Motor Development for Electric Drive Systems

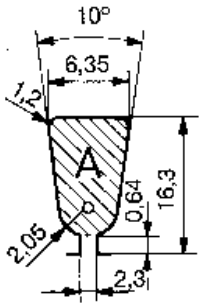
Tutorial 1

Permanent magnet excited synchronous motor with position encoder and surface magnets

A four-pole permanent magnet synchronous motor shall provide 30 kW continuous power at a speed of 24000 rpm. It is supplied by an inverter, which uses a filter to provide approximately sinusoidal voltages. By interpreting the signals of a position encoder, the inverter can align the current phasor with the back EMF E_0. The cooling of the machine is realised using a water jacket cooling of the stator housing. The main dimensions of the machine are as follows:

Stator outer/inner diameter 150 mm/90 mm; core length 90 mm; number of stator slots 36; slot dimension according to the drawing.

Two layer winding; short-pitching 7/9 to reduce the influence of higher harmonics armature reaction; number of turns per coil 4;
number of parallel paths 2; Y-connection;
diameter of copper wires 0.85 mm; number of conductor elements 7;
magnet material Sm_2Co_{17}; magnet height 3.5 mm; pole-pitch factor 87 %;
mechanical air gap 0.7 mm; thickness of bandage 2.8 mm;
end connector length 115 mm



B_R	T	1.07	1.03
${}_BH_C$	kA/m	720	650
Temp.	°C	20	150

1) Calculate the number of turns per phase, the phase resistance at 20°C and 145°C (temperature class F with 40°C water inlet temperature) and the leakage impedance. Take into account the slot and end winding leakage. Due to the large active air gap, the high order harmonics leakage is too small and can be neglected, therefore, like the large synchronous generators, the tooth-top leakage is dominating.

2) Calculate the magnetic operating point under no-load conditions and 150°C magnet temperature (worst case) and the back EMF E_0.

3) Estimate the efficiency to be 95% and determine the current consumption and the required stator voltage for 30kW output power. What is the current density inside the copper conductors?

4) Determine the maximum possible magnitude of the sudden short circuit current. Are the magnets protected against permanent demagnetisation?