Théorie des goupilles de raquette

Théorie avancée des goupilles de raquette

Perturbation de marche due à une goupille flexible

Caractéristiques du spiral avec une spire externe semi-circulaire

Référence :E:\Résonateur (TA)\Data\Bal_spiral plat (ex num).mcd(R)

Dimensions $\acute{e}p = 0.03\,mm$ $ha = 0.15\,mm$ $S = 4.5 \times 10^{-3}\,mm^2$

$d2_{sp} = 4.52\,mm$ $d1_{sp} = 1.1\,mm$ $p_{sp} = 0.135\,mm$ $n_{sp} = 12.667$

$L_{sp} = 11.182\,cm$ $\psi_0 := 2\cdot\pi\cdot n_{sp}$ $\psi_0 = 4.56 \times 10^3\,deg$ $E = 2.093 \times 10^{11}\,m^{-2}N$

Position du piton $r_P := 0.5\cdot d_{piton}$ $\alpha_P := 0$ $x_P := r_P\cdot cos(\alpha_P)$ $y_P := r_P\cdot sin(\alpha_P)$

$x_P = 2.55\,mm$ $y_P = 0\,mm$ $z_P := x_P + i\cdot y_P$

Position du point d'attache à la virole $r_V := 0.5\cdot d1_{sp}$ $\alpha_V(\theta) := \psi_0 + \theta$ $x_V(\theta) := r_V\cdot cos(\alpha_V(\theta))$ $y_V(\theta) := r_V\cdot sin(\alpha_V(\theta))$

Position du point de raccordement sur le spiral $\alpha_A := 180\cdot deg$ $r_A := 0.5\cdot d2_{sp}$ $z_A := r_A\cdot e^{i\cdot\alpha_A}$

Spire externe formée d'un demi-cercle $R_0 := r_P$ $x_{0t}(\alpha_t) := R_0\cdot cos(\alpha_t)$ $y_{0t}(\alpha_t) := R_0\cdot sin(\alpha_t)$ $z_{0t}(\alpha_t) := R_0\cdot e^{i\cdot\alpha_t}$

$s_t(\alpha_t) := R_0\cdot\alpha_t$ $l_t := s_t(\alpha_A)$ $l_t = 8.011\,mm$

Forme initiale du spiral

$a := \dfrac{p_{sp}}{2\cdot\pi}$ $r_s(\alpha) := r_A - a\cdot(\alpha - \alpha_A)$ $x_{0s}(\alpha) := r_s(\alpha)\cdot cos(\alpha)$ $y_{0s}(\alpha) := r_s(\alpha)\cdot sin(\alpha)$

$s_s(\alpha) := \dfrac{1}{2\cdot a}\cdot\left(r_A^{\,2} - r_s(\alpha)^2\right)$ $s_s(\alpha) := r_A\cdot(\alpha - \alpha_A) - \dfrac{a}{2}\cdot(\alpha - \alpha_A)^2$ $L_t := s_s(\psi_0 + \alpha_A) + l_t$

$L_t = 11.983\,cm$

Position angulaire des goupilles par rapport au piton:

$\varepsilon := 0.06$ $s_g := \varepsilon\cdot L_t$ $s_g = 7.19\,mm$ $\alpha_g := \dfrac{s_g}{R_0}$ $\alpha_g = 161.548\,deg$

Amplitude stationnaire du balancier $\theta_0 = 270\,deg$

Elongations de contact spiral - goupille $\theta_1 := 20\cdot deg$

Raideur de la goupille

Référence :E:\Résonateur (TA)\Data\Masse_vol - Coef_th - Mod_E.mcd(R)

$E_g := E_{laiton}$ $E_g = 1 \times 10^5\,N\cdot mm^{-2}$ $d_g := 0.1\cdot mm$ $l_g(\lambda) := \lambda\cdot d_g$

$k(\lambda) := \dfrac{3\cdot\pi\cdot E_g\cdot d_g}{64\cdot\lambda^3}$ $k(100) = 1.473\,m^{-1}\,N$ $\kappa(\lambda) := \dfrac{E\cdot I_s}{k(\lambda)\cdot R_0^{\,3}}$

Calcul du facteur $\mathcal{F}$

$x_{0g}(\alpha_g) := R_0 \cdot cos(\alpha_g)$ $\quad y_{0g}(\alpha_g) := R_0 \cdot sin(\alpha_g)$ $\quad x_g := x_{0g}(\alpha_g) \cdot m^{-1}$ $\quad y_g := y_{0g}(\alpha_g) \cdot m^{-1}$

$$\xi_{0g}(\alpha_g) := \frac{R_0}{\alpha_g} \cdot sin(\alpha_g) \qquad \eta_{0g}(\alpha_g) := \frac{R_0}{\alpha_g} \cdot (1 - cos(\alpha_g))$$

$$\Delta_g(\alpha_g) := \frac{R_0^{\,4}}{4 \cdot \alpha_g^{\,3}} \cdot (\alpha_g - sin(\alpha_g)) \cdot \left[\alpha_g \cdot (\alpha_g + sin(\alpha_g)) - 4 \cdot (1 - cos(\alpha_g))\right] \qquad \Delta_g(\alpha_g) = 1.237\, mm^4$$

$$W_{c2}(\alpha_g) := \frac{E \cdot I_s \cdot R_0^{\,3}}{8 \cdot \Delta_g(\alpha_g) \cdot \alpha_g^{\,3}} \cdot \left[3 \cdot \alpha_g^{\,2} - 2 \cdot \alpha_g \cdot sin(\alpha_g) \cdot (2 + cos(\alpha_g)) - (1 - cos(\alpha_g)) \cdot (1 - 7 \cdot cos(\alpha_g))\right]$$

$$\mathcal{N}(\alpha_g) := \frac{E \cdot I_s}{2 \cdot R_0 \cdot \alpha_g \cdot W_{c2}(\alpha_g)} \qquad \mathcal{N}(\alpha_g) = 0.131$$

$$a(\alpha_g) := \frac{4 \cdot \mathcal{N}(\alpha_g)}{\mathcal{N}(\alpha_g) - 1} \cdot \left[\frac{\alpha_g^{\,2} - 2 \cdot \alpha_g \cdot sin(\alpha_g) + 2 \cdot (1 - cos(\alpha_g))}{(\alpha_g - sin(\alpha_g)) \cdot \left[\alpha_g \cdot (\alpha_g + sin(\alpha_g)) - 4 \cdot (1 - cos(\alpha_g))\right]}\right]$$

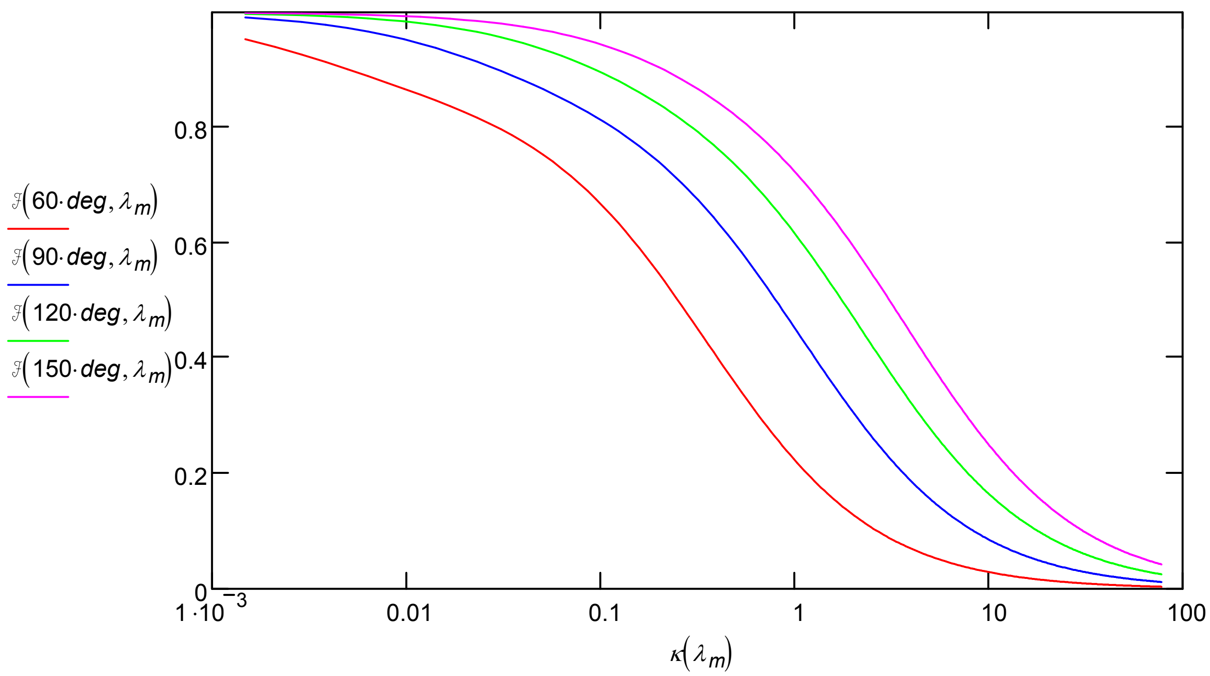
$$b(\alpha_g) := \frac{8 \cdot \alpha_g \cdot \mathcal{N}(\alpha_g)}{\alpha_g \cdot (\alpha_g + sin(\alpha_g)) - 4 \cdot (1 - cos(\alpha_g))}$$

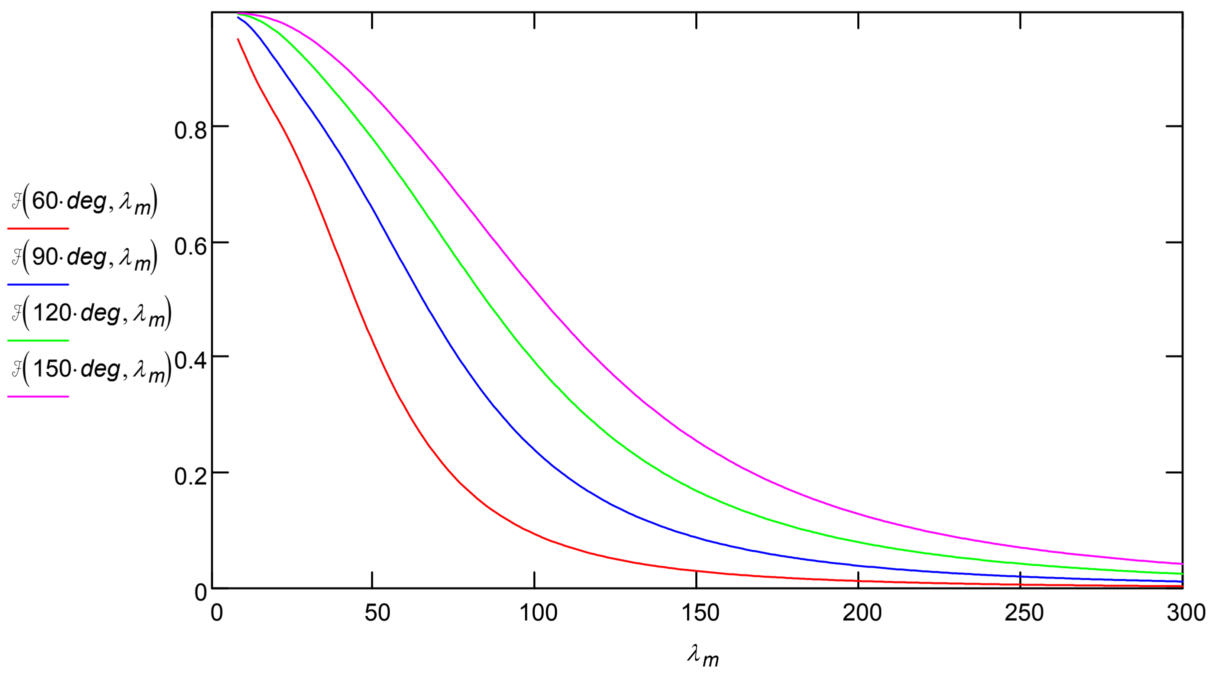
$$c(\alpha_g) := \frac{4 \cdot \alpha_g \cdot \mathcal{N}(\alpha_g)}{(\alpha_g - sin(\alpha_g)) \cdot \left[\alpha_g \cdot (\alpha_g + sin(\alpha_g)) - 4 \cdot (1 - cos(\alpha_g))\right]}$$

$$\mathcal{F}(\alpha_g, \lambda) := \frac{1 - \kappa(\lambda) \cdot a(\alpha_g)}{1 + \kappa(\lambda) \cdot b(\alpha_g) + \kappa(\lambda)^2 \cdot c(\alpha_g)} \qquad \mathcal{F}(\alpha_g, 100) = 0.555$$

Facteur de modification de la perturbation de marche dans le cas d'une goupille flexible

$\lambda_m := 8, 9 .. 300$




$\mathcal{F}(60\cdot deg, \lambda_m)$
$\mathcal{F}(90\cdot deg, \lambda_m)$
$\mathcal{F}(120\cdot deg, \lambda_m)$
$\mathcal{F}(150\cdot deg, \lambda_m)$
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
λ_m