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1) Design Requirements:

$V_A = 50V$, $P = 600W$ @ $1300 rpm$ $(136.13 rad/s)$, $T_{stall} = 1.55\, T_{Dop}$

$T_{fric} = 0.07\, T_{Dop}$

a) $T_{Dop} = \frac{P_{Dop}}{\omega_{Dop}} = \frac{0.600 kW}{1300 rpm}\left(9.5488\right) = 4.40E\text{-}3\ Nm$

$T_{stall} = 1.55\, T_{Dop} = 1.55\left(4.40E\text{-}3\ Nm\right) = 6.82E\text{-}3\ Nm$

$T_{fric} = 0.07\, T_{Dop} = 0.07\left(4.40E\text{-}3 Nm\right) = 308E\text{-}6\ Nm$

b) $T_{fric} = c\,\omega_{Dop} \rightarrow c = \frac{T_{fric}}{\omega_{Dop}} = \frac{308E\text{-}6\ Nm}{136.13\ rad/s} = 2.26E\text{-}6\ \frac{Nms}{rad}$

c) $\omega_{DOP} = \frac{K V_a - R_a T_{Dop}}{c R_a + K^2}$ $\qquad \omega_{stall} = \frac{K V_a - R_a T_{stall}}{c R_a + K^2} = 0$

$\omega_{Dop}\, c R_a + \omega_{Dop} K^2 = K V_a - R_a T_{Dop}$ $\qquad K V_a - R_a T_{stall} = 0$

$\omega_{Dop} K^2 - K V_a + \omega_{Dop}\, c R_a + R_a T_{op} = 0$ $\qquad K V_a - R_a T_{stall} = 0$

$R_a = \frac{K V_a}{T_{stall}}$

$\omega_{Dop} K^2 - K V_a + \left(\omega_{Dop} c + T_{Dop}\right)\frac{K V_a}{T_{stall}} = 0$

$\omega_{Dop} K^2 + K V_a\left(\frac{\omega_{Dop} c \mp T_{Dop}}{T_{stall}} - 1\right) = 0$

$\frac{K}{\omega_{Dop}}\left(K + \frac{V_a}{\omega_{Dop}}\left(\frac{\omega_{Dop} C + T_{Dop}}{T_{stall}} - 1\right)\right) = 0$

$K = 0 , -\frac{V_a}{\omega_{Dop}}\left(\frac{\omega_{Dop} C + T_{Dop}}{T_{stall}} - 1\right)$

$K_T, K_b = \frac{-V_a}{\omega_{Dop}}\left(\frac{\omega_{Dop} C - T_{Dop}}{T_{stall}} - 1\right)$

$R_a = \frac{-V_a^2}{T_{stall}\,\omega_{Dop}}\left(\frac{\omega_{Dop} C - T_{Dop}}{T_{stall}} - 1\right)$

$$K_T = K_b = \frac{-V_a}{\omega_{pop}}\left(\frac{\omega_{pop} c - T_{pop}}{T_{stall}} - 1\right) = -\frac{50V}{136.13\frac{rad}{s}}\left(\frac{(136.13\frac{rad}{s})(2.26E\text{-}6\frac{Nms}{rad}) - (4.4E\text{-}3Nm)}{6.82E\text{-}3\ Nm} - 1\right)$$

$$= 0.5893\ \frac{Nm}{A}$$

$$R_a = \frac{-V_a^2}{T_{stall}\,\omega_{pop}}\left(\frac{\omega_{pop} c - T_{pop}}{T_{stall}} - 1\right)$$

$$= 4.32E3\,\Omega$$

d) $$i_{stall} = \frac{V_a}{R_a} = \frac{50V}{4.32E3\Omega} = 11.57\ mA$$

$$i_{pop} = \frac{cV_a + K_b T_{pop}}{cR_a + K_b K_T} = \frac{(50V)(2.26E\text{-}6\frac{Nms}{rad}) + (0.5893\frac{Nm}{A})(4.4E\text{-}3Nm)}{(2.26E\text{-}6\frac{Nms}{rad})(4.32E3\Omega) + (0.5893\frac{Nm}{A})^2} = 7.58\ mA$$

e) $$\omega_{nL} = \frac{K_T V_a}{cR_a + K_b K_T} = \frac{(0.5893\frac{Nm}{A})(50V)}{(2.26E\text{-}6\frac{Nms}{rad})(4.32E3\Omega) + (0.5893\frac{Nm}{A})^2} = 82.5\ rad/s$$

f) $$\eta = \frac{P_{out}}{P_{in}} = \frac{600W}{(50V)(7.58E\text{-}3A)} = 158$$; (known to be wrong but cannot find computational mistakes)

g) $$\Omega(s) = \frac{V_a(s) K_T}{(R_a I + cL_a)s + cR_a + K_b K_T} \rightarrow \dot{\omega}(R_a I + cL_a) + \omega(cR_a + K_b K_T) = V_a K_T$$

$$\dot{\omega} + \frac{(cR_a + K_b K_T)}{R_a I + cL_a}\omega = V_a K_T \rightarrow \tau = \frac{R_a I + cL_a}{cR_a + K_b K_T}\ ;\ L_a \approx 0$$

$$\tau = \frac{R_a I}{cR_a + K_b K_T} \rightarrow I = \frac{\tau}{R_a}(cR_a + K_b K_T)$$

$$I = \frac{2.475s}{4.32E3\Omega}\left((2.26E\text{-}6\ Nms)(4.32E3\Omega) + (0.5893\frac{Nm}{A})^2\right)$$

$$I = 204.5E\text{-}6\ kg\,m^2$$

2)

a) $L_a I s^2 + (R_a I + cL_a)s + cR_a + K_b K_T = 0$

$240E{-}9 s^2 + (64E{-}6 + 3E{-}3c)s + 0.8c + 25E{-}6 = 0$

b) $c_1 = 0 \quad s_1 = -0.391, \; s_2 = -266.27$

$c_2 = 0.01 \quad s_1 = -125.73, \; s_2 = -265.9$

$c_3 = 0.1 \quad s_1 = -266.7, \; s_2 = -1249.9$

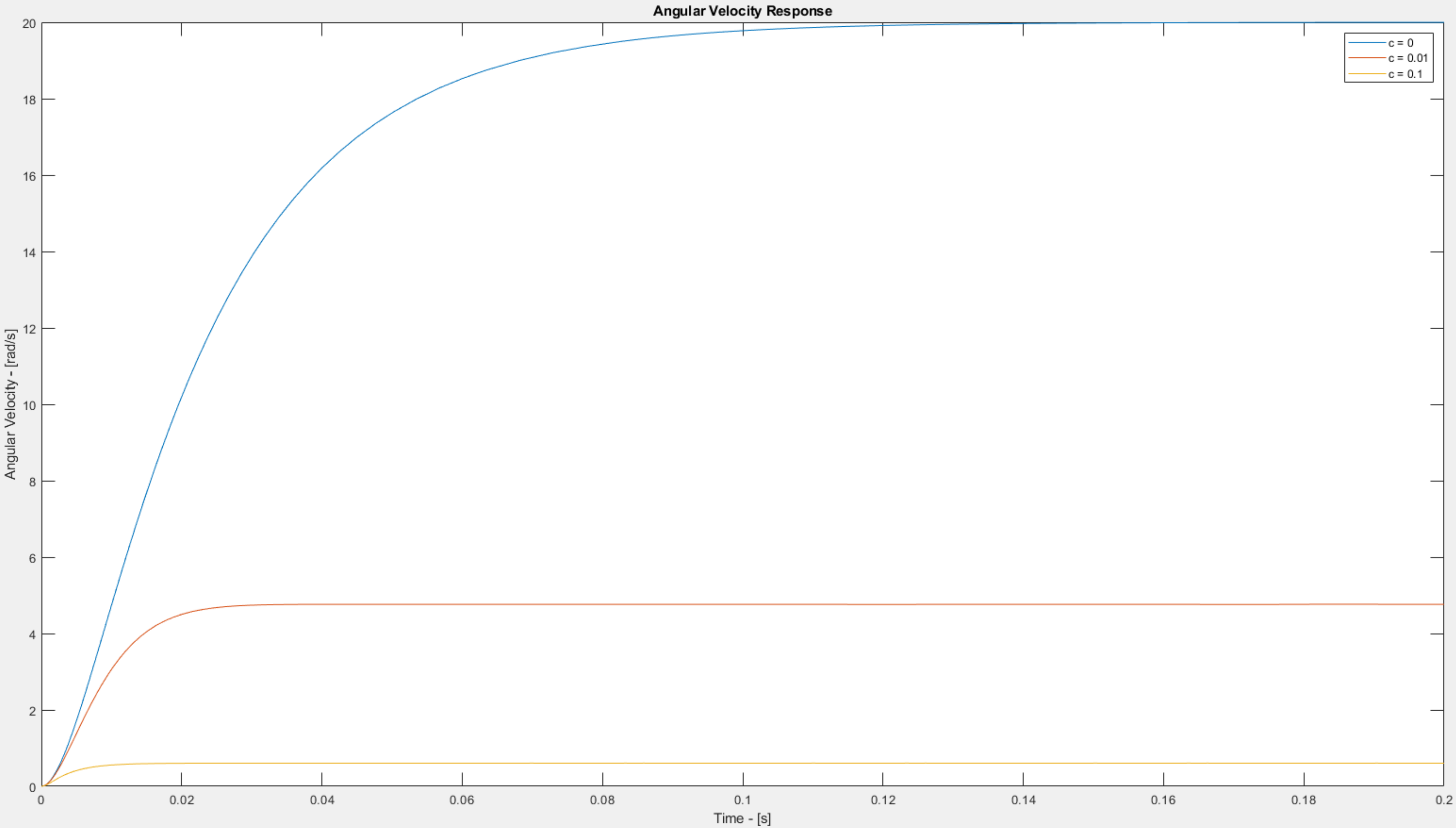
e)

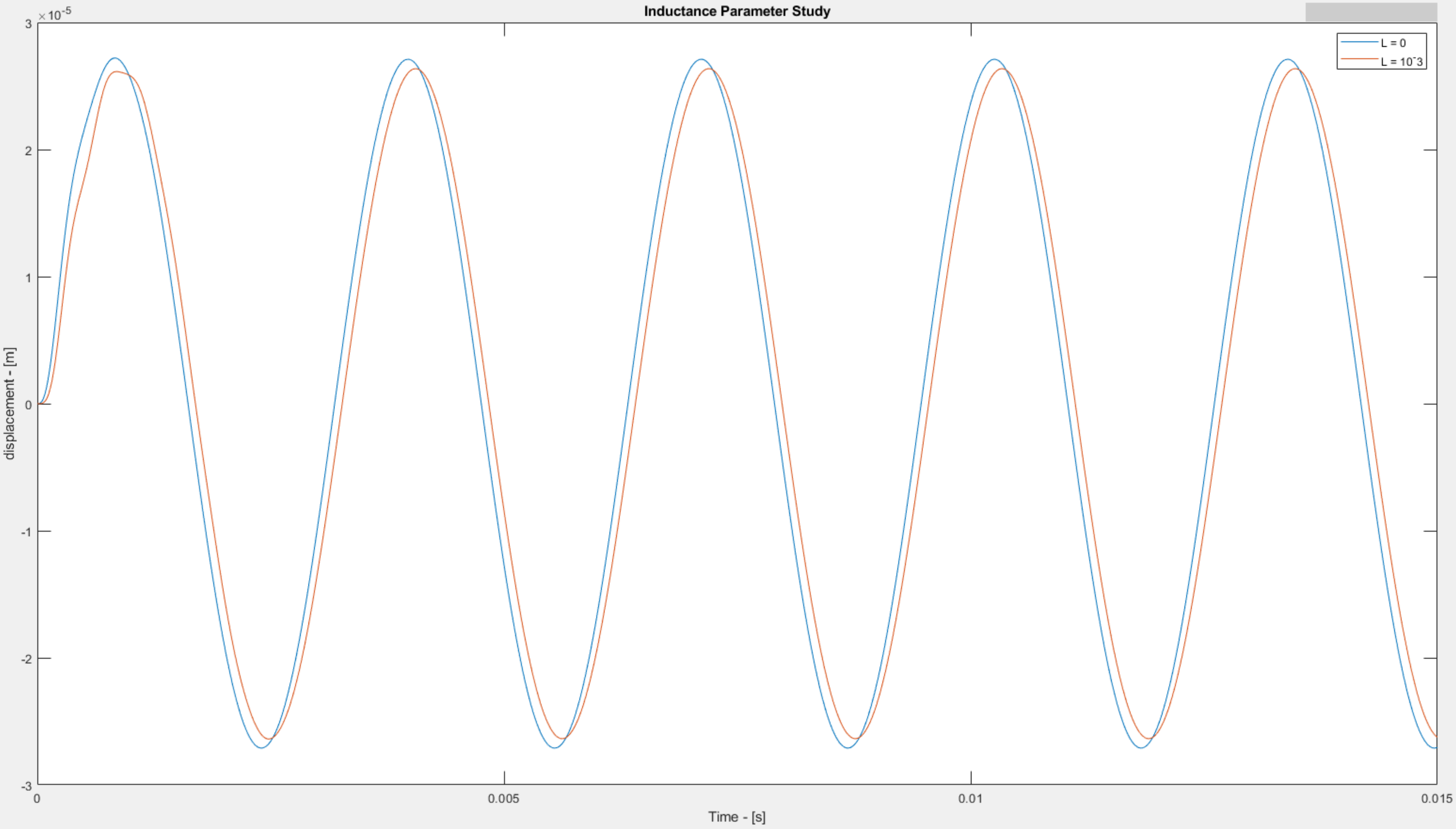
$$\tau = \frac{R_a I + cL_a}{cR_a + K_b K_T}$$

$c_1 = 0$	$\tau = 2.56\,ms$	$t_{ss} = 12.8\,ms$
$c_2 = 0.01$	$\tau = 11.7\,ms$	$t_{ss} = 58.5\,ms$
$c_3 = 0.1$	$\tau = 4.54\,ms$	$t_{ss} = 22.7\,ms$

f)

The ~~m~~simulated models do not fully agree with calculations given that the larger c becomes, the lower tss becomes in the simulation but not the calculations.


Angular Velocity Response
c = 0
c = 0.01
c = 0.1
Angular Velocity - [rad/s]
Time - [s]
0
2
4
6
8
10
12
14
16
18
20
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2



Inductance Parameter Study
× 10^-5
3
2
1
0
-1
-2
-3
displacement - [m]
0
0.005
0.01
0.015
Time - [s]
L = 0
L = 10^-3