AN IRONLESS ARMATURE BRUSHLESS TORQUE MOTOR

Phillip A. Studer

The object of this development was a high torque motor with improved servo characteristics. This included elimination of some of the nonlinearities that cause servo systems to be less than ideal, especially those that limit the ultimate system accuracy in pointing and rate control devices.

The construction technique employed dates back to the early days of electricity, before it was learned that conductors placed in slots in iron laminations behaved the same as when placed directly in the motor air gap. In the past, obtaining sufficient volume in the motor air gap for a high torque motor required a large heavy magnet structure, the rotating part of a brushless motor. The recent introduction of samarium cobalt magents has reduced the magnet length required by a factor of five over the best Alnico available.

Figure 1 shows the motor construction in which the armature windings are cast into an

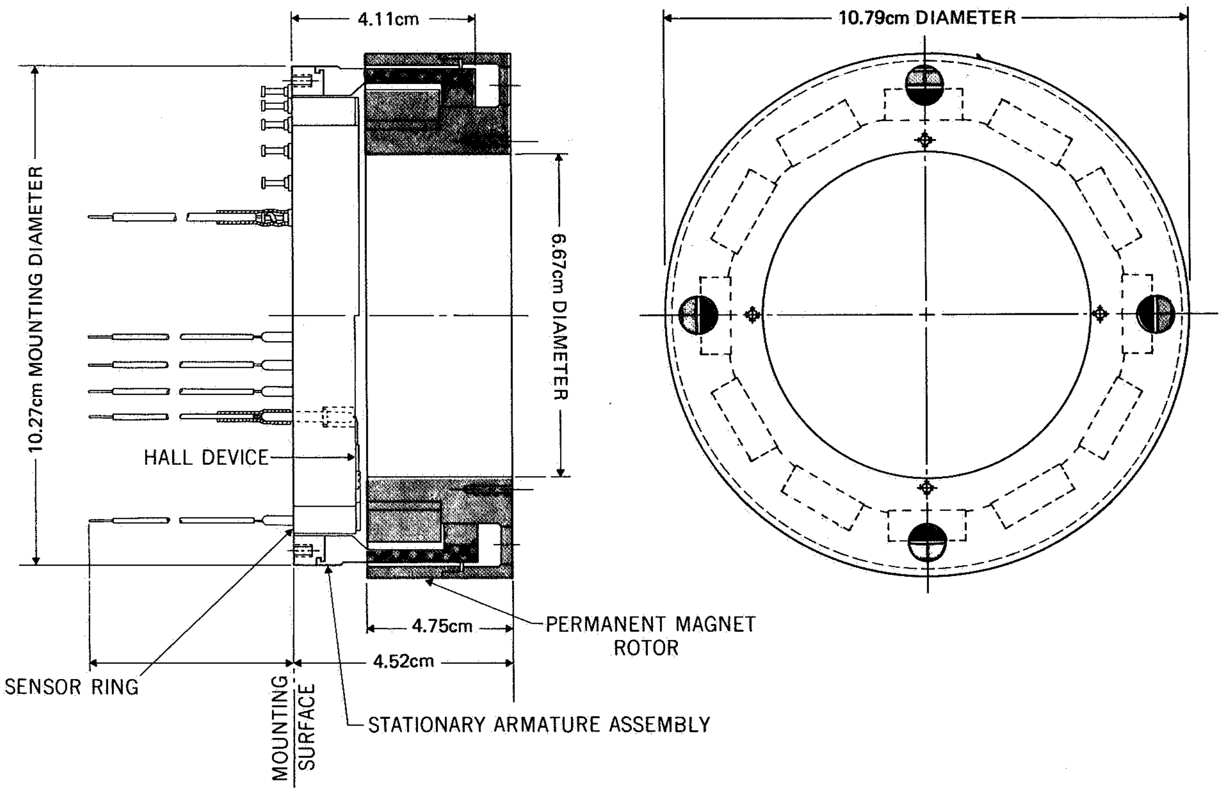

Figure 1. Ironless armature torque motor.

epoxy cylinder which is inserted into the air gap of the rotor. The armature conductors are a three-phase air core winding, integrally cast with an aluminum mounting ring which provides a good thermal path directly into the structure. The rotor is a 12-pole permanent magnet assembly with an air gap of 0.42 cm (0.165 inch) radially.

The primary reason for this type of construction is to eliminate magnetic hysteresis, which is nonexistent in this design because there is no relative motion between the rotating magnetic field and any stationary iron. The effect of hysteresis in a conventional motor is a static friction which introduces a deadband at the servo null position.

There are other benefits as well from the construction technique employed: There are no slot effects which cause "cogging" since the windings are not placed in discrete slots, and there are no static destabilizing forces between the armature and magnet assembly, which normally represent the most significant radial decentering force on the bearings at zero-g conditions. The electrical response is much faster (by an order of magnitude) since the armature is essentially an air core winding.

This motor was designed to meet the requirements of large despun systems such as flown on ITOS, INTELSAT, and others. It has a peak torque capability of 0.65 N·m (93 oz in.) in a construction with a hollow bore of 6.7 cm, and an outside diameter of 10.8 cm.

Figure 2 shows the measured performance of the engineering models compared to typical torquers of conventional construction. For a given peak torque requirement, the measured breakaway torque is substantially less than that obtainable from previously

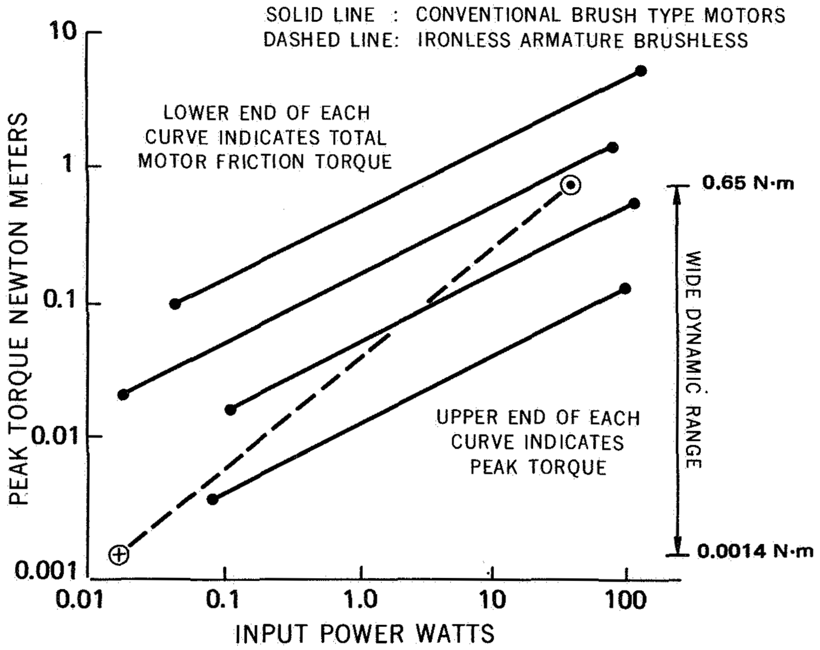

Figure 2. Working range for torque motors.

available motors. The result is not only a performance advantage but a power savings in constant speed and pointing applications, in which the motor and bearings represent the only mechanical load. These can be reduced to a fraction of a watt with a motor of this type; part of the improvement is due to the elimination of brush friction with electronic commutation and part due to a reduction of magnetic losses with the ironless armature construction. The engineering models indicate that a weight penalty of 0.23 kg is imposed by this construction for a motor of this rating.

This type of motor with its unique aspects of low losses, absence of destabilizing forces, and fast electrical response is uniquely suited to magnetically suspended systems. Combined with other developments such as magnetic bearings and rotary transformers, the motor provides a completely noncontacting system with no lubrication requirements and essentially unlimited life. Such a system will be able to attain and maintain higher accuracy at high levels of efficiency.

Four engineering models of this motor have been built and are currently under evaluation in the Mechanical Division labs. Smaller motors of this type could be built which would be ideal for scanning mirror devices such as radiometers. It is believed that a torque motor of this size and type would be ideal for laser communication applications which have beamwidths so narrow as to push the state-of-the-art in servo pointing systems.