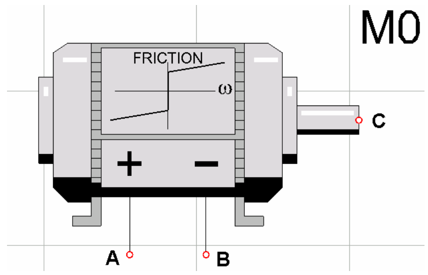

Name of Model: DcMotor_021708

Author: Vladimir L. Chervyakov

Date: 2002-10-26

Executable file name DcMotor_021708.vtm

Version number: 1.0

Description

This model represents a Nonlinear model of a permanent magnet DC motor with a rack-and-pinion mechanical drive [1][2]. Motor icon is shown in Fig. 1. Terminals A and B are the electrical nodes. Node C is a linear motion node representing the tip of the moving rack. The rack-and-pinion drive dimensions are such that when the rotor turns by on radian the rack moves by one meter. The rack moves in the positive direction when the voltage at node A with respect to node B positive. In this model, linear magnetic circuit is considered without magnetic saturation and dissertation.

Validity Range and Limitations

The following parameters are valid when positive or zero:

- Coefficient
- Armature Resistance
- Rotor Inertia
- Armature Inductance
- Coloumb Friction
- Viscous Drag Coefficient

Connections

Label	Description
A	Electrical terminal (Positive)
B	Electrical terminal (Negative)
C	Mechanical terminal

Adjustable Parameters

Name	Description	Valid Range	Default Value	Units
Coefficient	Electromechanical coefficient	Positive or zero	0.02	*N.m/A or V/rad/s*
Armature Resistance	The electrical resistance of the armature winding	Positive or zero	1.4	*Ω*
Armature Inductance	The inductance of the armature winding	Positive or zero	0.86e-3	*Henries*
Rotor Inertia	Rotor moment of inertia	Positive or zero	5e-7	kgm^2
Viscous Drag Coefficient	Dc Motor Viscous Drag Coefficient	Positive or zero	3e-6	*N.m/rad/s*
Coloumb Friction Torque	Dc Motor Coloumb Friction Torque	Positive or zero	0.0023	*N.m*

Output Variables

Name	Description	Units
Voltage	Voltage across device. Polarity is VA-VB.	*V*
Current	Electric current through device. Positive flow is from node A to node B	*A*
Electrical_Power	The electric power flowing into the model through the electrical terminals A and B.	*W*
Mechanical_Power	The mechanical power flowing into the device through the mechanical terminal C.	*W*
Electrical_Torque	The torque applied on the rotor due to the magnetic field	*Nm*
Mechanical_Torque	The torque applied on the rotor due to the mechanical load connected to terminal C	*Nm*
Speed	Rotational Speed of the motor shaft (Also numerically equal to rack speed)	*rad/s (m/s)*
Position	Angular position of the motor shaft (Also numerically equal to rack position)	*Rad (m)*

Model Assumptions

Magnetic circuit is assumed to be linear. The dry friction has a nonlinear dependence of a friction torque from a rotation frequency [1] and is defined by the following formula:

$$\text{Coulomb Friction} = T_{CF} \cdot signum(\omega)$$

Mathematical Description

Equation (1) and equation (2) represent model mathematical description.

$$v(t) = r \cdot i(t) + l\frac{di(t)}{dt} + a \cdot \omega(t) \quad (1)$$

$$T_e = a \cdot i(t) = J\frac{d\omega(t)}{dt} + b \cdot \omega(t) + T + T_{CF} \cdot \tanh(\frac{\omega}{\omega_{\min}}) \quad (2)$$

Where:

- v is the voltage across the motor electrical terminals.
- i is the electric current into the motor.
- ω is the rotor speed.
- Te is the electromagnetic torque imposed on the rotor.
- T is the mechanical torque due to the mechanical load.
- J is the rotor/rack/pinion equivalent moment of inertia.
- r is the armature electrical resistance.
- l is the armature self inductance.
- a is equal to the ratio of the motor rated voltage divided by the rated speed.
- b is the mechanical drag coefficient.

ω_{min} – minimum rotation frequency at which the dry friction is equal 0.76* T_{CF}.

Model Validation

In mathematical model [3] the linear relation of a friction torque from a rotation frequency (viscous drag) is accepted. The dry friction is not taken into account. For the taking into account of a dry friction it is possible to use coefficient of linearized mechanical drag instead of coefficient of viscous drag, but at a small shaft rotation frequency the friction torque differs from actual. The dry friction has a nonlinear dependence of a friction torque from a rotation frequency [1] and is defined by the following formula:

$$\text{Coulomb Friction} = T_{CF} \cdot signum(\omega)\,, (3)$$

where:
T_{CF} –torque of coulomb friction.

As function and its derivative have a rupture in a point $w = 0$, it will cause nonconvergence of nonlinear model. The following expression is offered to for reaching good convergence (4):

$$\text{Coulomb Friction} = T_{CF} \cdot \tanh(\frac{\omega}{\omega_{\min}})\,, (4)$$

where:
ω_{min} – minimum rotation frequency at which the dry friction is equal 0.76* T_{CF}.

Example Application and Model Verification

For verification of model of a dc motor we compare outcomes of model operation of one problem with use of different models. The circuit of experiment is figured on figure 3. Outcomes of model operation represented on figures 5-6.

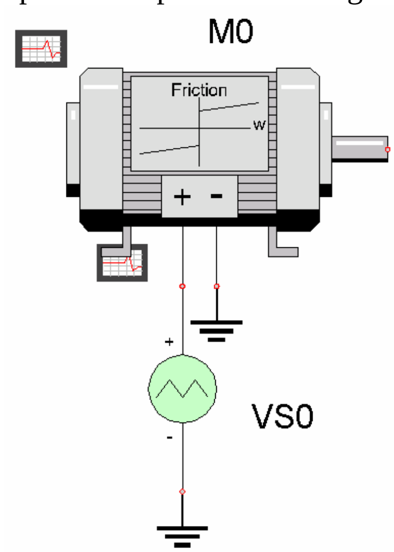

Figure 1. Schematic of motor driving

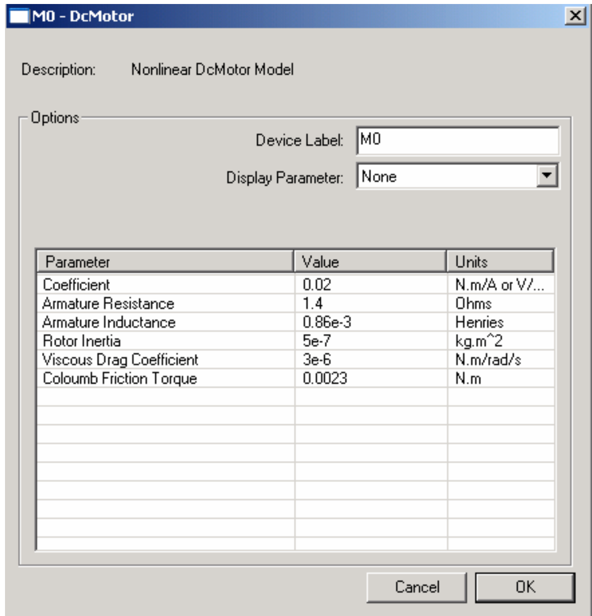

Figure 2. Parameters of DcMotor_021708

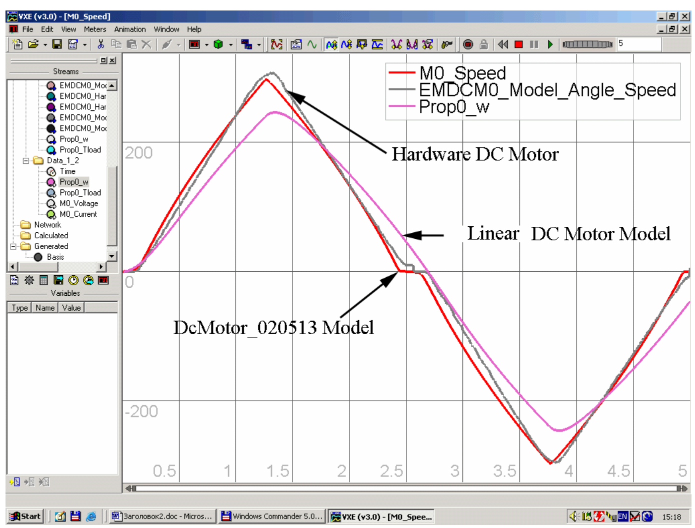

Figure 3. Rotor angular velocity of HIL-model and mathematical models of a dc motor

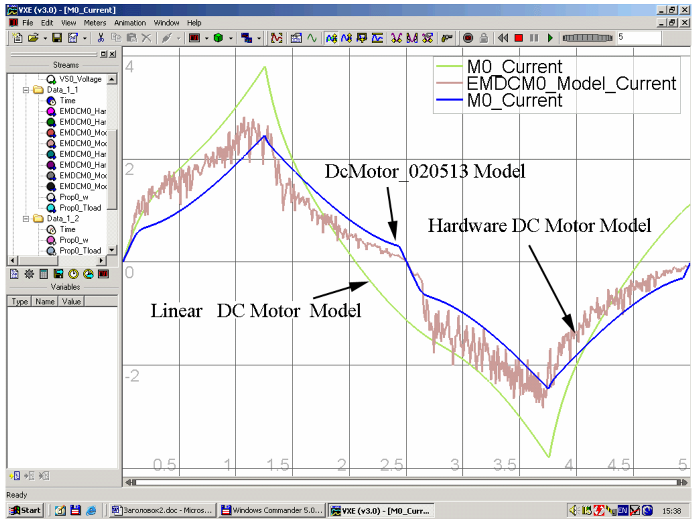

Figure 6. Current of HIL-model and mathematical models of a dc motor

References

1. ME 3210 Mechatronics II – Laboratory Exercise 3: Lumped Parameter Characterization of a Permanent Magnet DC Motor. http://www.mech.utah.edu/~me3200/labs/motorchar.pdf
2. G. Cokkinides and R. A. Dougal, "RC and AC models in the VTB Time Domain Solver", Department of Electrical and Computer Engineering, University of South Carolina, 1998.
3. VTB Model Author Documentation_DCMotor.doc; Author: Lijun Gao; Author's Organization: University of South Carolina; Date: 2002-10-26.