2 Permanent Magnet Synchronous Motors

2.1. Introduction

Permanent magnet synchronous motors (PMSMs) are an attractive solution for servo drives in the kW-range. They are being used in a wide range of applications, from general purpose line-start pump or fan drives to high performance machine tool servos, robotics, aerospace generators and actuators, and electric vehicles.

2.2. Materials For PMSMs

The desirable properties of the materials used for the construction of permanent magnets in PMSMs are:

a. High flux density
b. High coercivity

Certain "rare earth" magnetic materials best satisfy these requirements. Samarium-Cobalt, with high flux density (up to 1T) and very large coercive force (upto 7000 A/cm), is one of the materials used.

These days, Neodymium-Iron-Boron magnets are being used for their low cost. Further the magnets made of these materials require less space and, with proper design, there is no danger of accidental demagnetization through short circuit.

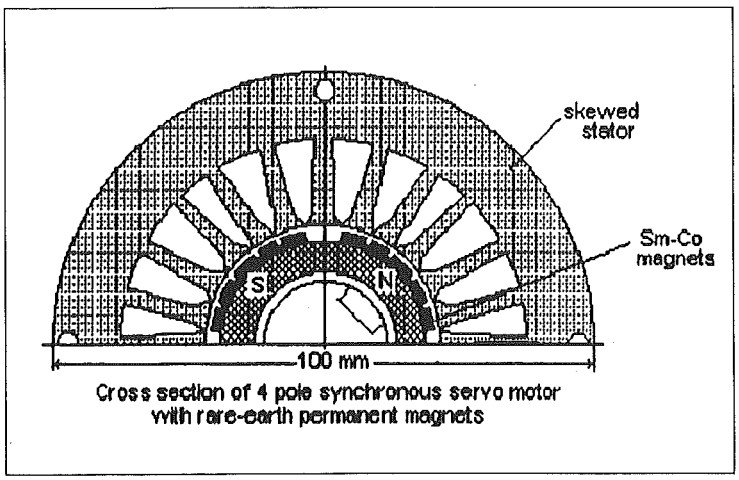

Figure 2.1

CONSTRUCTION

Figure 2.1 shows the cross section of a 4 pole synchronous motor with a solid steel rotor to which Sm-Co-Magnets assembled from standard size bars are attached.

One of the primary requirements for servo applications is smooth torque operation. Therefore cogging due to slotting must be avoided. The reduction of cogging torque can be achieved in a number of ways, such as skewing the magnets on the rotor with respect to the rotor axis, skewing of the stator, coordinating the number of stator slots, slot opening, and magnet dimensions.

The magnets can be fixed to the rotor in different ways. This is discussed later in this chapter.

2.3. Classification Of PMSMs

The PMSM consists of a three phase stator similar to that of an induction motor and a rotor with permanent magnets. The rotor is provided with a cage if the machine is to be line started. Most of the PMSM drives are fed from inverters and a cage is not necessary in the rotor. The motor characteristics depend on the type of the magnets used and the way they are located on the rotor. The magnets are either mounted on the surface of the rotor or buried in the interior of the rotor. Accordingly PMSMs are classified as

1. Surface mounted PMSMs
2. Buried or interior PMSMs

SURFACE MOUNTED PMSMs

There are two variations in the surface mounted PMSMs

a. Projecting type-in which the magnets project from the surface of the rotor as shown in *figure* 2.2.

b. Inset type -in which the magnets are inset into the rotor providing a smooth rotor surface as shown in *figure* 2.3.

PROJECTING TYPE

Mounting the magnets on the surface of the rotor is the simplest and cost effective method for constructing a PMSM. Epoxy glue is used to fix the magnets to the rotor surface in the projecting and inset surface mounted PMSMs. Therefore these constructions are less robust compared to interior magnet type rotor and are not suited for high speed applications.

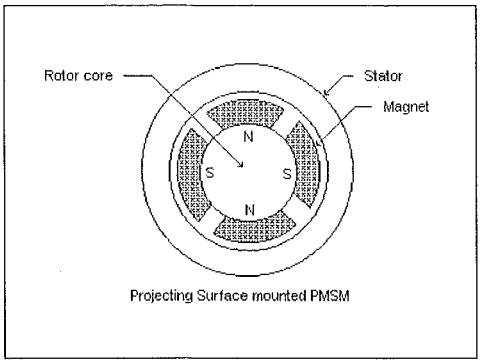

Figure 2.2

As the relative permeability of the magnet is approximately equal to that of air, the projecting surface mounted motor has almost uniform airgap. This results in equal direct and quadrature axis inductances. The motor torque is therefore derived from the magnet flux only, and there is no reluctance torque as might have been expected from the salient magnet construction. *The projecting magnets present a large airgap in the magnetic circuit*, so that the inductance in the machine is small. The lower value of inductance gives rise to a smaller stator time constant. Also the surface mounted designs tend to yield smaller rotor diameter with lower inertia.

This enables the machine to exhibit good dynamic performance. Such drives are suitable for high performance machine tool feed drives and industrial robots.

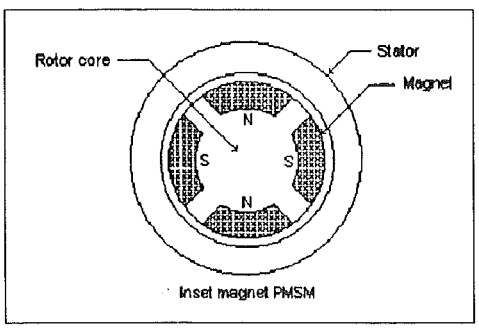

Figure 2.3

INSET TYPE

The inset PMSMs have magnets that span less than a pole pitch, mounted into the rotor surface with an iron rotor tooth filling the space between the magnets as shown in *figure* 2.3.

This design makes the machine mechanically more robust ; the inductance is much larger compared with the projecting surface mounted PMSM. The quadrature inductance is larger than the direct axis inductance, owing to the magnet being equivalent to an airgap in the direct axis. This saliency gives rise to a significant reluctance torque which adds to the magnetic torque.

INTERIOR PMSMs

The alternative to mounting magnets on the surface of the rotor is to embed them in the interior of the rotor as shown in *figure* 2.4. Interior magnet designs offer the advantage of mechanical robustness and a smaller airgap. The reluctance torque obtained is much higher than that in the inset magnet motors.

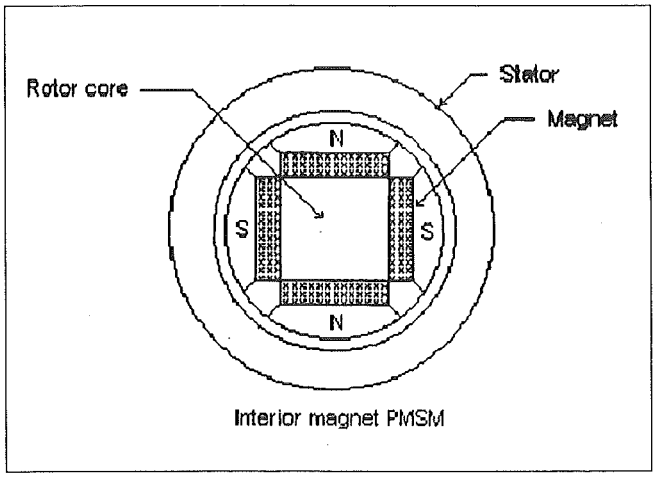

Figure 2.4

2.4. Brushless DC Motors

Brushless DC (BLDC) motor is also a permanent magnet motor. It has been developed by using interdisciplinary mechatronics engineering. A mechanical switching device is replaced by electronic circuits and controllers, resulting in a maintenance-free and high performance servo drive. Hence it may be thought of as a PMSM along with some electronic circuitry.

OPERATIONAL PRINCIPLES

The brushless DC motor has DC voltage as input and a DC to AC converter. The AC voltage is supplied to the motor. The peak of the AC voltage is determined based on the DC voltage set and the phase is determined based on the rotor position.

NOTES