1) Test terrain :

- Raideur de la butée flexible qui attache la tuyère au bâti
- Poid de la tuyère (quand elle est braquée)
- Force générée par l'actionneur

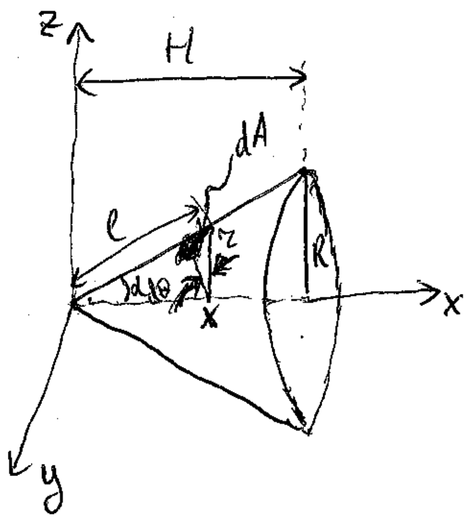
Pendant le vol :

- Effort généré par l'excentrement du vecteur poussé
- Efforts aéros

2)

$$J\ddot{\theta} = \ell(\theta)F_a - MgL\sin\theta - K\theta$$

3) a)



$$I_{yy} = \oint (x^2+z^2)\,dm$$

$$dm = \frac{M}{\text{surface cône}} \cdot dA = \frac{M\sin\alpha}{\pi R^2}\,dA$$

$$dA = r\,d\theta\,d\ell$$

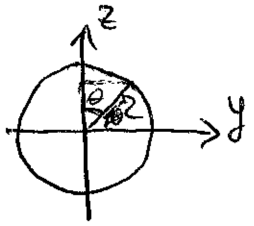
$$\frac{r}{x} = \frac{R}{H} \Rightarrow r = \frac{R}{H}x$$

$$\ell = \frac{r}{\sin\alpha} = \frac{R}{H\sin\alpha}x \Rightarrow d\ell = \frac{R}{H\sin\alpha}dx$$

$$dA = \frac{R}{H}x\,d\theta\,\frac{R}{H\sin\alpha}dx = x\frac{R^2}{H^2\sin\alpha}\,d\theta\,dx$$

$$dm = \frac{M\sin\alpha}{\pi R^2}\cdot x\frac{R^2}{H^2\sin\alpha}\,d\theta\,dx = x\frac{M}{\pi H^2}\,dx\,d\theta$$

$$I_{yy} = \int_0^{2\pi}\int_0^{H} (x^2+z^2)\, x \frac{M}{\pi H^2}\, dx\, d\theta$$



$$z = r\cos\theta = x\frac{R}{H}\cos\theta$$

$$I_{yy} = \frac{M}{\pi H^2}\iint \left(x^2 + x^2\frac{R^2}{H^2}\cos^2\theta\right) x\, dx\, d\theta$$

$$= \frac{M}{\pi H^2}\left(\int_0^{2\pi}\int_0^{H} x^3\, dx\, d\theta + \frac{R^2}{H^2}\int_0^{2\pi}\int_0^{H} x^3 \cos^2\theta\, dx\, d\theta\right)$$

$$= \frac{M}{\pi H^2}\left(2\pi\frac{H^4}{4} + \frac{R^2}{H^2}\cdot\frac{H^4}{4}\int_0^{2\pi}\frac{1}{2}(1+\cos(2\theta))\, d\theta\right)$$

Rappel : $\cos^2\theta = \dfrac{1+\cos(2\theta)}{2}$

$$= \frac{M}{\pi H^2}\left(\frac{2\pi H^4}{4} + \frac{R^2H^2}{4}\cdot\frac{1}{2}\left(2\pi + \underbrace{\frac{\sin(2\theta)}{2}\Big|_0^{2\pi}}_{=0}\right)\right)$$

$$\boxed{I_{yy} = \frac{M}{4}\left(2H^2 + R^2\right)}$$

A.N. $\quad I_{yy} = \dfrac{1616}{4}\left(2\cdot 2{,}5^2 + 1^2\right) = 5454 \ kg\cdot m^2$

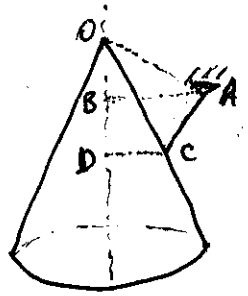
b) $\quad G : (x_G, y_G, z_G) - ?$

$X_G = z_G = 0 \quad$ évident

$$x_G = \frac{\oint x\, dm}{M} = \frac{1}{M}\int_0^{2\pi}\int_0^{H} x\cdot x\frac{M}{\pi H^2}\, dx\, d\theta = \frac{1}{\pi H^2}\int_0^{2\pi}\int_0^{H} x^2\, dx\, d\theta =$$

$$= \frac{1}{\pi H^2}\,\frac{H^3}{3}\cdot 2\pi = \frac{2}{3}H$$

c)



Travaux virtuels:

$$F \cdot dx = C\,d\theta \qquad \text{avec } x = AC$$

$$F \underbrace{\frac{dx}{d\theta}}_{l\text{ – bras de levier}} = C$$

$$x = AC = \sqrt{OC^2 + OA^2 - 2 \cdot OC \cdot OA \cdot \cos(\measuredangle AOC)}$$

$$OC = \sqrt{OD^2 + DC^2} = \sqrt{(0{,}197 + 0{,}947)^2 + 0{,}967^2} = 1{,}498\ m$$

$$OA = \sqrt{OB^2 + BA^2} = \sqrt{1{,}368^2 + 0{,}197^2} = 1{,}382\ m$$

$$\measuredangle AOC = \measuredangle AOB - \measuredangle COD + \theta$$

$$tg\,\measuredangle AOB = \frac{AB}{OB} \Rightarrow \measuredangle AOB = arctg\,\frac{1{,}368}{0{,}197} = 81{,}8^\circ$$

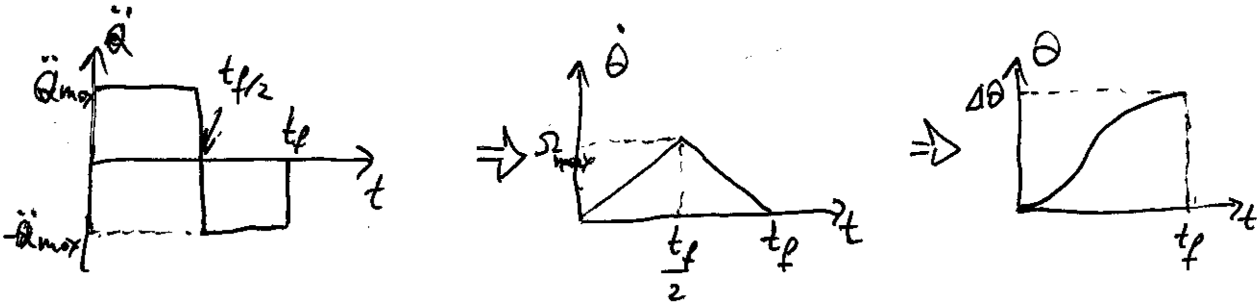
$$tg\,\measuredangle COD = \frac{DC}{DO} \Rightarrow \measuredangle COD = arctg\,\frac{0{,}967}{0{,}197 + 0{,}947} = 40{,}2^\circ$$

$$\measuredangle AOC = 81{,}8^\circ - 40{,}2^\circ + \theta = 41{,}6^\circ + \theta$$

$$dx = \frac{1}{\cancel{2}} \frac{\cancel{2} \cdot OC \cdot OA \cdot \sin(41{,}6^\circ + \theta)}{\sqrt{OC^2 + OA^2 - 2 \cdot OC \cdot OA \cdot \cos(41{,}6^\circ + \theta)}}\, d\theta$$

$$\boxed{l = \frac{dx}{d\theta} = \frac{2{,}07 \sin(41{,}6^\circ + \theta)}{\sqrt{4{,}154 - 4{,}14 \cos(41{,}6^\circ + \theta)}}}$$

4) Pour un déplacement $\Delta\theta$ dans un temp minimal, l'accélération doit avoir la forme:



$$\theta(t) = \underbrace{\theta_0}_{=0} + \underbrace{\dot{\theta}_0}_{=0} t + \frac{\ddot{\theta}(t)\, t^2}{2}$$

si $\Delta\theta = \theta(t_f)$ alors $\frac{\Delta\theta}{2} = \theta\left(\frac{t_f}{2}\right) = \frac{\ddot{\theta}_{max}\left(\frac{t_f}{2}\right)^2}{2}$

$$\ddot{\theta}_{max} = \frac{4 \cdot \Delta\theta}{t_f^2}$$

comme $\theta \in (-5{,}7° \div +5{,}7°)$ on approxime $\sin\theta \approx \theta$

entre $\theta = 5{,}5°$ et $\theta = 0°$ ℓ varie seulement de $2{,}4$ cm $\Rightarrow \ell = \text{constant}$

$\ell = 1{,}33$ m

i) $F\ell = J\ddot{\theta}_{max} + (M_g L + K)\,\theta$ pour $\theta \in \left(0 \div \frac{\Delta\theta}{2}\right)$

ii) $F\ell = -J\ddot{\theta}_{max} + (M_g L + K)\,\theta$ pour $\theta \in \left(\frac{\Delta\theta}{2} \div \Delta\theta\right)$

~~[illegible]~~

i) $F\ell = \max$ pour $\theta = \frac{\Delta\theta}{2}$

ii) $F.\ell = \min$ pour $\theta = \frac{\Delta\theta}{2}$

car on freine

} effort max pour $\theta = \frac{\Delta\theta}{2}$

$$F_{max} = \frac{J\ddot{\theta}_{max} + (M_g L + K)\,\theta}{[illegible]} = \frac{J\frac{4\Delta\theta}{t_f^2} + (M_g L + K)\frac{\Delta\theta}{2}}{[illegible]}$$

a) Scenario 1: $F_{max} \approx 5$[illegible] kN

b) Scenario 2: $F_{max} \approx 4$[illegible] kN