EE8005 - Special electrical Machines

Unit-5 other Special electrical Machines

Year/sem/dept: III/VI/EEE A SUBHASHINI, AP/EEE

① Explain the construction and working operation of hysteresis motor?

Construction:

i) stator ii) Rotor iii) Main windings iv) Auxiliary windings
v) shaft

Stator → It consists of main winding and an auxiliary winding. These 2 winding generate RMF due to 1φ supply. This type of construction is called as split phase construction. If the operation of the hysteresis motor depends upon the effect of shaded pole it is called as shaded pole hysteresis motor.

Rotor → It is made up of chrome steel or Alnico type hard material. It does not carry any winding. Its hysteresis loop area be high in order to high hysteresis loss. It consists of 2 or more rings at outer side and cross bars. The rotor is made by heat treatment of hard steel material. The rotor is made of smooth cylindrical. The hysteresis ring is made of chrome, cobalt or Alnico material. The resistivity of rotor material is kept high in order to reduce eddy current in the rotor. The o/p of the motor reduces as the thickness of the ring increases.

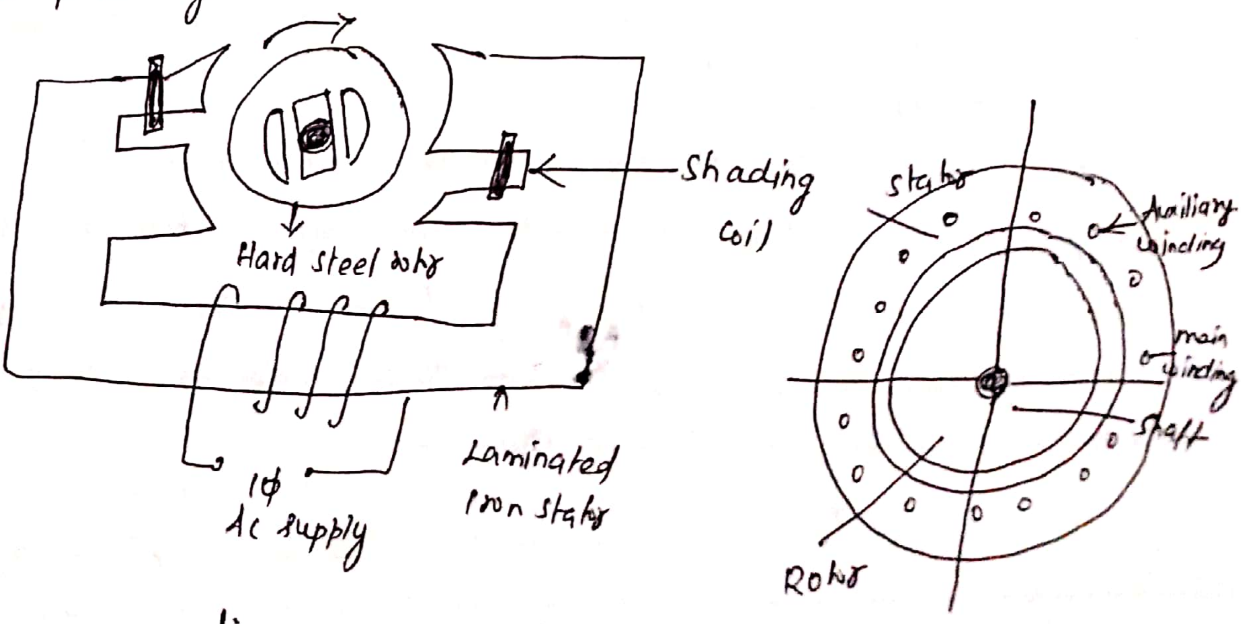


fig: Construction of hysteresis motor

Working principle of operation:

Starting behaviour is like 1φ IM and running behaviour is like Synchronous motor.

At the starting condition

When the stator is energized with 1φ AC supply, RMF is produced in stator. By induction principle secondary voltage is induced in the rotor by stator RMF. Hence eddy current is generated to flow in the rotor and it develops torque. Thus eddy torque is developed along with the hysteresis torque in the rotor. Hysteresis torque in the rotor develops at the rotor magnetic material is with high hysteresis loss property and high retentivity.

At steady state running condition

When the speed of the rotor reaches near about the syn-speed the stator pulls the rotor into synchronism. At this condition, the relative motion between stator field and rotor field vanishes. So there is no further induction principle to continue. Hence no eddy current to generate in the rotor. Thus the torque due to eddy current vanishes.

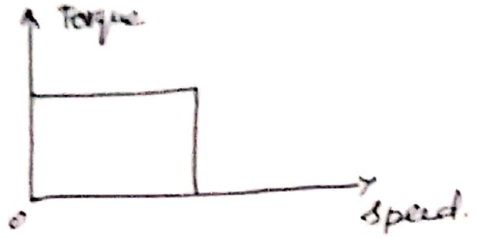
At the time of rotor's rotation at the syn. speed, RMF flux in the stator produces poles on the rotor by induction. They are names as North (N) and south (S) poles. Thus rotor behaves as a PM. The high retentivity enables the continuous magnetic locking between stator and rotor and thus the motor rotates at syn. speed.

Rotor pole axis lags the RMF axis of the stator at an angle δ_h. Hence the rotor pole axis tries to catch up the stator magnetic field axis. If the load torque is increased this lagging angle will be increased upto δ_{max} before dropping below the synchronous condition. The rotor poles are attracted towards the moving stator poles and runs at syn. speed.

$$T_h = \frac{P_h}{\omega_s} = k = \text{Constant} \quad \text{where} \quad k = \frac{K_h f_1 B^{1.6}}{\omega_s} = \text{Constant.}$$

② Explain the torque-speed characteristics of hysteresis motor? Also write the advantages, disadvantages and applications.

Torque - speed characteristics



W.K.T constant hysteresis torque occurs in the hysteresis motor. This constant torque allows the motor to synchronize any load it can accelerate. The torque is almost constant from starting to running condition. At starting condition the starting torque is the eddy current torque along with the hysteresis torque. But in the running condition net running torque means only the hysteresis torque.

Advantages:

① As no teeth and no winding in rotor, no mechanical vibrations takes place during its operation.

② Suitability to accelerate high inertia loads.

③ possibility of multispeed operation by employing gear to train.

④ Due to absence of vibrations, the operation is quiet and noiseless

⑤ Available in very small size

Disadvantages:

① Low efficiency ② Low torque ③ Low p.f ④ poor output

Applications:

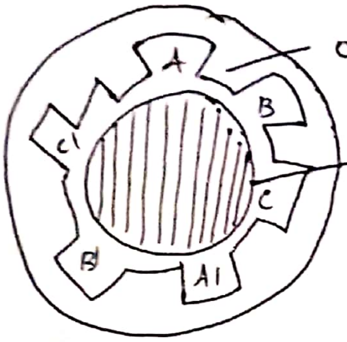
① sound recording instruments ② Electric clocks ③ Teleprinters ④ Timing devices ⑤ Tape Recorders ⑥ Sound producing equipments ⑦ high quality record players.

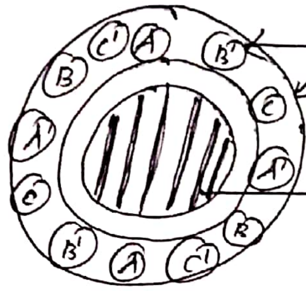
③ With a neat diagram, Explain the constructional features and the theory of operation of synchronous Reluctance motor?

The synchronous reluctance motor consists of 2 main parts

a) stator and b) Rotor.

<u>Stator</u> → It has smooth distributed poles. It has a laminated iron core with open or semiclosed uniformly distributed slots.





The openslot structure used to house multiphase concentrated coils/ph. This open slot structure allows for automated insertion of coils in the slots and used either for low power or two/three phase motors for higher torque. In this open slot structure, because of the presence of the airgap field and considerable harmonics, torque pulsations occur. In order to improve the performance semiclosed slots are used.

The stator has multiple slots which are placed at an even pitch angle. Each slot is consisting of a stator winding for creating stator magnetic poles.

<u>Rotor</u> → It is made up of salient poles to create a variable reluctance in the motor's magnetic circuit which depends on the angular position of the rotor. These salient poles can be created by milling axial slots along the length of a squirrel cage rotor. It consists of pairs of slots. The slots may be at outer or inner. The outer side slots are formed at an outer periphery and the inner slots are formed at inside of the rotor. The distance between the outer periphery of the rotor and the outer side slot is determined to be the width of the magnetic pole portion of the stator multiplied by 0.7 to 1.3.

The explosion bonding technique is used to construct the rotor. Some other techniques are brazing, roll bonding, diffusion bonding etc.

<u>Working operation:</u>

when the supply is given to the stator winding, the revolving magnetic field exerts reluctance torque on the unsymmetrical rotor tending to align the salient poles of the rotor with the axis of the revolving magnetic field. It is the position where the reluctance of the magnetic path would be minimum. So the reluctance torque is developed by the tendancy of ferromagnetic rotor to align itself with the magnetic field. The reluctance torque is

$$T_e = 3\left(P/2\right) \psi_s^2 \frac{L_{ds} - L_{qs}}{2 L_{ds} L_{qs}} \sin 2\delta$$

where $p \rightarrow$ no. of poles

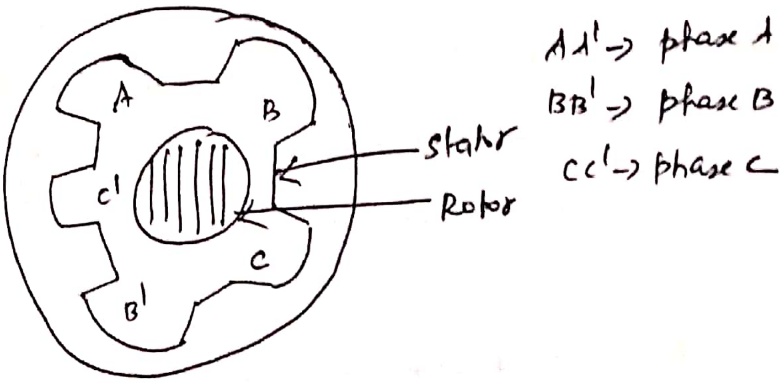
$\psi_s \rightarrow$ stator flux linkage

$\delta \rightarrow$ Torque angle

$L_{ds} \rightarrow$ direct axis stator inductance

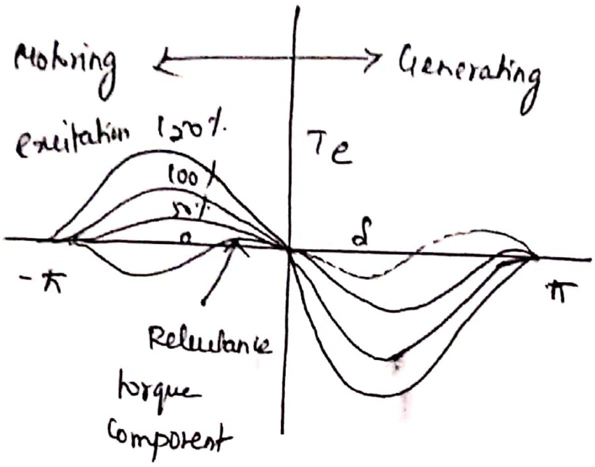
$L_{qs} \rightarrow$ quadrature axis stator inductance.

The motor starts as an IM and after it has reached its maximum speed as an IM the reluctance torque pulls its rotor into step with the revolving field so that the motor now runs as syn. motor by virtue of its saliency.



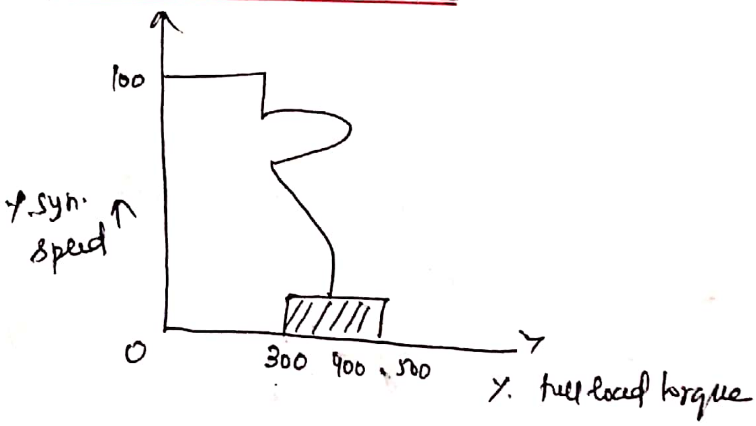
(4) Draw and discuss the performance characteristics of synrel motor. Also mention its advantages, disadvantages and applications.

Torque angle characteristics:



For a fixed excitation and torque angle the developed torque remains constant. The inductance of the stator windings in the dq reference frame varies sinusoidally from a maximum value L_d to a minimum value L_q, as a function of angular displacement of the rotor.

Torque-speed characteristics:



The motor starts as an IM from 300 to 400% of its full load. when the motor reaches its maximum speed the reluctance torque pulls its rotor into step with the revolving field so that the motor now runs at syn. speed by virtue of its saliency. when the torque exceeds maximum value, the motor goes out of synchronism.

The motor operates at constant speed up to 200% of its full load torque.

Advantages:

① Torque ripple is low

② operated from standard PWM ac inverters

③ has the capability to survive very high temperature

④ high speed capability

⑤ simple and rugged construction

Disadvantages:

① Cost is higher than IM

② when compared with IM, It is slightly heavier and has low pf, but By increasing the saliency ratio $\frac{L_{ds}}{L_{qs}}$ the p.f can be improved.

Applications:

① used in regulators and turntables

② Used in metering pumps

③ used in synthetic fibre manufacturing equipment

④ widely used for many constant speed applications such as recording instruments, timing devices, control apparatus and phonograph.

⑤ used in processing of continuous sheet or film material

⑥ used as proportioning devices in pumps or conveyors.

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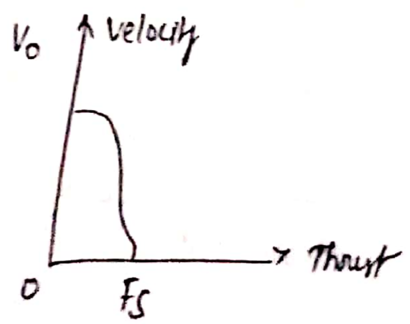
⑥ Draw and explain the characteristics of linear Induction motor. Also give some advantages, disadvantages and applications.

Characteristics:



The speed-torque characteristic of a conventional IM is equivalent to the velocity-thrust characteristic of a linear IM.

The velocity of a linear IM decreases rapidly with the increasing thrust. For this reason, these motors operate with low slip, leading to a relatively low efficiency.

Advantages:

① Simple construction ② Low initial cost ③ No over heating of rotor ④ Better power to weight ratio ⑤ Maintenance cost is low due to the absence of rotating parts ⑥ No limitation of maximum speed due to centrifugal forces.

Disadvantages:

① Capital cost is very high
② Frequent maintenance is required
③ Utilization of motor is poor
④ More magnetising current results low efficiency and low p.f

Applications:

① Trolley cars ② Conveyors ③ Metallic belt conveyors ④ High speed rail reaction ⑤ Electromagnetic pumps.

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⑥ Explain the characteristics of Repulsion motor. Also mention its applications.

Characteristics:

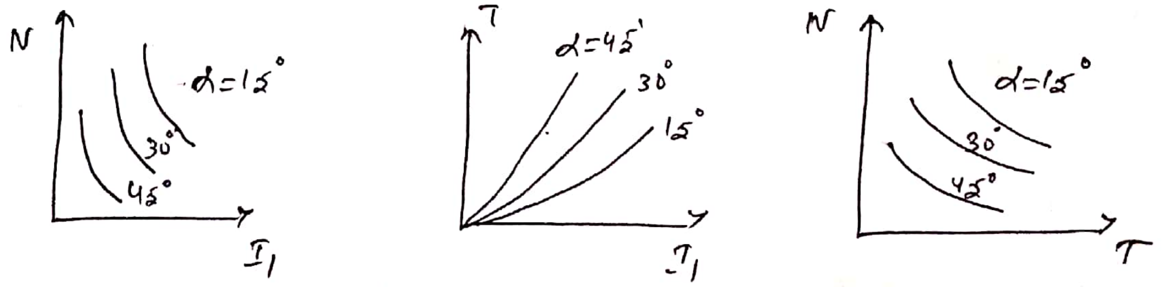
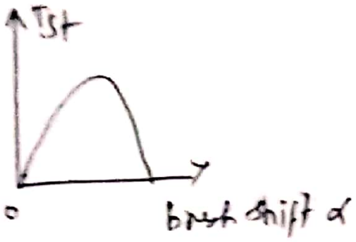


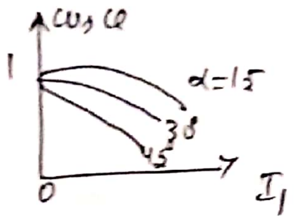
fig: Speed-current, Torque-current and speed-Torque for different angle of brush shift

W.K.T $I_1 = \dfrac{V}{\sqrt{R_s^2+(X_s+X_m\sin^2\alpha)^2}}$

$$T_{stg} = \frac{P_d}{S} = \frac{1}{2} I_1^2 X_m \sin 2\alpha = \frac{1}{2}\,\frac{V^2 X_m \sin 2\alpha}{R_s^2+(X_s+X_m\sin^2\alpha)^2}$$

The maximum torque is obtained at the value α is lying between 20° to 40°





From phasor diagram, $\sin\phi = \dfrac{X_s + X_m\sin^2\alpha}{V} I_1$

$$\text{p.f } \cos\phi = \sqrt{\frac{(X_s+X_m\sin^2\alpha)^2 I_1^2}{V^2}}$$

Applications:

① Machine Tools ② pumps ③ Hoists ④ Compressors ⑤ commercial refrigerators
⑥ Floor polishing and grinding devices etc.

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⑦ Discuss the construction and operating principle of Repulsion motor.

Construction:

It is a type of 1φ ac commutator motor. The stator houses a single phase winding distributed in slots and the armature winding short circuited through brushes. Generally the brushes are movable on either side of the axis of the stator winding, by which the speed can be controlled in either direction.

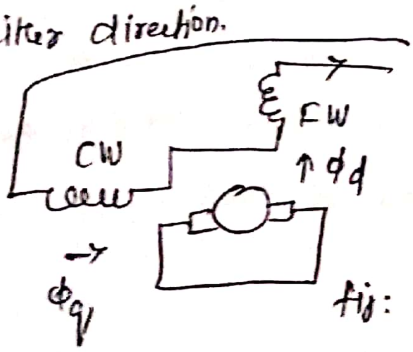


fig: Double winding repulsion motor

The stator consists of two stator windings. One is field winding FW and other compensated winding CW. There two winding axis are 90° apart and connected in series across the line. They are completely detached from the armature winding which is short circuited by the brushes. Since the commutator is not connected electrically with the stator windings. The brushes are usually adjustable.

Working operation:

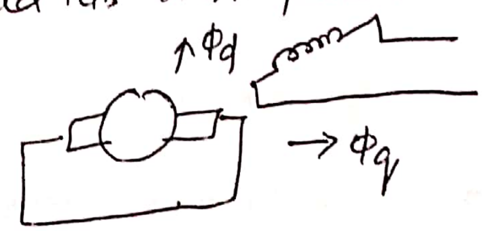
The axis of the armature winding coincides with the axis of the brushes and with the stator winding excited from a 1ϕ supply.

Case-I:

Brush axis at right angle to the axis of the stator winding.

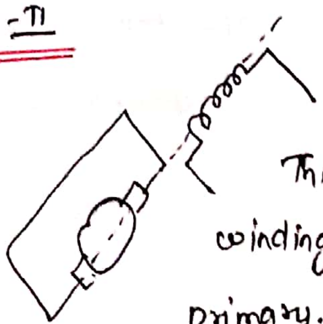
At standstill, with the axis of the armature winding at right angles to the axis of the field winding. There is no interaction between the fixed flux and armature winding.

Here the armature winding acts as an open circuited secondary winding of a transformer, the field winding being the primary. Thus no torque is developed. The effective impedance across the motor terminals is large and this brush position is called as high impedance position.



Case-II

Axis of armature and field windings are coincident.

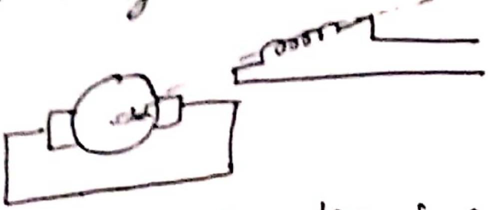


The armature winding behaves as the short circuited secondary winding of a transformer with the stator field winding as the primary. The space angle between the field flux and the armature mmf is 180° electrical and hence the electromagnetic torque is zero.

Heavy demagnetisation of the field flux results in a smaller effective reactance across the motor terminals, and this brush position is called as lower impedance position.

Case - III

The brushes given a shift in the counter clockwise direction through an angle α electric radians from the low impedance position.



At any instant when there is a south pole on the stator, the demagnetizing armature flux will have a south pole on the armature surface resulting in repulsion.

The armature will rotate in the counter clockwise directions and the electromagnetic torque developed will also be in the same direction. The electromagnetic torque and rotation are in the clockwise direction when the brush shift is in the clockwise direction from the low impedance position.

$T = X_m I_1^2 \sin\alpha \cos\alpha$ α varies b/w 30° to 40°