# Performance of Permanent Magnet Motors

by Steve Vitkovits

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Summary of Technical Talk for June 2003

Determining the performance of unspecified permanent magnet motors was the topic for the June 2003 meeting. The electrodynamometer and its use in measuring motor performance were discussed first. An assumption was made that at least the rated voltage of the motor under test was known. The dynamometer used in the demonstrations was built using a 2HP, cradled mounted, PM motor. Running motor tests also requires voltmeters, ammeters, a scale, a tachometer, and a lots of patience.

Next, the efficiency of a typical motor was defined by describing the two main factors that cause the output power to be less than the input power. First, there is copper loss caused by armature current passing through the brush and winding resistance. Second, several loss factors that arise because the armature is revolving were identified. Namely, friction from the brushes and bearings, core hysteresis and eddy current loss because the armature is rotating in a magnetic field, and windage. Thus, output power is equal to input power minus the sum of all the losses. Efficiency is then output power divided by the input power. For fractional horsepower motors that the model builder is likely to use, the efficiency is between 50 to 70 percent.

The equivalent circuit of an electric motor was introduced next in order to explain motor operation. The equivalent circuit is simply a single loop in which the battery, the armature resistance and the back EMF generator are connected in series. The magnitude of the back EMF voltage is proportional to the motor speed. The constant of proportionality, Ke, (an important motor parameter) was measured in the next demonstration. The motor under test was driven by the electrodynamometer and the open circuit voltage was measured as a function of speed. In this test, the motor under test was acting as a generator. The specific motor tested had a Ke of 5.5 Volts per 1000 RPM. Thus, knowing the battery voltage, armature resistance and the speed, the armature current for any speed can be determined.

The amount of torque developed in the armature is proportional to the armature current and the constant of proportionality is Kt. The constant Kt may be determined by measuring the torque as a function of armature current directly by the electrodynamometer, but there is an easier way. The two proportionality constants, Ke and Kt are related by a very simple expression. Kt is equal to 1.35 times Ke where the units of Kt are Oz-In per Ampere and for Ke they are volts per 1000RPM. For the motor cited above, a Ke of 5.5 V per 1000RPM gives a Kt of 7.4 Oz-In per Ampere.

The next section dealt with a method of determining the efficiency and power output of an unspecified motor. The procedure was described by Mark Phillips in Model Engineer 6 Feb.1981 and 6 March 1981. The detailed steps are too involved to repeat here, but the result is a plot of power output and efficiency versus speed for the rated operating voltage. With this knowledge and Ke and Kt, the suitability of a motor for traction use may be determined. As a motor magnets heat up, the magnetic flux density falls (Ke and Kt go down) and the motor's ability to deliver torque goes down. Thus, some method of limiting the armature current is desirable to prevent motor damage from over heating. Good heat sinking of the motor to its mounting and forced air cooling will help minimize temperature de-rating.

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