"PALLAB GANGULY" # "LE DUC TOAN"

TEAMHOTEL

$M_{mass} := 8830\ kg$ mass of the machine

$V_{TOP} := 6.95\ \frac{m}{s}$ Top Speed

$F_{max} := 32600\ N$ Max Transtion Force

$L_{hoses} := 1.5\ m$ Length of hoses

$R_{wheel} := 0.6\ m$ Radius of wheel

$I_{wheel} := 23.32\ kg \cdot m^2$ Interia wheel $1\ rpm = 0.105\ \frac{1}{s}$

$P_{diesel} := 80000\ W$ Power of diesel engine

$n_p := 33.33\ \frac{1}{s}$ Constant speed

$eff_{vp} := .97$ vol eff of pump

$eff_{vm} := .95$ vol eff of motor

$eff_{hmp} := .96$ hyd mech eff of pump

$eff_{hmm} := .95$ hyd mech eff of motor

$eff_g := .98$ tot eff of gear

$i_g := 15.5$ gear ratio (assumation)

$eff_{tm} := .931$

$\Delta P_{max} := 400\ bar$ max pressure (assumation)

$eff_{tp} := .931$

Hydrostatic transmission power

"Boost Pump"
"LINK 1:https://www.boschrexroth.com/ics/cat/?language=en&id=&cat=Mobile−Hydraulics−
"According to data sheet as in link 1"

$p_{boost} := 22\ bar$ "pressure of boost pump"

$n_{boost} := 2000\ rpm$ “speed of the pump”

$V_{boost} := 32\ \frac{cm^3}{rev}$ “volumetric displacement of the pump”

$$Q_{boost} := V_{boost} \cdot n_{boost} \cdot eff_{vp} = 62.08\ \frac{l}{min}$$

$$P_{boost} := \frac{Q_{boost} \cdot p_{boost}}{eff_{tm}} = 2.445\ kW$$

$$P_{hsm} := P_{diesel} - P_{boost} = \left(7.756 \cdot 10^4\right)\ W$$

CONVERSION RATIO

$$R := \frac{V_{TOP} \cdot F_{max}}{P_{hsm} \cdot eff_g \cdot eff_{tp} \cdot eff_{tm}} = 3.439$$

$$R_m := \sqrt{R} = 1.855$$

$$V_{gp0} := \frac{V_{TOP} \cdot F_{max}}{n_p \cdot \Delta P_{max} \cdot eff_g \cdot eff_{tp} \cdot eff_{tm} \cdot R_m} = 107.882\ cm^3$$

$V_{gp} := 115\ cm^3$

Volumetric Displacement of pump $:= 115$ *(assumed)*

“LINK 1:https://www.boschrexroth.com/ics/cat/?language=en&id=&cat=Mobile–Hydraulics–Catal

$$V_{gm0} := \frac{F_{max} \cdot 2 \cdot \pi \cdot R_{wheel}}{\Delta P_{max} \cdot eff_{hmm} \cdot i_g \cdot eff_g} = 212.916\ cm^3$$

$V_{gm} := 215\ cm^3$

Volumetric Displacment of motor $:= 215$

“LINK 2:https://www.boschrexroth.com/ics/cat/?language=en&id=&cat=Mobile–Hydraulics–Ca

Velocity and Wudqvwlrq#irufh#dw#srlqw#4

$$Q_{p1} := \frac{P_{hsm} \cdot eff_{tp}}{\Delta P_{max}} = 0.002\ \frac{m^3}{s}$$

$$V_{gp1} := \frac{Q_{p1}}{n_p \cdot eff_{vp}} = 55.833\ cm^3$$

$$T_{m1} := \frac{V_{gm} \cdot \Delta P_{max} \cdot eff_{hmm}}{2 \cdot \pi} = \left(1.3 \cdot 10^{3}\right) \, N \cdot m$$

$$n_{m1} := \frac{Q_{p1} \cdot eff_{vm}}{V_{gm}} = 7.976 \, \frac{1}{s}$$

$$p_1 := \frac{P_{hsm} \cdot eff_{tp}}{Q_{p1}} = 400 \, bar$$

$$F_1 := \frac{T_{m1} \cdot i_g \cdot eff_g}{R_{wheel}} = 32.919 \, kN$$

$$v_1 := \frac{2 \cdot \pi \cdot n_{m1} \cdot R_{wheel}}{i_g} = 6.984 \, \frac{km}{hr}$$

$F_1 \cdot v_1 = 63.861 \, kW$ “Power at point 1”

Velocity and Transtion force at point2

$$Q_{p2} := V_{gp} \cdot n_p \cdot eff_{vp} = 0.004 \, \frac{m^3}{s}$$

$$p_2 := \frac{P_{hsm} \cdot eff_{tp}}{Q_{p2}} = 194.202 \, bar$$

$$n_{mmax} := \frac{V_{TOP} \cdot i_g}{R_{wheel} \cdot \pi \cdot 2} = 28.575 \, \frac{1}{s}$$

$$V_{gm1} := \frac{Q_{p2} \cdot eff_{vm}}{n_{mmax}} = 123.607 \, cm^3$$

$$T_{m2} := \frac{V_{gm1} \cdot p_2 \cdot eff_{hmm}}{2 \cdot \pi} = 362.946 \, J$$

$$F_2 := \frac{T_{m2} \cdot i_g \cdot eff_g}{R_{wheel}} = 9.189 \, kN$$

$$n_{p2} := 12566.3706 \, \frac{rad}{s}$$

$$v_2 := \frac{2 \cdot \pi \cdot n_{mmax} \cdot R_{wheel}}{i_g} = 25.02 \, \frac{km}{hr} \quad (same)$$

$F_2 \cdot v_2 = 63.861 \, kW$ “power at point 2”

$DYNAMIC \quad CHARACTERISTC \quad OF \quad HST$

$D_{m1} displacement \quad volume \quad of \quad motor$

$$D_{m1} := \frac{V_{gm}}{2 \cdot \pi} = \left(3.422 \cdot 10^{-5}\right) \, m^3$$

$C_t leakage \quad coefficient \quad of \quad HST$

$$C_{t0} := eff_{vp} \cdot \left(1 - eff_{vm}\right) \cdot n_p \cdot V_{gp1} + \left(1 - eff_{vp}\right) \cdot n_p \cdot V_{gp1} = \left(1.461 \cdot 10^{-4}\right) \frac{m^3}{s}$$

$$C_t := \frac{C_{t0}}{\Delta P_{max}} = \left(3.652 \cdot 10^{-12}\right) \frac{m^4 \cdot s}{kg}$$

$$B_e := 400 \; MPa$$

$V_1 \quad dead \quad volume \quad under \quad pressure \quad between \quad pump \& motor \; (assumed)$

$Corner \quad Power$

$$P_{cp} := V_{TOP} \cdot F_1 = 228.788 \; kW$$

$$v := \left(0 \frac{m}{s}, 0.2 \frac{m}{s} .. 6 \frac{m}{s}\right) = \begin{bmatrix} 0 \\ 0.2 \\ 0.4 \\ 0.6 \\ 0.8 \\ 1 \\ 1.2 \\ 1.4 \\ 1.6 \\ 1.8 \\ 2 \\ 2.2 \\ \vdots \end{bmatrix} \frac{m}{s}$$

$$v_{ao} := v + 1.5 \frac{m}{s}$$

$$F(v) := \frac{Q_{p2} \cdot eff_{vm} \cdot p_2 \cdot eff_{hmm} \cdot eff_g}{v_{ao}} = \begin{bmatrix} 4.257 \cdot 10^4 \\ 3.757 \cdot 10^4 \\ 3.361 \cdot 10^4 \\ 3.041 \cdot 10^4 \\ 2.777 \cdot 10^4 \\ 2.554 \cdot 10^4 \\ 2.365 \cdot 10^4 \\ 2.202 \cdot 10^4 \\ 2.06 \cdot 10^4 \\ 1.935 \cdot 10^4 \\ 1.825 \cdot 10^4 \\ 1.726 \cdot 10^4 \\ \vdots \end{bmatrix} N$$

"Reynolds number/hoses, laminar flow"

$$v_n := 100 \frac{mm^2}{s} = \left(1 \cdot 10^{-4}\right) \frac{m^2}{s}$$ "kinematic oil viscocity at temperature 15°℃"

$R_e := 2450$

"oil density at 15°℃"

$$\rho_n := 0.876 \frac{kg}{L} = 876 \frac{kg}{m^3}$$

"LINK 3:http://www.hydroscand.co.uk/storage/ma/a3e942dd69f04b0c8f47c5e13db78355/3faa6b28

"Dynamic viscocity"

$$\mu_n := v_n \cdot \rho_n = 0.088 \frac{kg}{m \cdot s}$$

$$A_n := \frac{R_e \cdot \mu_n}{\rho_n} = 0.245 \frac{m^2}{s}$$

$$Q_{max} := .004 \frac{m^3}{s}$$

$$v_{ao} := \frac{{A_n}^2 \cdot \pi}{Q_{max} \cdot 4} = 11.786 \frac{m}{s}$$

$$A := \left(\frac{A_n}{2 \cdot v_{ao}}\right)^2 \cdot \pi = \left(3.394 \cdot 10^{-4}\right) m^2$$

$$D_{hoses1} := \frac{A_n}{v_{ao}} = 0.021 \ m$$

$LINK3$ "http://www.gates.com/~/media/files/gates/industrial/

$D_{hoses} := 0.0254 \ m$ "from link 3"

$$V_1 := \frac{\pi}{4} \cdot D_{hoses}{}^2 \cdot L_{hoses} = \left(7.601 \cdot 10^{-4}\right)\ m^3$$

J_L *Moment of Interia*

$$J_L := M_{mass} \cdot R_{wheel}{}^2 = \left(3.179 \cdot 10^3\right)\ kg \cdot m^2$$

$$J_{red} := \frac{J_L}{i_g{}^2} = 13.231\ kg \cdot m^2$$

B_t *veloocity dependent dynamic damping*

$$\omega_1 := \frac{v_2}{R_{wheel}} = 11.583\ \frac{1}{s}$$

$$B_t := \frac{0.5 \cdot T_{m2}}{\omega_1 \cdot i_g} = 1.011\ \frac{N \cdot m \cdot s}{rad}$$

C_1 *Hydraulic Capacitance of dead volume*

$$C_1 := \frac{V_1}{B_e} = \left(1.9 \cdot 10^{-12}\right)\ \frac{m^3}{Pa}$$

$$\omega_h := \sqrt[2]{\frac{D_{m1}{}^2 \cdot i_g{}^2 + C_t \cdot B_t}{J_L \cdot C_1}} = 6.824\ \frac{rad}{s}$$

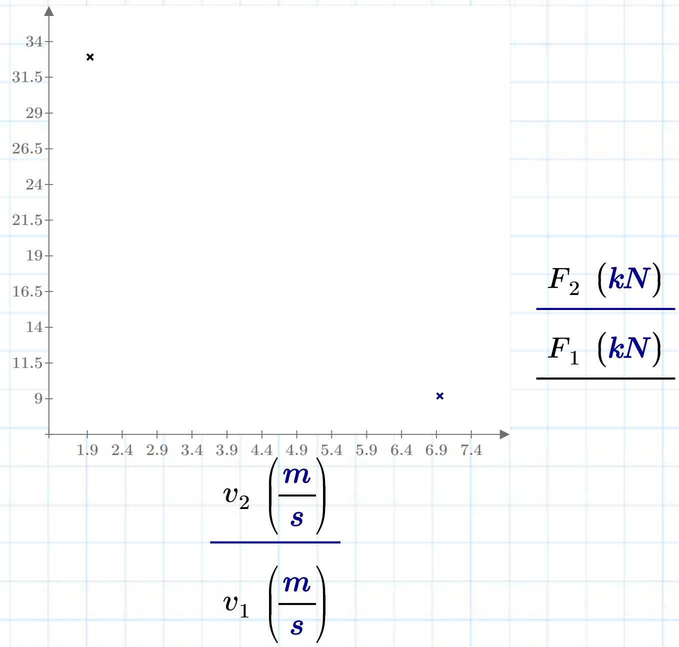
$$\delta_g := \frac{C_t}{2} \cdot \sqrt[2]{\frac{J_L}{C_1 \cdot \left(D_{m1}{}^2 \cdot i_g{}^2 + C_t \cdot B_t\right)}} + \frac{B_t}{2} \cdot \sqrt[2]{\frac{C_1}{J_L \cdot \left(D_{m1}{}^2 \cdot i_g{}^2 + C_t \cdot B_t\right)}} = 0.141$$

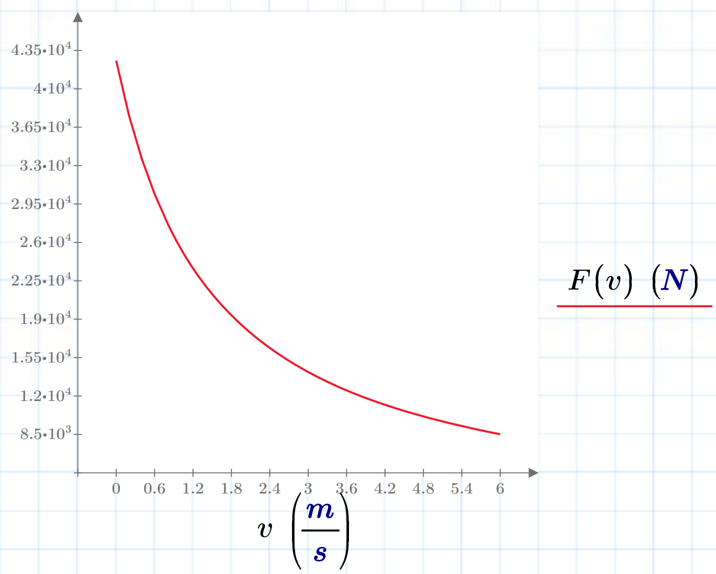
“natural frequency obtained from simulation”

$$T_1 := 26.62\ s - 25.7\ s = 0.92\ s$$

$$f_{sim} := \frac{1}{T_1} = 1.087\ \frac{1}{s}$$

$$f_{sim1} := 2 \cdot \pi \cdot f_{sim} = 6.83\ \frac{rad}{s}$$





"Heat Exchanger of the machine"

$$Q_{leakagep\&m} := C_{t0} = \left(1.461 \cdot 10^{-4}\right) \frac{m^3}{s}$$

$$P_{leak} := Q_{leakagep\&m} \cdot \Delta P_{max} = \left(5.843 \cdot 10^{3}\right) W$$

$T_{oil} := 50\ °C$ $\quad T_{ambient} := 10\ °C$ $\quad \Delta T := T_{oil} - T_{ambient} = 40\ K$

$$C_{heat} := \frac{P_{leak}}{\Delta T} = 146.082\ \frac{W}{K}$$

"Link4:https://www.hydac.com/de−en/products/heat−exchangers−coolers/show/Download

"HEAT EXCHANGER" "OK−ELH 3"

"ENGINE BRAKING "

$\varepsilon_m := 1$

$$P_{braking} := 0.1 \cdot P_{hsm} = \left(7.756 \cdot 10^{3}\right) W$$

$$P_{valve} := P_{hsm} - P_{braking} = \left(6.98 \cdot 10^{4}\right) W$$

"Force exerted by the car in downhill"

$$F_{car} := M_{mass} \cdot g \cdot \sin(7) = 56.89\ kN$$

$$T_{wheel} := F_{car} \cdot R_{wheel} = \left(3.413 \cdot 10^{4}\right) J$$ "Torque at the wheel"

$$T_{motor} := \frac{T_{wheel}}{i_g} = \left(2.202 \cdot 10^{3}\right) J$$ "Torque at the motor"

$$\Delta P_{motor} := \frac{T_{motor} \cdot 2 \cdot \pi}{V_{gm} \cdot \varepsilon_m} = 643.575\ bar$$

"The power lost in the Hydraulic pump is 10% of the Hydrostatic power"