Chattering Reduction Technique using Neural Network based Smart Multi Segment Sliding Mode Control for Induction Motor

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Abstract: Induction motor is widely used in Industries and it is an efficient motor than the other motors. Its simple construction, easy installation and high robustness are most advantageous factors. Induction motor is used for the different applications and performance requires velocity control, position control and accuracy control in various loading condition. Better performance, precise control is required in Industries. Different control methods are used for control of induction motor and those are known as DTC, VC, SMC. Trapezoidal control command is suitable method for speed control of the Induction Motor for Velocity and position control. MS-MSC technique is most suitable than sliding mode control method for the Trapezoidal control command of IM. From the recent years, numbers of works have been done on fuzzy logic and neural network based speed control techniques for different motors and neural network based MSSMC control is effective solution to reduce the chattering in torque of IM.

Keywords: ANN, DTC, MS-SMC, SMC, VC.

Introduction

Widely, Induction Motor have been universally used in the industries due to its advantages like simple built, high robustness, reliable and good operation and more over relatively low cost. But the evaluation of behavior and control of induction motors are more complex than other AC drives. The main reasons are complexity like need of variable frequency, machine parameter variations and main problem found chattering in torque current and due to that the performance of the drives became poor. Hence, many researchers who had developed conventional control techniques like VC, DTC, PI, SMC and MS-SMC. Except MS-SMC, all the control techniques are used only for one segment either speed control or position control. MS-SMC is the trapezoidal control command and it is useful to control speed and position. Study of mathematical modeling and simulation modeling for MS-SMC is done by the researcher but the available information about MS-SMC is only for speed control of Synchronous Motor while Induction Motor is mostly used in industries. So, this propose Neural Network based smart MS-SMC is very helpful for better performances like reduce chattering problem and incremental motion control etc.

Objectives of work

The main research objectives of the research work are to do a simulation for conventional MS-SMC and smart controller using Neural Network with MS-SMC of Induction Motor. Also, to enhance the performance of the system by employing a new control technique for IM and compare the performances of propose smart controller using Neural Network with MS-SMC and conventional MS-SMC for IM.

Neural Network based Smart control

Neural Networks are successfully applied for many problems finding across the area like engineering, geology, finance, physics etc. from the last few years and hence neural network is helpful in problem of prediction and control.

With the help of interconnection of artificial neurons and its objectives is to compete and solve the engineering, scientific and many more real-life problems. Neural Network is classified as feedback and feed forward types. In a feed forward network flow of signals from neuron to neuron only in forward direction while in feedback or recurrent network flow of signals in lateral direction (forward and backward direction).

Most popular training method for multilayer feed-forward network of NN is Back propagation; therefore, multilayer feed-forward network trained by this algorithm is knows as BP network. Here aim is to train the ANN with the help of Back propagation algorithm to reduce chattering in the sliding mode. The multilayer feed forward network structure is given in fig 1.

To develop the ANN model for the velocity control mode, by using the control gain as the input so that from the conventional method the chattering can be used. Same could be develop for the position control mode. Finally, the MSSMC can be reduced by totally ANN model by replacing ANN switch.

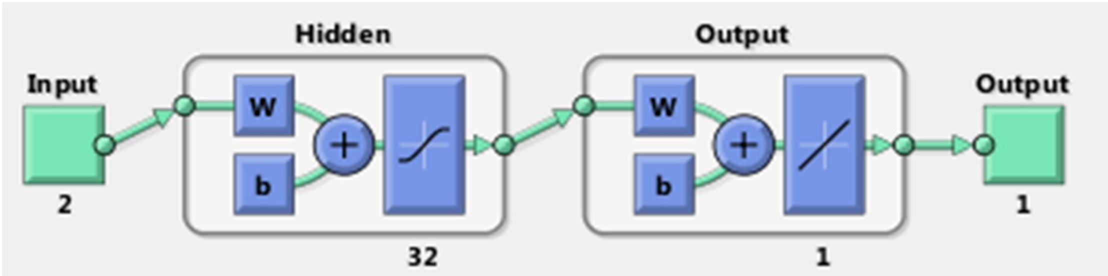

Fig. 1 Artificial neural network model

After the trained Neural Network, conventional MS_SMC is replaced by the ANN-MSSMC which is discussed in results section.

Design of Neural Network based smart Controller

Design and simulation

The control object is to rotate the rotor 6π rad in 2s following the trapezoidal speed command profile with α_{d1}=43.1 rad/s^2, w_d=10.78 rad/s, α_{d2}=-43.1 rad/s^2, t_1=0.25s, t_2=1.75s and t_3=2s. the control gains α_i and β_i of the MS-SMC are set as α_1= 15, β_1 = 10, α_2= 12, β_2 = 10, α_3= 15, β_3 = 10, α_4= 300, β_4 = 200 & T_0= 7.5. since the system dynamics in conventional sliding $s_4=x_2+cx_1=0$ converge at a rate of e^{-ct}, c=10 are set to have a settling time of 0.4s. The model used in Simulink to study the response of MSSMC using Neural Network technique is shown below.

Develop simulation model and result discussion

The effectiveness control of proposed ANN-MSSMC, three different cases are simulated with parameter variations in different loading conditions using trapezoidal command. And those three cases are simulated for convention MS-SMC and ANN based MS-SMC.

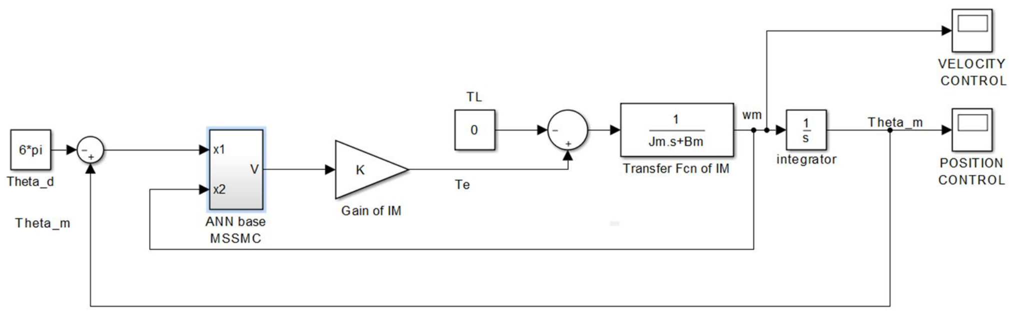

Fig. 7 Simulation model of multi-segment sliding mode control

Three different cases are simulated with parameter variations in different loading condition like no load to full load condition with changes in Jm and Bm of Induction motor. As we seen the result in fig.9 to fig. 12 case -1 Jm and Bm are changed with Tl = zero and results are almost same in conventional MSSMC and ANN-MSSMC for speed control and position control. While in case -2 results are seen in fig. 13 to fig. 16 and case – 3 results are seen in fig. 17 to fig. 20, the Jm and Bm are actual value of IM and change are made in load from zero load (Tl=0) to full load (Tl=7.5) for speed control and position control. And we can see the charting effect in conventional MSSMC results and its directly effect on motor operation and its response. After that ANN based MSSMC gives far better results in same motor parameters with different load and reduce the chattering problem compare to conventional MSSMC.

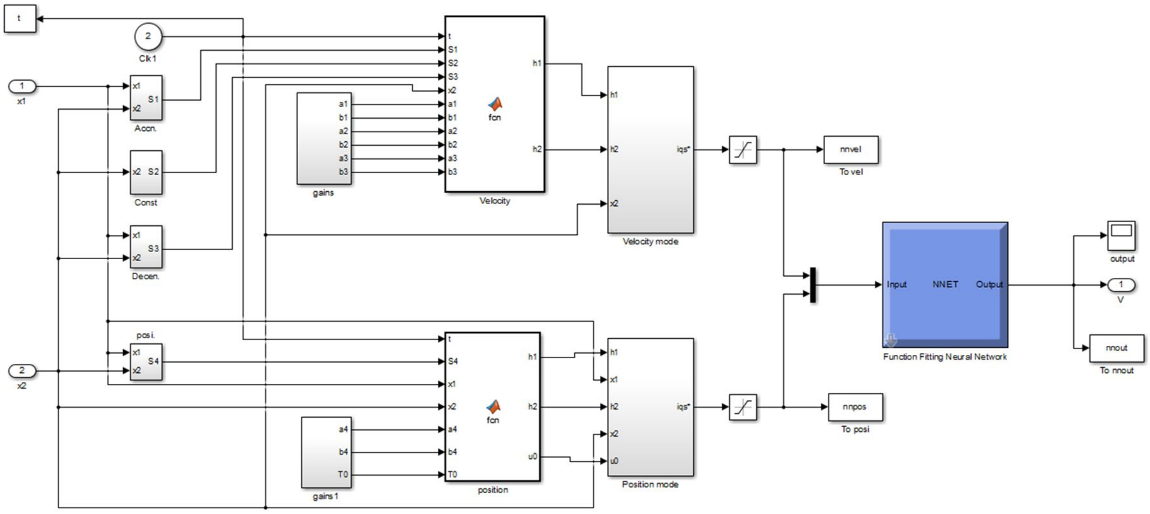

Fig. 8 Simulation model of MSSMC using fuzzy logic control Results

Case 1: $J_m = 2.5J_m B_m = 5B_m T_l = 0$ *N for speed control*

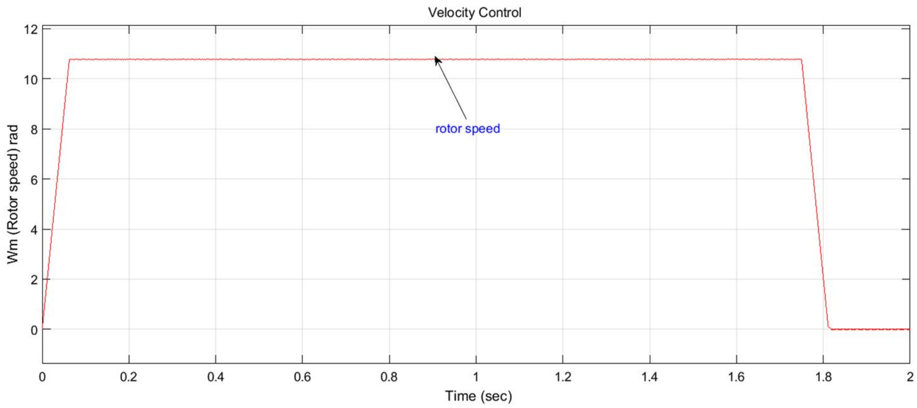

Fig. 9 Velocity Control with conventional MSSMC for case-2

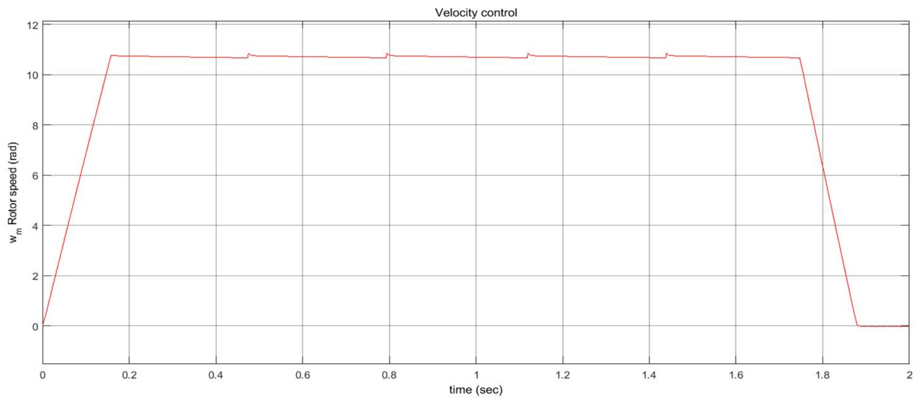

Fig. 10 Velocity Control with ANN based MSSMC control for case-2

Case 1: $J_m = 2.5J_m B_m = 5B_m T_l = 0$ N for position control

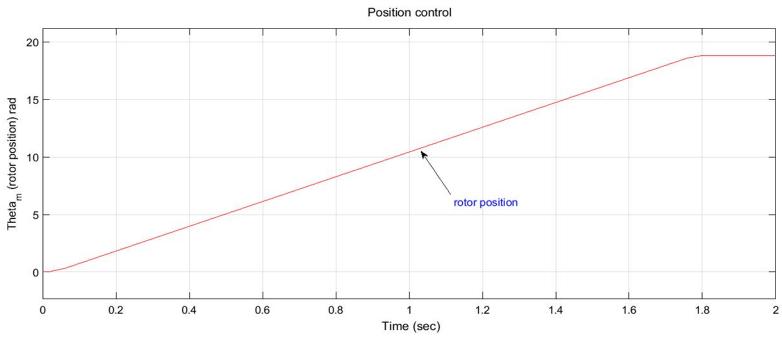

Fig. 11 Position Control with conventional MSSMC for case-2

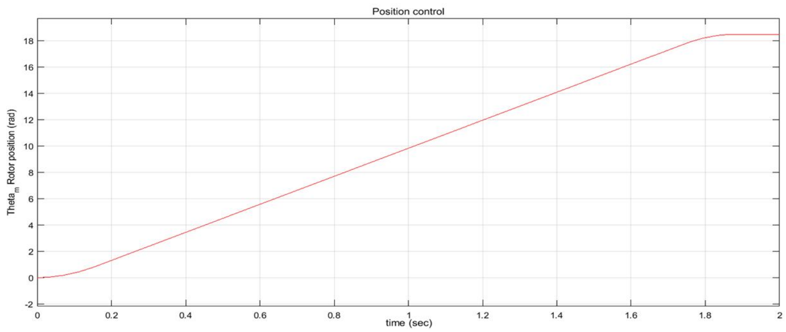

Fig. 12 Position Control with ANN based MSSMC for case-2

Case 2: $J_m = J_m B_m = B_m T_l = 0$ Nm for Velocity speed control

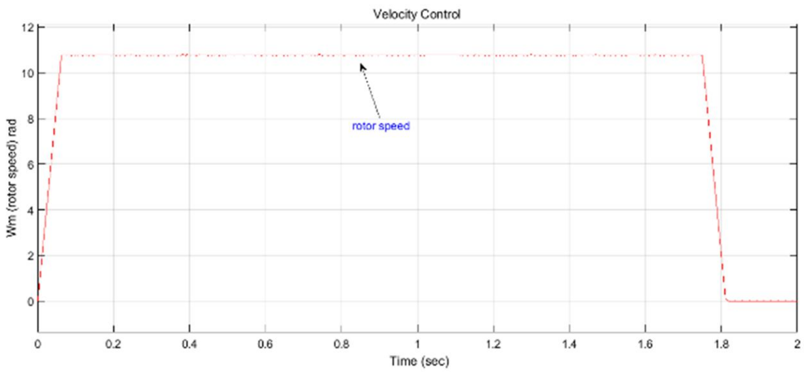

Fig. 13 Velocity Control with conventional MSSMC for case-2

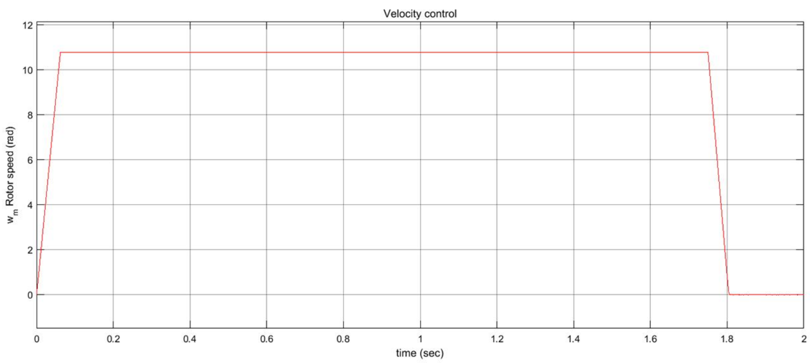

Fig. 14 Velocity Control with ANN based MSSMC for case-2

Case 2: $J_m = J_m B_m = B_m T_l = 0$ Nm for position control

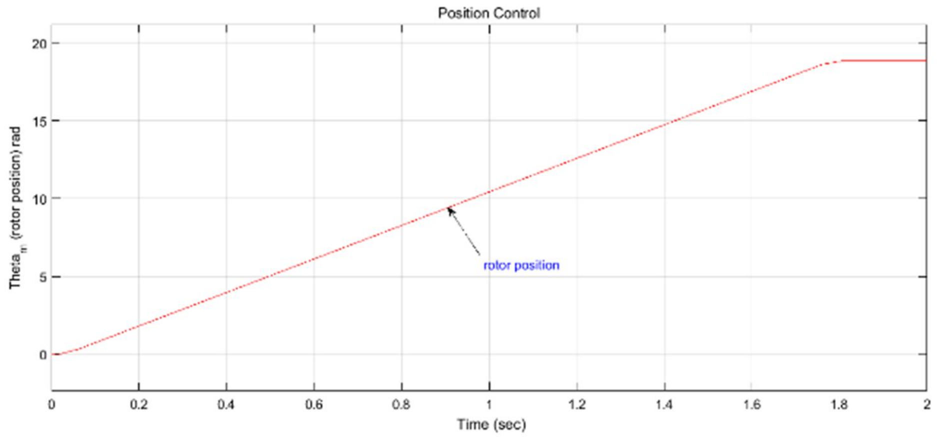

Fig. 15 Position Control with conventional MSSMC for case-2

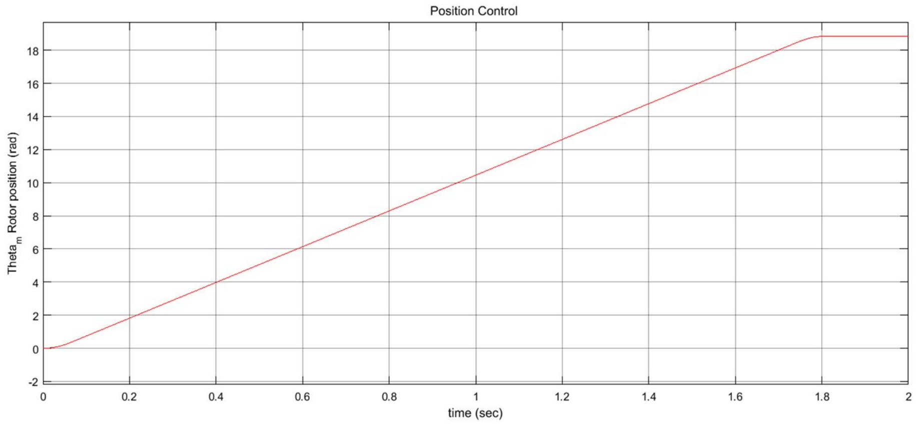

Fig. 16 Position Control with ANN based MSSMC for case-2

Case 3: $J_m = J_m B_m = B_m T_l = 7.5$ Nm for speed control

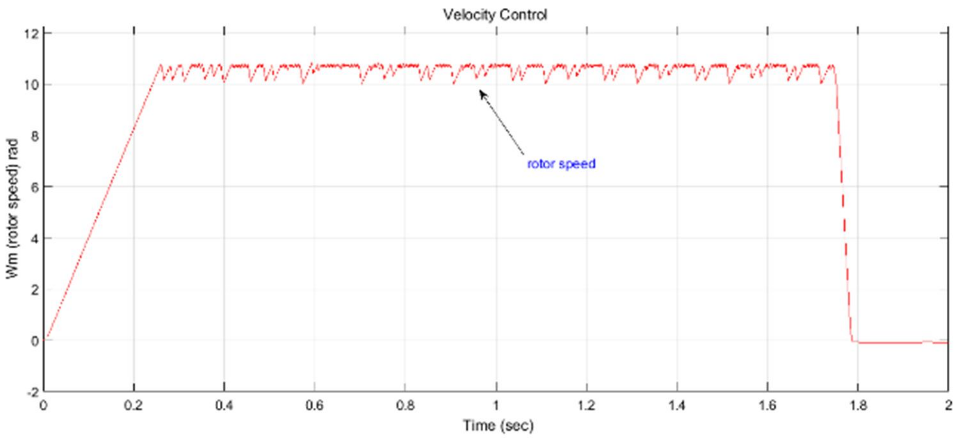

Fig. 17 Velocity Control with conventional MSSMC for case-3

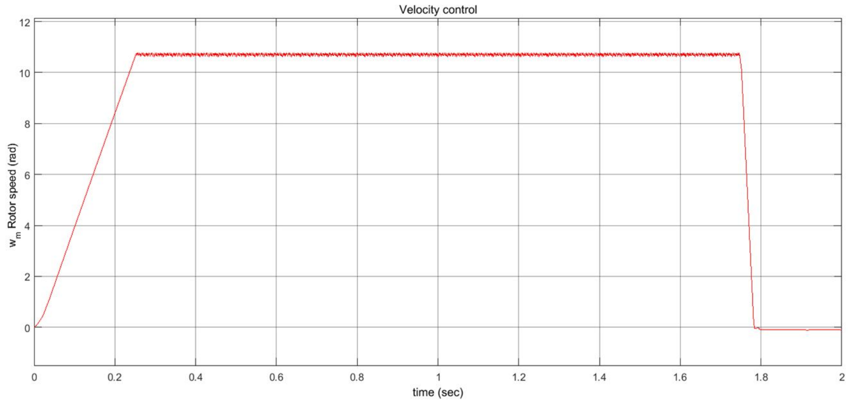

Fig. 18 Velocity Control with ANN based MSSMC for case-3

Case 3: $J_m = J_m B_m = B_m T_l = 7.5$ Nm for position control

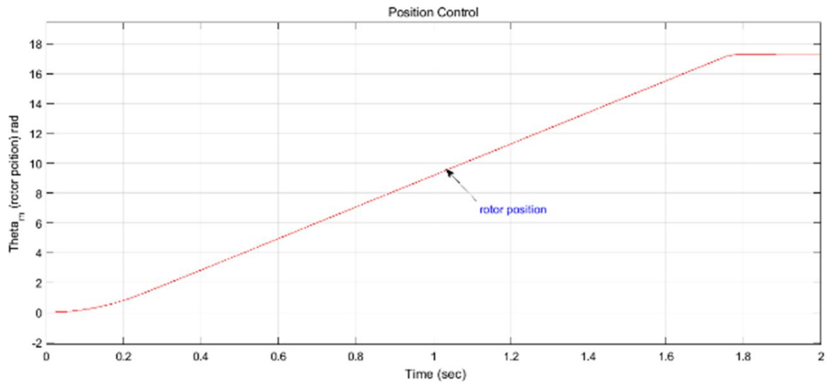

Fig. 19 Position Control with conventional MSSMC for case-3

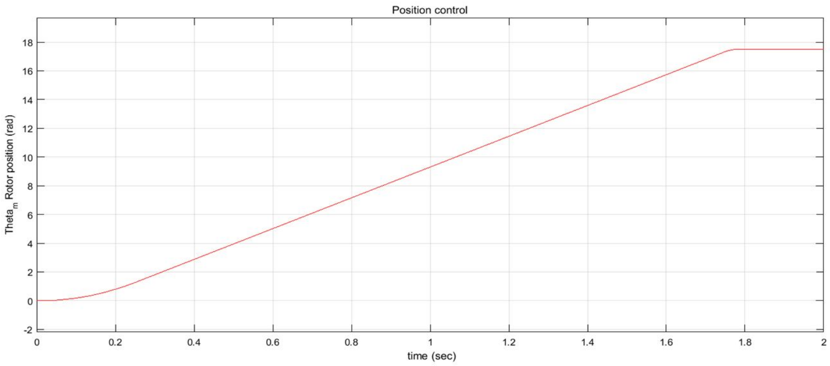

Fig. 20 Position Control with ANN based MSSMC for case-3

Conclusion

Finally, after completion of the work we have studied the incremental motion control of IM in various loading conditions. Our focus is to develop Neural Network based MSSMC for IM and overcome the main problems finding like chattering in conventional MSSMC technique in various loading conditions. It has also shown that the dynamics of the MS-SMC for IM is fully satisfied the desire velocity and acceleration of IM in the velocity control mode of the incremental motion. In this work, designing have been done the simulation of smart controller using ANN based MSSMC with the help of MATLAB. ANN is used for reducing the computation and with help of conventional MSSMC system and it gives fast response than conventional MSSMC. After the simulation of ANN based MSSMC for IM in MATLAB/SIMULINK, study has been presented that ANN based smart controller give the better result (reduced chattering) for MSSMC for IM in various loading conditions.

Appendix

Parameters of Typical Induction Machine
3-phase, 60 Hz, Y connected, 7.5kW, 120V, 54A, 2000rpm
Ls= 0.028H (Stator Inductance)
Lr= 0.028H (Rotor Inductance)
Lm = 0.024 H (Mutual Inductance)
n_p = 4 (No. of poles)
K=0.667 Nm/A
Moment of inertia of motor and load, J_m= 0.0577 Nms^2
Viscous friction coefficient, B_m = 0.0088 Nm s/rad

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