Aspects of analysis and simulation of a wing ditching scenario

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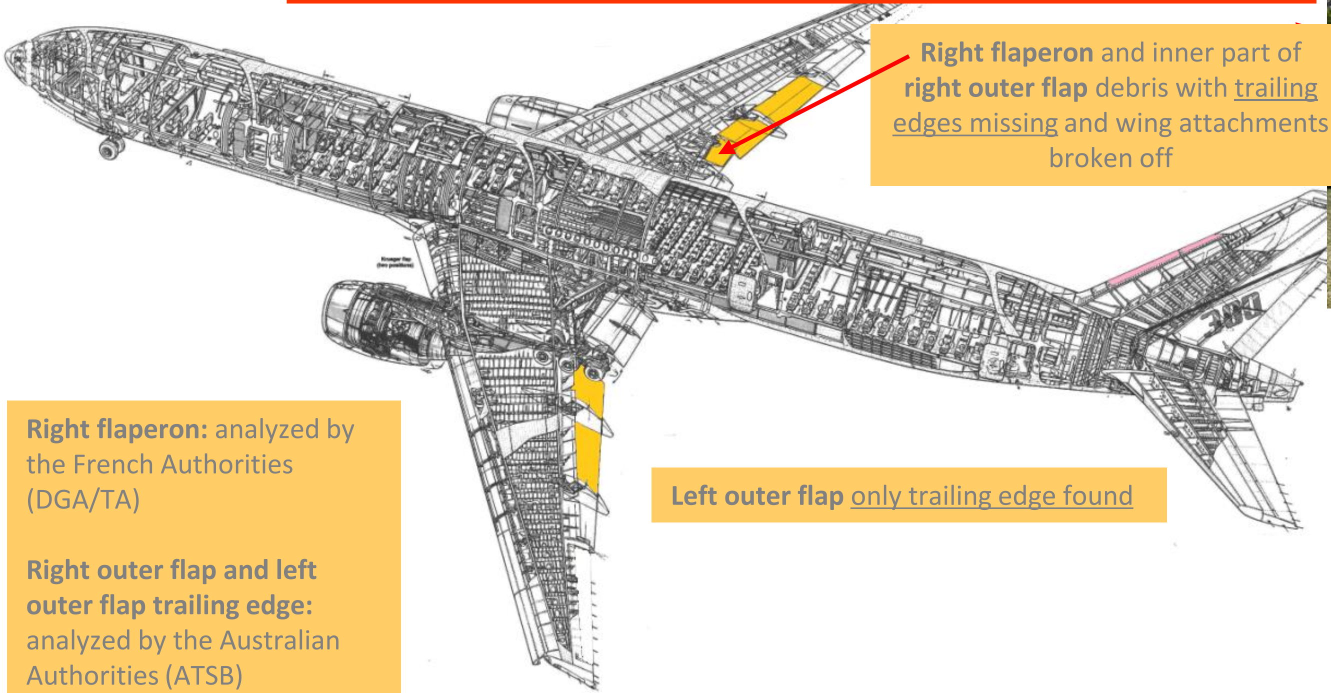
2021 AIAA AVIATION FORUM, 2-6 August

Motivation of this study: the flaperon discovery

Only three Debris items 100% certain to be from MH370



Right flaperon and inner part of **right outer flap** debris with trailing edges missing and wing attachments broken off

Left outer flap only trailing edge found

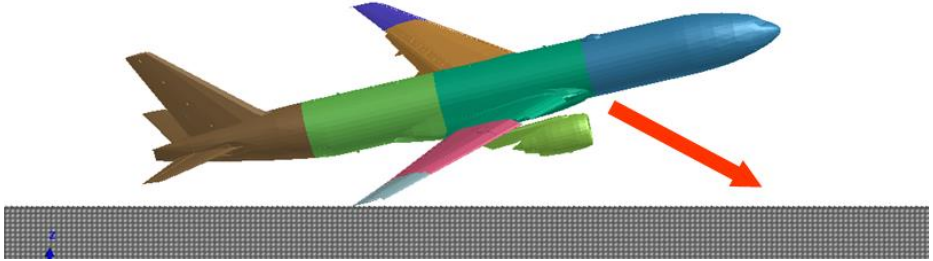
Right flaperon: analyzed by the French Authorities (DGA/TA)

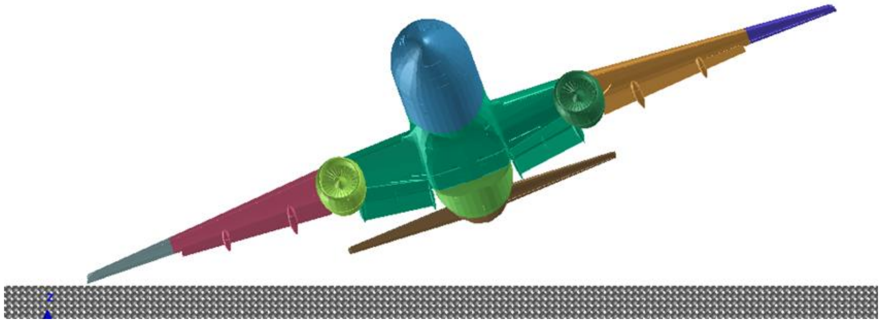
Right outer flap and left outer flap trailing edge: analyzed by the Australian Authorities (ATSB)

"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

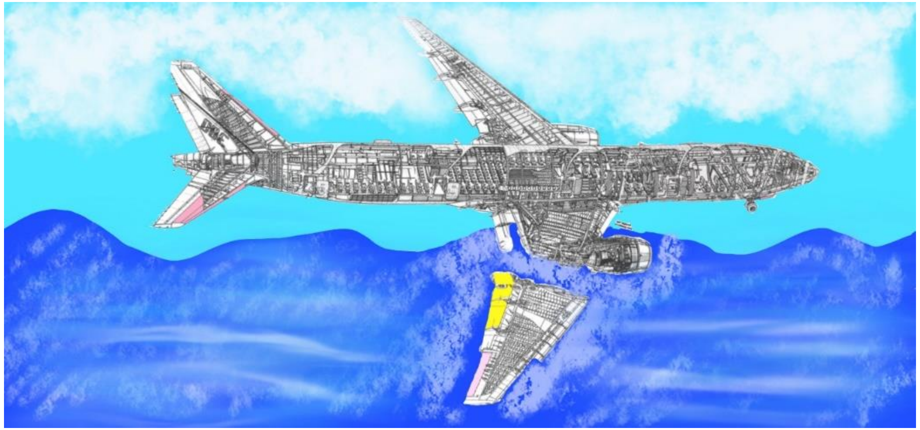
A ditching scenario strongly suspected

The case for a violent right wing first impact
Uncontrolled ditching





Drawing by my son, Alexander



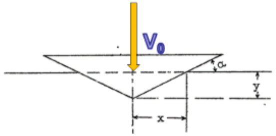
Possible wing rupture

Basic Von Karman theory

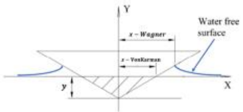
- Basic conservation of momentum upon impact
- Assumptions: no buoyancy (ie. no gravity), no cavitation, no air entrapment, no viscosity, etc.

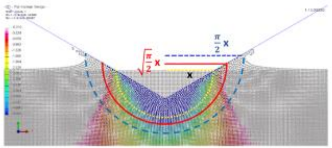
$$mV_0 = mV + \frac{1}{2}\pi x^2 \rho V$$

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



Adapting Von Karman theory for the added mass





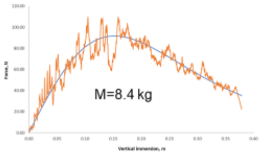
- Examining the estimate of the added mass

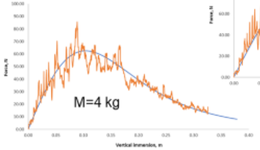
$$x_{eff} = \sqrt{\frac{\pi}{2}}\, x_{VonKarman}$$

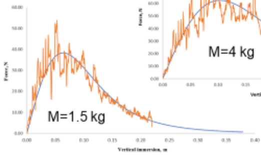
$$F_v = \frac{\pi^2}{2} {V_0}^2 \frac{\rho l x \cot\alpha}{\left(1+\frac{\rho l \pi^2 x^2}{4M}\right)^3}$$

Validation of x_{eff} for finite mass wedge vertical drop

Simulation: orange
Theory F_v : blue

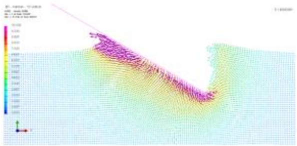


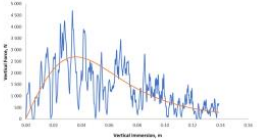




$$F_v = \frac{\pi^2}{2} {V_0}^2 \frac{\rho l x \cot\alpha}{\left(1+\frac{\rho l \pi^2 x^2}{4M}\right)^3}$$

Adapting Von Karman theory for a flat plate





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

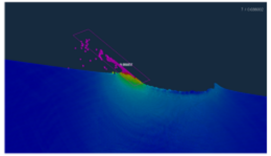
$$F_v = C_\alpha \left(\frac{\pi}{2}\right)^2 {V_0}^2 \frac{\rho l x \cot\alpha}{\left(1+\frac{\rho l \pi^2 x^2}{8M_p}\right)^3}$$

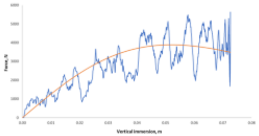
Adapting Von Karman theory for inclined impact

$$V_i = V_0 \cos\alpha$$

$$V_n = V_{x0}\sin\alpha + V_{y0}\cos\alpha$$

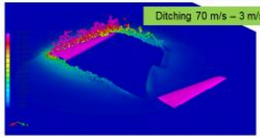
$$F_v = C_\alpha \left(\frac{\pi}{2}\right)^2 (V_{x0} + V_{y0}\cot\alpha)^2 \frac{\rho l y}{\left(1+\frac{\rho l \pi^2 x^2}{8M_p}\right)^3}$$





Force versus immersion depth for 55 m/s initial horizontal – 10 m/s initial vertical speeds

Ditching versus equivalent vertical slamming rigid wing



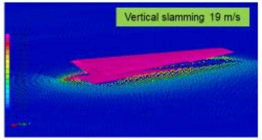
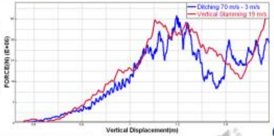


Table 2 Equivalence between inclined ditching and vertical immersion [2]

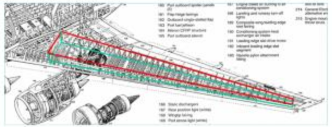
V_{x0} (m/s)	V_{y0} (m/s)	V_n (m/s)	V_0 (m/s)
55	**10**	[illegible]	**41.76**
55	20	[illegible]	51.75
50	30	50.98	58.87
68.42	2.54	36.41	42.04
68.42	5.08	38.61	44.58
70	20	52.32	60.41
70	**3**		**19**

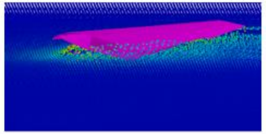
From [2]

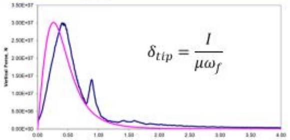


Vertical slamming of finite mass rigid wing

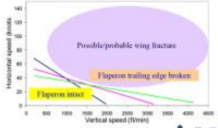
link with flaperon analysis of [2]







$$\delta_{tip} = \frac{I}{\mu\omega_f}$$



SHAPING THE FUTURE OF AEROSPACE

Conclusions

- The Von Karman water impact theory was modified by suitably redefining the added mass estimation and adapting it to a wing-like body with a **finite** mass under ditching.
- A simple analytical relation for the hydrodynamic force as a function of horizontal and vertical speeds and angle of impact was obtained and validated through Smoothed Particle Hydrodynamics (SPH) water impact simulations.
- The existence of an equivalence between inclined ditching and vertical slamming of a wing-like body was demonstrated. This allows to drastically reduce the sizes of the numerical models for parametric evaluation and the corresponding CPU usage, by modelling the sea in the vicinity of the wing (under equivalent slamming) and not necessarily all along its trajectory in ditching.
  - It can have also value in devising simpler and smaller experimental setups for laboratory testing of ditching.

A Great Thank You !

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