





ORTA DOĞU TEKNİK ÜNİVERSİTESİ  
MIDDLE EAST TECHNICAL UNIVERSITY

## Axial Flux Machines

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# Outline

1. Introduction
2. Principles of Operation
3. Advantages
4. Disadvantages
5. Application Areas
6. Conclusion
7. References

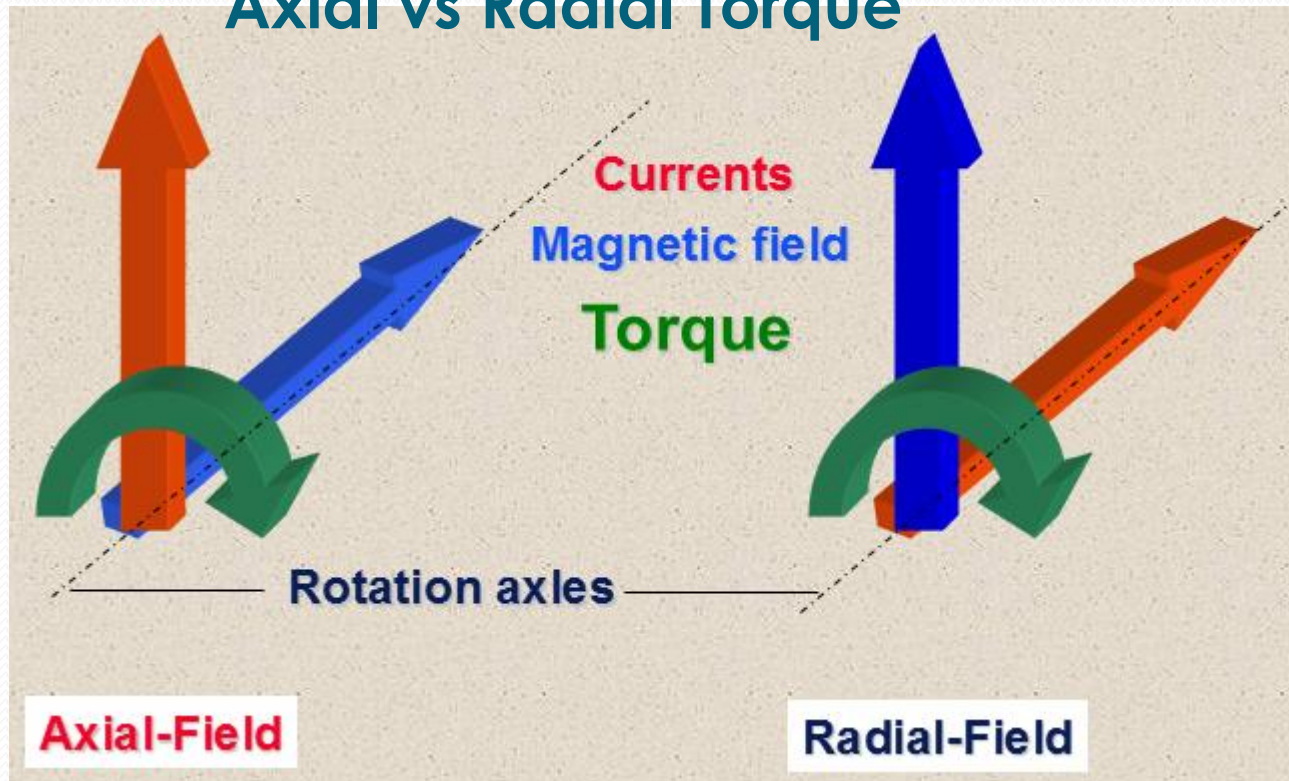
# 1-INTRODUCTION



- Michael Faraday, early 1900s
- Development methods bottleneck
- 1980s focus on axial flux (axial DC M/C at University of Warwick)

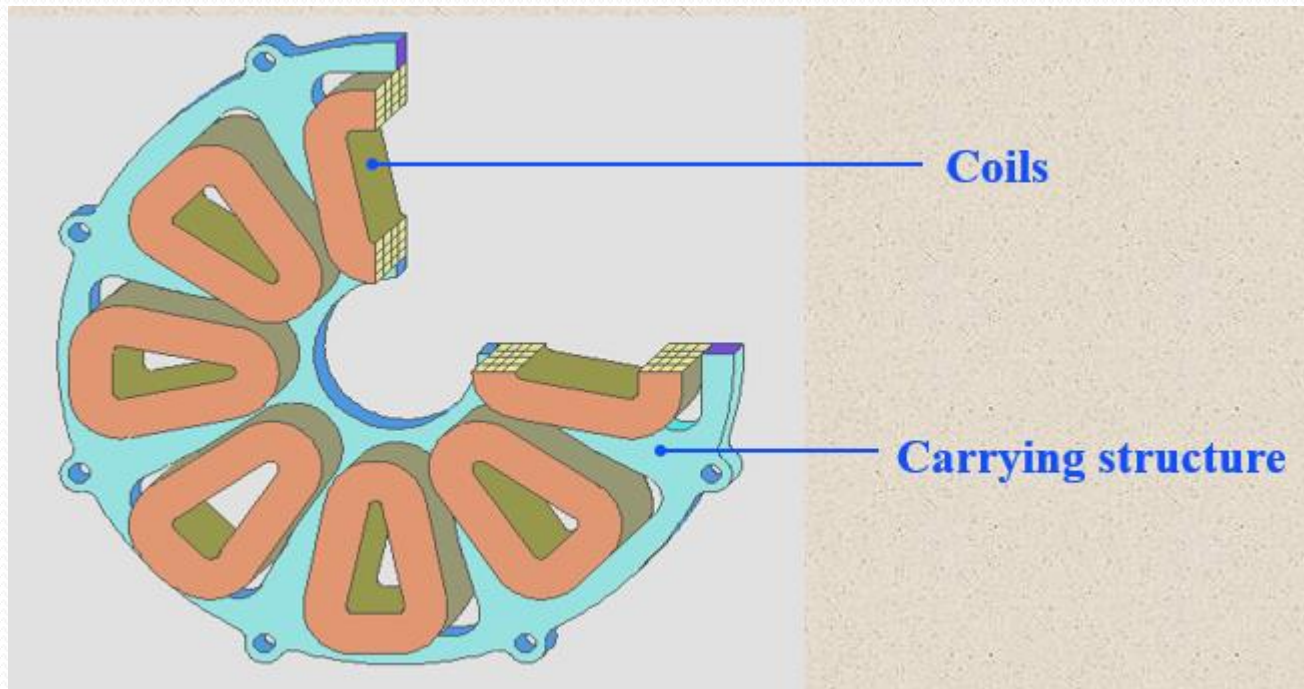
# 1-INTRODUCTION

## Axial vs Radial Torque



## 2-PRINCIPLES OF OPERATION

Stator



## 2-PRINCIPLES OF OPERATION

### Torque Generation

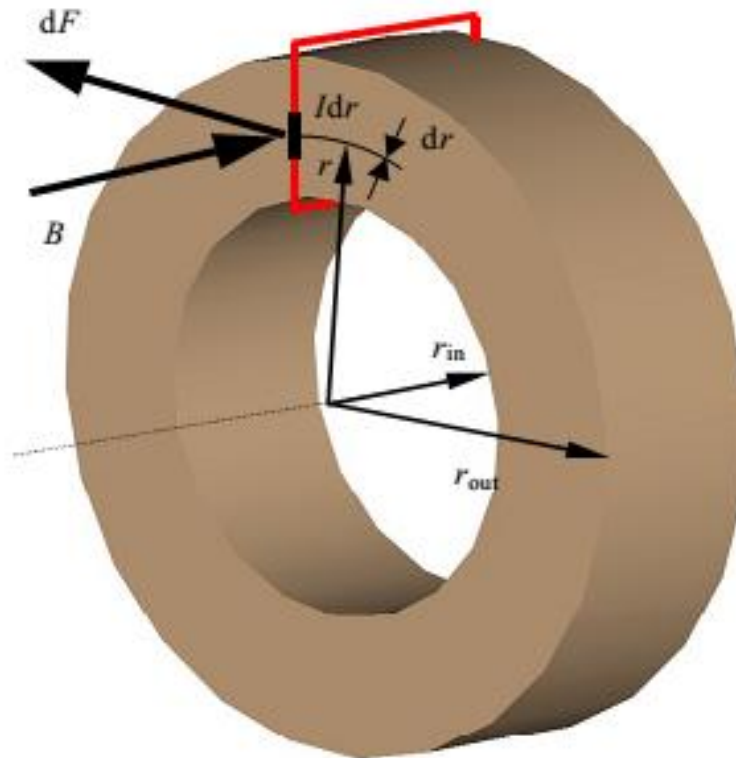
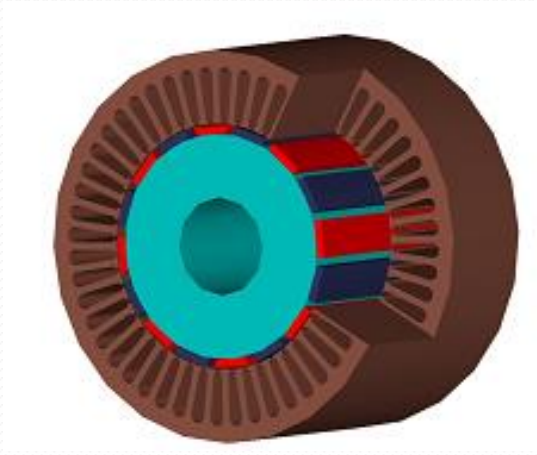
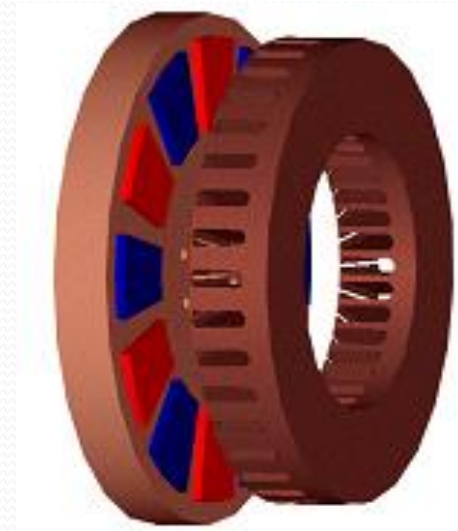


Fig. 1.8. Illustration of torque production mechanism in axial-flux machines.

## 2-PRINCIPLES OF OPERATION



Conventional Radial Flux M/C



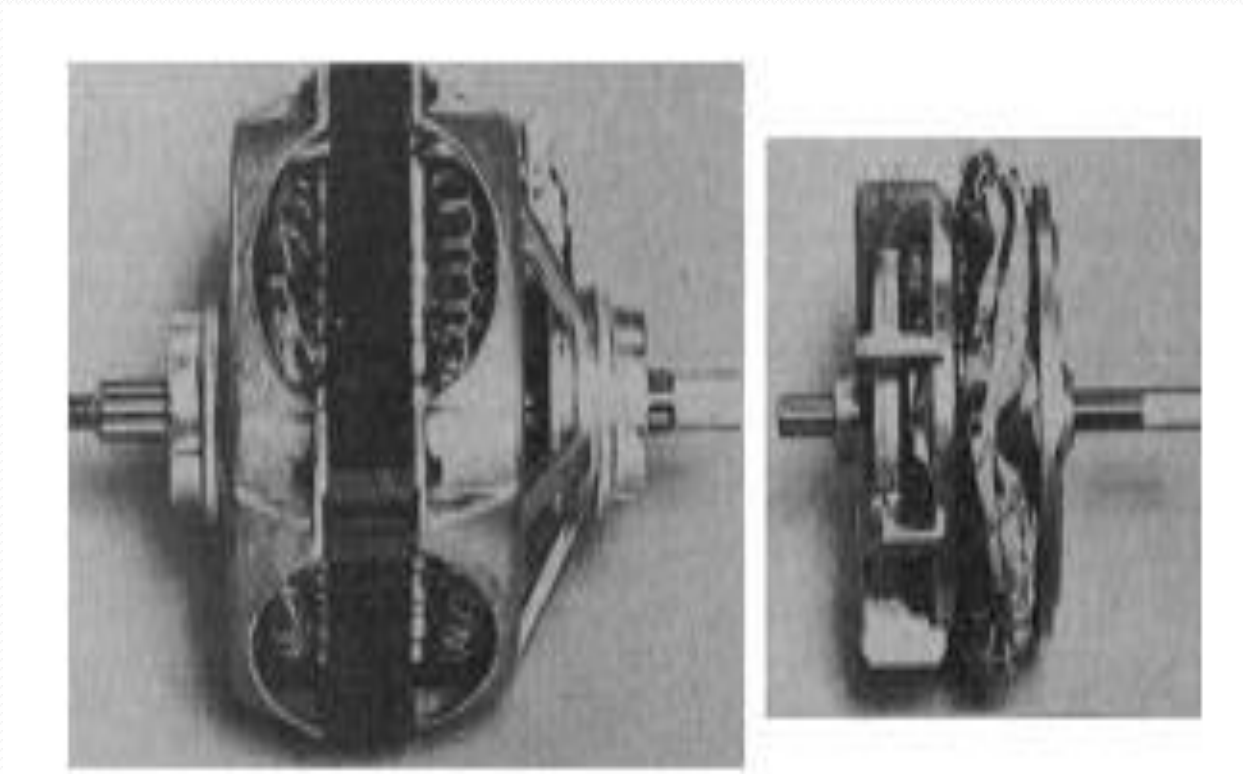
Axial Flux M/C

What is wrong???



## 2-PRINCIPLES OF OPERATION

150 W radial and axial M/Cs



## 2-PRINCIPLES OF OPERATION

- Every Radial M/C type has axial counterpart
- Multistage structure
- Single stator single rotor bearing stress

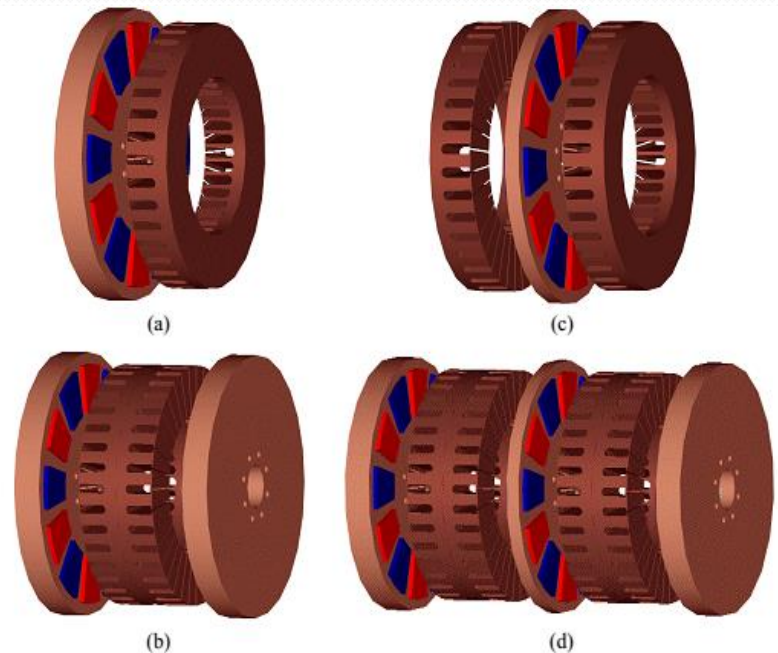
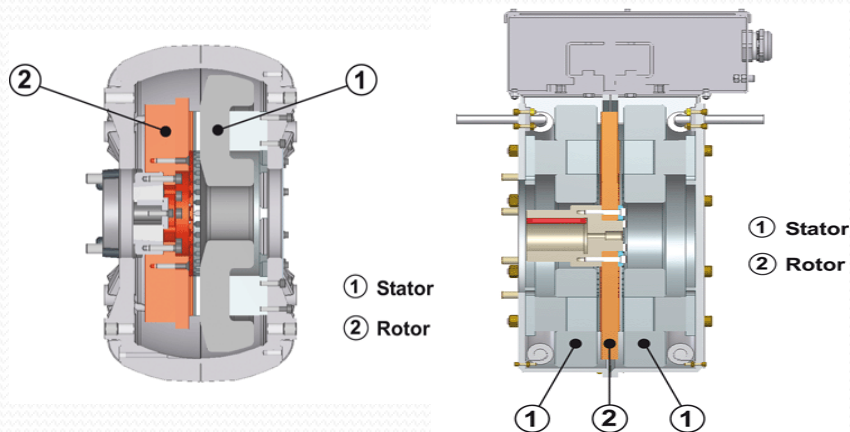


Fig. 1.3. Axial-flux machine configurations. (a) Single-rotor – single-stator structure. (b) Two-rotors – single-stator structure. (c) Single-rotor – two-stators structure, called hereafter also as AFIPM machine (Axial-Flux Interior rotor Permanent-Magnet machine). (d) Multistage structure including two stator blocks and three rotor blocks.

## 2-PRINCIPLES OF OPERATION

Coil Types-distributed or concentrated?  
Less harmonics vs ease of implementation

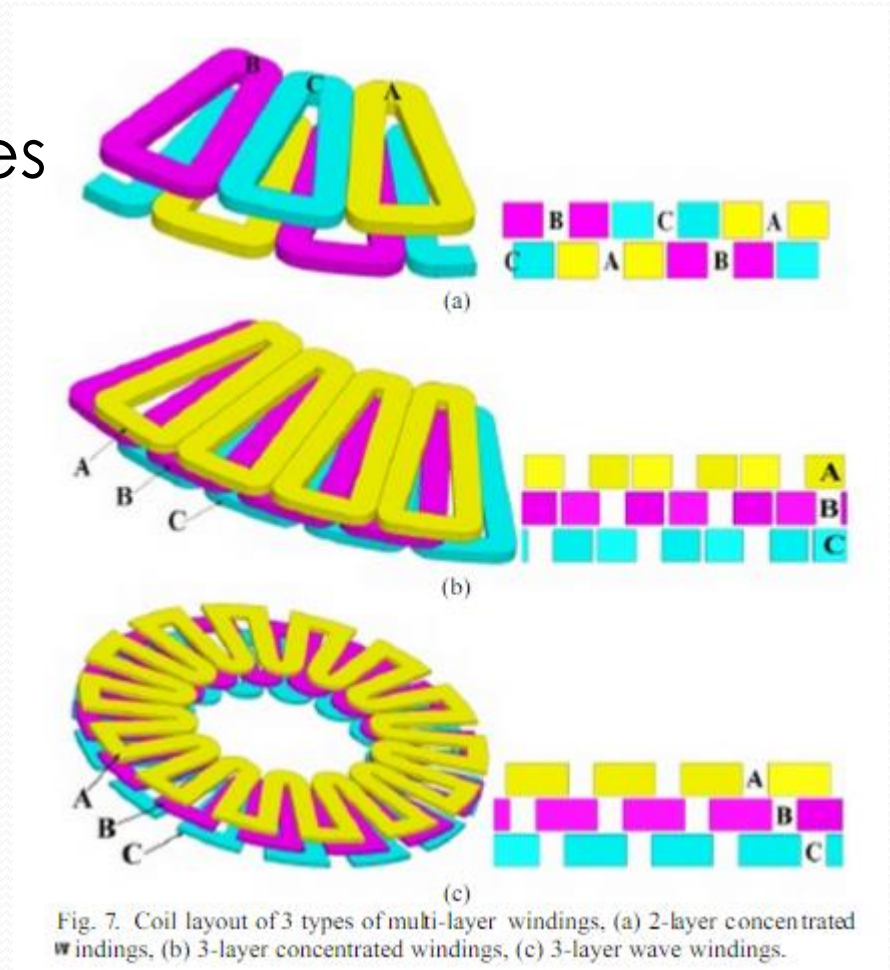


Fig. 1.10. (a) Limited space on the inner radius of the axial-flux machine ( $Q_s = 36$ ,  $p = 6$ ,  $q = 1$ ) while winding the axial-flux machine stator. A conventional two-layer lap winding is employed. (b) Concentrated stator winding enabling values for  $k_D$  lower than 0.6.

## 2-PRINCIPLES OF OPERATION

### Concentrated winding types

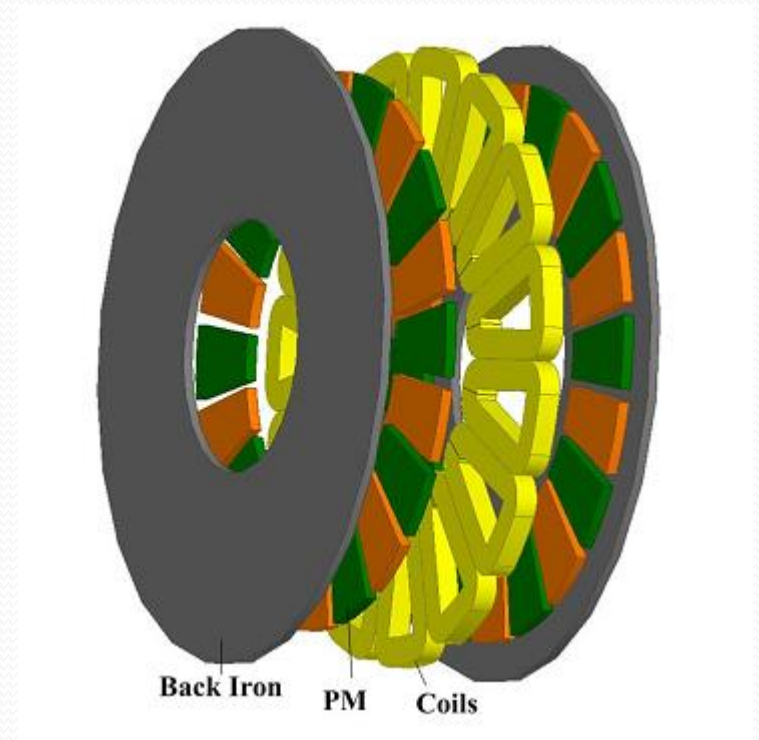
- Double Layer
- Three layer
- Wave winding



## 2-PRINCIPLES OF OPERATION

Air core?

- Increased copper
- Increased air-gap
- Less harmonics
- No saturation of back core
- Improved mechanical attributes



<https://www.youtube.com/watch?v=flHOG7EcCU>



## 2-PRINCIPLES OF OPERATION

### Other M/C types

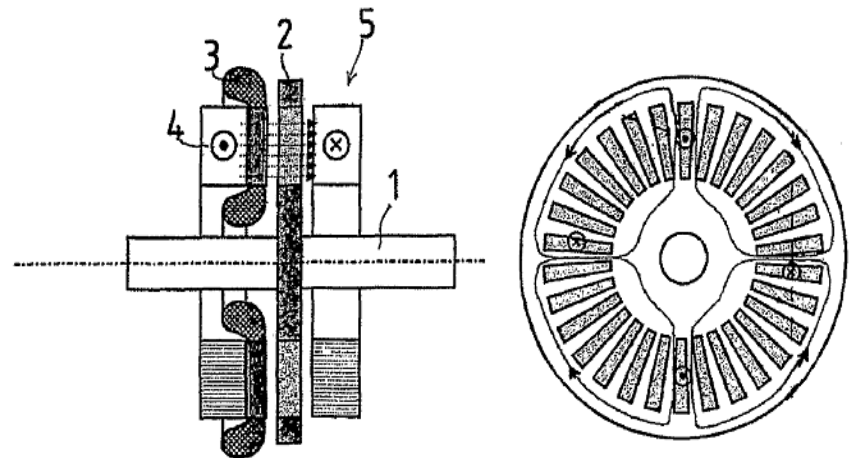
- All radial flux M/C
- Ongoing research

(54) **AXIAL FLUX INDUCTION ELECTRIC MACHINE**

(75) Inventors: **Juha Pyrhonen**, Lappeenranta (FI); **Ari Piispanen**, Lappeenranta (FI)

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[http://www.axcomotors.com/axial-flux\\_technology.html](http://www.axcomotors.com/axial-flux_technology.html)

## 3-ADVANTAGES

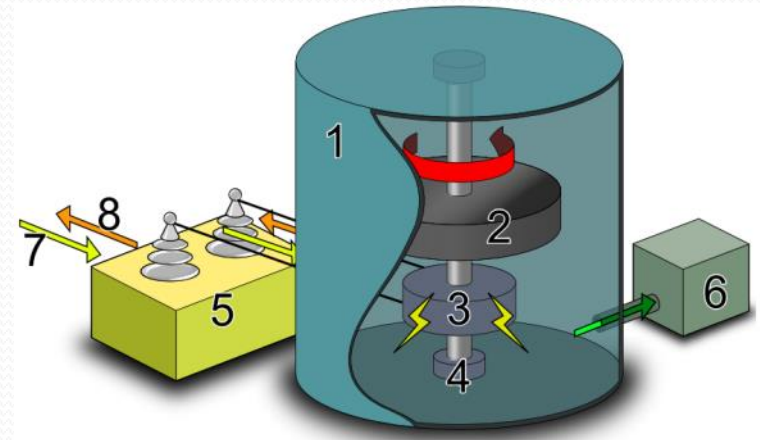
- **High Torque and Power Density**
- **High Utilization of Materials**
- **High Power Density**
- **Small inertia**
- **Excellent mechanical/dynamical characteristics**
- **Reduced Time Constant**
- **Better Ventilation**
- **Reduced mass**

## 4-LIMITATIONS & DISADVANTAGES

- Concentrated winding
- Coil flood in the inner part
- Current, torque harmonics
- More copper
- Size limitation
- Uneffective utilization of core
- Single stator single rotor bearing stress
- Leakage inductance



## 5-APPLICATIONS



- Wind Turbines
- Electric Vehicle
- Pump
- Compressor
- Blower
- Flywheel energy storage
- Aircraft



## 6-Conclusion

- Reduced size, cost
- Improved torque, power, efficiency
- Light construction
- Excellent mechanical/dynamical performance
- Better ventilation
- Applicability of conventional drive techniques
- Ongoing research, open to further advances

## 7-References

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<http://www.yasamotors.com/technology/>

<http://www.ngmcorp.com/Products.htm>



Thank you for your attention.