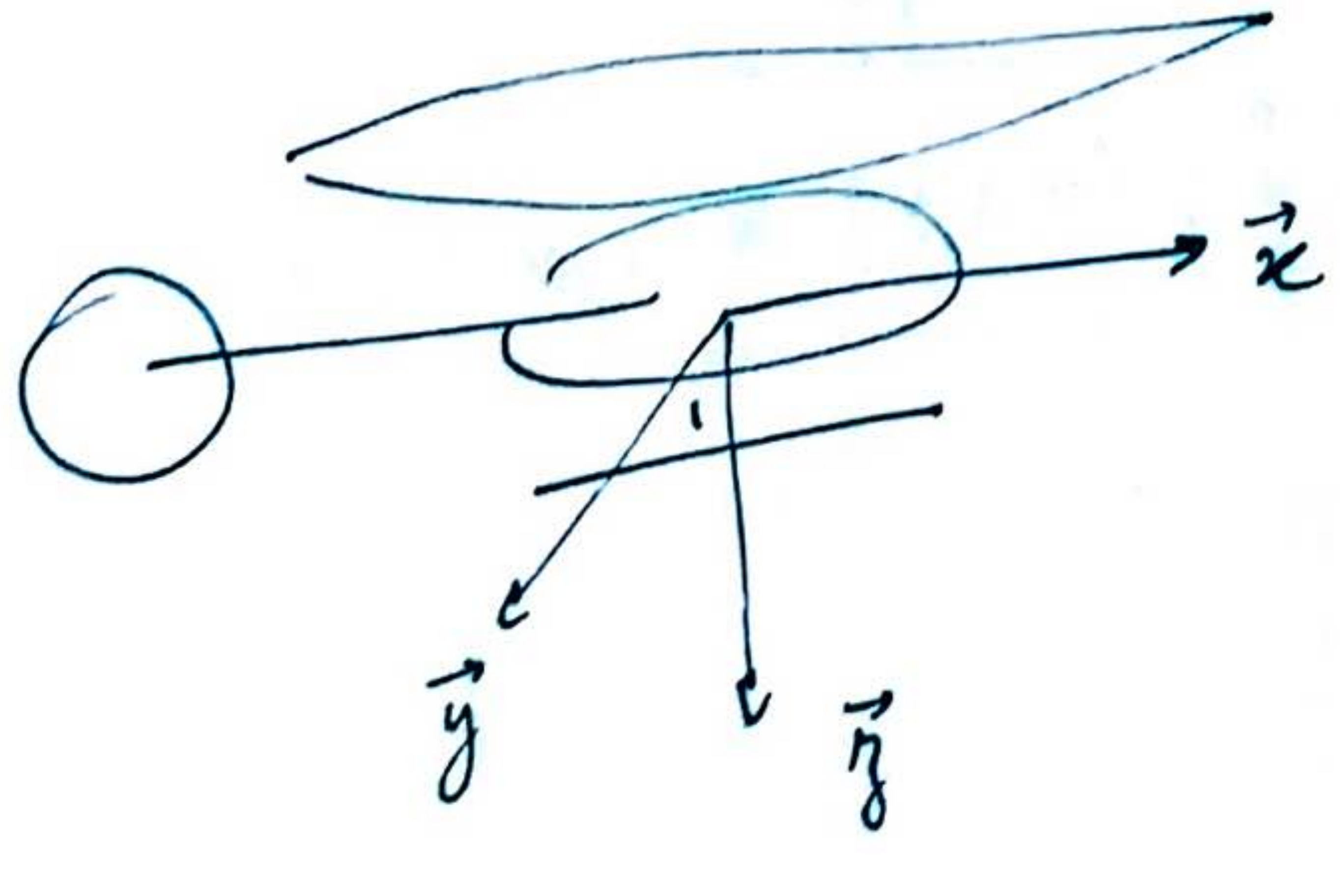
équation d'état de l'hélicoptère.

on note : R : orientation
p : position
v_r : vecteur vitesse.
τ_0 : total poussée générée par le rotor principal
τ_1 : couple lié au roulis.
τ_2 : couple lié au tangage.
τ_3 : couple généré par rotor arrière.

$$\begin{cases} \dot{p} = R \cdot v_r \\ \dot{R} = R \cdot (\omega_r \wedge) \\ \dot{v}_r = R^T \cdot \begin{pmatrix} 0 \\ 0 \\ g \end{pmatrix} + \frac{1}{m} \cdot f_r - \omega_r \wedge v_r \\ \dot{\omega}_r = I^{-1} \cdot \left(\tau_r - \omega_r \wedge (I \cdot \omega_r) \right) \end{cases}$$

avec
$$\begin{pmatrix} \tau_0 \\ \tau_1 \\ \tau_2 \\ \tau_3 \end{pmatrix} = \overbrace{\begin{pmatrix} \beta_1 \cdot \omega_1^2 & 0 & 0 & 0 \\ 0 & \beta_2 \omega_1^2 & 0 & 0 \\ 0 & 0 & \beta_3 \omega_1^2 & 0 \\ -\delta_1 \omega_1^2 & 0 & 0 & -\beta_4 \ell \omega_2^2 \end{pmatrix}}^{= B} \cdot \begin{pmatrix} u_1 \\ u_2 \\ u_3 \\ u_4 \end{pmatrix}$$

$$f_r = \begin{pmatrix} 0 \\ 0 \\ -\tau_0 \end{pmatrix} \quad \text{et} \quad \tau_r = \begin{pmatrix} \tau_1 \\ \tau_2 \\ \tau_3 \end{pmatrix}$$



équation du looping :
$$\begin{cases} \frac{dx}{ds} = \cos\theta \\ \frac{dy}{ds} = \sin\theta \\ \frac{d\theta}{ds} = \frac{1}{r} \end{cases}$$

$$\begin{pmatrix}\varphi^d\\ \theta^d\\ \psi^d\end{pmatrix}$$

$(c)^{-1}$

$$\omega_r^d = k_{\varphi\theta\psi}\cdot\begin{pmatrix}1 & \tan\theta\sin\varphi & \tan\theta\cos\varphi\\ 0 & \cos\varphi & -\sin\varphi\\ 0 & \frac{\sin\varphi}{\cos\theta} & \frac{\cos\varphi}{\cos\theta}\end{pmatrix}^{-1}\left(\begin{pmatrix}\varphi^d\\ \theta^d\\ \psi^d\end{pmatrix}-\begin{pmatrix}\varphi\\ \theta\\ \psi\end{pmatrix}\right)$$

$\downarrow \omega_r^d$

(b^{-1})

$$\tau_{1:3}^d = I\cdot k_\omega\cdot(\omega_r^d-\omega_r)+\omega_r\wedge(I\cdot\omega_r)$$

$\downarrow \begin{pmatrix}\tau_1^d\\ \tau_2^d\\ \tau_3^d\end{pmatrix}$

τ_0^d

$(a)^{-1}$

$$\begin{pmatrix}u_1\\ u_2\\ u_3\\ u_4\end{pmatrix} = \sqrt{\left(B^{-1}\cdot\begin{pmatrix}\tau_0^d\\ \tau_1^d\\ \tau_2^d\\ \tau_3^d\end{pmatrix}\right)}$$

$\downarrow \begin{pmatrix}u_1\\ u_3\\ u_4\end{pmatrix}$

(a)

$$B\cdot\begin{pmatrix}\omega_1\cdot|\omega_1|\\ \omega_2\cdot|\omega_2|\\ \omega_3\cdot|\omega_3|\\ \omega_4\cdot|\omega_4|\end{pmatrix}$$

$\downarrow \begin{pmatrix}\tau_1\\ \tau_2\\ \tau_3\end{pmatrix}$

(b)

$$\dot\omega_r = I^{-1}\cdot\left(\begin{pmatrix}\tau_1\\ \tau_2\\ \tau_3\end{pmatrix}-\omega_r\wedge(I\cdot\omega_r)\right)$$

$\downarrow \omega_r$

(c)

$$\begin{pmatrix}\dot\varphi\\ \dot\theta\\ \dot\psi\end{pmatrix} = \begin{pmatrix}1 & \tan\theta\sin\varphi & \tan\theta\cos\varphi\\ 0 & \cos\varphi & -\sin\varphi\\ 0 & \frac{\sin\varphi}{\cos\theta} & \frac{\cos\varphi}{\cos\theta}\end{pmatrix}\cdot\omega_r$$

$\downarrow \begin{pmatrix}\varphi\\ \theta\\ \psi\end{pmatrix}$

(d)

$$\dot v_r = R^T(\varphi,\theta,\psi)\cdot\begin{pmatrix}0\\ 0\\ g\end{pmatrix}+\begin{pmatrix}0\\ 0\\ -\frac{\tau_0}{m}\end{pmatrix}-\omega_r\wedge v_r$$

$\downarrow v_r$

$$\dot p = R(\varphi,\theta,\psi)\cdot v_r$$ (e)

$\downarrow p$

ω_r