5.1 CONSTRUCTIONAL FEATURES OF SYNCHRONOUS RELUCTANCE MOTOR

CONSTRUCTION OF SYNCHRONOUS RELUCTANCE MOTOR

The structure of reluctance motor is same as that of salient pole synchronous machine as shown in fig. The rotor does not have any field winding .The stator has three phase symmetrical winding, which creates sinusoidal rotating magnetic field in the air gap, and the reluctance torque is developed because the induced magnetic field in the rotor has a tendency to cause the rotor to align with the stator field at a minimum reluctance position

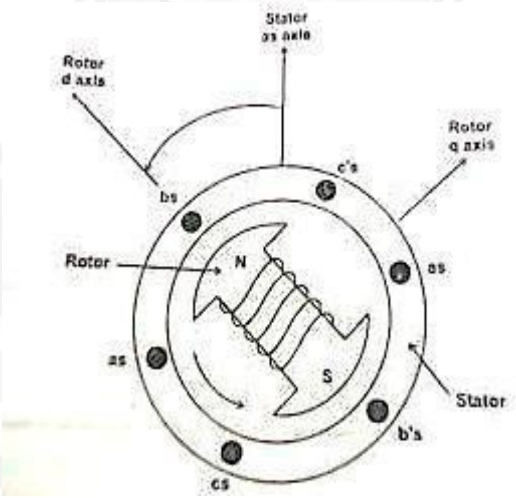

Figure 5.1.1 Idealized Three Phase Four Pole Synchronous Machine (Salient Pole)

[Source: "special electric machines" by Srinivasan page:1.3]

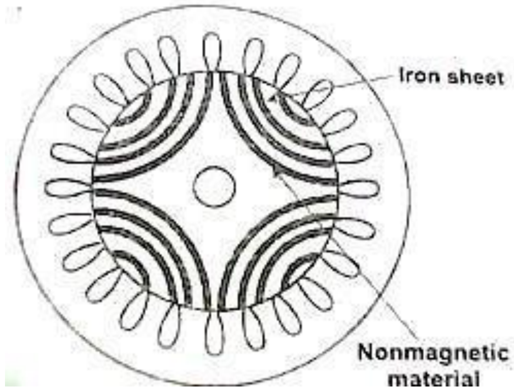

Figure 5.1.2 cross section of synchronous reluctance motor
[Source: "special electric machines" by Srinivasan page:1.3]

The rotor of the modern reluctance machine is designed with iron laminations in the axial direction separated by non-magnetic material. The performance of the reluctance motor may approach that of induction machine. With high saliency ratio a power factor oh 0.8 can be reached. The efficiency of a reluctance machine may be higher than an induction motor because there is no rotor copper loss. Because of inherent simplicity, robustness of construction and low cost.

The synchronous reluctance motor has no synchronous starting torque and runs up from stand still by induction action. There is an auxiliary starting winding. This has increased the pull out torque, the power factor and the efficiency. Synchronous reluctance motor is designed for high power applications. It can broadly be classified into Axially laminated and Radially laminated.

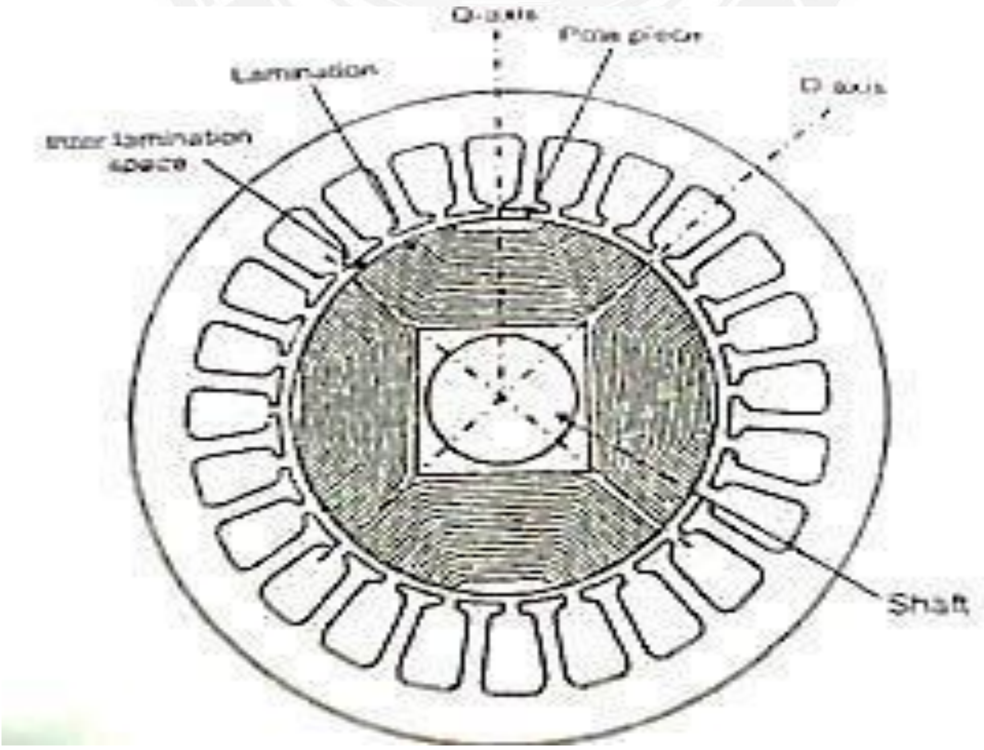

Figure 5.1.3 cross section of axially laminated
[Source: "special electric machines" by Srinivasan page:1.3]

Reluctance motors can deliver very high power density at low cost, making them ideal for many applications. Disadvantages are high torque ripple (the difference between maximum and minimum torque during one revolution) when operated at low speed, and noise caused by torque ripple. Until the early twenty-first century their use was limited by the complexity of designing and controlling them.

These challenges are being overcome by advances in the theory, by the use of sophisticated computer design tools, and by the use of low-cost embedded systems for control, typically based on microcontrollers using control algorithms and real-time computing to tailor drive waveforms according to rotor position and current or voltage feedback. Before the development of large-scale integrated circuits the control electronics would have been prohibitively costly.

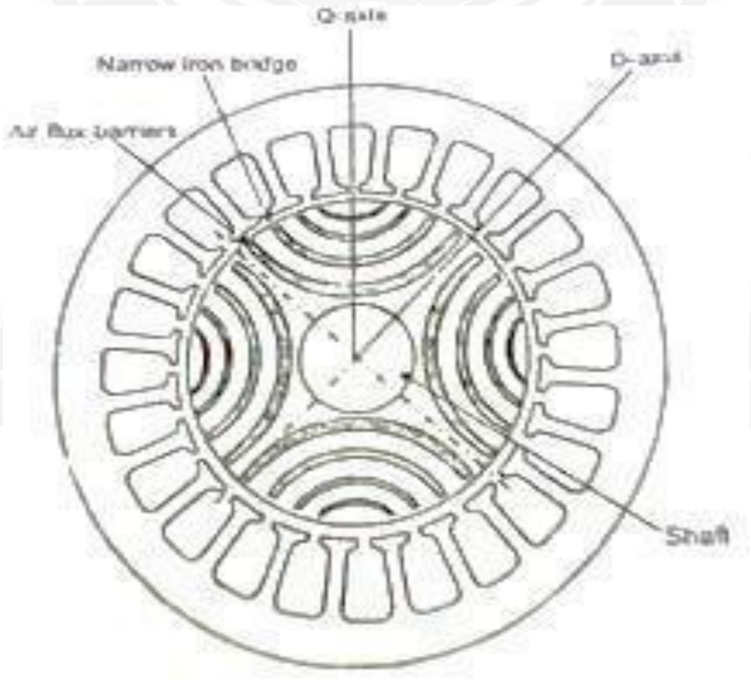

Figure 5.1.3 cross section of radially laminated

[Source: "special electric machines" by Srinivasan page:1.3]

The stator consists of multiple projecting (salient) electromagnet poles, similar to a wound field brushed DC motor. The rotor consists of soft magnetic material, such as laminated silicon steel, which has multiple projections acting as salient magnetic poles through magnetic reluctance. The number of rotor poles is typically less than the number of stator poles, which minimizes torque ripple and prevents the poles from all aligning simultaneously—a position which cannot generate torque.

When a rotor pole is equidistant from the two adjacent stator poles, the rotor pole is said to be in the "fully unaligned position". This is the position of maximum magnetic reluctance for the rotor pole. In the "aligned position", two (or more) rotor poles are fully aligned with two (or more) stator poles, (which mean the rotor poles completely face the stator poles) and is a position of minimum reluctance.

When a stator pole is energized, the rotor torque is in the direction that will reduce reluctance. Thus the nearest rotor pole is pulled from the unaligned position into alignment with the stator field (a position of less reluctance). (This is the same effect used by a solenoid, or when picking up ferromagnetic metal with a magnet.) In order to sustain rotation, the stator field must rotate in advance of the rotor poles, thus constantly "pulling" the rotor along. Some motor variants will run on 3-phase AC power (see the synchronous reluctance variant below).

Most modern designs are of the switched reluctance type, because electronic commutation gives significant control advantages for motor starting, speed control, and smooth operation (low torque ripple).

Dual-rotor layouts provide more torque at lower price per volume or per mass. The inductance of each phase winding in the motor will vary with position, because the reluctance also varies with position. This presents a control systems challenge.

Applications

1. Some washing machine designs.
2. Control rod drive mechanisms of nuclear reactors.
3. The Dyson Digital Motor used in some products produced by the Dyson company.

ROTOR DESIGN

Salient rotor (Segmental)

Salient rotor shape such that the quadrature air gap is much larger than the direct air gap. This yields reactively small L_d/L_qrations in the range of.5.1.4

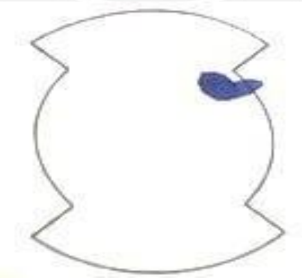

Figure 5.1.4 cross section of salient rotor
[Source: "special electric machines" by Srinivasan page:1.3]

Salient rotor design is as shown. The low $L_d.$ /$L_q$ratios are largely the result of circulating flux in the pole faces of the rotor. However the ruggedness and simplicity of the rotor structure has encouraged for high speed applications.

Radially Laminated Rotor (Flux Barrier)

Another approach is to use laminations with flux barriers punched into the steel for a 4 pole machine. The flux barriers and the central hole of the lamination required for the shaft weaken the rotor structurally and thus make this approach a poor choice for high speed design.

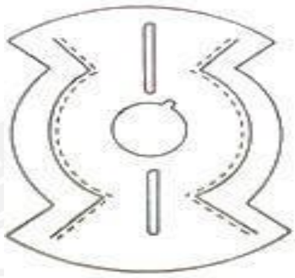

Figure 5.1.5 cross section of Radially laminated Rotor
[Source: "special electric machines" by Srinivasan page:1.4]

Axially Laminated Rotor

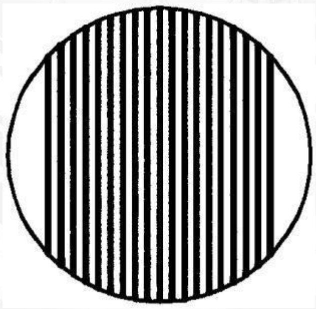

Figure 5.1.6 cross section of axially laminated Rotor
[Source: "special electric machines" by Srinivasan page:1.3]

Fig.5.1.6 Axially Laminated Rotor Two pole phase axially laminated rotor with a Ld. /Lqratio of 20, the maximum efficiency is 94% has been reported in the literature. It is observed that torque ripple and iron losses are more axially laminated rotor than radially laminated rotor. Another rotor design as shown in fig. The rotor consists of alternating layers of ferromagnetic and non-magnetic steel. If choose the thickness of the steel such that the pitch of the ferromagnetic rotor segments matched the slot pitch of the stator. The ferromagnetic rotor segments always see a stator tooth pitch regardless of the angle of rotation of the rotor. This is done to maximize flux variations and hence iron losses in the rotor.

Special rotor laminations make it possible to produce the same number of reluctance path as there are magnetic poles in the stator. Synchronous speed is achieved as the poles lock in step with magnetic poles of the rotating stator field and cause the stator to run at the same speed as the rotating fields. The rotor is pressures with end rings similar to induction motor .Stator winding are similar to squirrel cage induction motor.

ROTOR CONSTRUCTION

Explosion bonding technique as shown in fig. Other joining techniques such as brazing roll bonding, or diffusion bonding may also appropriate for rotor construction.

First sheets of ferromagnetic and non-ferromagnetic steel are bonded. The bonded sheets are then cut into rectangular blocks h\which are machined into the desired rotor. The rotor shaft can also be machined out of the same block as the rotor.

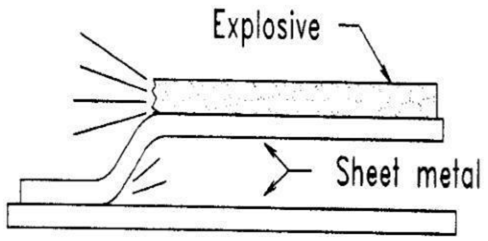

Figure 5.1.7 Explosion bonding

[Source: "special electric machines" by Srinivasan page:1.3]

The rotor joining technique known as explosion bonding. Explosion bonding uses explosive energy to force two or more metal sheets together at high pressures. Conventionally the high pressure causes several atomic layers on the surface of each sheet to behave as a fluid. The angle of collision between the two metals forces this fluid to jet outward. Effectively cleaning the metal surface, these ultra clean surfaces along with the high pressure forcing the metal plates together provide the necessary condition for solid phase welding.

Experimental tests on a stainless steel/mild steel bond indicate that the tensile and fatigue strengths of the bond are greater than those of either of the component materials due to the shock hardening which occurs during the process. The bond was also subjected to 10 cycles of temperature variation from 20° C - 70°C, with no significant reduction in tensile strength.

WORKING OF SYNCHRONOUS RELUCTANCE MOTOR

In order to understand the working of synchronous reluctance motor, when a piece of magnetic material is located in a magnetic field, a force acts on the material tending to bring it into the desert portion of the field. The force tends to align the specimen of the material in such a way that the reluctance of the magnetic path that passes through the material will be minimum.

When supply is given to the stator winding, the revolving magnetic field will exert reluctance torque on the unsymmetrical rotor tending to align the salient pole axis of the rotor with the axis of the revolving magnetic field, because in this position, the reluctance of the magnetic path would be minimum. If the reluctance torque is sufficient to start the motor and its load, the rotor will pull into step with the revolving field and continue to run at the speed of the revolving field. Actually the motor starts as an induction motor and after it has reached its maximum speed as an induction motor, the reluctance torque pulls its rotor into step with the revolving field, motor now runs as synchronous motor by virtue of its saliency.

Reluctance motors have approximately one third the HP rating they would have as induction motors with cylindrical rotors. Although the ratio may be increased to 9one half by proper design of the field windings, power factor and efficiency are poorer than for the equivalent induction motor. Reluctance motors are subject to cogging, since the locked rotor torque varies with the rotor position, but the effect may be minimized by skewing the rotor bars and by not having the number of poles.

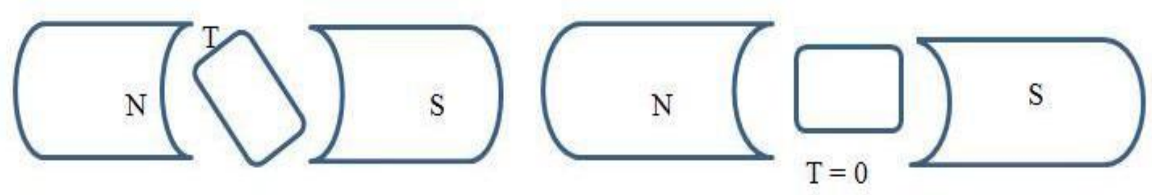

Figure 5.1.7 Rotor position due to revolving magnetic field

[Source: "special electric machines" by Srinivasan page:1.3]