Problems with commutation in real DC machines

1. Armature reaction

If the magnetic field windings of a DC machine are connected to the power source and the rotor is turned by an external means, a voltage will be induced in the conductors of the rotor. This voltage is rectified and can be supplied to external loads. However, if a load is connected, a current will flow through the armature winding. This current produces its own magnetic field that distorts the original magnetic field from the machine's poles. This distortion of the machine's flux as the load increases is called armature reaction and can cause two problems:

1) neutral-plane shift: The magnetic neutral plane is the plane within the machine where the velocity of the rotor wires is exactly parallel to the magnetic flux lines, so that the induced voltage in the conductors in the plane is exactly zero.

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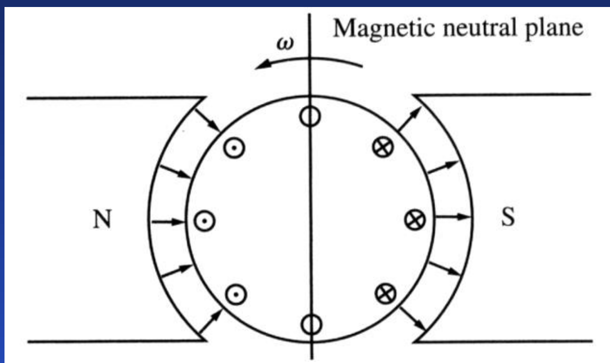
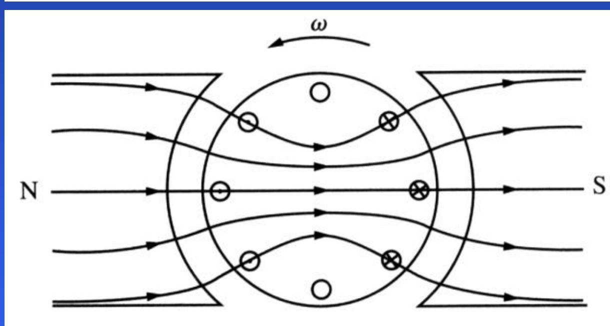
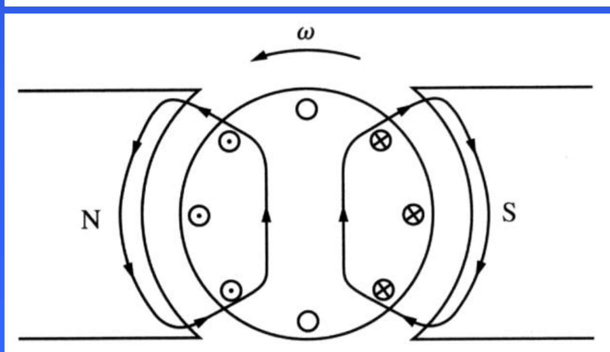
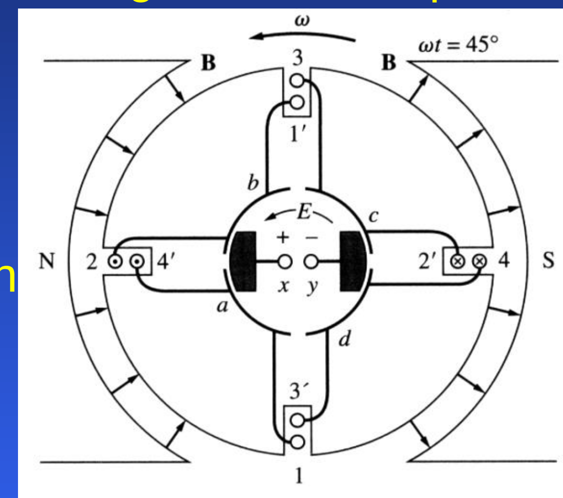






A two-pole DC machine: initially, the pole flux is uniformly distributed and the magnetic neutral plane is vertical.



The effect of the air gap on

When the load is connected, a current – flowing through the rotor – will generate a magnetic field from the rotor windings.

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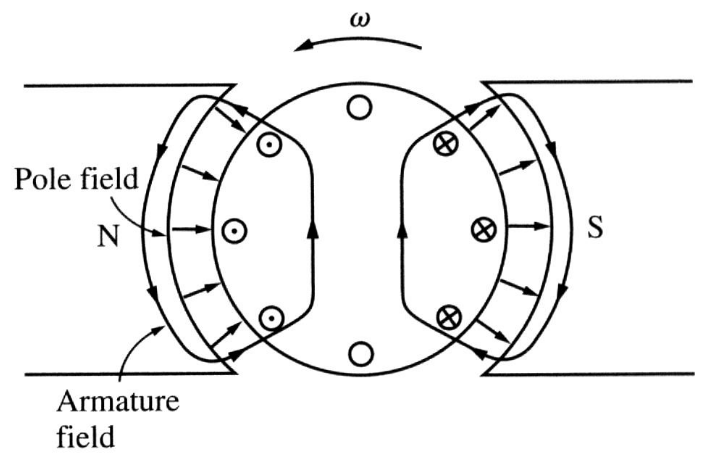
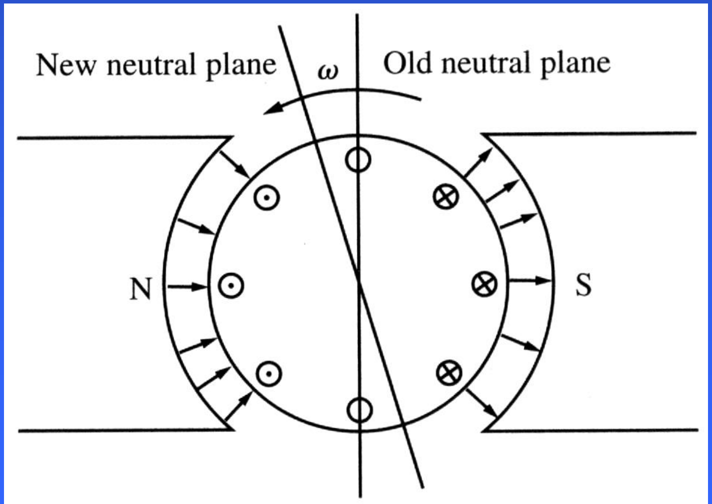


This rotor magnetic field will affect the original magnetic field from the poles. In some places under the poles, both fields will sum together, in other places, they will subtract from each other



Therefore, the net magnetic field will not be uniform and the neutral plane will be shifted.

In general, the neutral plane shifts in the direction of motion for a generator and opposite to the direction of motion for a motor. The amount of the shift depends on the load of the machine.

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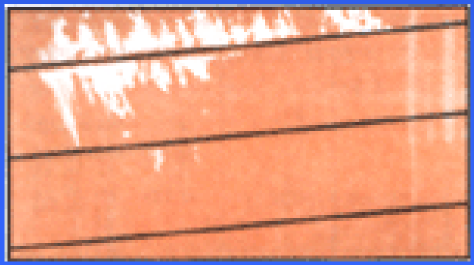
The commutator must short out the commutator segments right at the moment when the voltage across them is zero. The neutral-plane shift may cause the brushes short out commutator segments with a non-zero voltage across them. This leads to arcing and sparkling at the brushes!



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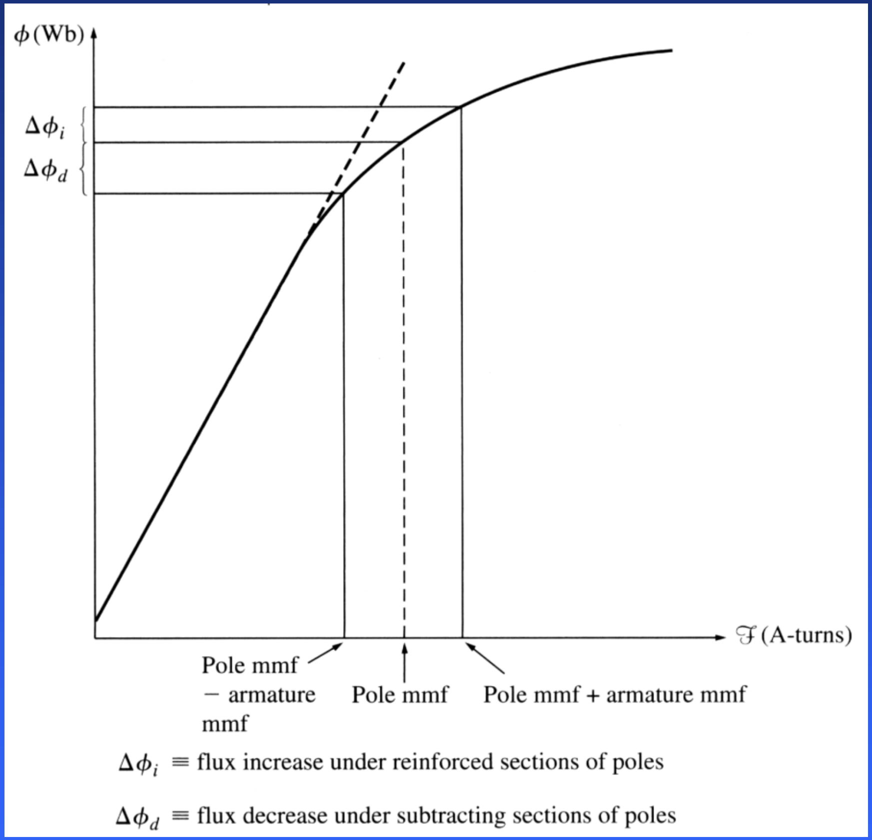
2) Flux weakening.

Most machines operate at flux densities near the saturation point.

At the locations on the pole surfaces where the rotor mmf adds to the pole mmf, only a small increase in flux occurs (due to saturation).

However, at the locations on the pole surfaces where the rotor mmf subtracts from the pole mmf, there is a large decrease in flux.

Therefore, the total average flux under the entire pole face decreases.



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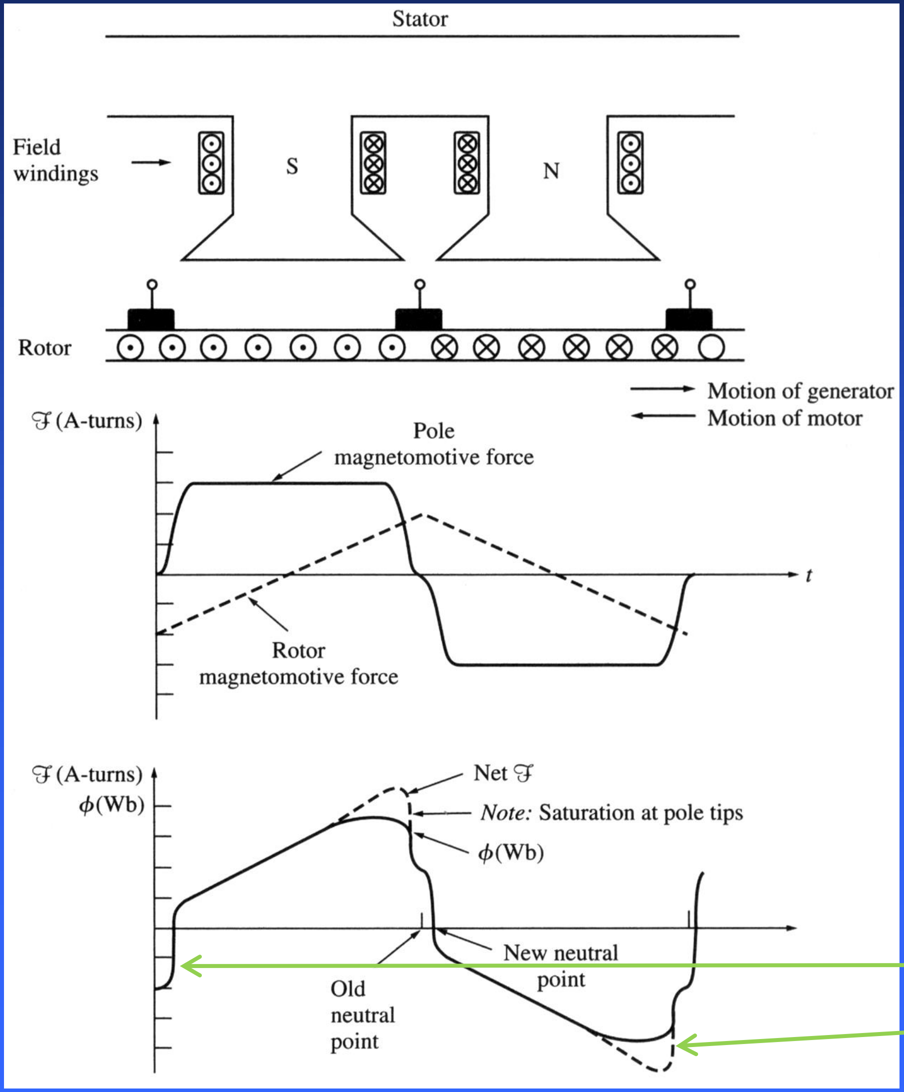

In generators, flux weakening reduces the voltage supplied by a generator.

In motors, flux weakening leads to increase of the motor speed. Increase of speed may increase the load, which, in turns, results in more flux weakening. Some shunt DC motors may reach runaway conditions this way…

Observe a considerable decrease in the region where two mmfs are subtracted and a saturation…

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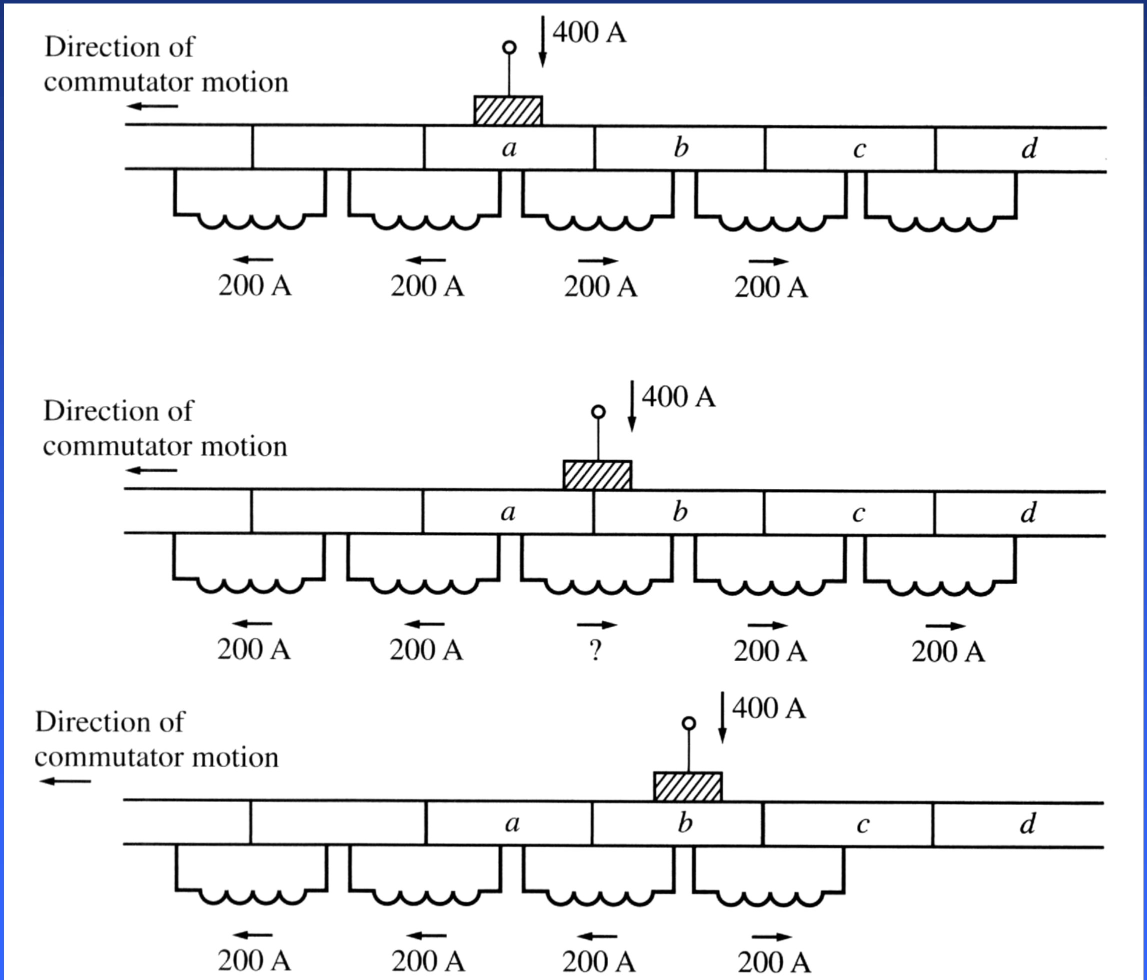
2. *L di/dt* voltages

This problem occurs in commutator segments being shorten by brushes and is called sometimes an inductive kick.

Assuming that the current in the brush is 400 A, the current in each path is 200 A. When a commutator segment is shorted out, the current flow through that segment must reverse.

Assuming that the machine is running at 800 rpm and has 50 commutator segments, each segment moves under the brush and clears it again in 0.0015 s.



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The rate of change in current in the shorted loop averages

$$\frac{di}{dt} = \frac{400}{0.0015} \approx 266\,667\ A/s$$

Therefore, even with a small inductance in the loop, a very large inductive voltage kick *L di/dt* will be induced in the shorted commutator segment.

This voltage causes sparkling at the brushes.