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Permanent Magnet Motor Design for Elevator Application Using Induction motor Standard Lamination

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Abstract - *In today's world permanent magnet motor is more used for elevator application because of its feature like high efficiency, high starting torque, and silent working. In this paper design of PM motor is carried out for this rating and finite element analysis is done for design validation by two approach using motor solve. It is very difficult to make different lamination for each different rating of motor. It will increase cost of motor and also it requires time. In this paper induction motor lamination is used for design of PM motor.*

1. INTRODUCTION

In this paper PM motor for elevator application is designed by two approaches. In first approach rating of PM motor is calculated using below Torque and speed equation. And based on PM motor design calculation PM motor is design. So in this approach one have to manufacture special lamination for PM motor. This will increase money and time consumption.

So to reduce money and time consumption one can design PM motor by fixing Main dimension like Stator outer Diameter and rotor outer diameter according to number of slot and available stator stamping in market. Here interesting things is that we can use induction motor stamping. By fixing above parameter and changing length and aspect ratio one can design PM motor which has same specification like same torque, speed, output power, efficiency and flux density etc.

Hence in second approach after taking rating of PM motor One can directly design PM motor by fixing Stator outer Diameter and rotor outer diameter according to number of slot and available stator stamping in market. Only one condition should be satisfied that is ratio of length and aspect ratio must match with stator outer diameter.

1.1 Requirements of elevator systems

The major requirements in the motor design of gearless elevator systems are torque and speed. These two parameters can be calculated by operating speed, cabin weight capacity, type of suspension and pulley diameter of designed elevator system

For some given elevator specifications such as 680 kg (For 10 people) weight capacity, 1.5 m/s cabin velocity, 2: 1 Suspension ratio following motor requirements can be Calculated.

Tmotor = [rpulley x g x (Mcarry) x η / µ]]

Where,

Rpulley:

The radius of drive pulley (m) (0.12 m),
g: The force of gravity (m/s2) (9.88 m/s2)

Mcarry:

Maximum carrying capacity (kg) (680 kg)
µ: The coefficient for suspension type. I for direct Suspension, 2 for 2: 1 suspension. Design was carried out for µ =2.
η: Well and rope system efficiency (70%)
Tmotor = [0.12 x 9.88x(680) x (0.7)/2]
Tmotor = 279.88 N.m

Motor rated speed;

ω = µ x (v / rpulley) (rad/ s)

v: cabin vertical velocity = 1.5 m/s

ω = 2 x (1.5/ 0.12) = 25 (rad/s)

n = ω x (60/2 x π) (rpm)

n = 25 x (60/2 x π) = 238.8 (rpm)

Rated power;

Pmotor = T. ω

Pmotor = 279.88 x 25 = 7000 W

1.2 Simple design of PM motor

In first approach, conventional design method is carried out. In which first one has to calculate main dimension of PM motor and design that motor into motor solve software and match result with calculated output. So same processes is carried out below

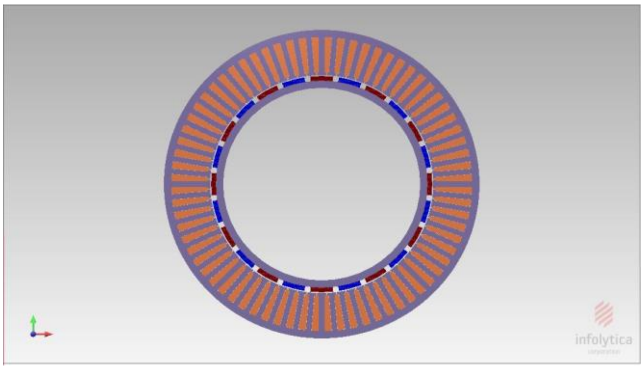

Fig -1: motor solve model of 7 kW motor

Specifications	
Supply voltage	400
Rated current	15
Rated speed	239
Global	
Outer diameter	320
Air gap thickness	0.877
Stack length	160
Description	
Protected dimension method	Automatic
Rotor	
Rotor location	Interior
Rotor type	Surface mounted with radial
Number of poles	24
Stator	
Stator type	Square
Number of phases	3
Number of slots	72
Mechanical Losses	
Friction loss	0
Windage loss	0
Stray loss factor	0

Fig -2: General input of 7 kW motor

General	
Skew	0
Skew angle	0
Protected dimensions	Back iron depth, Tooth width
Diameters	
Back iron depth	6.9
Inner diameter	260
Outer diameter	320
Teeth	
Bifurcation radius	0
Shank length	21.2
Slot area	157
Slot depth	22.9
Tooth edge inset	1.69E-11
Tooth gap angle	0.652
Tooth gap width	1.48
Tooth tang angle	0
Tooth tang depth	1.63
Tooth width	5
Fillets	
Bottom shaft radius	0.592
Tooth tang radius	0
Top shaft radius	0.592
Viewing Options	

Fig -3: stator input of 7 kW motor

General	
Skew	0
Skew angle	0
Number of magnets per pole	1
Rotor overhang	0
Override with parallel magnetization	False
Protected dimensions	Core thickness, Magnet angle
Core	
Core thickness	7.2
Diameters	
Inner diameter	235
Outer diameter	258
Sleeve thickness	0
Magnets	
Magnet angle	12
Magnet edge inset	-1.72E-09
Magnet gap angle	3
Magnet thickness	4.39
Fillets	
Magnet tip radius	0
Viewing Options	
Rotor core transparency	50
Rotor sleeve transparency	50
Rotor magnet transparency	50

Fig -4: Rotor input of 7 kW motor

Input

Rotor Materials	
Rotor core material	M-19 29 Ga
Rotor magnet material	NdFeB: Neodymium Iron Boron
Sleeve material	304 Stainless steel
Rotor stacking factor	1
Rotor eddy current loss adjustment factor	1
Rotor iron loss adjustment factor	1
Stator Materials	
Stator back iron material	M-19 29 Ga
Stator tooth material	M-19 29 Ga
Stator coil material	Copper: 100% IACS
Stator slot liner material	Epoxy resin
Stator stacking factor	1
Stator iron loss adjustment factor	1
Shaft & Hub Materials	
Shaft material	CR10: Cold rolled 1010 steel
Hub material	Non-magnetic
Include shaft & hub in magnetic analysis	No
Viewing Options	
Rotor core transparency	50
Rotor sleeve transparency	50
Rotor magnet transparency	50
Stator core transparency	50
Stator winding transparency	50
Stator end winding transparency	50
Shaft transparency	50

Stator back iron material
The material assigned to the stator back iron. Only materials with 'Core material' in their Categories property are listed.

Fig -5: Material

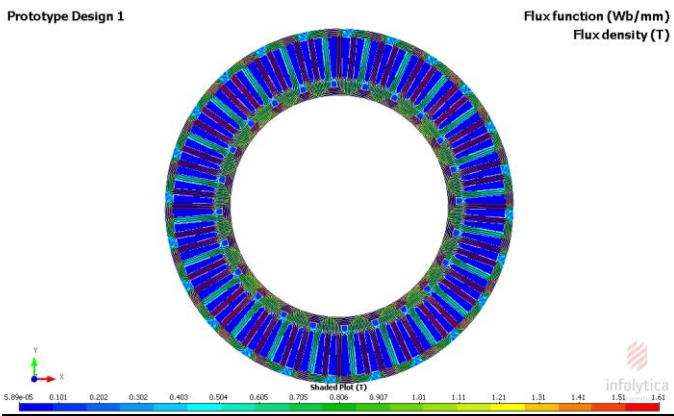

Fig -6: flux density

Fig -7: torque profile

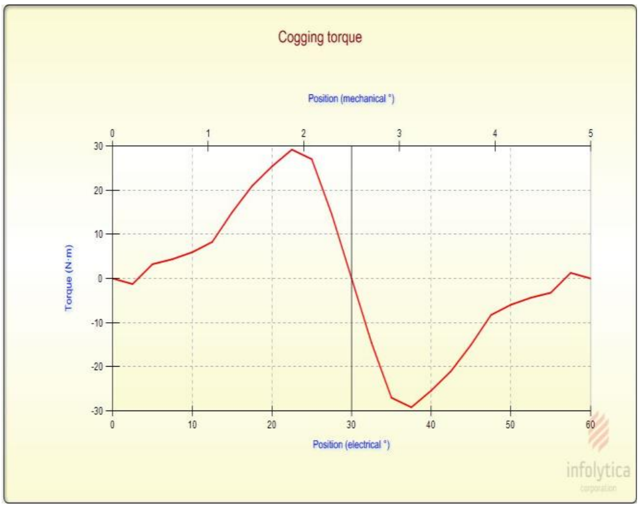

Fig -8: cogging torque

	Prototype Design 1
Torque (N·m)	282
Reluctance torque (N·m)	0.1
Input power (kW)	7.47
Output power (kW)	7.06
Efficiency (%)	94.6
RMS voltage (V)	317
RMS current (A)	15.4
Supply current (A)	18.7
Loss - Total (kW)	0.39

Fig -9: Result of motor solve

2. Design of PM motor by second approach

We have taken the standard stamping for 7 kW motor
Stator Outer Diameter Dso = 300 mm
Rotor Outer Diameter Dro = 210 mm
Number of slot = 72

In second approach one can take induction motor standard stamping and fulfill one condition describe above by changing aspect ratio and length.

Table -1: design variable

Quantity	Simple design	Design with standard stamping
Stator outer diameter(Dso)	320 mm	300mm
Rotor outer diameter(Dro)	258 mm	210 mm
Length(L)	160 mm	231 mm
Aspect ratio	0.5	0.77

So from above table it is clear that one can design same rating motor by changing length and aspect ratio and all other parameter is same in both cases.

Specifications	
Supply voltage	400
Rated current	17
Rated speed	239.3
Global	
Outer diameter	300
Air gap thickness	0.877
Stack length	231
Description	
Protected dimension method	Automatic
Rotor	
Rotor location	Interior
Rotor type	Surface mounted with radial ma...
Number of poles	24
Stator	
Stator type	Square
Number of phases	3
Number of slots	72
Mechanical Losses	
Friction loss	0
Windage loss	0
Stray loss factor	0

Fig -10: General Input of 7 KW motor with induction motor standard stamping

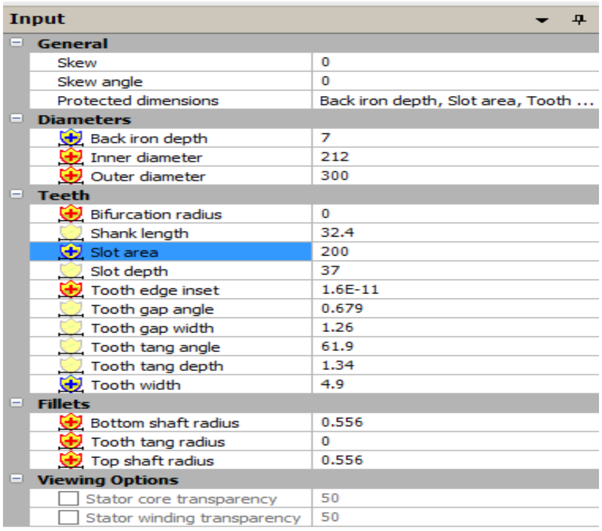

Fig -11: stator input of 7 KW motor with standard Stamping

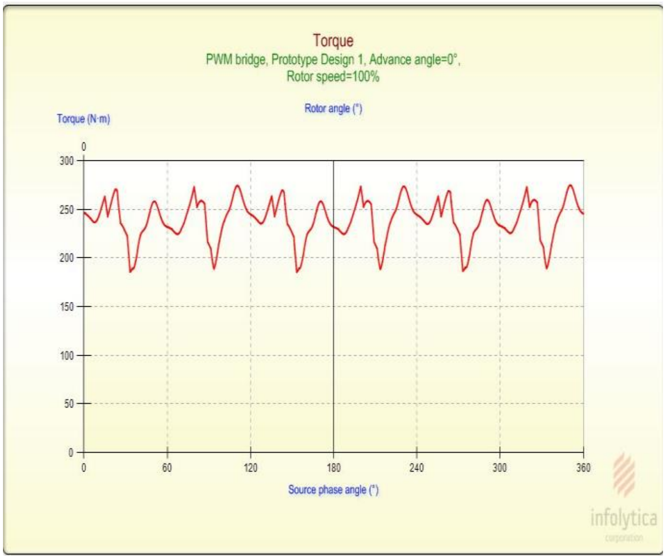

Fig -14: torque profile with standard stamping

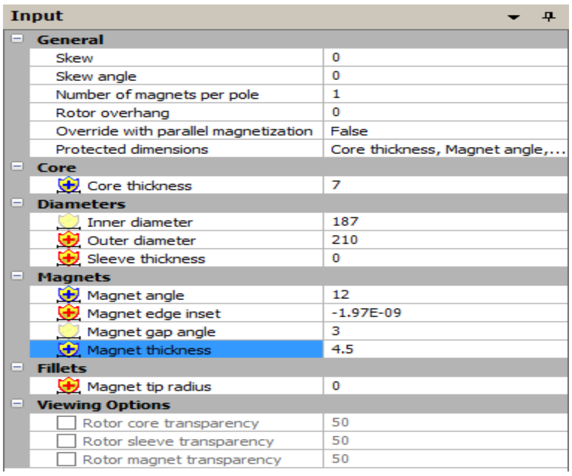

Fig -12: Rotor input of 7 KW motor with standard stamping

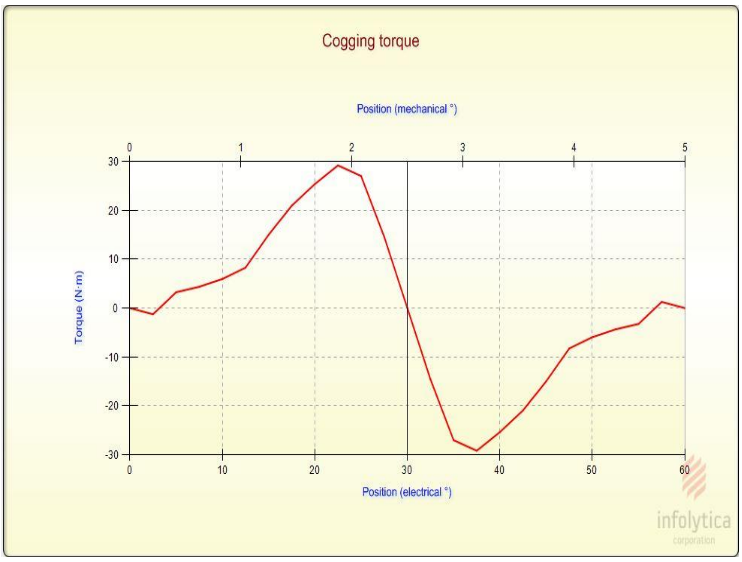

Fig -15: cogging torque with standard stamping

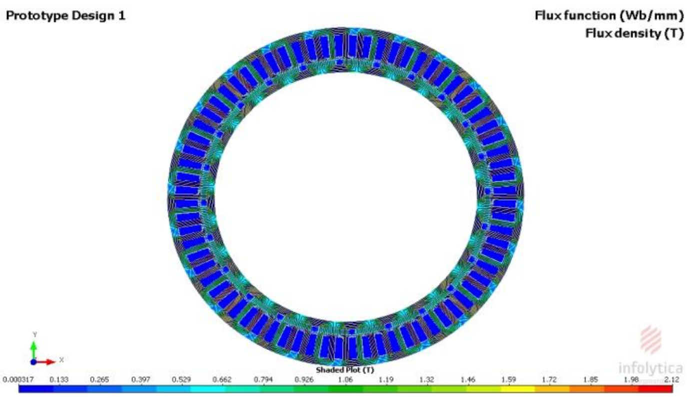

Fig -13: flux density with standard stamping

	Prototype Design 1
Torque (N·m)	281
Reluctance torque (N·m)	-0.0207
Input power (kW)	7.42
Output power (kW)	7.03
Efficiency (%)	94.8
RMS voltage (V)	326
RMS current (A)	14.9
Supply current (A)	18.5
Loss - Total (kW)	0.385

Fig -14: Result of motor solve with standard stamping

1.3 Comparison

Table -2: design variable

Quantity	Simple design	Design with standard stamping
Stator outer diameter(Dso)	320 mm	300mm
Rotor outer diameter(Dro)	258 mm	210 mm
Length(L)	160 mm	231 mm
Torque constant	35 N.m/m^3	35 N.m/m^3
Voltage	400 V	400 V
Number of slots	72	72
Number of magnet	24	24

From above table it is clear that there is huge difference between sizes of two motor but in result, both motor gives same output in terms of torque and power.

Table -3: comparison of motor solve result

Quantity	Simple design	Design with standard stamping
Torque	282 N.m	281 N.m
Output power	7.06 kW	7.03 kW
Efficiency	94.6	94.8
Flux desity in stator yoke	1.45 T	1.4 T
Flux desity in stator teeth	1.66 T	1.64 T
Flux desity in rotor yoke	1.46 T	1.43 T

From above table it is clear that result of both approaches is very nearer to each other. So one can use second approach and design motor for any rating.

3. CONCLUSIONS

From above analysis we can conclude that by using standard stamping of induction motor which is nearest with calculated data can be used to design permanent magnet motor for elevator application by varying length of permanent motor with changing aspect ratio of permanent magnet motor.

So there is no need to make special stamping for calculated diameter which gives us more saving in terms of cost and time.

Hence, we can use only one stamping to manufacture any rating of permanent magnet motor. We only need to make length as variable.

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BIOGRAPHIES

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