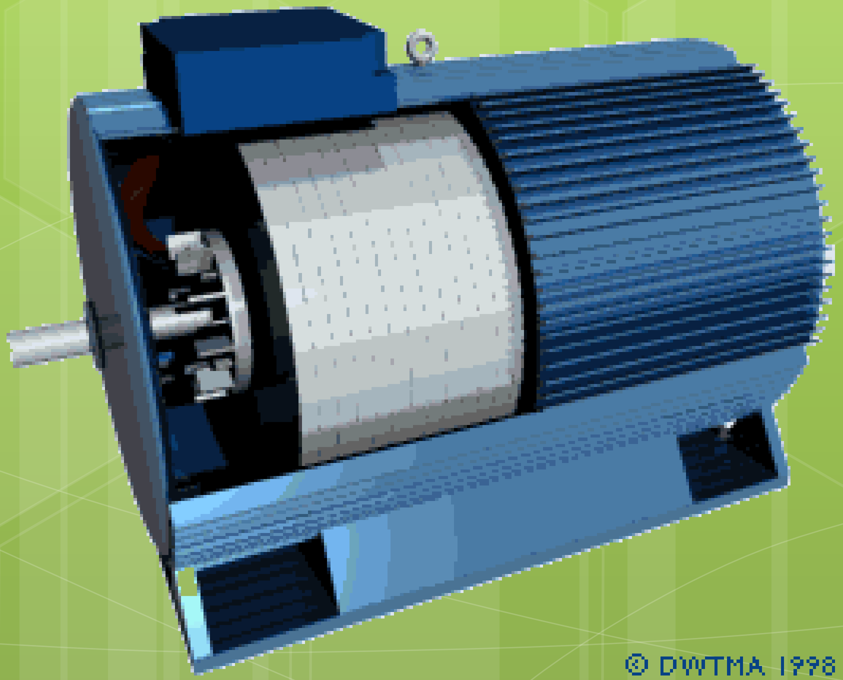


# Electrical Machine Design – I (170902)

www.vishaldevdhar.org

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Lecturer

Electrical Engineering Department
Government Polytechnic, Rajkot

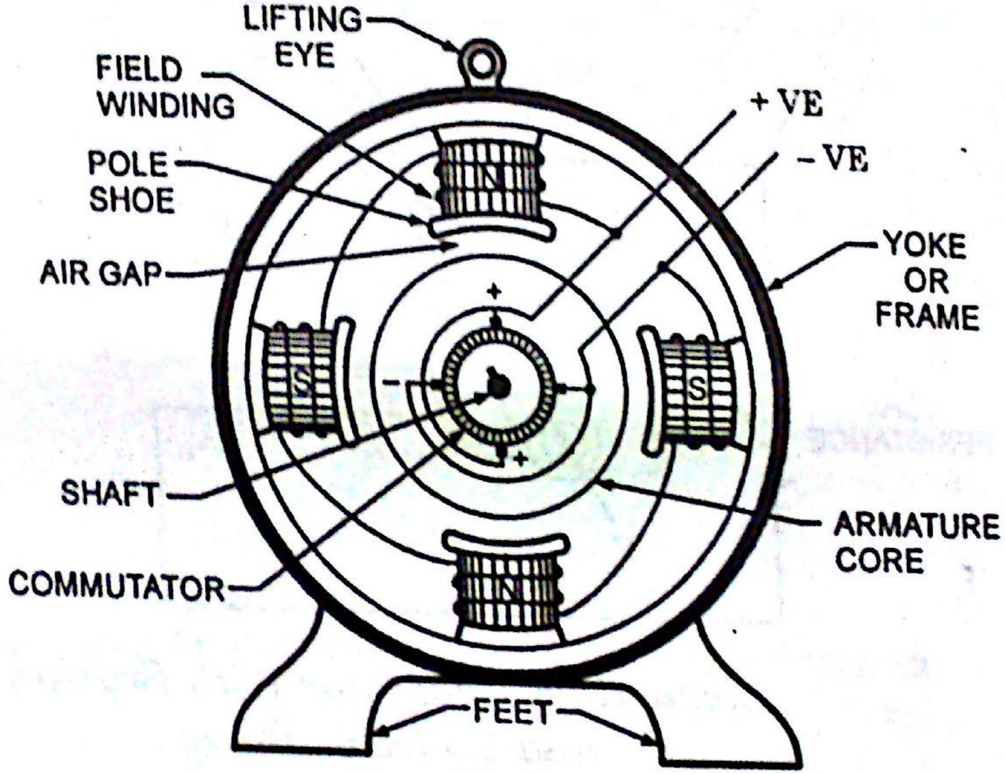
# DC Machine Construction

- Field System
  - Yoke/ Frame
  - Pole Core
  - Pole Shoes
  - Magnetizing Coils
- Armature
- Commutator
- Brushes
- Bearings
- Shaft

# DC Machine Construction

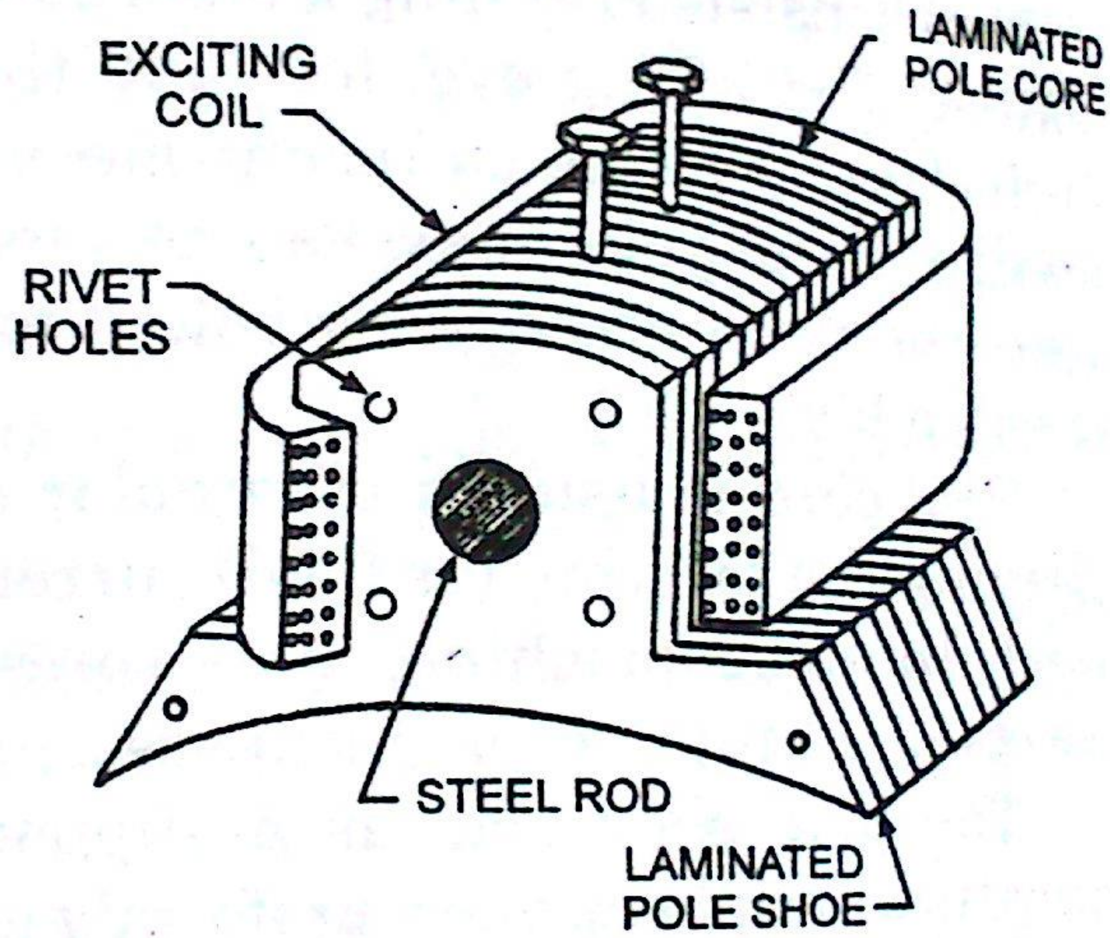
- Armature
- Commutator
- Brushes
- Bearings
- Shaft

# Yoke / Frame




4-Pole DC Machine

# Pole Core, Pole Shoes, Magnetizing Coils




*Laminated Pole Core and Pole Shoe*

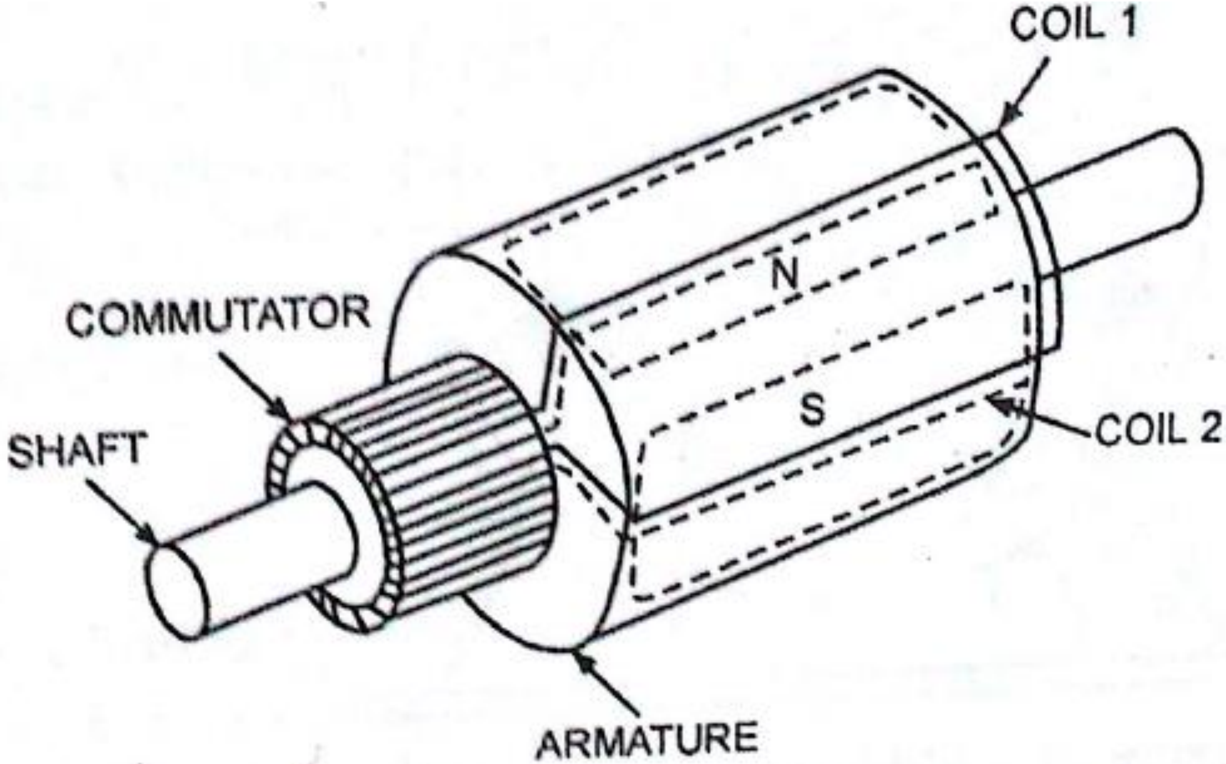
# Pole Core, Pole Shoes, Magnetizing Coils


for small machines

Fixing pole to the yoke.

for large machines

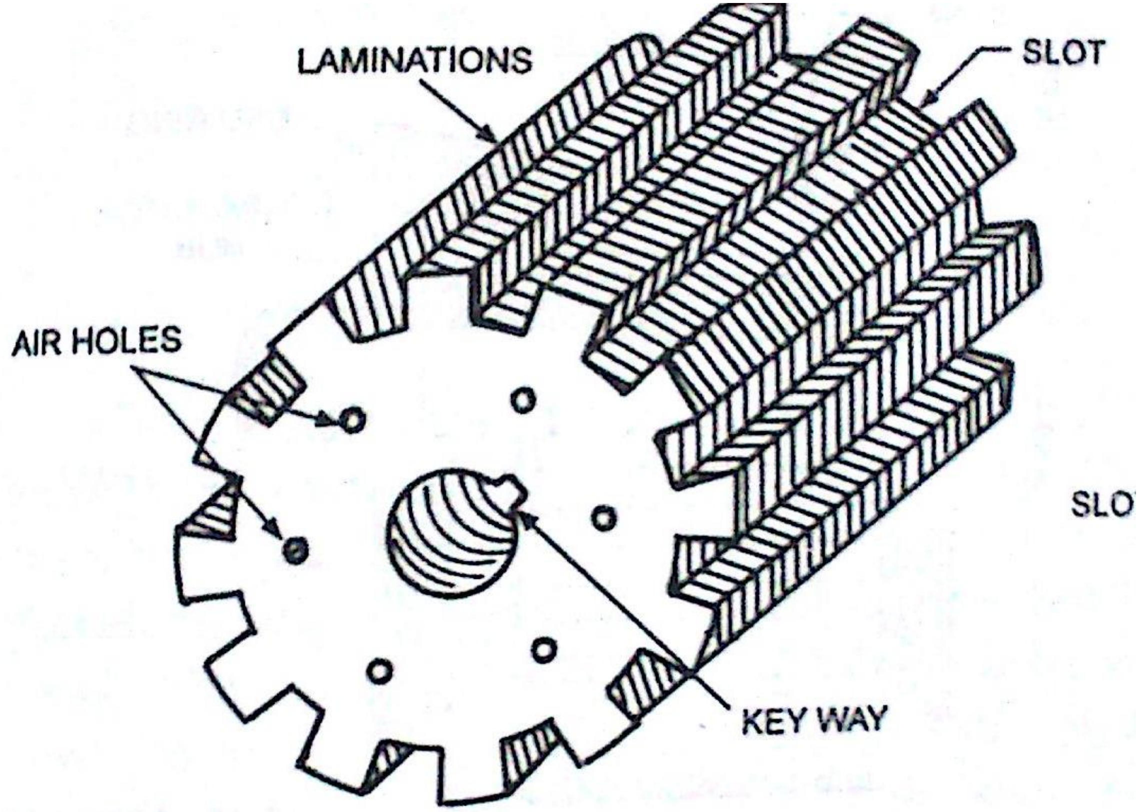
# Armature




*(a) Longitudinal View of Armature*

*Armature*

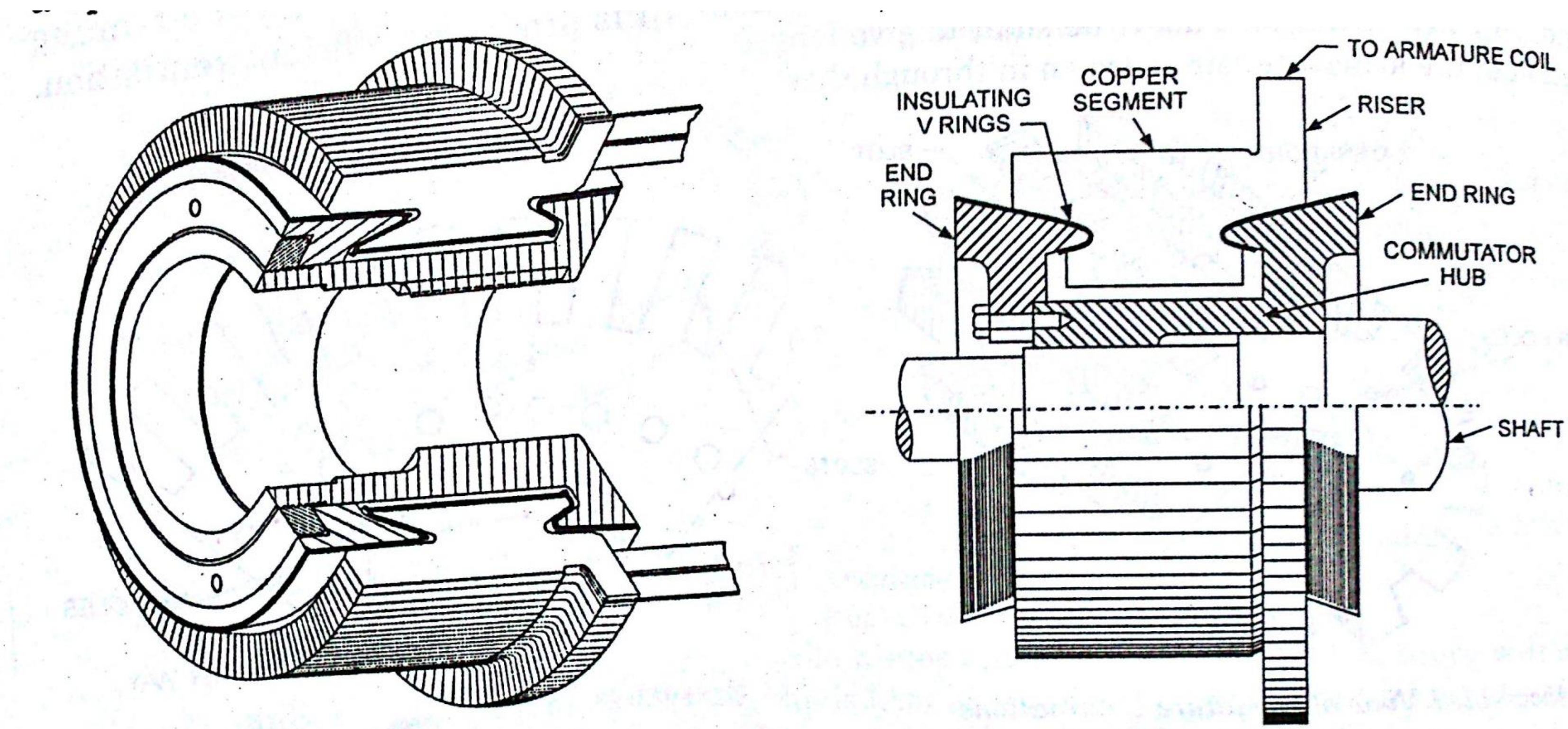
# Armature Lamination




*Assembled View of Armature Laminations*

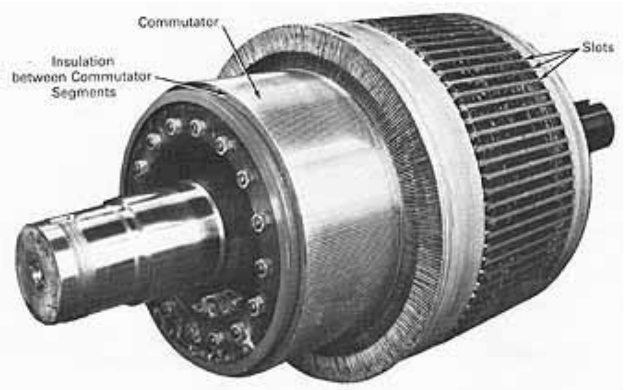
# Armature

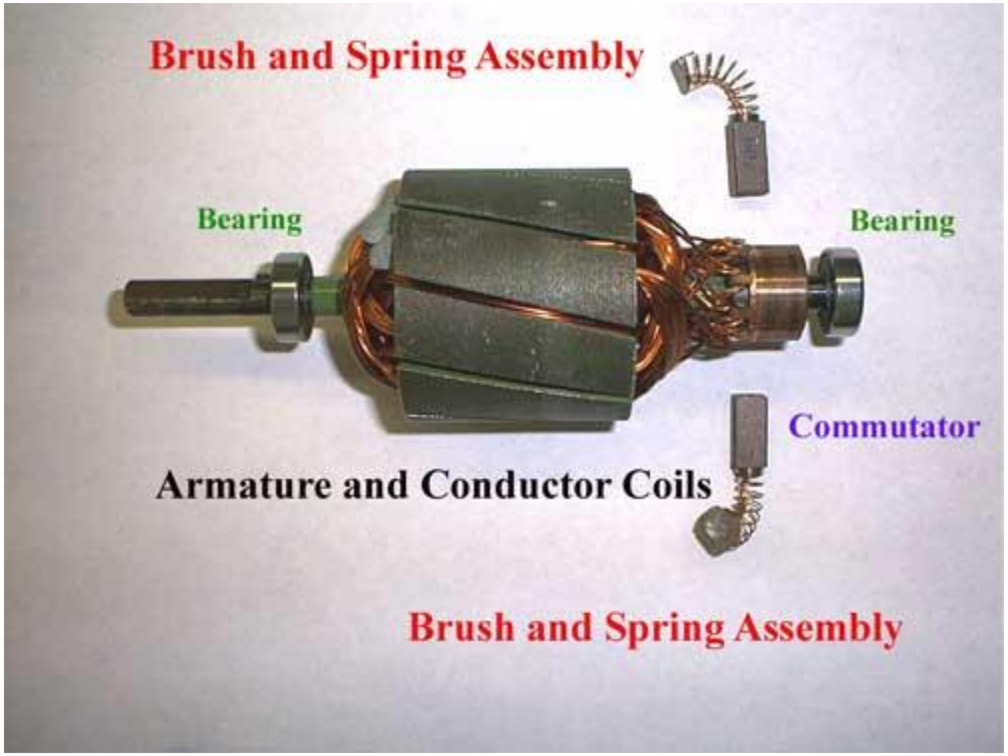
# Commutator



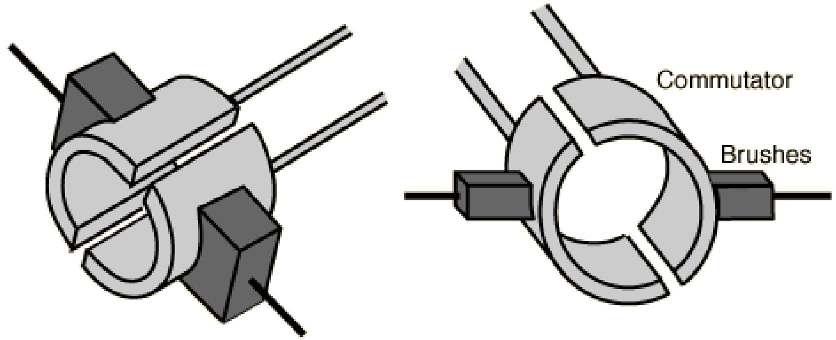

*(b) Section View of Commutator Segments*

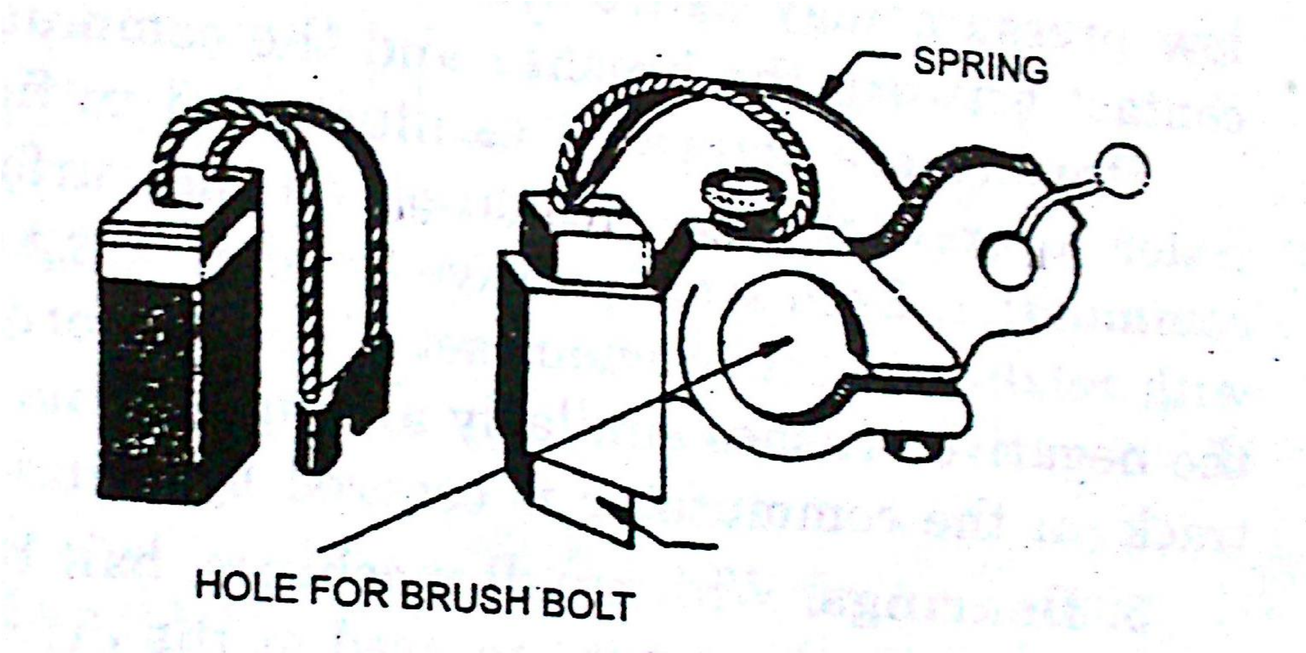
# Armature & Commutator



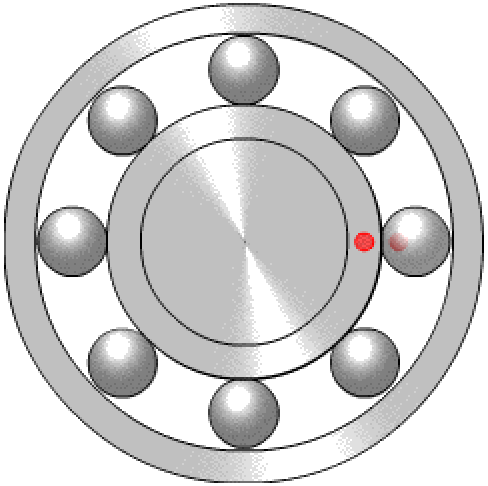



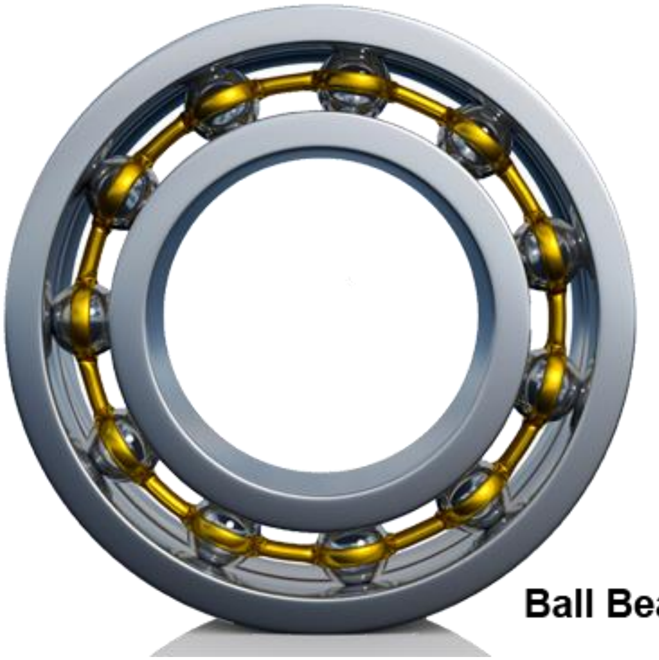
# Brushes



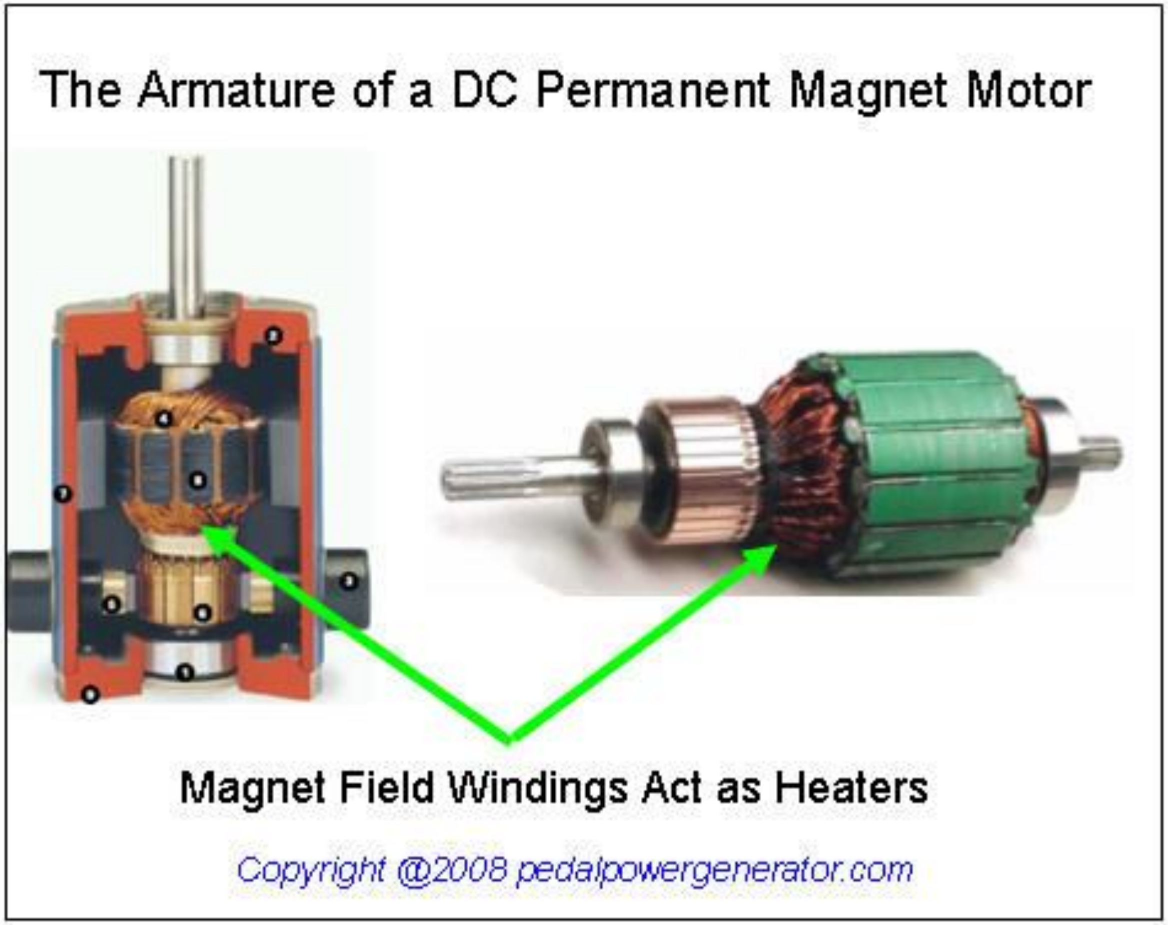
# Bearings



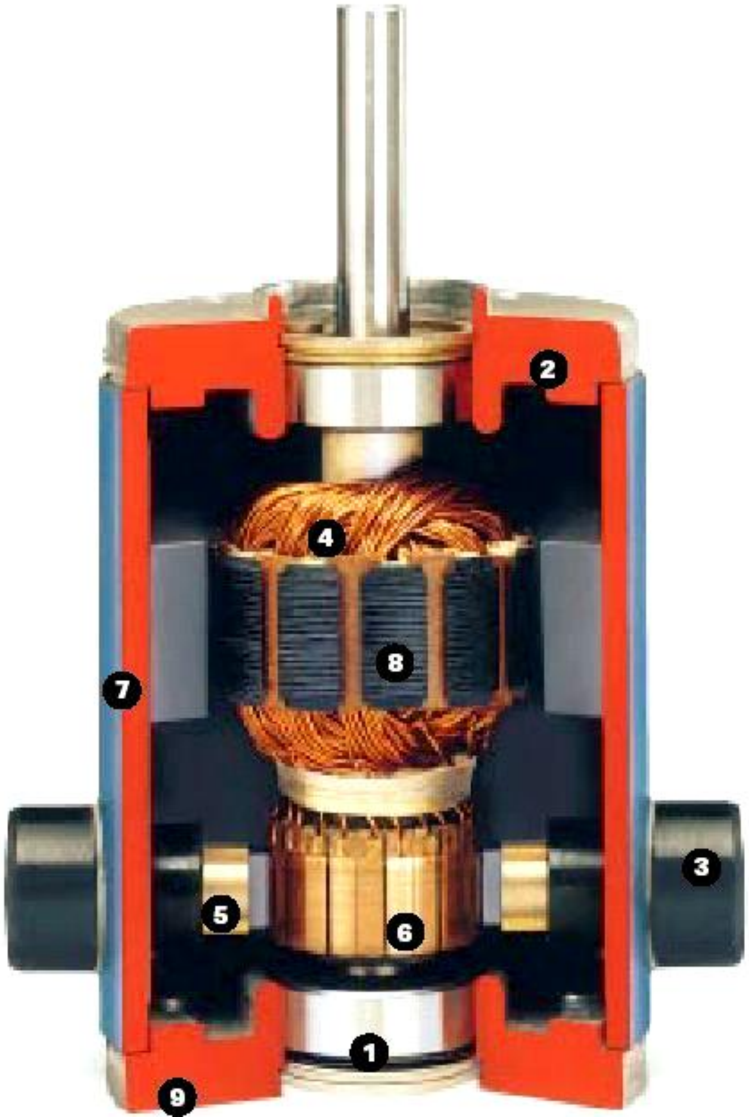


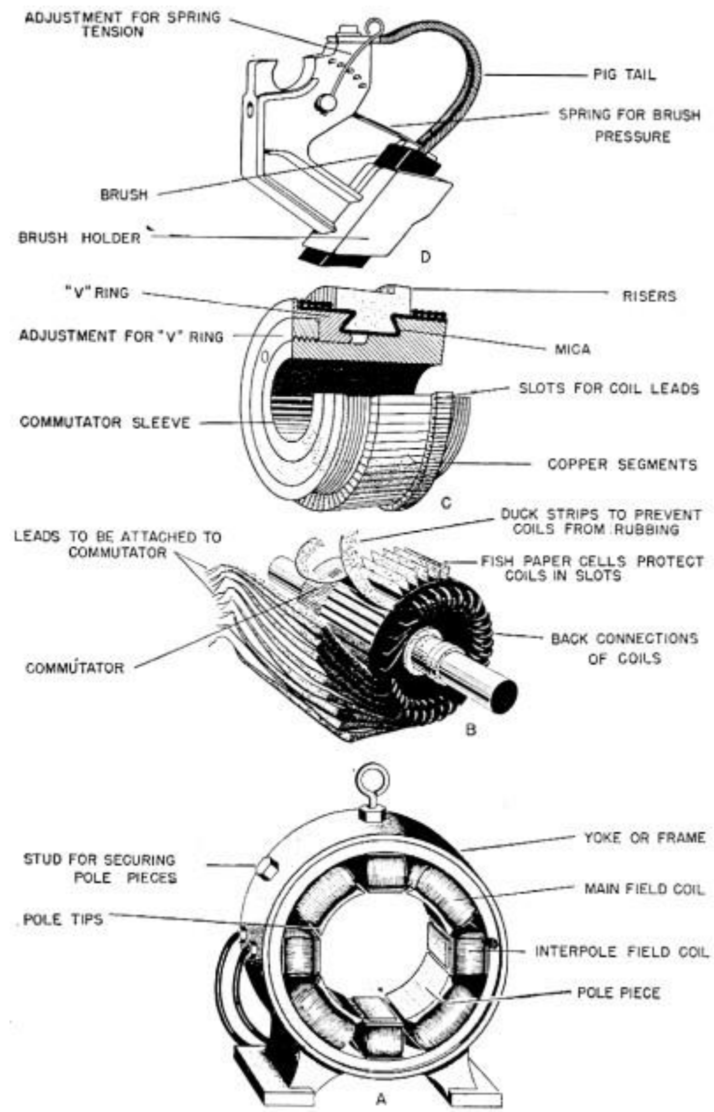
Ball Bearing

# Shaft



The Armature of a DC Permanent Magnet Motor
Magnet Field Windings Act as Heaters
Copyright @2008 pedalpowergenerator.com

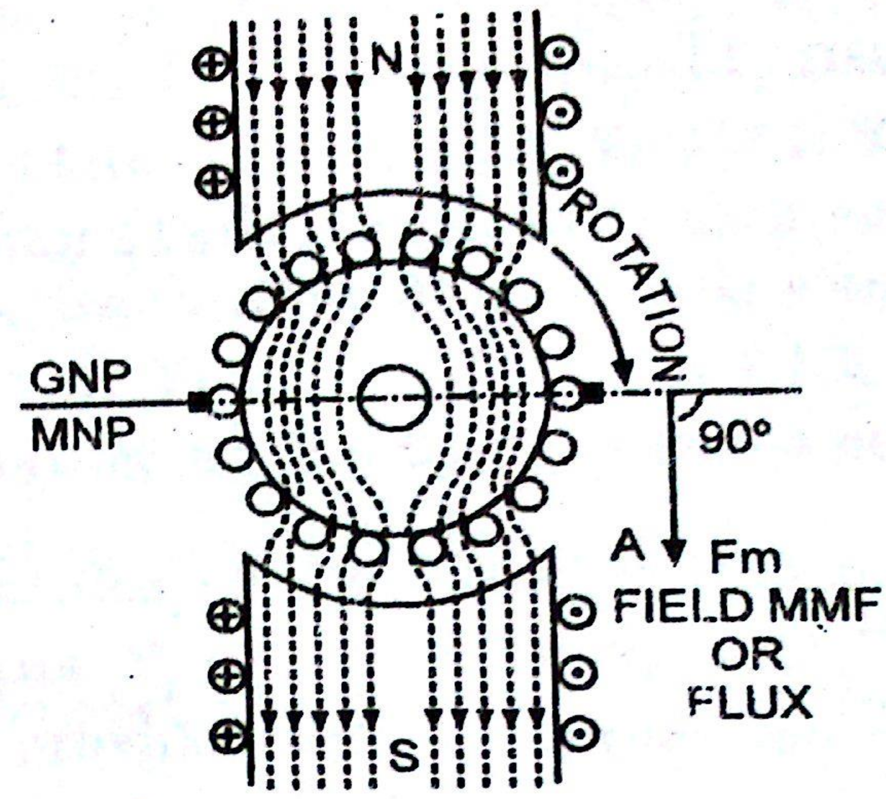

2
4
8
7
3
5
6
1
9


ADJUSTMENT FOR SPRING TENSION
PIG TAIL
SPRING FOR BRUSH PRESSURE
BRUSH
BRUSH HOLDER
D
"V" RING
RISERS
ADJUSTMENT FOR "V" RING
MICA
SLOTS FOR COIL LEADS
COMMUTATOR SLEEVE
COPPER SEGMENTS
C
DUCK STRIPS TO PREVENT COILS FROM RUBBING
LEADS TO BE ATTACHED TO COMMUTATOR
FISH PAPER CELLS PROTECT COILS IN SLOTS
BACK CONNECTIONS OF COILS
COMMUTATOR
B
YOKE OR FRAME
STUD FOR SECURING POLE PIECES
MAIN FIELD COIL
POLE TIPS
INTERPOLE FIELD COIL
POLE PIECE
A

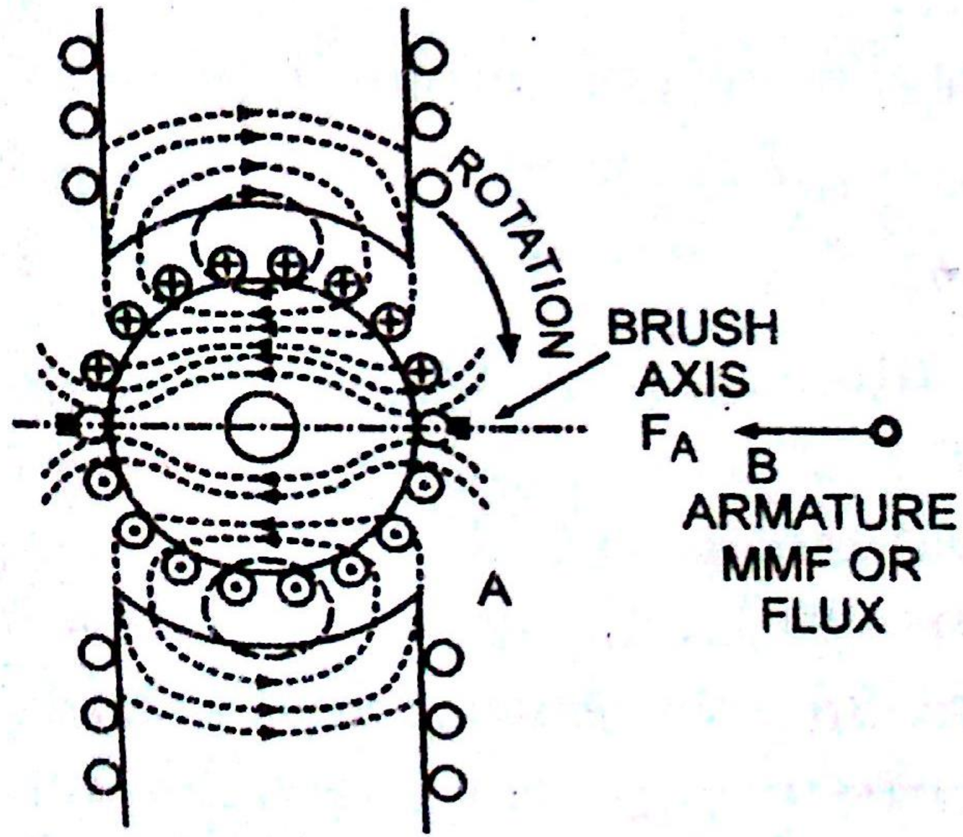
# Armature Reaction

# DC Machine: Armature Reaction

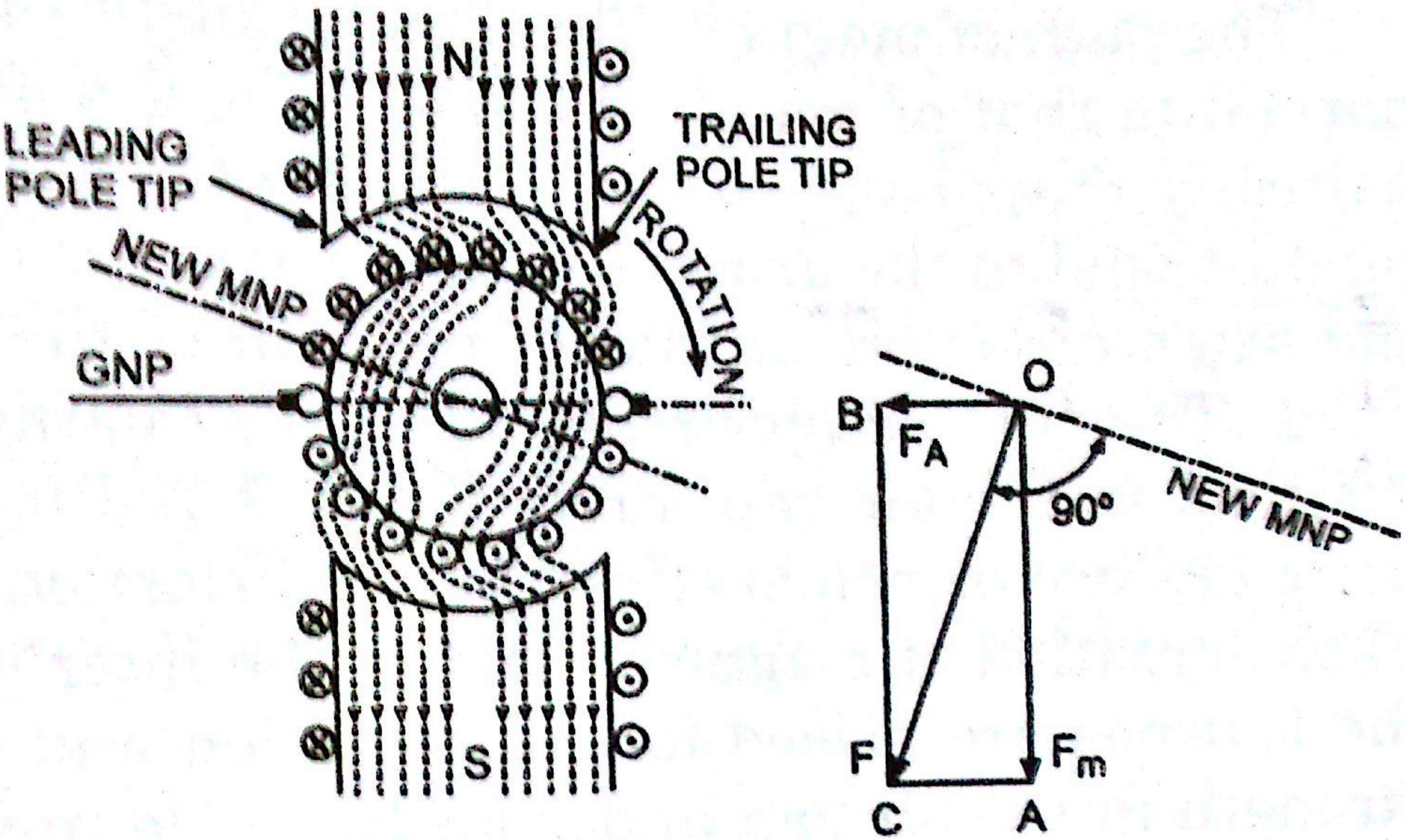
**The effect of magnetic field set up by the armature current on the distribution of flux under the main poles of a DC machine is known as Armature Reaction**




*Distribution of Flux Due To Main Poles When Generator is Supplying No Load*




*Distribution of Flux Due To Armature Current Carrying Conductors While Field Coils Carrying No Current*




*Distribution of Resultant Flux Established From Simultaneous Action of Field and Armature Current*

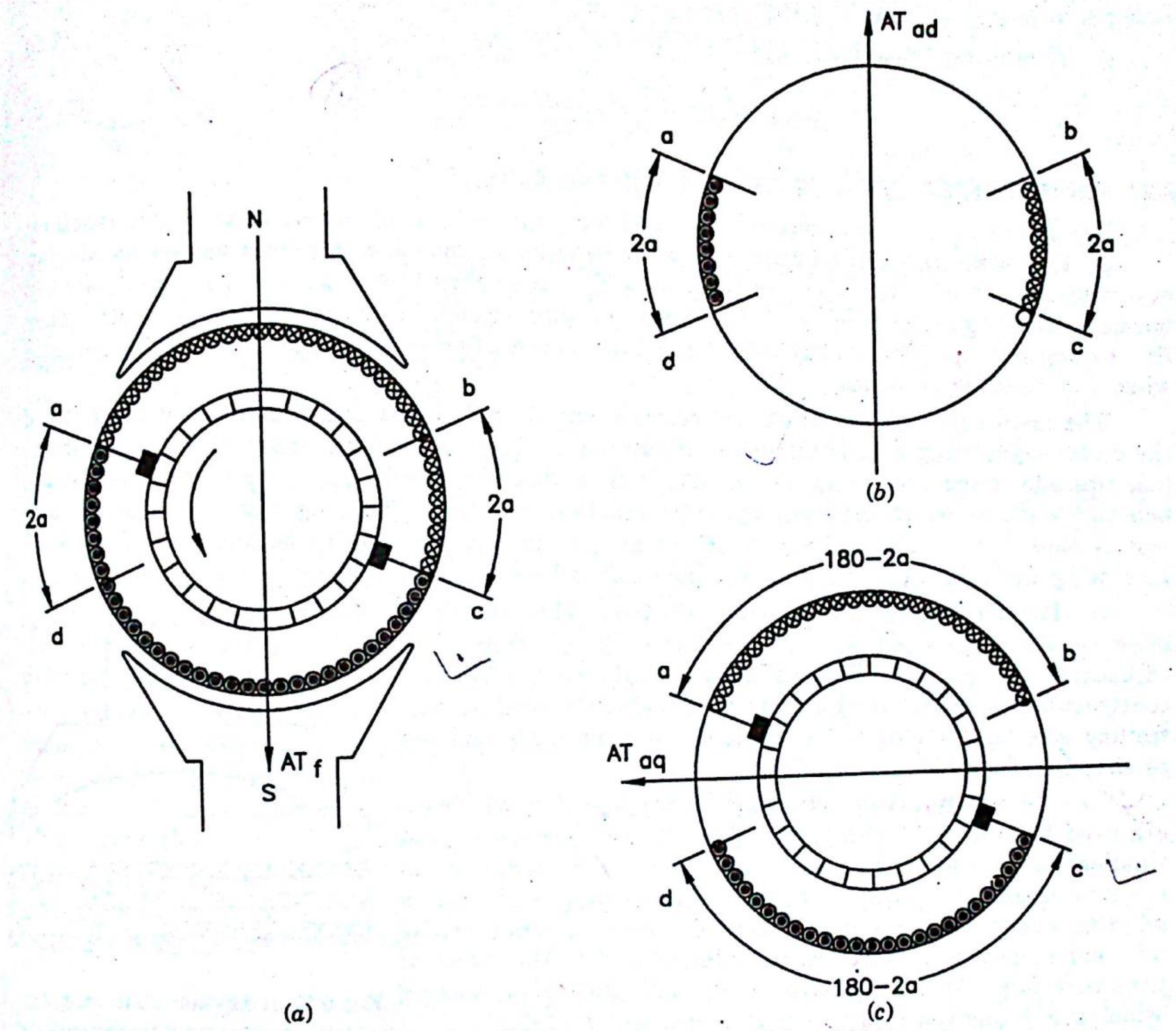



**Fig. 9.31.** Distribution of armature current with brush shift.

# Demagnetizing MMF/Pole

$$AT_{ad} = AT_a \times \frac{2\alpha}{180}$$

$$= \left(\frac{I_a}{a}\right)\left(\frac{Z}{2p}\right)\left(\frac{2\alpha}{180}\right)$$

$$= \frac{I_a Z}{ap}\left(\frac{\alpha}{180}\right)$$

# Cross-magnetizing MMF/Pole

$$AT_{aq} = AT_a - AT_{ad}$$

$$= AT_a\left(1 - \frac{2\alpha}{180}\right)$$

$$= \frac{I_a Z}{2ap}\left(1 - \frac{2\alpha}{180}\right)$$

# Effects of Armature Reaction

- Reduction in total flux
  - Decrease in generated EMF: Generator
  - Decrease in Torque: Motor
- More Iron Losses at Full load than No load
- Commutation
  - Sparking
  - Delayed Commutation

# Reduction of Effects of Armature Reaction

- Increase in length of Airgap at pole tips
- Increasing in reluctance of pole tips
- Interpoles
- Compensating Windings

# Increase in length of Airgap at pole tips

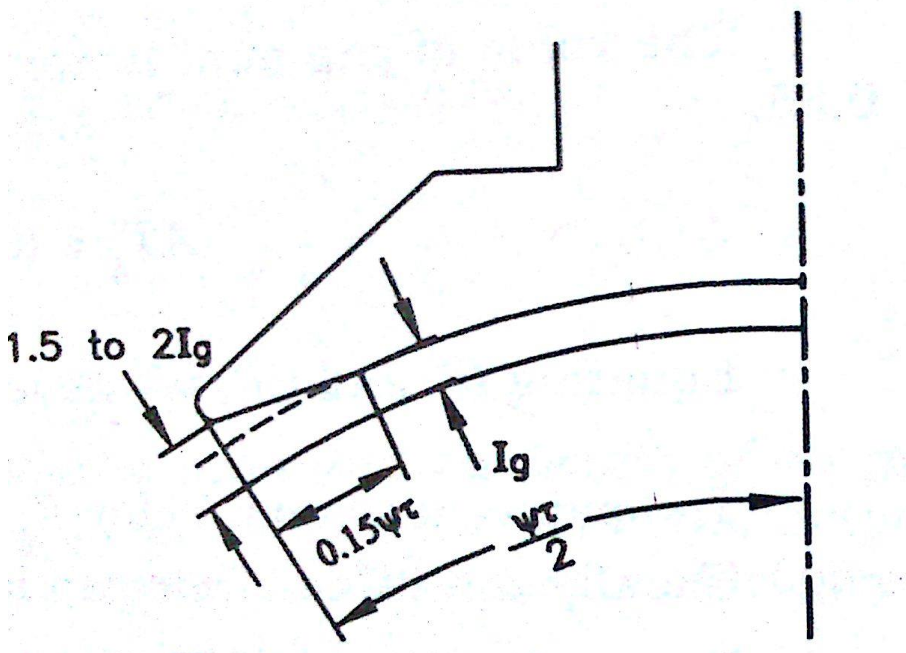



Fig. 9.27. Profile and chamfering of pole face.

# Increasing in reluctance of pole tips

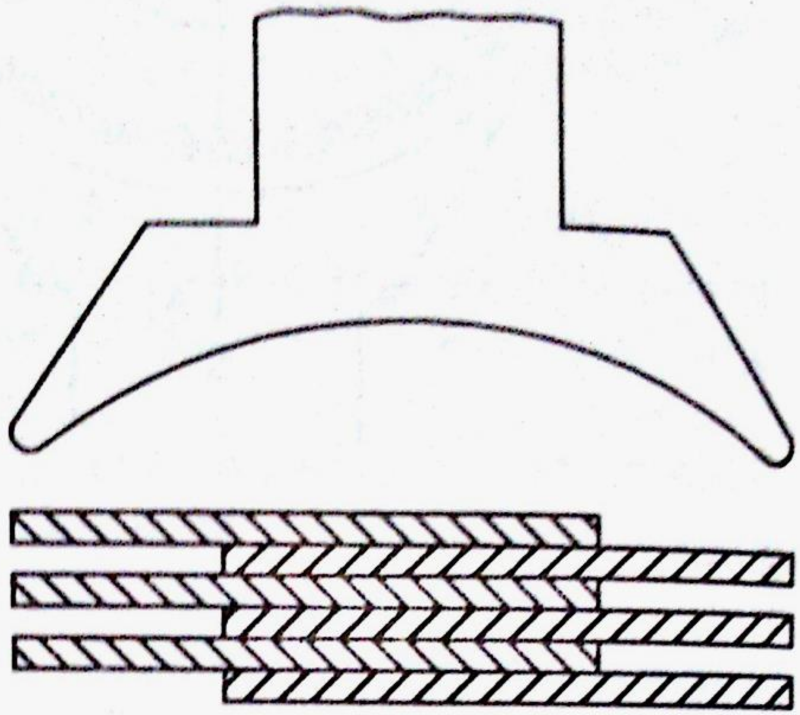
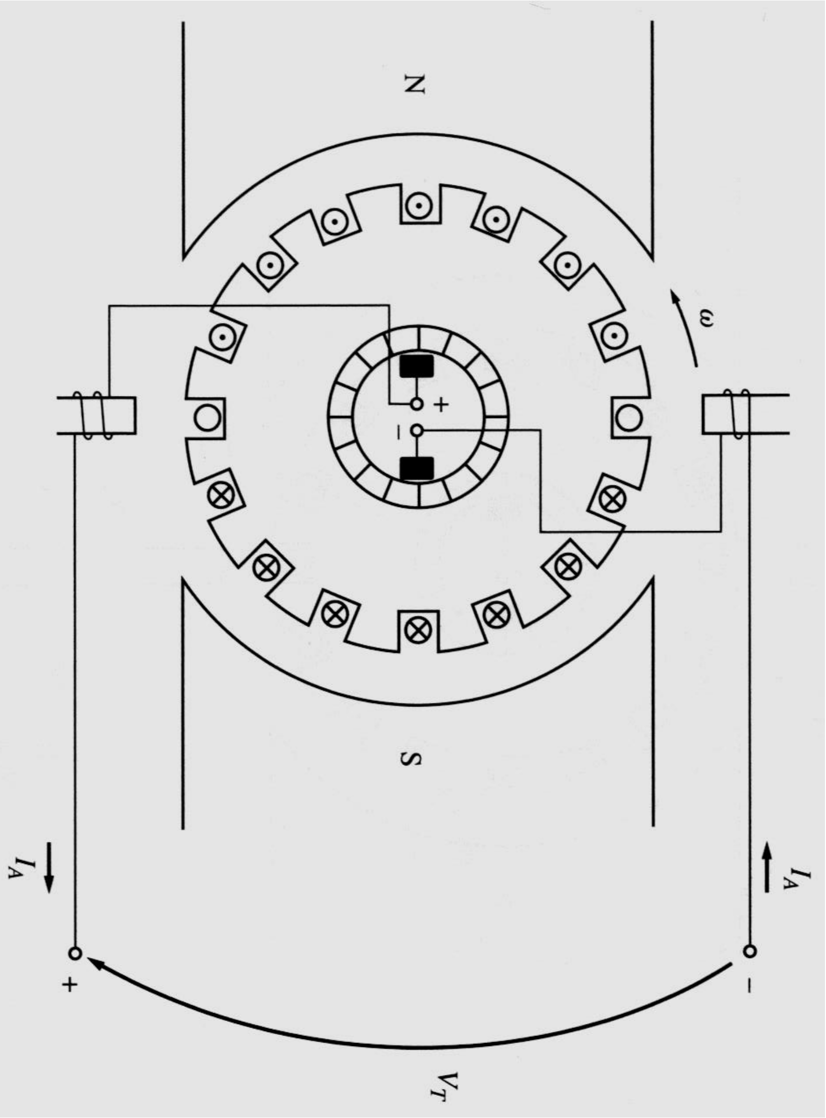
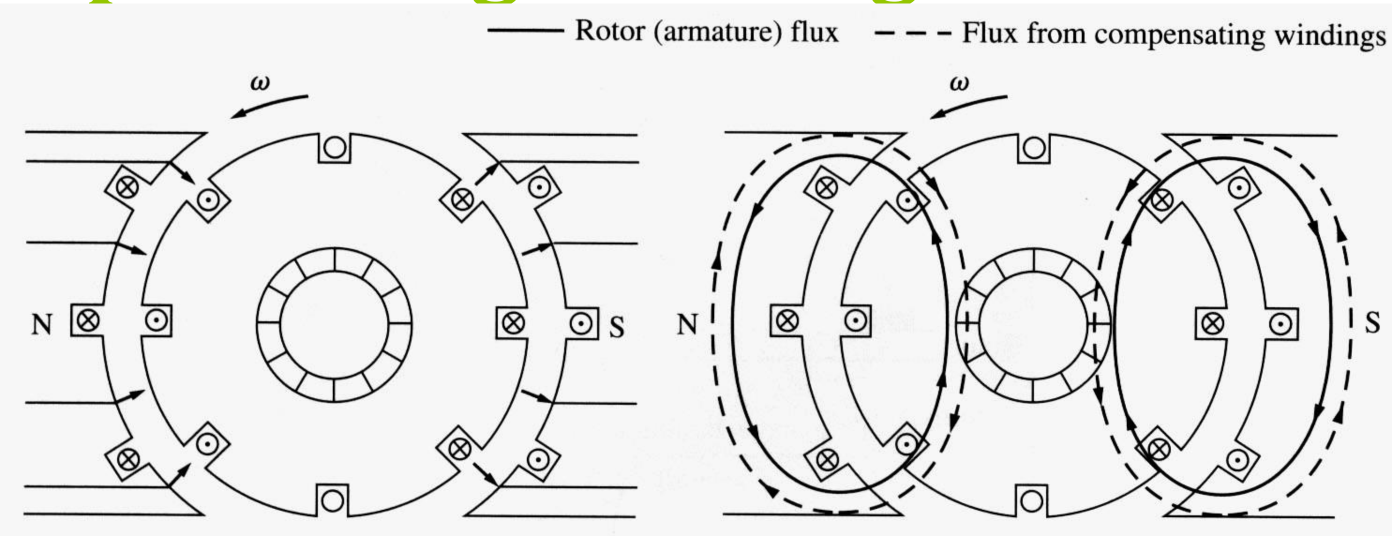


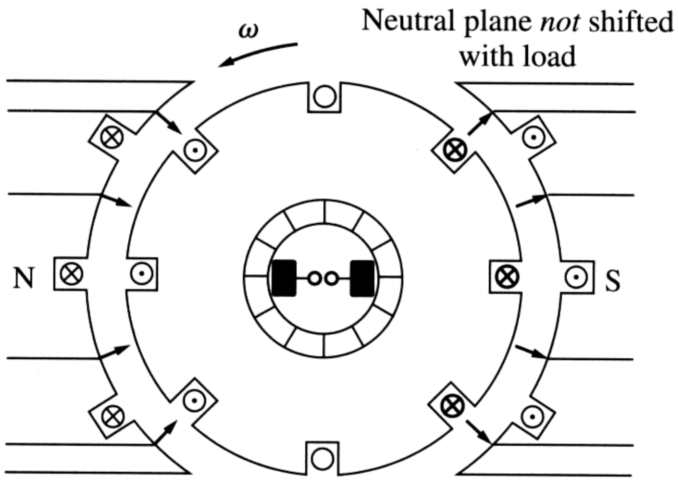
**Fig. 9.32.** Omission of alternate tips of pole laminations to reduce effect of armature reaction.

# Inter Poles



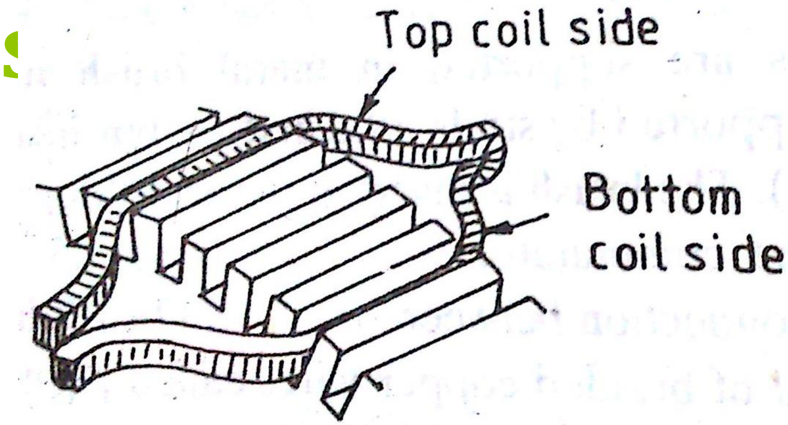
# Compensating Windings



# Armature Windings

- Single turn coil
- Multi turn coil



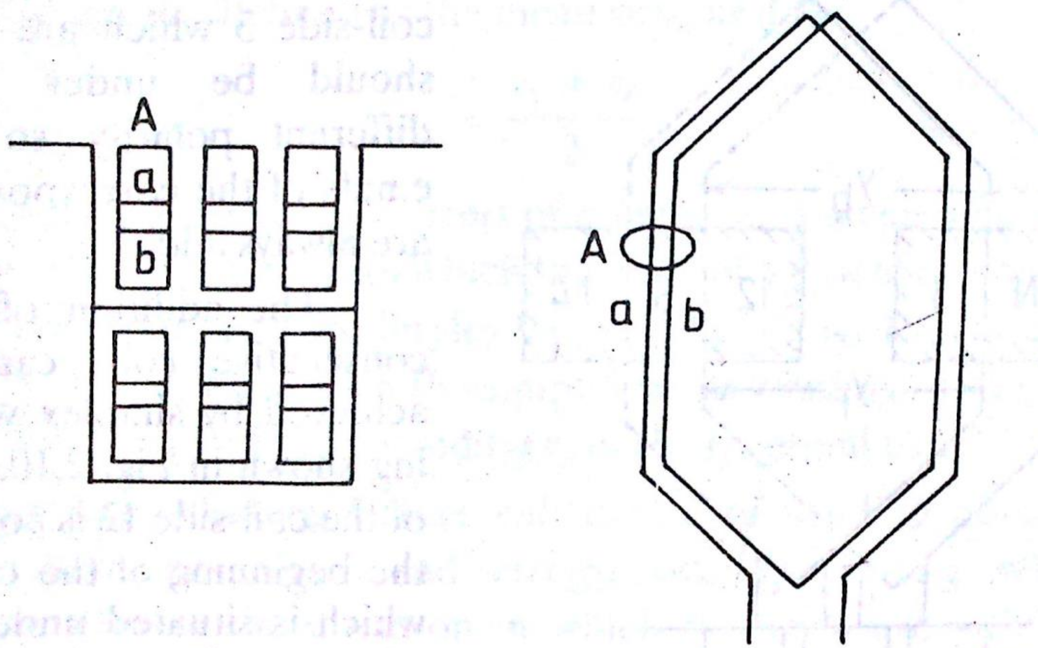




Fig. 2.7. Arrangement of conductors in a slot and a 2 turn coil.

# Armature Windings

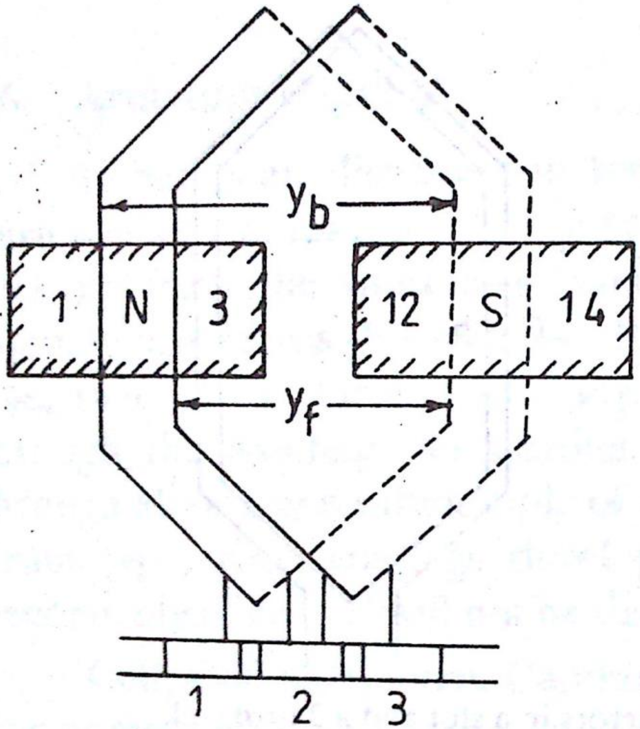



Fig. 2.9. Simplex lap winding.

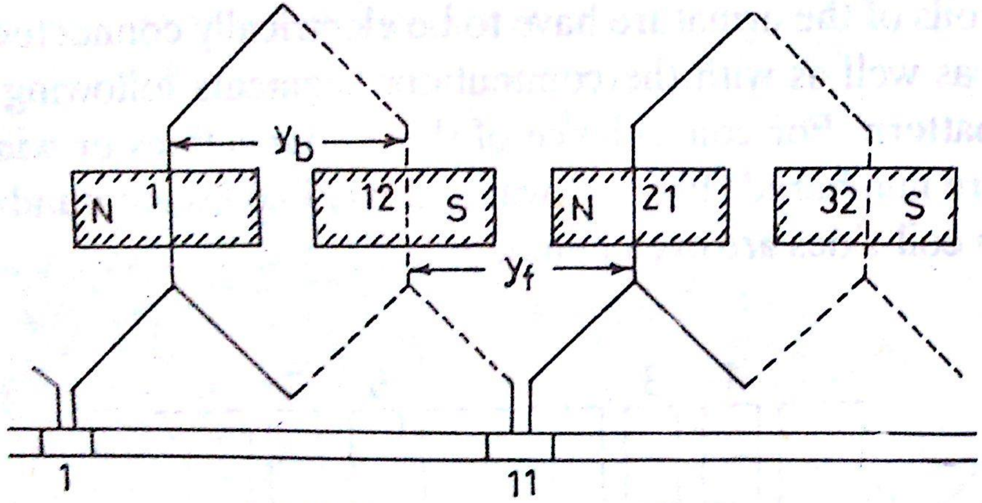



Fig. 2.10. Simplex wave winding.

# Armature Windings

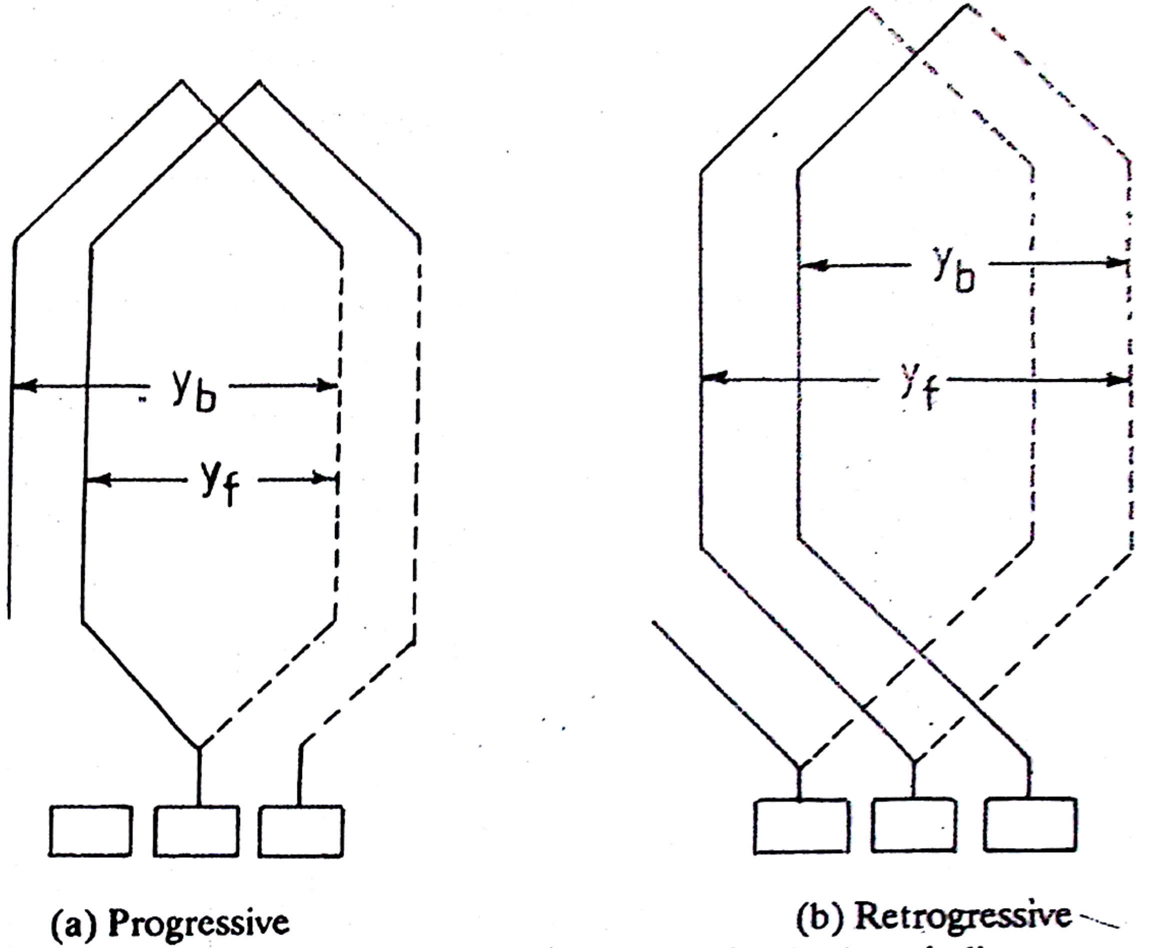



Fig. 2.11. Progressive and retrogressive simplex lap winding.

# Armature Windings

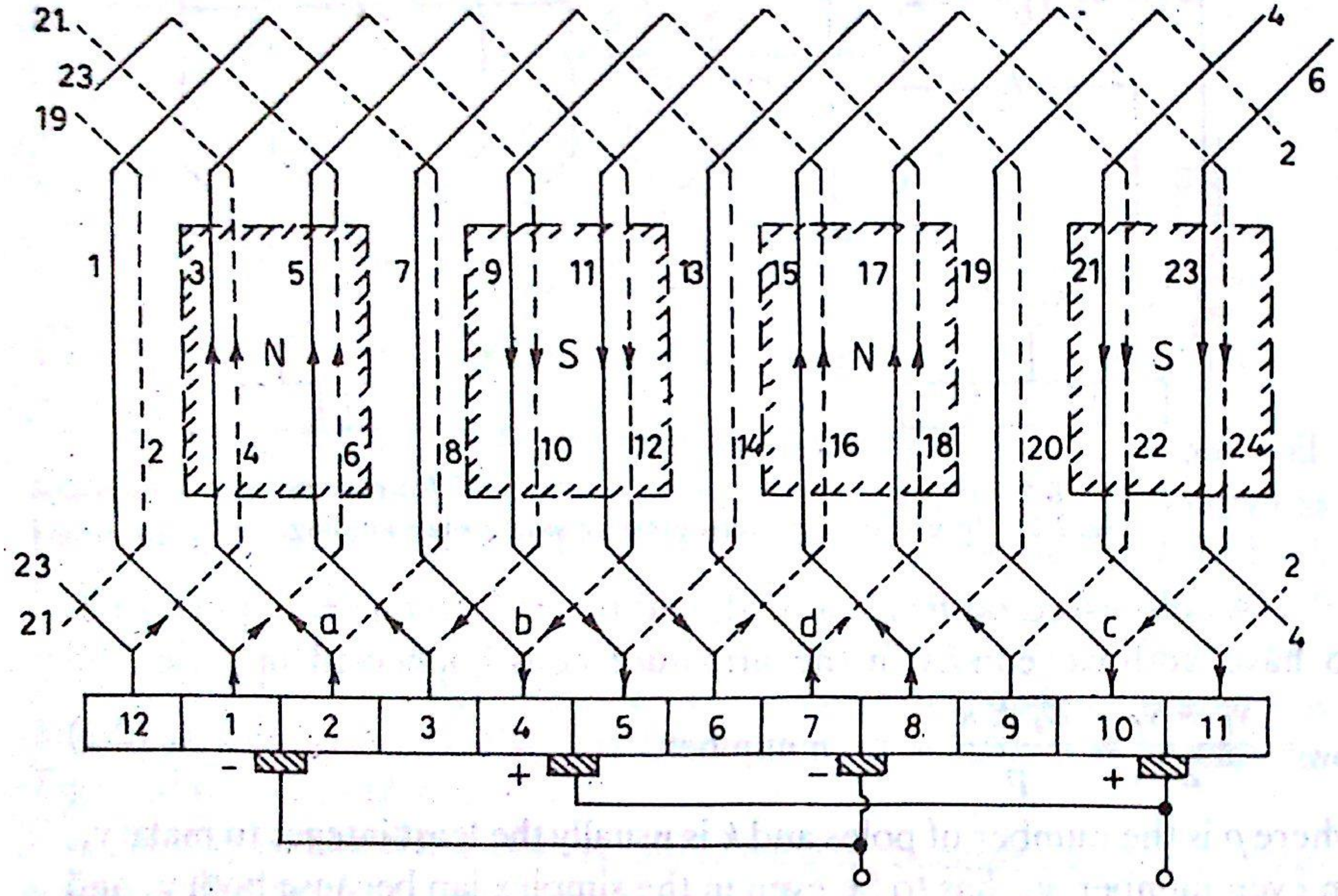



Fig. 2.12. Developed view of 4-pole, 12-coils simplex lap winding.

# Armature Windings

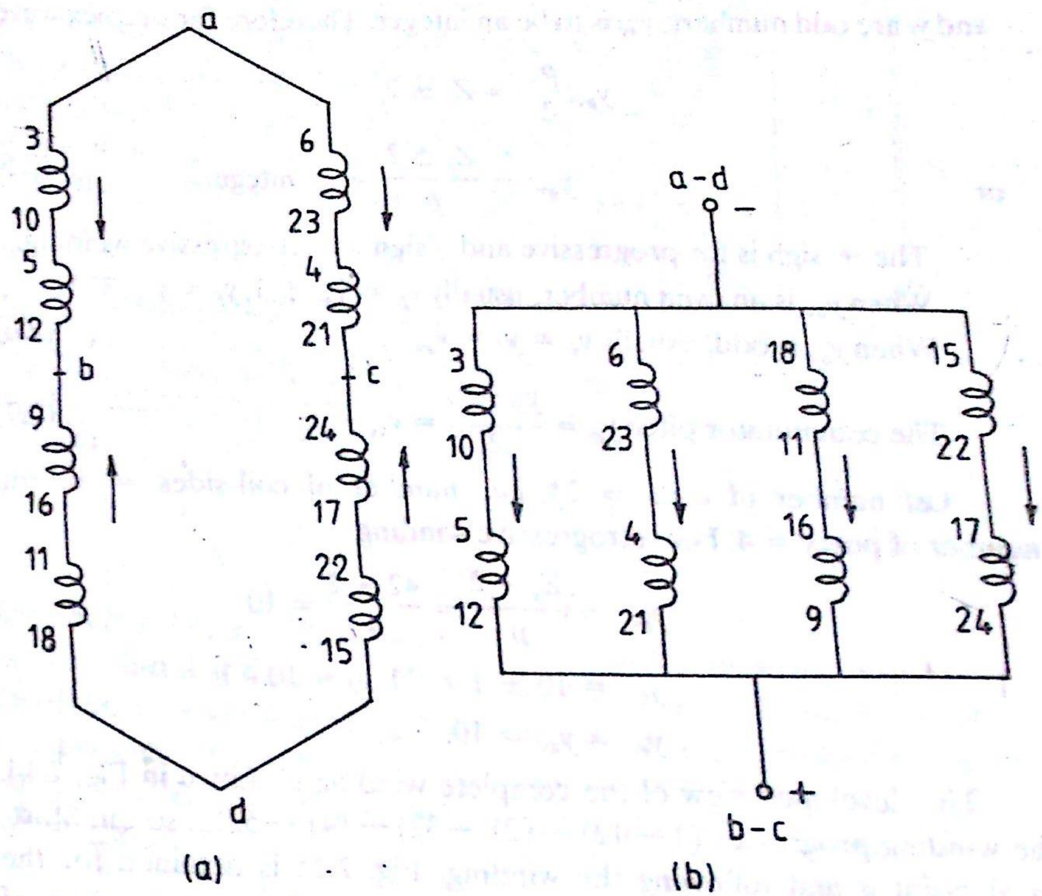
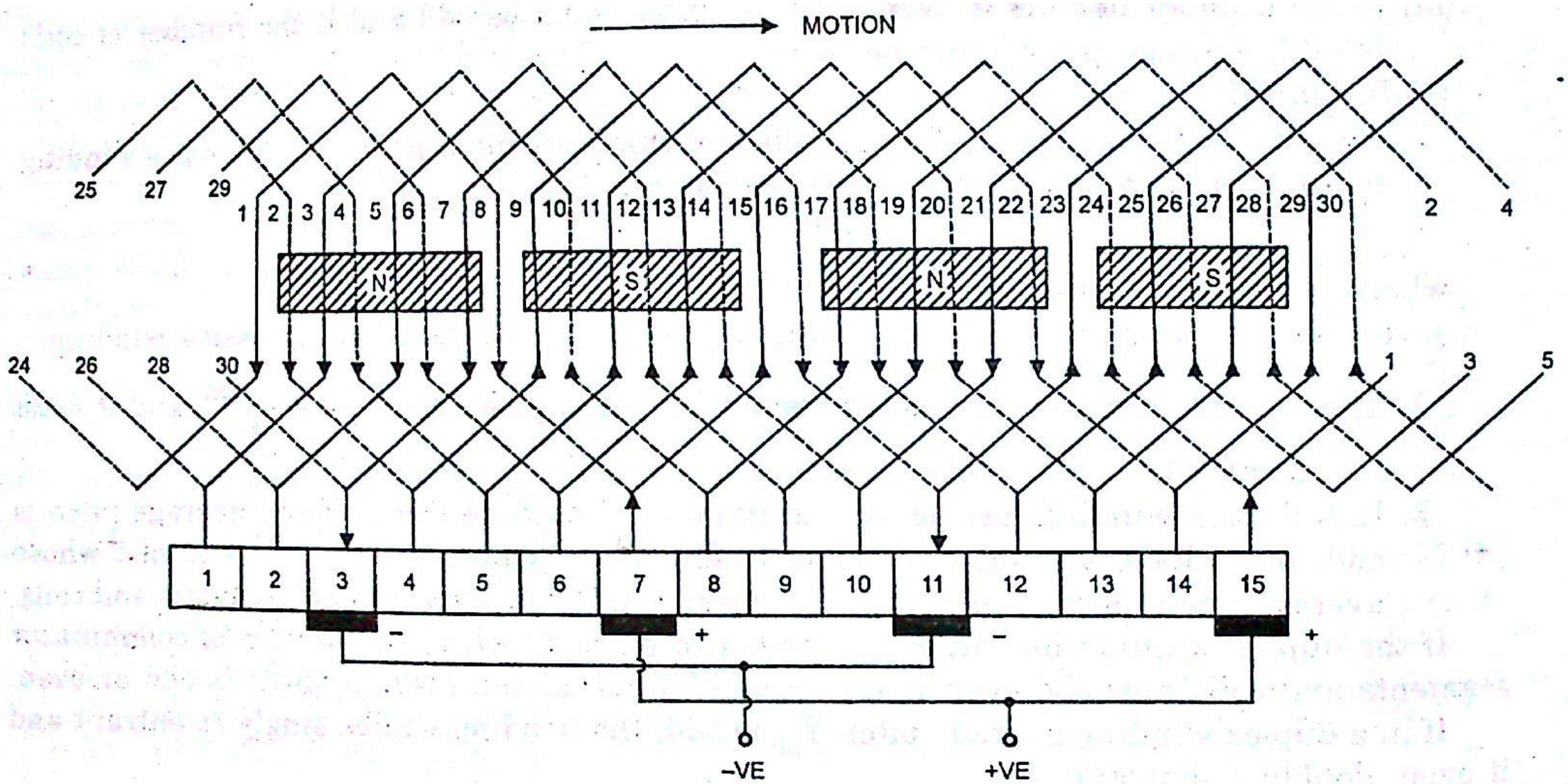



Fig. 2.13. Sequence of induced e.m.fs in conductors and four parallel circuits of the winding of Fig. 2.12.

# Armature Windings




*Developed View of 4-pole, Double Layer, Simplex Wave Winding With 30 Coil Sides*

*Fig. 4.30*

| Lap Winding | Wave Winding |
| --- | --- |
| $Y_b \approx \frac{Z}{P}$ | $Y_b \approx \frac{Z}{P}$ |
| $Y_b = Y_f \pm 2m$ | $Y_b = Y_f \pm 2$ |
| $Y_{av} = \frac{Y_b + Y_f}{2}$ | $Y_{av} = \frac{Y_b + Y_f}{2}$ |
| $Y_c = m$ | $Y_c = Y_{av}$ |

# Choice of Armature Winding

| Lap Winding | Wave Winding |
|---|---|
| A=P, Less current in each path | A=2, Each path carries half current |
| | |
| Low voltage, high current | High voltage, Low current |
| | |
| Equalizer connection required | Equalizer connection not required |
| | |
| Precise placing of brush | Independent |

# Commutation

# Commutation

- Process of converting generated alternating current to externally available direct current.
- Reversal of current in armature coil by means of brush and commutator bars is called *commutation process.*
- Time period during which coil remains short circuited is called *commutation period.*

# Good Commutation

- Current in a coil should be completely reversed
- No sparking at brushes
- No damage to commutator surface

# Poor Commutation

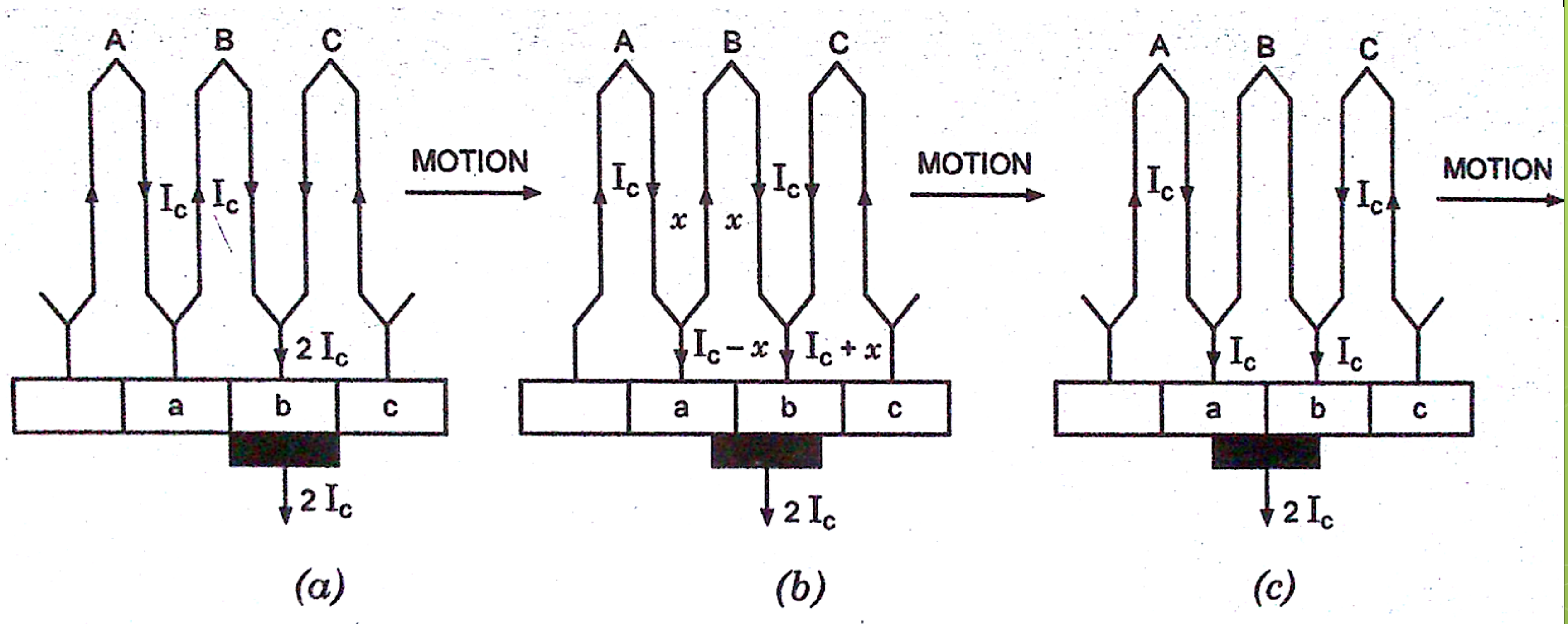
- **Mechanical Conditions**
  - **Uneven commutator surface**
  - **Non-uniform brush pressure**
  - **Vibration of brushes in holder**

- **Electrical conditions**
  - **Increase in voltage between two adjacent commutator segments**
  - **Increase in current density at trailing edge of brush**
  - **Armature reaction & Armature leakage flux**

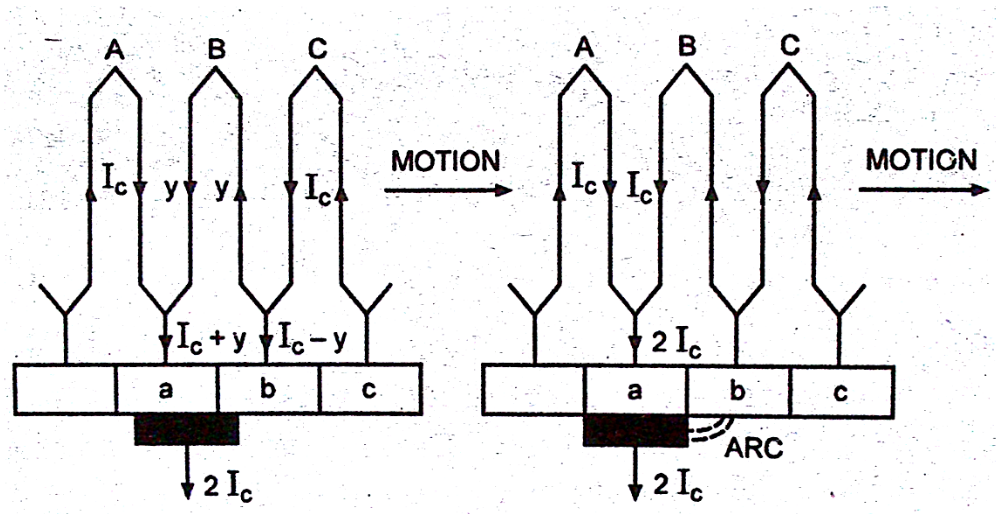
# Effects of Poor Commutation

- **Sparking**
  - **Overheating at brush-commutator contact**
  - **Damages to brush & commutator surface**
  - **Damage to brush, increase sparking progressively worse**

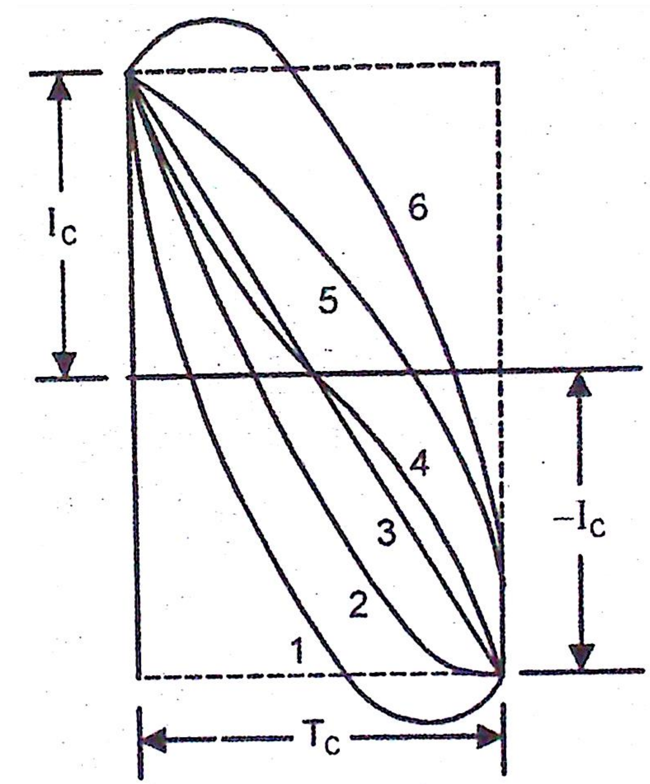
# Commutation Process



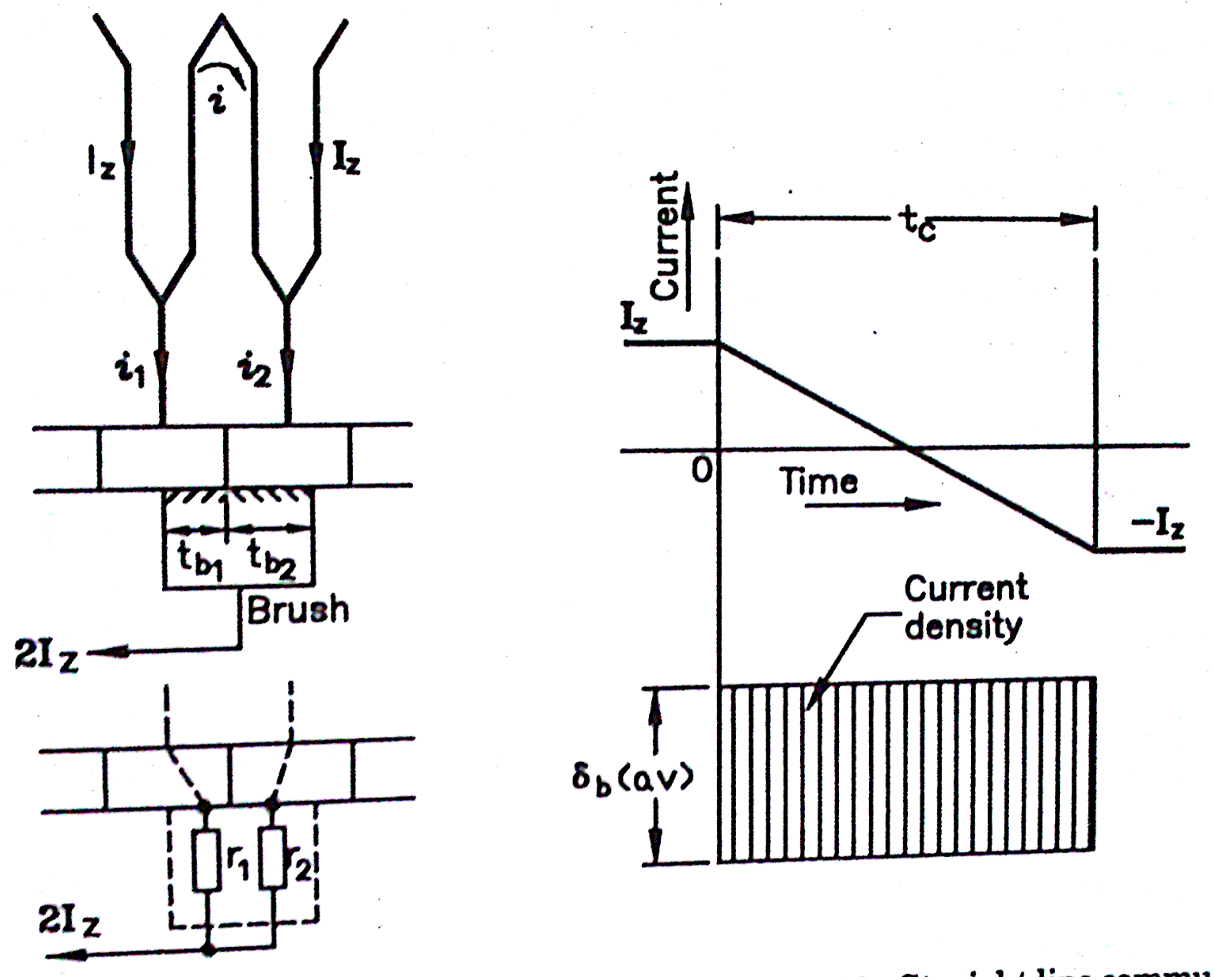
# Commutation Process



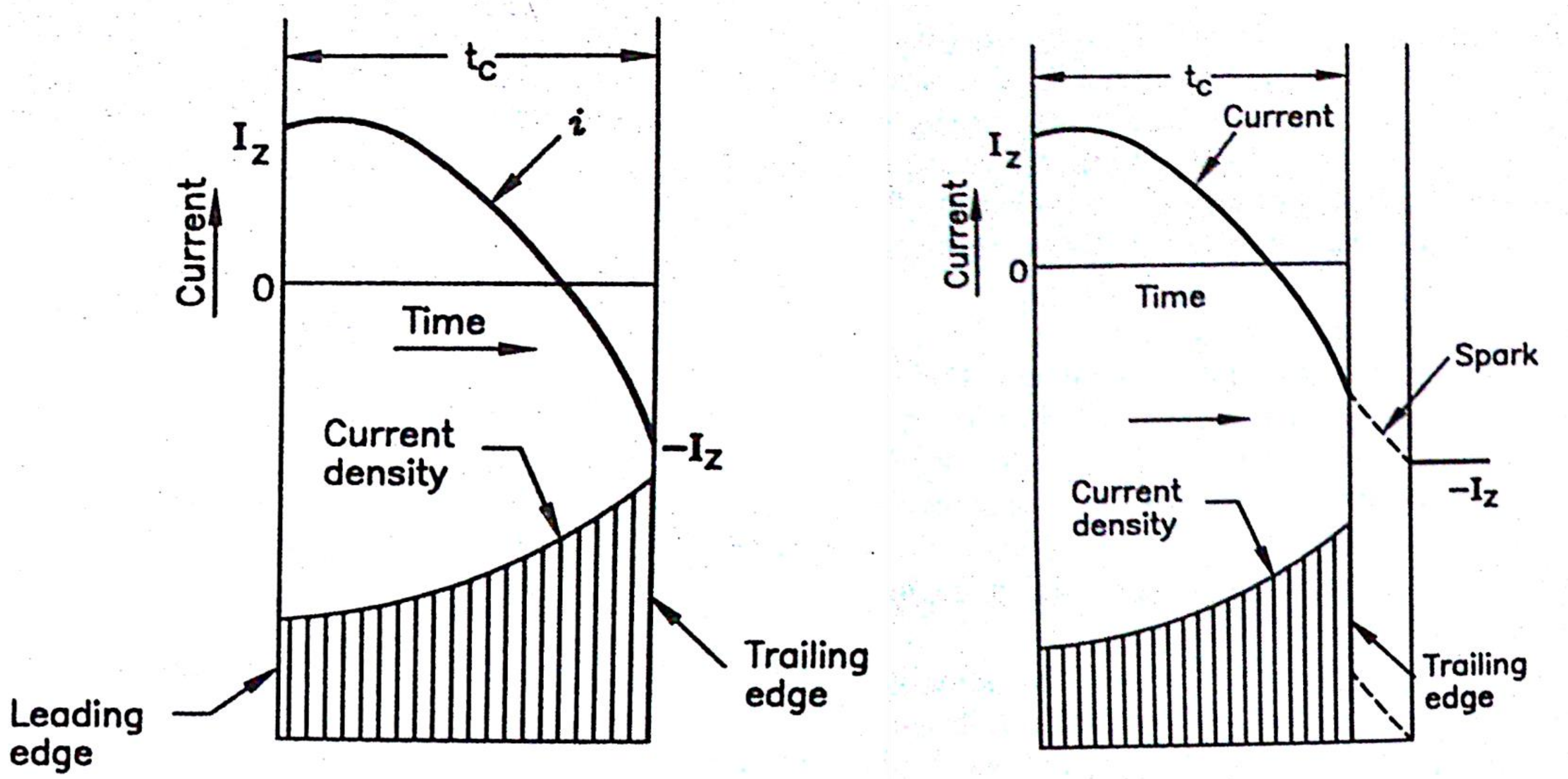

(d) (e)



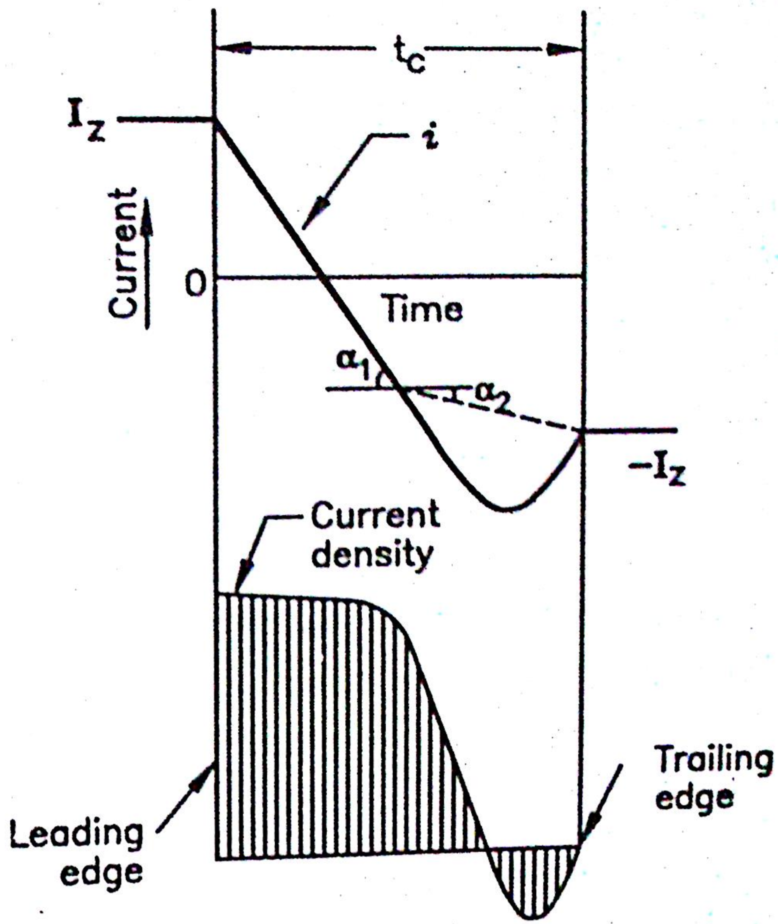
# Straight Line Commutation



# Retarded Commutation



# Accelerated Commutation



# Reactance Voltage (Pitchelmayer's Equation)

$$\text{Inductance of coil} = 2T_c^2 L\lambda$$

Reactance Voltage

$$E_{rav} = L\frac{di}{dt}$$

$$E_{rav} = 2T_c^2 L\lambda \times \frac{2I_z}{\tau_c}$$

$$\tau_c = t_c = \frac{\beta_c}{V_c} = \frac{\pi D_c}{C} \times \frac{1}{\pi D_c n} = \frac{1}{Cn}$$

# Reactance Voltage (Pitchelmayer's Equation)

$$E_{rav} = 2T_c^{\,2}L\lambda \times 2I_zCn = 2T_cL\lambda I_zZn$$

$$\because 2CT_c = Z$$

$$E_{rav} = 2T_cL\lambda\left(I_z\frac{Z}{\pi D}\right)\pi Dn$$

$$E_{rav} = 2T_cL\lambda\, ac\, V_a$$

# Flux Density under Interpole Shoe

$B_{ci}$ = Flux density under interpole shoe

$L_{ip}$ = Length of interpole

$E_{gi}$ = Voltage generated in a coil by interpole field

$T_c$ = No. of coil turns

$\lambda$ = Specific permeaance

# Flux Density under Interpole Shoe

$$B_{ci} = \text{Flux density under interpole shoe}$$

$$E_{gi} = 2 \times \mathrm{T_c} \times \text{Voltage generated in each condt.}$$

$$E_{gi} = 2\mathrm{T_c} B_{gi} L_{pi} V_a$$

$$E_{rav} = \frac{4T_c \lambda L I_z Z_s}{T_c}$$

$$\frac{4T_c \lambda L I_z Z_s}{T_c} = 2\mathrm{T_c} B_{gi} L_{pi} V_a$$

$$B_{gi} = 2 I_z Z_s \frac{L}{L_{ip}} \frac{1}{V_a T_c} \lambda$$

# Design of Interpole Winding

$l_{gi}$ = Length of airgap under interpole shoe

$K_{gi}$ = Interpole gap contraction factor

$$AT_a = \frac{I_z Z}{2p}$$

$MMF$ required to establish $B_{gi} = 800000 B_{gi} K_{gi} l_{gi}$

$MMF$ required to overcome armature reaction $= \dfrac{I_z Z}{2p}$

$$\text{Interpole MMF } AT_i = 800000 B_{gi} K_{gi} l_{gi} + \frac{I_z Z}{2p}$$

$$\text{No. of Interpole Turns} = \frac{AT_i}{I_a}$$

# Thank You