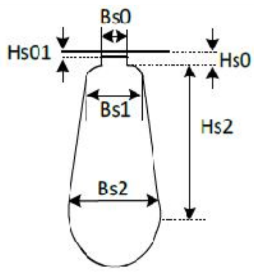
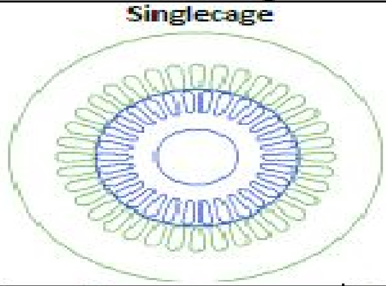
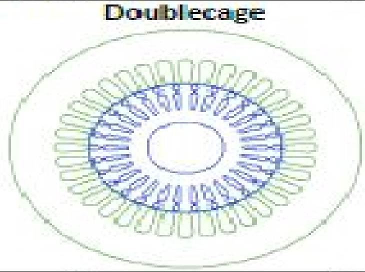
Description	Value
Rotor outerdiameter	109.4 mm
Inner diameter	45 mm
Length	140 mm
Number of slots	30
Skewwidth	1
StackingFactor of rotor Core	0.95
Type of Steel	M530-50A
Squirelcagematerial	Aluminum
	$H_s0 = 0.8\,mm$
	$H_s01 = 0\,mm$
	$H_s2 = 14\,mm$
	$B_s0 = 1\,mm$
	$B_s1 = 6\,mm$
	$B_s2 = 4\,mm$

Table IV.The combination of single and double cage.

Singlecage	
	
Efficiency [%]	86.67
RatedTorque [Nm]	24.28
Startingtorque [Nm]	96.26
Total weight [kg]	33.71
Doublecage	
	
Efficiency [%]	86.41
RatedTorque [Nm]	24.37
Startingtorque [Nm]	104.54
Total weight [kg]	33.406

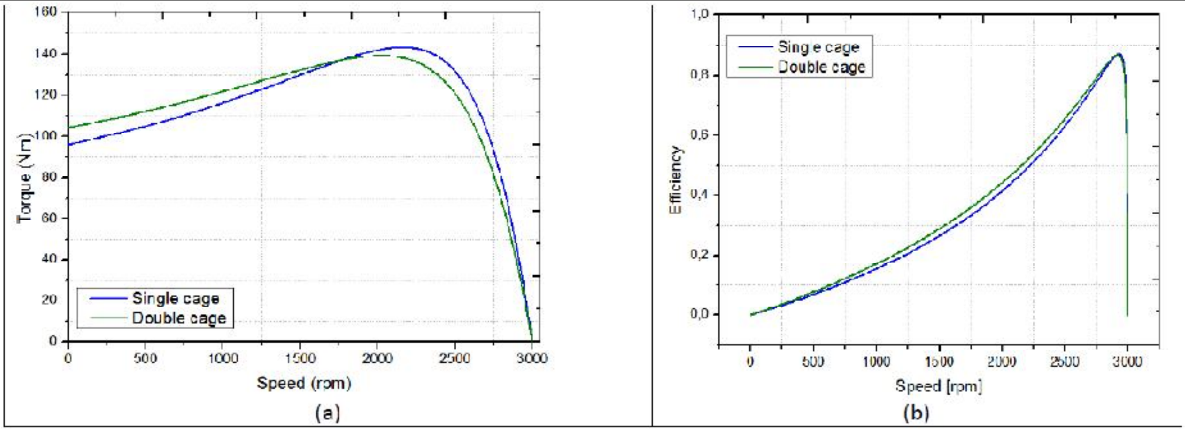


Fig. 2. a) Torque – speedcharacteristics of singleanddoublecagedesigns, b) Efficiency – speedcharacteristics of singleanddoublecagedesigns.

IV. RESULTS AND DISCUSSIONS

We designed a 3-phase squirrel cage induction motor with higher take-off torque for urban using EV, which has some limitation such asunsteady velocity and stop-go options.We optimized the design to improve efficiency and take-off torque. So we compared single cage and double cage structures with the groove numbers 36 and 30 for stator and rotor respectively on this design.And we analyzed the designs by FEM. According to the analysis results take-off torque of double cage is better than single one, while the efficiencies are approximately equal.

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