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 because of its feature like high efficiency, high starting torque, and silent working. 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 9.88 x (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

**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**
- Size: 0
- Slew angle: 0
- Protected dimensions: Back iron depth, Tooth width

**Diameters**
- Back iron depth: 6.0
- Inner diameter: 260
- Outer diameter: 320

**Teeth**
- Base diameter radius: 0
- Shank length: 21.2
- Set area: 157
- Set depth: 22.9
- Tooth edge inset: 1.615E-11
- Tooth gap angle: 0.852
- Tooth gap width: 1.48
- Tooth tang angle: 0
- Tooth tang depth: 1.613
- Tooth width: 0

**Flutes**
- Bottom shaft radius: 0.592
- Top shaft radius: 0.592

#### Fig - 4: Rotor input of 7 kW motor

### Fig - 3: Stator input of 7 kW motor

### Fig - 5: Material

#### Fig - 6: Flux density
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>
<thead>
<tr>
<th>Table -1: design variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
</tr>
<tr>
<td>Stator outer diameter(Dso)</td>
</tr>
<tr>
<td>Rotor outer diameter(Dro)</td>
</tr>
<tr>
<td>Length (L)</td>
</tr>
<tr>
<td>Aspect ratio</td>
</tr>
</tbody>
</table>

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.

![Fig-7: torque profile](image1.png)

![Fig-8: cogging torque](image2.png)

![Fig-9: Result of motor solve](image3.png)

![Fig-10: General Input of 7 KW motor with induction motor standard stamping](image4.png)
Fig -11: stator input of 7 KW motor with standard stamping

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

Fig -13: flux density with standard stamping

Fig -14: torque profile with standard stamping

Fig -15: cogging torque with standard stamping

Fig -14: Result of motor solve with standard stamping
1.3 Comparison

Table -2: design variable

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Simple design</th>
<th>Design with standard stamping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stator outer diameter(Dso)</td>
<td>320 mm</td>
<td>300 mm</td>
</tr>
<tr>
<td>Rotor outer diameter(Dro)</td>
<td>258 mm</td>
<td>210 mm</td>
</tr>
<tr>
<td>Length(L)</td>
<td>160 mm</td>
<td>231 mm</td>
</tr>
<tr>
<td>Torque constant</td>
<td>35 N.m/m³</td>
<td>35 N.m/m³</td>
</tr>
<tr>
<td>Voltage</td>
<td>400 V</td>
<td>400 V</td>
</tr>
<tr>
<td>Number of slots</td>
<td>72</td>
<td>72</td>
</tr>
<tr>
<td>Number of magnet</td>
<td>24</td>
<td>24</td>
</tr>
</tbody>
</table>

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

<table>
<thead>
<tr>
<th>Quantity</th>
<th>Simple design</th>
<th>Design with standard stamping</th>
</tr>
</thead>
<tbody>
<tr>
<td>Torque</td>
<td>282 N.m</td>
<td>281 N.m</td>
</tr>
<tr>
<td>Output power</td>
<td>7.06 kW</td>
<td>7.03 kW</td>
</tr>
<tr>
<td>Efficiency</td>
<td>94.6</td>
<td>94.8</td>
</tr>
<tr>
<td>Flux density in stator yoke</td>
<td>1.45 T</td>
<td>1.4 T</td>
</tr>
<tr>
<td>Flux density in stator teeth</td>
<td>1.66 T</td>
<td>1.64 T</td>
</tr>
<tr>
<td>Flux density in rotor yoke</td>
<td>1.46 T</td>
<td>1.43 T</td>
</tr>
</tbody>
</table>

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.

REFERENCES

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BIOGRAPHIES

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