No-Load Analysis of Permanent Magnet AC Servomotors - A Comparative Study

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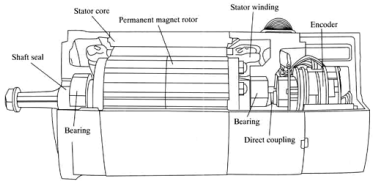
Outline

1. PM SERVOMOTORS

PM Servomotors application areas:

- Automotive,
- Robotics
- Defense industry,
- Position control applications,
- Cranes,
- Drills,
- ...



PM servomotor rotor, stator and cross-section

Advantages of PM Servomotors :

- High efficiency,
- High power density
- High torque density,
- Large torque to weight ratio,
- ...

Disadvantages of PM Servomotors :

- Temperature,
- High cost,
- Complicated control,
- Complicated design process,
- ...

1. PM SERVOMOTORS

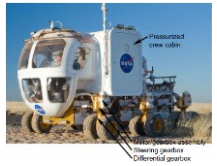
Project on design of a biped robot with efficient motion control (Source: Indian Institute of Technology Roorkee)

Einstein robot head has muscles , each moved by a tiny servo motor (Source: University of California)

Linear actuator with linear servo motor (Source: IntelLiDrives manufacturing)

Lynx SEMA axial flux motor tested in University of Tennessee's future truck (Source: University of Tennessee)

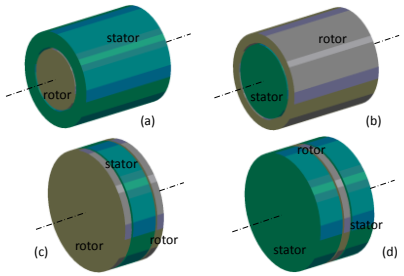
Single stator double rotor NN or NS type AFI motor traction system



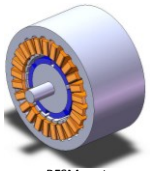
NASA Chariot lunar rover vehicle (Source: NASA)

To design the DART hand researchers used servo motors (Source: IOP Publishing Ltd.)

1. PM SERVOMOTORS



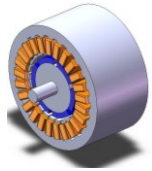
a) Inner rotor, outer stator RFSM,
b) Inner stator, outer rotor RFSM,
c) Two rotor, One stator AFSM,
d) Two stator, One rotor AFSM



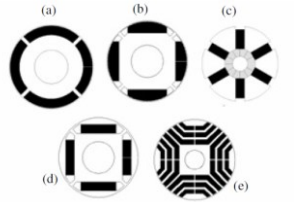
RFSM motor

One-stator-One-rotor AFSM motor

1. PM SERVOMOTORS



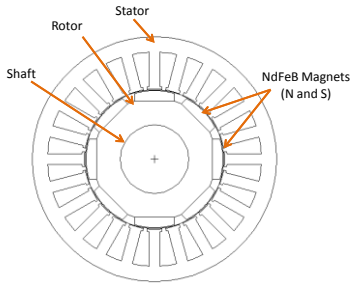
Classical RFSM motor



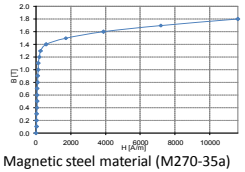
a) Surface mounted permanent magnet (PM) motor
b) Inset PM motor
c) Spoke type interior PM (IPM) motor
d) Single layer IPM motor
e) Multiple layer IPM motor

Outline

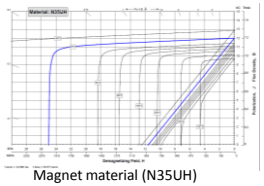
2. PM AC SERVOMOTOR STRUCTURE AND DESIGN CRITERIA



24 slots with 8 poles
AC Servomotor Structure



Magnetic steel material (M270-35a)



Magnet material (N35UH)

2. PM AC SERVOMOTOR STRUCTURE AND DESIGN CRITERIA

- All the motors are designed for 1.5kW and 2000rpm rated speeds.
- Five of the are conventional balanced motors
- Some of the others unbalanced and unconventional motors

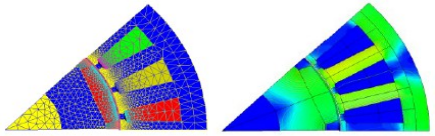
Summary of the motors analyzed

	Balanced		Odd Slot-pole comb.	
Number of Poles	**Number of Slots**	***q* (Slots/Pole/ Phase)**	**Number of Slots**	***q* (Slots/Pole/ Phase)**
6-Pole	18 Slots	1	21 Slots	1.167
8-Pole	24 Slots	1	27 Slots	1.125
10-Pole	30 Slots	1	33 Slots	1.1
12-Pole	36 Slots	1	39 Slots	1.083
14-Pole	42 Slots	1	45 Slots	1.071

Outline

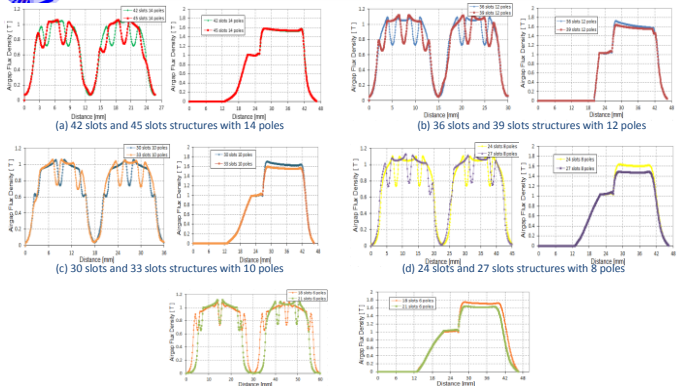
3. NO-LOAD FEA

- In this no-load analysis the results are obtained for control range, cogging torque and back EMF.
- The maximum flux densities in the teeth in each motor are roughly the same



24 slots with 8 poles motor mesh structure and flux density distribution

3. NO-LOAD FEA



(a) 42 slots and 45 slots structures with 14 poles
(b) 36 slots and 39 slots structures with 12 poles
(c) 30 slots and 33 slots structures with 10 poles
(d) 24 slots and 27 slots structures with 8 poles
(e) 18 slots and 21 slots structures with 6 poles

Airgap flux density variations over two poles

3. NO-LOAD FEA

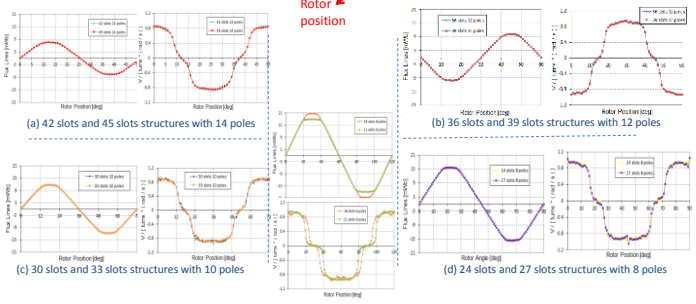
- Back EMF can be expressed as;

Back EMF $e(t) = -\frac{d\psi}{d\theta}\omega_r$ (1)

Flux linkage

Angular speed

Rotor position



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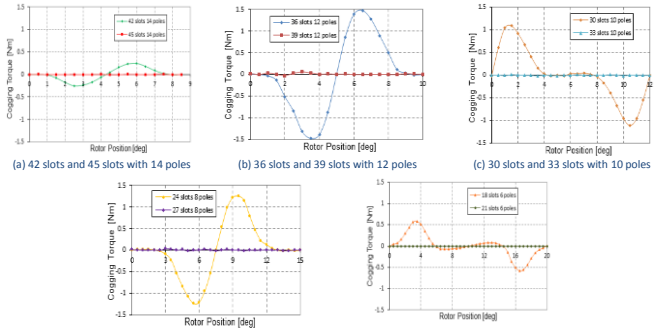
Back EMF waveforms

Outline

4. COGGING TORQUE COMPONENT OF SERVOMOTORS

- Cogging torque is one of the most important sources of torque pulsations in PM servomotors.
- It can be minimized using various teqhniques such as magnet pole-arc ratio, stator or magnet skew, magnet-pole shifting, dummy slots, stepped rotor.
- This unwanted component is usually 5 to 10% of the rated torque for most standard industrial applications and less than 1% for applications where low speed control is critical and high precision is required.

4. COGGING TORQUE COMPONENT OF SERVOMOTORS



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Cogging torque waveforms for each servomotor

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1. PM SERVOMOTORS
2. PM AC SERVOMOTOR STRUCTURE AND DESIGN CRITERIA
3. NO-LOAD FEA
4. FEA ANALYSIS
5. CONCLUSION

5. CONCLUSION

- ✓ This study shows a comparative no-load analysis of 10 different surface mounted PM servomotors.
- ✓ The motors are investigated for cogging torque components for both balanced and unbalanced structures and it was found that motors with odd-slot-pole combinations provide almost no-cogging component.
- ✓ These motors are well suited for low speed control and applications which require precise position control.

QUESTIONS…

Thank You For
Your Attention