Massachusetts Institute of Technology  
Department of Mechanical Engineering  

2.141 Modeling and Simulation of Dynamic Systems  

Assignment #2  
Out: 9/19/02  
Due: 10/3/02  

Electromagnetic Brake  

An experimental apparatus for human movement control studies (Won, J. and Hogan, N. (1995) Stability Properties of Human Reaching Movements. Experimental Brain Research, 107:125-136) used an electromagnetic brake to immobilize (or release) a linkage under computer control. For the purpose of the study, the precise time at which the linkage was immobilized (or released) was of particular concern. Several pages from a catalog for electromagnetic clutches and brakes (Electroid Corp., USA) are attached. Your task in this assignment is to model and simulate the electrical and mechanical behavior of electromagnetic brake model number EC-56B-12 with a 90 VDC coil.

When the coil is not energized, the armature is held by an axial translational spring such that it is free to rotate relative to the stationary coil. When the coil is energized, the magnetic field pulls the armature, deflects the spring axially and brings mating surfaces on the armature and stationary housing firmly into contact. (In the experimental apparatus, when the brake was energized, it made an unacceptably loud noise, so a thin pad of absorbent material was interposed between the mating surfaces on the armature and the housing to cushion the impact.) The normal (axial) force holding the surfaces together results in a (tangential) frictional force due largely to dry friction. De-energizing the coil allows the spring to pull the mating surfaces of the armature and housing apart axially, thereby releasing the armature. As you will see from the sketch in figure 2, the time course of the coil current shows some brief transients (at time t₁ and time t₄) that appear not to be reflected in the braking torque developed.

1. Develop the simplest model competent to describe the current and torque profiles shown in figure 2. (Hint: it will probably be nonlinear).

2. Explain the origin of the current transients at time t₁ and t₄ in physical terms. (Please be brief — lengthy essays are unnecessary.)

3. Simulate the coil current and braking torque profiles shown in figure 2. For the purpose of this assignment, assume the armature is mounted on the shaft of a motor. Assume the motor torque exceeds the rated static torque of the brake (so that the brake never brings the shaft to rest) and that the motor rotates the shaft at constant speed. Make sure your simulation does a reasonable job of reproducing the difference in the "on" times (t₁ and t₂ – t₁) and the "off" time (t₄ – t₃).

4. Specify how you determined numerical values of the parameters of your model. (Some numerical parameter values are available — if you tell me what you need and why it would be impractical for you to get it yourself, I’ll provide it.)

5. Develop a linearized model of this system, which would be valid when the armature is in motion. Draw a corresponding bond graph. Comment on its competence. (Again, be brief).