Echappement à ancre suisse à repos équidistants

Impulsion d'entrée - Rapports de transmission roue - ancre

Calibre 11 1/2''' - seconde au centre - automatique - balancier à vis

Référence :E:\Résonateur (TA)\Data\Calibre ASCBV.mcd(R)

$T_0 = 0.4\ s$ $\quad f = 2.5\ s^{-1}$ $\quad \omega_0 := 2\cdot\pi\cdot f$ $\quad J_b = 20\,mg\cdot cm^2$ $\quad \theta_0 = 270\,deg$

Coordonnée généralisée $\quad \psi$ = angle parcouru par l'ancre à partir de sa position de repos

Assortiment

Distance des centres balancier - ancre $\quad b = 3.4\,mm$

Distance des centres ancre - roue d'échappement $\quad a = 3.15\,mm$

Diamètre de la cheville $\quad d_{cheville} = 0.4\,mm$

Distance axe de balancier - centre de courbure de la cheville $\quad \rho_3 = 0.71\,mm$

Coordonnées du point de contact C du bec de dent contre le plan de repos de la palette en **fin de dégagement**

$\alpha_0 = 30\,deg$ $\quad \gamma_0 := \frac{\pi}{2} - \alpha_0$ $\quad R_1 := a\cdot cos(\alpha_0)$ $\quad R_1 = 2.728\,mm$ $\quad R_2 := R_1\cdot tan(\alpha_0)$ $\quad R_2 = 1.575\,mm$

Coefficient de frottement dent - palette $\quad \phi := 8\cdot deg$ $\quad f_c := tan(\phi)$ $\quad f_c = 0.141$

Angles parcourus par l'ancre

Angle de levée total de l'ancre $\quad \lambda_a = 12\,deg$

Angles de repos $\quad \varepsilon = 2.5\,deg$

Angles d'impulsion partagée $\quad \Delta\psi_{ep} = 6\,deg$ $\quad \Delta\psi_{ed} = 3\,deg$ $\quad \Delta\psi_{ie} = 9\,deg$

Déplacement de l'ancre lors de l'impulsion $\quad \varepsilon = 2.5\,deg$ $\quad \varepsilon + \Delta\psi_{ie} = 11.5\,deg$

Angles parcourus par la roue d'échappement

Angles d'impulsion partagée $\quad \Delta\alpha_p = 6.5\,deg$ $\quad \Delta\alpha_d = 4\,deg$ $\quad \Delta\alpha_p + \Delta\alpha_d = 10.5\,deg$

Angle de chute $\quad \Delta\alpha_{ch} = 1.5\,deg$

Dimensions dent et palette d'entrée

Rayon du bec de dent $\quad R_d := a\cdot cos(\alpha_0)$ $\quad R_d = 2.728\times 10^{-3}\ m$

Rayons des becs de palettes $\quad R_A := R_d\cdot tan(\alpha_0)$ $\quad R_A = 1.575\times 10^{-3}\ m$

$$\gamma' := arctan\left(\frac{R_d\cdot sin(\alpha_0 - \Delta\alpha_p)}{a - R_d\cdot cos(\alpha_0 - \Delta\alpha_p)}\right) \qquad \gamma' = 59.207\,deg \qquad R_B := \frac{R_d\cdot sin(\alpha_0 - \Delta\alpha_p)}{sin(\gamma')} \qquad R_B = 1.266\,mm$$

Rayon des talons de la dent = rayon externe de la roue

$$\alpha' := arctan\left(\frac{R_B\cdot sin(\gamma' + \Delta\psi_{ed})}{a - R_B\cdot cos(\gamma' + \Delta\psi_{ed})}\right) \qquad \alpha' = 23.637\,deg \qquad R_{ext} := \frac{R_B\cdot sin(\gamma' + \Delta\psi_{ed})}{sin(\alpha')} \qquad R_{ext} = 2.794\,mm$$

Transmission par le bec de dent sur le plan d'impulsion de la palette

Valeur de contrôle

Plan d'impulsion de la palette d'entrée

$R_1 := R_d \qquad \psi_m := \varepsilon + 0.5\cdot\Delta\psi_{ep} \qquad \psi_m = 5.5\,deg$

$$\mathbf{r_A}(\psi) := \begin{pmatrix} -R_A\cdot\sin(\gamma_0 + \psi - \varepsilon) \\ a - R_A\cdot\cos(\gamma_0 + \psi - \varepsilon) \\ 0 \end{pmatrix} \qquad \mathbf{r_B}(\psi) := \begin{pmatrix} -R_B\cdot\sin(\gamma' - \Delta\psi_{ep} + \psi - \varepsilon) \\ a - R_B\cdot\cos(\gamma' - \Delta\psi_{ep} + \psi - \varepsilon) \\ 0 \end{pmatrix} \qquad \mathbf{r_A}(\psi_m) = \begin{pmatrix} -1.403 \\ 2.435 \\ 0 \end{pmatrix} mm$$

$$\mathbf{r_B}(\psi_m) = \begin{pmatrix} -1.052 \\ 2.446 \\ 0 \end{pmatrix} mm \qquad m_{BA}(\psi) := \frac{\mathbf{r_A}(\psi)_1 - \mathbf{r_B}(\psi)_1}{\mathbf{r_A}(\psi)_0 - \mathbf{r_B}(\psi)_0} \qquad h_{BA}(\psi) := \mathbf{r_A}(\psi)_1 - m_{BA}(\psi)\cdot\mathbf{r_A}(\psi)_0$$

$\beta_{BA}(\psi) := -0.5\cdot\pi - \arctan(m_{BA}(\varepsilon)) + \psi - \varepsilon \quad \beta_{BA}(\psi_m) = -91.749\,deg \qquad h_{BA}(\psi_m) = 2.478\,mm$

$$x_C(\psi) := \frac{-m_{BA}(\psi)\cdot h_{BA}(\psi) - \sqrt{(m_{BA}(\psi)\cdot h_{BA}(\psi))^2 + (m_{BA}(\psi)^2 + 1)\cdot(R_d^{\,2} - h_{BA}(\psi)^2)}}{m_{BA}(\psi)^2 + 1}$$

$y_C(\psi) := m_{BA}(\psi)\cdot x_C(\psi) + h_{BA}(\psi)$ Contrôle $\quad x_C(\psi_m)^2 + y_C(\psi_m)^2 - R_d^{\,2} = 0\,mm^2$

$$\boldsymbol{\rho_C}(\psi) := \begin{pmatrix} x_C(\psi) \\ a - y_C(\psi) \\ 0 \end{pmatrix} \qquad R_2(\psi) := |\boldsymbol{\rho_C}(\psi)| \qquad \gamma_C(\psi) := -\arcsin\left(\frac{x_C(\psi)}{R_2(\psi)}\right) \qquad \alpha_C(\psi) := \arcsin\left(\frac{x_C(\psi)}{R_d}\right)$$

$x_C(\psi_m) = -1.219\,mm \qquad y_C(\psi_m) = 2.441\,mm \qquad \gamma_C(\psi_m) = 59.797\,deg \qquad \alpha_{rp}(\psi) := \alpha_C(\psi)$

$R_2(\psi_m) = 1.41\,mm \qquad \alpha_{rp}(\psi_m) = -26.536\,deg$

Rapport des vitesses angulaires roue - ancre $\quad K_{iep} = \omega_r / \omega_a$

$$K_{iep}(\psi) := \frac{-R_2(\psi)}{R_1}\cdot\frac{\cos(\beta_{BA}(\psi) - \gamma_C(\psi))}{\cos(\beta_{BA}(\psi) - \alpha_C(\psi))}$$

$\varepsilon = 2.5\,deg \qquad \Delta\psi_{ep} + \varepsilon = 8.5\,deg$

$K_{iep}(\psi_m) = 1.08405$

Variation du rapport de vitesses

$X_{iep}(\psi) := \frac{d}{d\psi}K_{iep}(\psi) \qquad X_{iep}(\psi_m) = -2.73763$

Linéarisation

$AK_{iep} := K_{iep}(\varepsilon) \qquad \Delta K_{iep} := K_{iep}(\Delta\psi_{ep} + \varepsilon) - K_{iep}(\varepsilon) \qquad Xl_{iep} := \frac{\Delta K_{iep}}{\Delta\psi_{ep}} \qquad Xl_{iep} = -2.715$

$Kl_{iep}(\psi) := AK_{iep} + Xl_{iep}\cdot(\psi - \varepsilon) \qquad Kl_{iep}(\psi_m) = 1.08193$

Rapport des vitesses tangentielles

$v_{Ca}(\psi) := R_2(\psi)\cdot\sin(\beta_{BA}(\psi) - \gamma_C(\psi)) \qquad v_{Cr}(\psi) := -K_{iep}(\psi)\cdot R_1\cdot\sin(\beta_{BA}(\psi) - \alpha_C(\psi)) \qquad \frac{v_{Ca}(\psi_m)}{v_{Cr}(\psi_m)} = -0.25$

$$\varepsilon_C(\psi) := \frac{v_{Cr}(\psi) - v_{Ca}(\psi)}{|v_{Cr}(\psi) - v_{Ca}(\psi)|} \qquad \varepsilon_C(0) = 1 \qquad \varepsilon_C(\varepsilon) = 1$$

Rapport des couples ancre - roue $\quad K'_{iep} = C_a / C_r$

$$K'_{iep}(\psi) := \frac{-R_2(\psi)}{R_1}\cdot\frac{\cos(\beta_{BA}(\psi) - \gamma_C(\psi) + \phi\cdot\varepsilon_C(\psi))}{\cos(\beta_{BA}(\psi) - \alpha_C(\psi) + \phi\cdot\varepsilon_C(\psi))} \qquad K'_{iep}(\psi_m) = 0.76781$$

Variation du rapport de couples

$X'_{iep}(\psi) := \frac{d}{d\psi}K'_{iep}(\psi) \qquad X'_{iep}(\psi_m) = -2.14995$

Linéarisation

$AK'_{iep} := K'_{iep}(\varepsilon)$ $\quad \Delta K'_{iep} := K'_{iep}(\Delta\psi_{ep} + \varepsilon) - K'_{iep}(\varepsilon)$ $\quad XI'_{iep} := \dfrac{\Delta K'_{iep}}{\Delta\psi_{ep}}$ $\quad XI'_{iep} = -2.136$

$KI'_{iep}(\psi) := AK'_{iep} + XI'_{iep}\cdot(\psi - \varepsilon)$ $\quad KI'_{iep}(\psi_m) = 0.76871$

Transmission par le plan d'impulsion de la dent

Valeur de contrôle

Plan d'impulsion de la dent sur la palette d'entrée

$\psi_m := \varepsilon + \Delta\psi_{ep} + \dfrac{\Delta\psi_{ed}}{2}$ $\quad \psi_m = 10\,deg$

$R_B = 1.266\,mm$

$\mathbf{r_A}(\psi_m) = \begin{pmatrix} -1.455 \\ 2.547 \\ 0 \end{pmatrix} mm$ $\quad \mathbf{r_B}(\psi_m) = \begin{pmatrix} -1.104 \\ 2.53 \\ 0 \end{pmatrix} mm$ $\quad \beta_{BA}(\psi_m) = -87.249\,deg$ $\quad m_{BA}(\psi_m) = -0.048$ $\quad h_{BA}(\psi_m) = 2.477\,mm$

$x_B(\psi) := \mathbf{r_B}(\psi)_0$ $\quad y_B(\psi) := \mathbf{r_B}(\psi)_1$

$\mathbf{r_C}(\alpha_r) := \begin{pmatrix} R_d\cdot sin(\alpha_r) \\ R_d\cdot cos(\alpha_r) \\ 0 \end{pmatrix}$ $\quad \mathbf{r_D}(\alpha_r) := \begin{pmatrix} R_{ext}\cdot sin(\alpha_r - \Delta\alpha_d) \\ R_{ext}\cdot cos(\alpha_r - \Delta\alpha_d) \\ 0 \end{pmatrix}$ $\quad \mathbf{r_C}(-\alpha_0) = \begin{pmatrix} -1.364 \\ 2.363 \\ 0 \end{pmatrix} mm$ $\quad \mathbf{r_D}(-\alpha_0) = \begin{pmatrix} -1.562 \\ 2.316 \\ 0 \end{pmatrix} mm$

$m_{CD}(\alpha_r) := \dfrac{\mathbf{r_D}(\alpha_r)_1 - \mathbf{r_C}(\alpha_r)_1}{\mathbf{r_D}(\alpha_r)_0 - \mathbf{r_C}(\alpha_r)_0}$ $\quad h_{CD}(\alpha_r) := \mathbf{r_D}(\alpha_r)_1 - m_{CD}(\alpha_r)\cdot\mathbf{r_D}(\alpha_r)_0$ $\quad \beta_{CD}(\alpha_r) := -\dfrac{\pi}{2} - arctan(m_{CD}(\alpha_r))$

$\alpha_B := -20\cdot deg$ $\quad \alpha_{rd}(\psi) := racine(m_{CD}(\alpha_B)\cdot x_B(\psi) + h_{CD}(\alpha_B) - y_B(\psi), \alpha_B)$ $\quad \alpha_{rd}(\psi_m) = -21.456\,deg$

$m_{CD}(\alpha_{rd}(\psi_m)) = 0.08$ $\quad \beta_{CD}(\alpha_{rd}(\psi_m)) = -94.57\,deg$ $\quad h_{CD}(\alpha_{rd}(\psi_m)) = 2.619\,mm$

$R_1(\psi) := |\mathbf{r_B}(\psi)|$ $\quad R_1(\psi_m) = 2.761\,mm$

$\gamma_B(\psi) := -arcsin\left(\dfrac{x_B(\psi)}{R_B}\right)$ $\quad \gamma_B(\psi_m) = 60.707\,deg$ $\quad \alpha_B(\psi) := arctan\left(\dfrac{x_B(\psi)}{y_B(\psi)}\right)$ $\quad \alpha_B(\psi_m) = -23.578\,deg$

Rapport des vitesses angulaires roue - ancre $\quad K_{ied} = \omega_r / \omega_a$

$K_{ied}(\psi) := \dfrac{-R_B}{R_1(\psi)}\cdot\dfrac{cos(\beta_{CD}(\alpha_{rd}(\psi)) - \gamma_B(\psi))}{cos(\beta_{CD}(\alpha_{rd}(\psi)) - \alpha_B(\psi))}$ $\quad \varepsilon + \Delta\psi_{ep} = 8.5\,deg$ $\quad \varepsilon + \Delta\psi_{ie} = 11.5\,deg$

$K_{ied}(\psi_m) = 1.279$

Variation du rapport de vitesses

$X_{ied}(\psi) := \dfrac{d}{d\psi}K_{ied}(\psi)$ $\quad X_{ied}(\psi_m) = -5.66726$

Linéarisation

$AK_{ied} := K_{ied}(\varepsilon + \Delta\psi_{ep})$ $\quad \Delta K_{ied} := K_{ied}(\varepsilon + \Delta\psi_{ie}) - K_{ied}(\varepsilon + \Delta\psi_{ep})$ $\quad XI_{ied} := \dfrac{\Delta K_{ied}}{\Delta\psi_{ed}}$ $\quad XI_{ied} = -5.846$

$KI_{ied}(\psi) := AK_{ied} + XI_{ied}\cdot(\psi - \varepsilon - \Delta\psi_{ep})$ $\quad KI_{ied}(\psi_m) = 1.30489$

Rapport des vitesses tangentielles

$v_{Ba}(\psi) := R_B\cdot sin(\beta_{CD}(\alpha_{rd}(\psi)) - \gamma_B(\psi))$ $\quad v_{Br}(\psi) := -K_{ied}(\psi)\cdot R_1(\psi)\cdot sin(\beta_{CD}(\alpha_{rd}(\psi)) - \alpha_B(\psi))$

$\varepsilon_B(\psi) := \dfrac{v_{Br}(\psi) - v_{Ba}(\psi)}{|v_{Br}(\psi) - v_{Ba}(\psi)|}$ $\quad \varepsilon_B(\varepsilon + \Delta\psi_{ep}) = 1$ $\quad \varepsilon_C(\varepsilon + \Delta\psi_{ie}) = 1$ $\quad \dfrac{v_{Ba}(\psi_m)}{v_{Br}(\psi_m)} = -0.159$

Rapport des couples ancre - roue $\quad K'_{ied} = C_a \,/\, C_r$

$$K'_{ied}(\psi) := \frac{-R_B}{R_1(\psi)} \cdot \frac{\cos\left(\beta_{CD}\left(\alpha_{rd}(\psi)\right) - \gamma_B(\psi) + \phi\cdot\varepsilon_B(\psi)\right)}{\cos\left(\beta_{CD}\left(\alpha_{rd}(\psi)\right) - \alpha_B(\psi) + \phi\cdot\varepsilon_B(\psi)\right)} \qquad K'_{ied}(\psi_m) = 0.85$$

Variation du rapport de couples

$$X'_{ied}(\psi) := \frac{d}{d\psi}K'_{iep}(\psi) \qquad X'_{ied}(\psi_m) = -2.008$$

Linéarisation

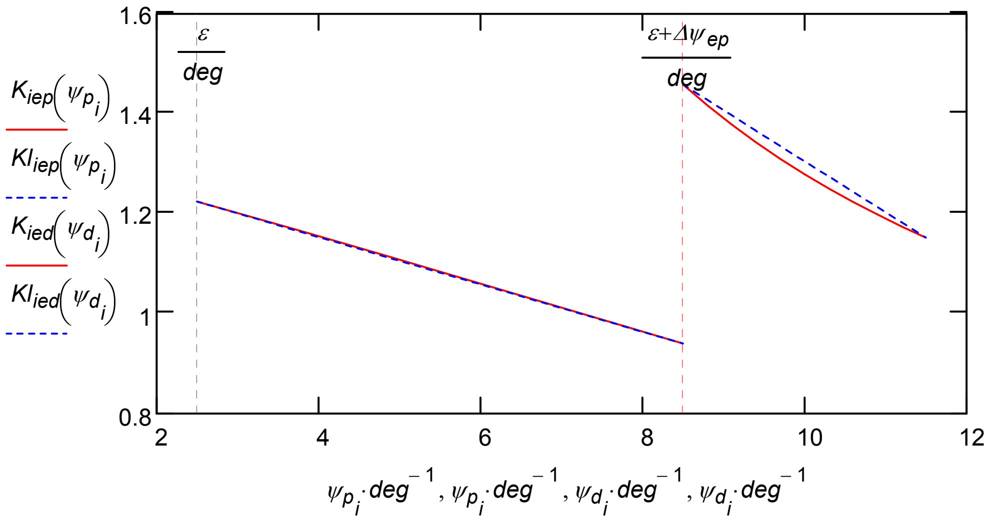
$$AK'_{ied} := K'_{ied}(\varepsilon + \Delta\psi_{ep}) \qquad \Delta K'_{ied} := K'_{ied}(\varepsilon + \Delta\psi_{ie}) - K'_{ied}(\varepsilon + \Delta\psi_{ep}) \qquad Xl'_{ied} := \frac{\Delta K'_{ied}}{\Delta\psi_{ed}} \qquad Xl'_{ied} = -2.81$$

$$Kl'_{ied}(\psi) := AK'_{ied} + Xl'_{ied}\cdot\left(\psi - \Delta\psi_{ep} - \varepsilon\right) \qquad Kl'_{ied}(\psi_m) = 0.86009$$

Graphes

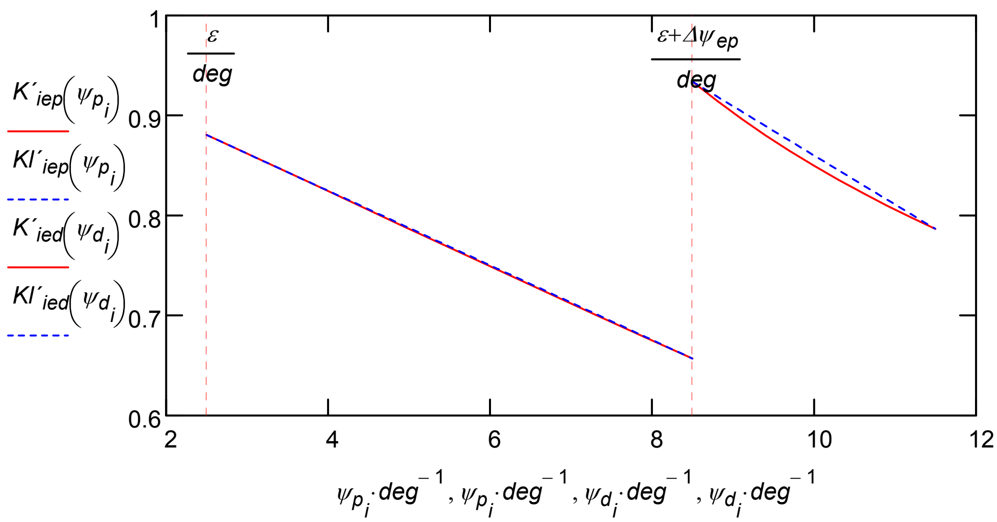
$$n := 10 \qquad i := 0 .. n \qquad \psi_{p_i} := \varepsilon + i\cdot\frac{\Delta\psi_{ep}}{n} \qquad \psi_{d_i} := \varepsilon + \Delta\psi_{ep} + i\cdot\frac{\Delta\psi_{ed}}{n}$$

Rapports de vitesses



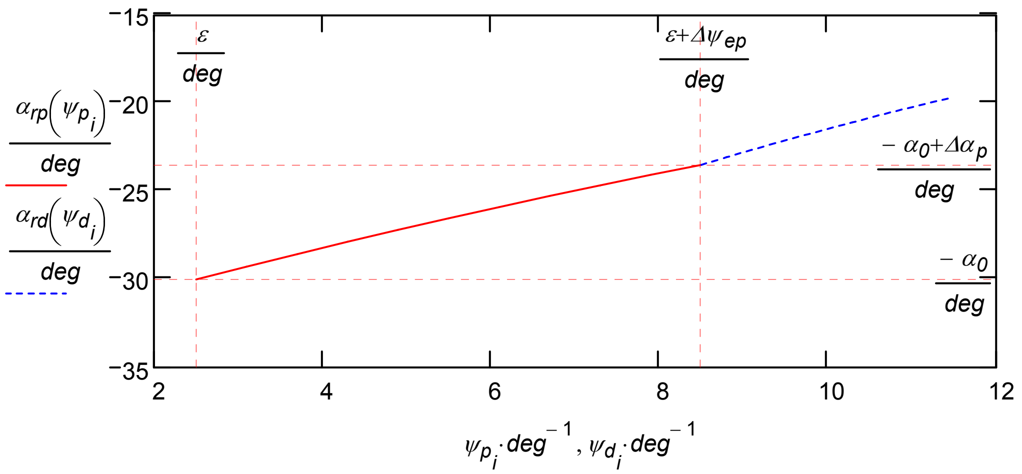
$$K_{iep}(\varepsilon) = 1.224 \qquad K_{iep}(\varepsilon + \Delta\psi_{ep}) = 0.94 \qquad K_{ied}(\varepsilon + \Delta\psi_{ep}) = 1.458 \qquad K_{ied}(\varepsilon + \Delta\psi_{ie}) = 1.152$$

Rapports de couples



$$K'_{iep}(\varepsilon) = 0.881 \qquad K'_{iep}(\varepsilon + \Delta\psi_{ep}) = 0.657 \qquad K'_{ied}(\varepsilon + \Delta\psi_{ep}) = 0.934 \qquad K'_{ied}(\varepsilon + \Delta\psi_{ie}) = 0.787$$

Déplacement de la roue d'échappement



$-\alpha_0 = -30\,deg$ $\qquad -\alpha_0 + \Delta\alpha_p = -23.5\,deg$ $\qquad -\alpha_0 + \Delta\alpha_p + \Delta\alpha_d = -19.5\,deg$

Rapports de couples en fonction de la position de la roue