Aspects of analysis and simulation of a flaperon ditching scenario

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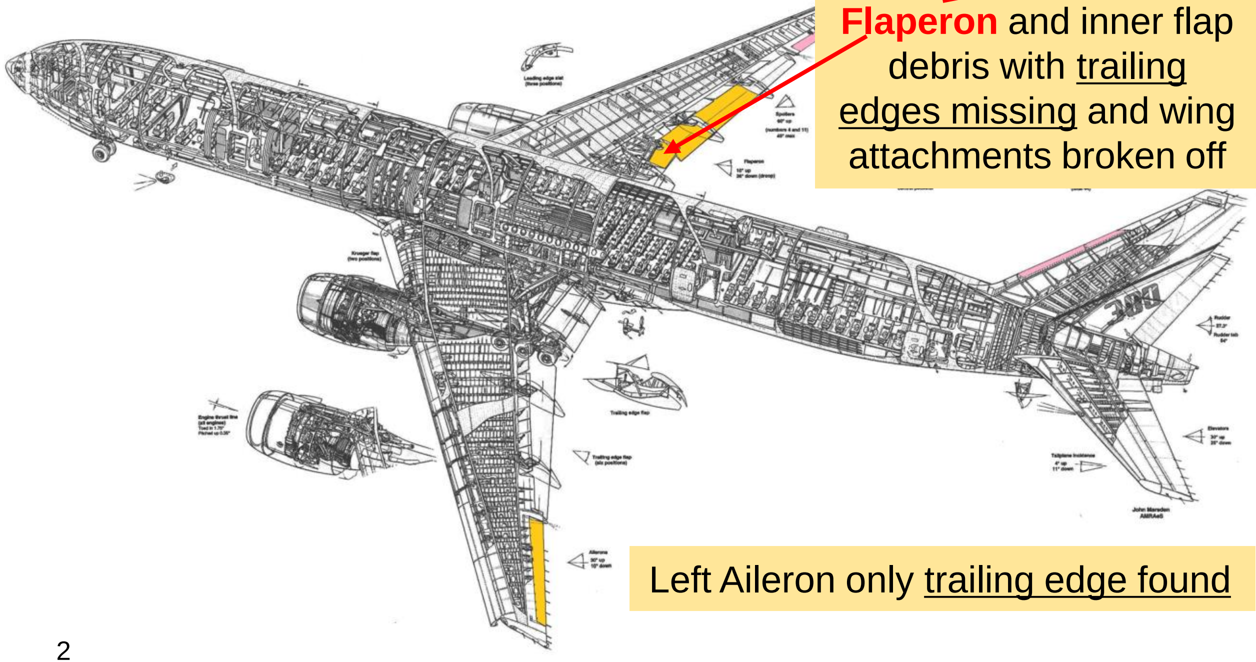
Motivation of this study: the flaperon discovery

Debris 100% certain to be from MH370



Flaperon and inner flap debris with trailing edges missing and wing attachments broken off

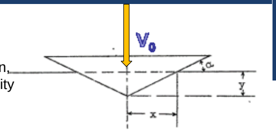
Left Aileron only trailing edge found

“APPENDIX 1.12A-2 - DEBRIS EXAMINATION, ITEM 1 – FLAPERON", *Safety Investigation Report MH370 (9M-MRO)*, Direction Générale De L’Armement (DGA), Ministère de La Défense, Sept. 2015

A ditching scenario strongly suspected

Basic Von Karman theory

- Basic conservation of momentum upon impact
- Assumptions: no buoyancy, no cavitation, no air entrapment, no viscosity etc.



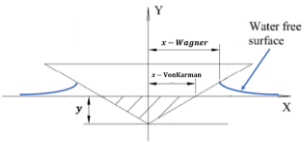
$$mV_0 = mV + \frac{1}{2}\pi x^2 \rho V$$

$$F_v = M\frac{d^2y}{dt^2} = \frac{V_0^2 \cot\alpha}{\left(1+\frac{\rho l \pi x^2}{2M}\right)^3}\rho l \pi x$$

When M → ∞ $F_v = V_0^2 \rho l \pi x \cot\alpha$

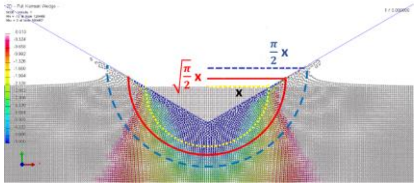
Vertical force evolution under constant vertical immersion speed

Adapting Von Karman theory for the added mass



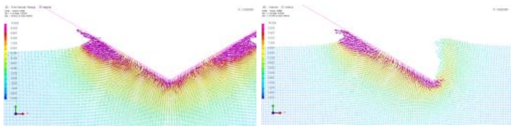
- Examining the estimate of the added mass

$$x_{eff} = \sqrt{\frac{\pi}{2}}\, x_{VonKarman}$$



$$F_v = \frac{\pi^2}{2} V_0^2 \rho l x \cot\alpha$$

Adapting Von Karman theory for a flat plate



- Dividing in half the wedge vertical force and adapting it for the open lower end

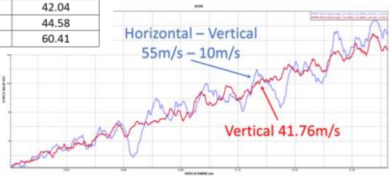
$$F_v = C_\alpha \left(\frac{\pi}{2}\right)^2 V_0^2 \rho l x \cot\alpha$$

Linking steady inclined impact to equivalent vertical

Table 2 Equivalence between inclined ditching and vertical immersion

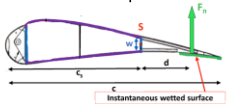
V_{x0} (m/s)	V_{y0} (m/s)	V_n (m/s)	V_0 (m/s)
55	10	36.16	41.76
55	20	44.82	51.75
50	30	50.98	58.87
68.42	2.54	36.41	42.04
68.42	5.08	38.61	44.58
70	20	52.32	60.41

$$F_v = C_\alpha \left(\frac{\pi}{2}\right)^2 (V_{x0} + V_{y0}\cot\alpha)^2 \rho l y$$



Deriving skin equilibrium maximal stresses

- For a typical section of the 3D flaperon, at the intersection of the skin with the spar S



$$Bending\ Moment = F_n d = F_m w$$

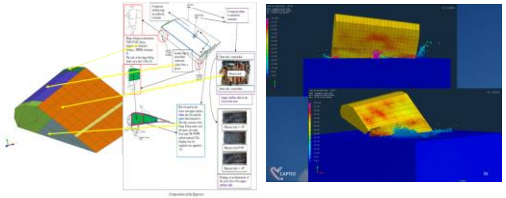
$$F_m = \sigma_{av} l n_{ply} t_{ply}$$

(order of magnitude)

$$\sigma_{max} = C_\alpha C_{3D} C_\sigma \left(\frac{\pi}{2}\right)^2 \left[\frac{(V_{x0}+V_{y0}\cot\alpha)^2 \rho y d}{n_{ply} t_{ply} w \cos\alpha}\right]$$

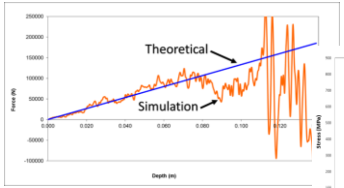
$$2 < C_\sigma < 3$$

FE analysis of the 3D elastic flaperon

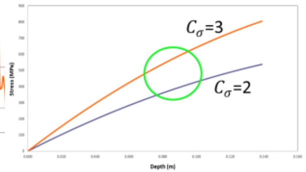


68 m/s horizontal speed - 10 m/s vertical speed

Order of magnitude of equilibrium stresses of rigid model at moment of rupture of elastic model



$$\sigma_{max} = C_\alpha C_{3D} C_\sigma \left(\frac{\pi}{2}\right)^2 \left[\frac{(V_{x0}+V_{y0}\cot\alpha)^2 \rho y d}{n_{ply} t_{ply} w \cos\alpha}\right]$$



$$F_v = C_\alpha C_{3D} \left(\frac{\pi}{2}\right)^2 (V_{x0} + V_{y0}\cot\alpha)^2 \rho l y$$

68 m/s horizontal speed - 10 m/s vertical speed

SHAPING THE FUTURE OF AEROSPACE

Conclusions

- A new estimate of the added mass for the Von Karman water impact theory has been suggested.
- The Von Karman theory was adapted, through high fidelity simulation means, for the vertical immersion of a flat plate and then extended to the case of inclined ditching.
  - An interesting equivalence between vertical immersion and inclined ditching was demonstrated.
- As applied to a flaperon ditching scenario, the foundation was laid for obtaining simple but meaningful analytical expressions for parametric evaluation of the fluid-structure interaction, which can be eventually linked to the sea state.

A Great Thank You !

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