Perturbation de période due au poids du spiral

Spiral cylindrique dextre sans courbes terminales

Exemple numérique

$n_{sp} := 12 \qquad \psi := 2\cdot\pi\cdot n_{sp} \qquad \theta_0 := 270deg$

$R := 5\cdot mm \qquad L := R\cdot\psi \qquad T_0 := 0.4\cdot s \qquad \omega_0 := \frac{2\cdot\pi}{T_0} \qquad t := \frac{T_0}{8} \qquad \theta_0\cdot\frac{R}{L} = 0.063$

Balancier $\qquad M_b := 657\cdot mg \qquad J_b := 550\cdot mg\cdot cm^2$

Spiral acier $\qquad \rho_{ac} := 7.8\cdot 10^3\cdot kg\cdot m^{-3} \qquad E_{ac} := 21\cdot 10^4\cdot N\cdot mm^{-2}$

$C := \omega_0^{\,2}\cdot J_b \qquad I_s := \frac{C\cdot L}{E_{ac}} \qquad h_s := 0.8\cdot mm \qquad e_s := \sqrt[3]{\frac{12\cdot I_s}{h_s}} \qquad e_s = 0.071\,mm$

Masse spiral $\qquad m_s := \rho_{ac}\cdot e_s\cdot h_s\cdot L \qquad m_s = 168.184\,mg$

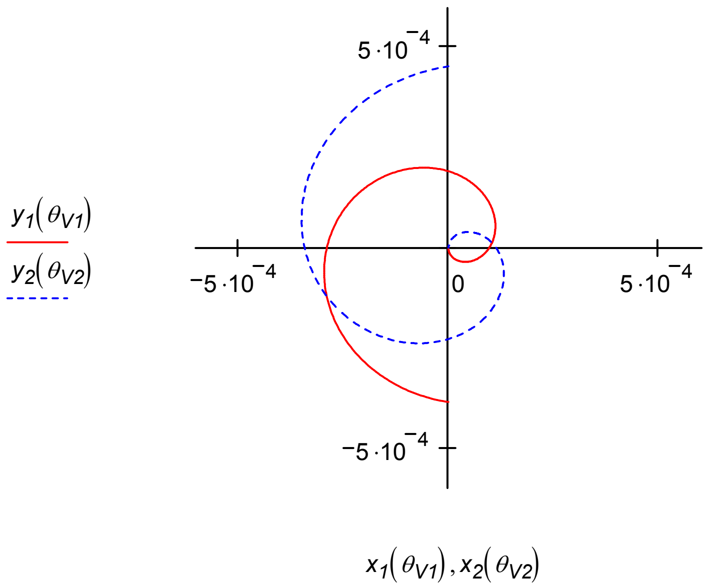
Point d'attache à la virole verticalement sous l'axe de balancier

Déplacement du centre de gravité du spiral (approximation)

contraction $\qquad b_1 := \frac{1}{2\cdot\pi}\cdot\frac{1}{n_{sp}+1}\cdot R \qquad \zeta_1(\theta) := b_1\cdot\theta \qquad x_1(\theta) := \zeta_1(\theta)\cdot sin(\theta) \qquad y_1(\theta) := -\zeta_1(\theta)\cdot cos(\theta)$

expansion $\qquad b_2 := \frac{1}{2\cdot\pi}\cdot\frac{1}{n_{sp}-1}\cdot R \qquad \zeta_2(\theta) := b_2\cdot\theta \qquad x_2(\theta) := \zeta_2(\theta)\cdot sin(\theta) \qquad y_2(\theta) := -\zeta_2(\theta)\cdot cos(\theta)$

$\theta_{V1} := 0\cdot deg, 1\cdot deg .. 360\cdot deg \qquad \theta_{V2} := -360\cdot deg, -359\cdot deg .. 0\cdot deg$



$\Gamma_1(\theta) := -m_s\cdot g\cdot b_1\cdot\theta\cdot sin(\theta)$

$\Gamma_2(\theta) := -m_s\cdot g\cdot b_2\cdot\theta\cdot sin(\theta)$

$\theta(\varphi) := \theta_0\cdot sin(\varphi)$

$A_1 := \frac{m_s\cdot g\cdot b_1}{C} \qquad A_2 := \frac{m_s\cdot g\cdot b_2}{C}$

$I_1(\theta_0) := \frac{1}{\pi}\cdot\int_0^{\pi} sin(\theta_0\cdot sin(\varphi))\cdot sin(\varphi)^2\,d\varphi \qquad \delta_B(\theta_0) := \frac{A_2 - A_1}{2}\cdot I_1(\theta_0)$

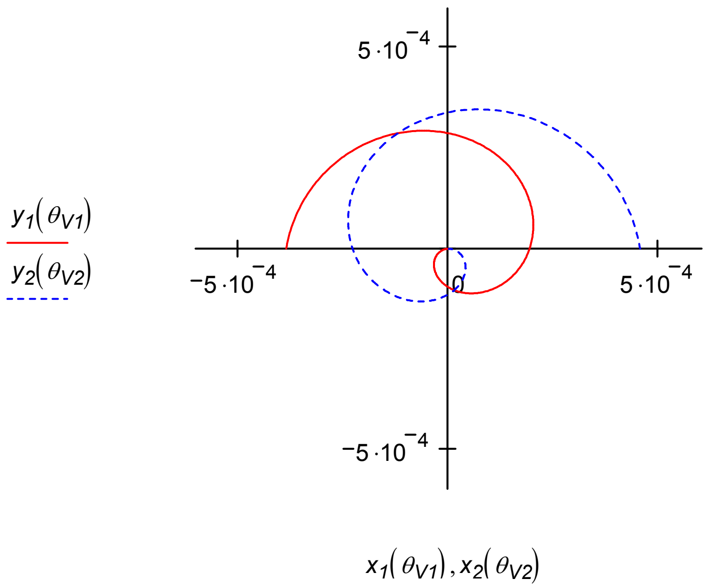
$\mu_B(\theta_0) := -86400\cdot\delta_B(\theta_0)$

Point d'attache à la virole horizontalement à gauche de l'axe de balancier

Déplacement du centre de gravité du spiral (approximation)

contraction $b_1 := \frac{1}{2\cdot\pi}\cdot\frac{1}{n_{sp}+1}\cdot R \quad \zeta_1(\theta) := b_1\cdot\theta \quad x_1(\theta) := -\zeta_1(\theta)\cdot\cos(\theta) \quad y_1(\theta) := -\zeta_1(\theta)\cdot\sin(\theta)$

expansion $b_2 := \frac{1}{2\cdot\pi}\cdot\frac{1}{n_{sp}-1}\cdot R \quad \zeta_2(\theta) := b_2\cdot\theta \quad x_2(\theta) := -\zeta_2(\theta)\cdot\cos(\theta) \quad y_2(\theta) := -\zeta_2(\theta)\cdot\sin(\theta)$



$\Gamma_1(\theta) := m_s\cdot g\cdot b_1\cdot\theta\cdot\cos(\theta)$

$\Gamma_2(\theta) := m_s\cdot g\cdot b_2\cdot\theta\cdot\cos(\theta)$

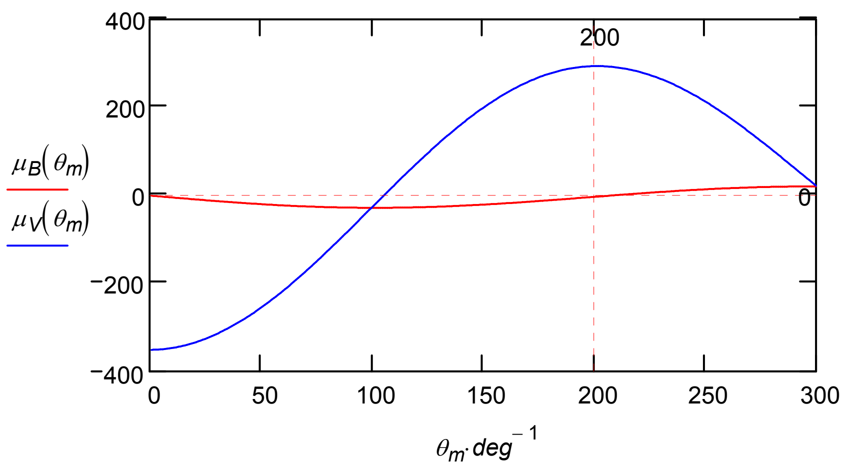
$\theta(\varphi) := \theta_0\cdot\sin(\varphi)$

$A_1 := \frac{m_s\cdot g\cdot b_1}{C} \qquad A_2 := \frac{m_s\cdot g\cdot b_2}{C}$

$I_2(\theta_0) := \frac{1}{\pi}\cdot\int_0^{\pi}\cos(\theta_0\cdot\sin(\varphi))\cdot\sin(\varphi)^2\,d\varphi \qquad \delta_V(\theta_0) := \frac{A_2+A_1}{2}\cdot I_2(\theta_0)$

$\mu_V(\theta_0) := -86400\cdot\delta_V(\theta_0) \qquad I_2(220\cdot deg) = -0.402$

$\theta_m := 1\cdot deg, 2\cdot deg .. 300\cdot deg$



$I'_2(x) := \frac{d}{dx}I_2(x) \qquad x := 200\cdot deg \qquad racine(I'_2(x), x) = 201.585\,deg$