

Aspects of analysis and simulation of a wing ditching scenario

Argiris Kamoulakos

MH370-CAPTIO

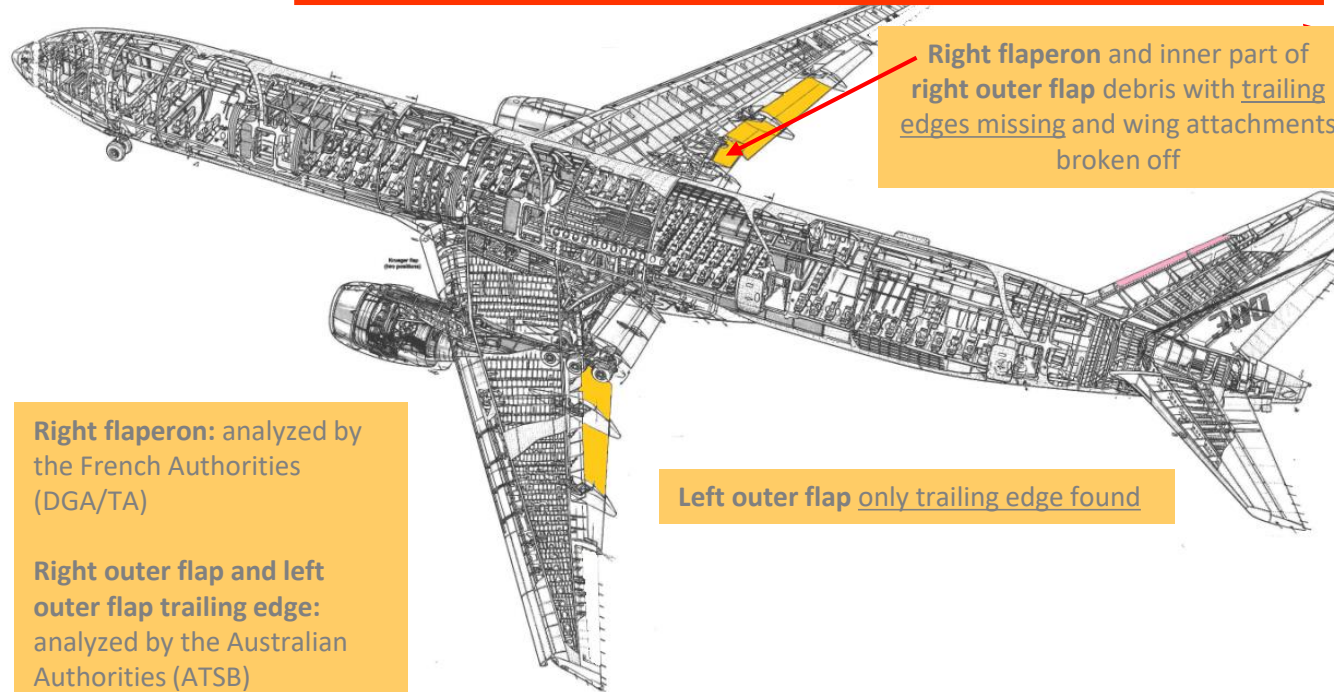
2021 AIAA AVIATION FORUM, 2-6 August

Copyright © by Argiris Kamoulakos

Published by the American Institute of Aeronautics and Astronautics, Inc., with permission.

Motivation of this study: the flaperon discovery

Only three Debris items 100% certain to be from MH370



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

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

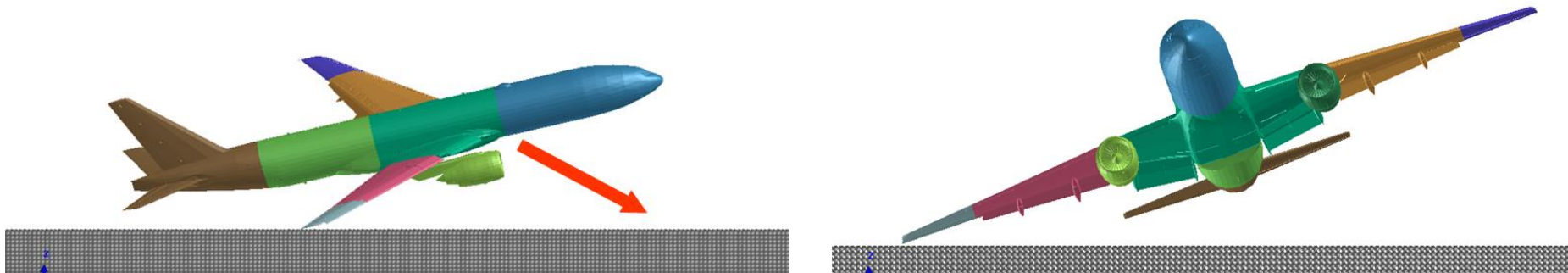


"APPENDIX 1.12A-2 - DEBRIS EXAMINATION, ITEM 1 – FLAPERON", *Safety Investigation Report MH370 (9M-MRO)*, Direction Générale De L'Armement (DGA), Ministère de La Défense, Sept. 2015

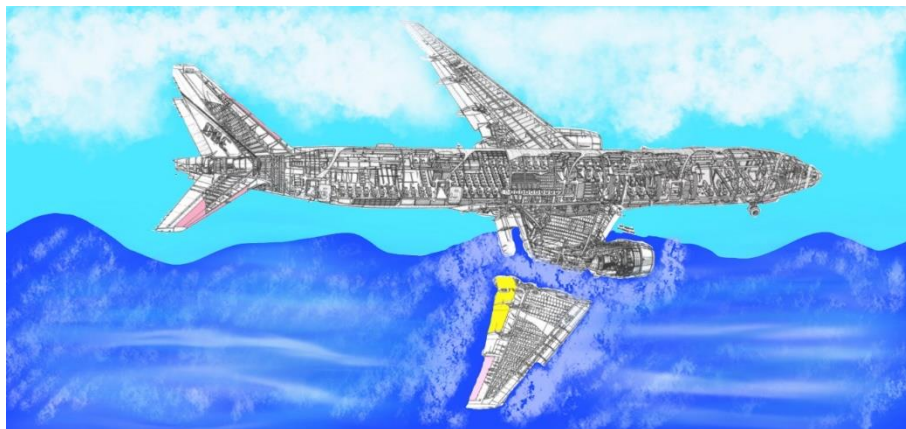
A ditching scenario strongly suspected

The case for a violent right wing first impact

Uncontrolled ditching



Drawing by my son,
Alexander



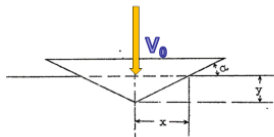
Possible wing
rupture

Basic Von Karman theory

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

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

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

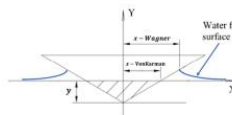


5
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS | AIAA.ORG



AIAA
SHAPING THE FUTURE OF AEROSPACE

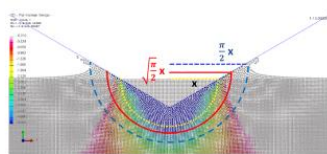
Adapting Von Karman theory for the added mass



- Examining the estimate of the added mass

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

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



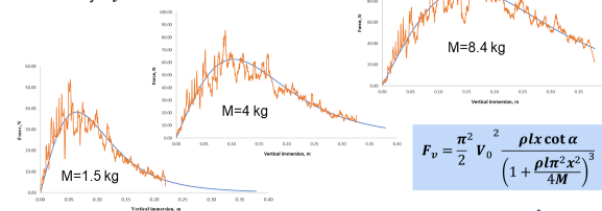
6
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS | AIAA.ORG



AIAA
SHAPING THE FUTURE OF AEROSPACE

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

Simulation: orange
Theory F_v : blue

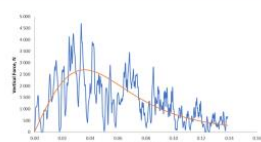
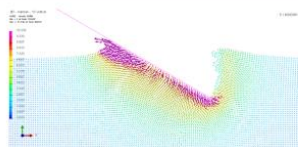


7
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS | AIAA.ORG



AIAA
SHAPING THE FUTURE OF AEROSPACE

Adapting Von Karman theory for a flat plate



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

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

8
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS | AIAA.ORG



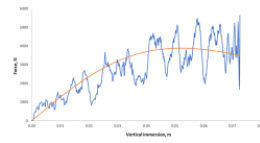
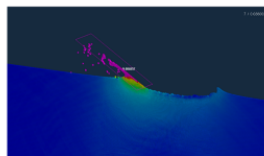
AIAA
SHAPING THE FUTURE OF AEROSPACE

Adapting Von Karman theory for inclined impact

$$V_n = V_0 \cos \alpha$$

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

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



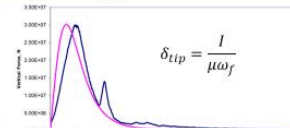
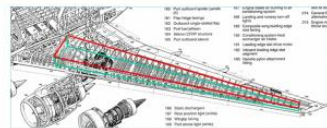
Force versus immersion depth for 55 m/s initial horizontal – 10 m/s initial vertical speeds

9
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS | AIAA.ORG

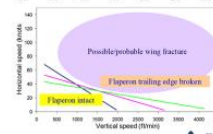
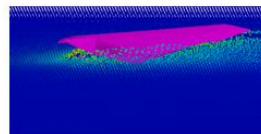


AIAA
SHAPING THE FUTURE OF AEROSPACE

Vertical slamming of finite mass rigid wing link with flaperon analysis of [2]



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



11
AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS | AIAA.ORG



AIAA
SHAPING THE FUTURE OF AEROSPACE

Ditching versus equivalent vertical slamming rigid wing

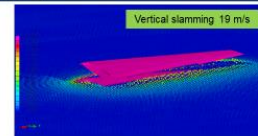
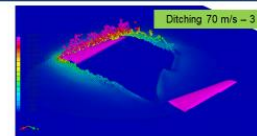


Table 2 Equivalence between inclined ditching and vertical immersion [2]

V_{x0} (m/s)	V_{y0} (m/s)	V_n (m/s)	V_{x0} (m/s)
55	10	44.78	55
55	10	51.75	55
55	10	58.87	55
55	10	65.99	55
55	10	73.12	55
55	10	80.24	55
55	10	87.36	55
55	10	94.48	55
55	10	101.60	55
55	10	108.72	55
55	10	115.84	55
55	10	122.96	55
55	10	130.08	55
55	10	137.20	55
55	10	144.32	55
55	10	151.44	55
55	10	158.56	55
55	10	165.68	55
55	10	172.80	55
55	10	179.92	55
55	10	187.04	55
55	10	194.16	55
55	10	201.28	55
55	10	208.40	55
55	10	215.52	55
55	10	222.64	55
55	10	229.76	55
55	10	236.88	55
55	10	244.00	55
55	10	251.12	55
55	10	258.24	55
55	10	265.36	55
55	10	272.48	55
55	10	279.60	55
55	10	286.72	55
55	10	293.84	55
55	10	300.96	55
55	10	308.08	55
55	10	315.20	55
55	10	322.32	55
55	10	329.44	55
55	10	336.56	55
55	10	343.68	55
55	10	350.80	55
55	10	357.92	55
55	10	365.04	55
55	10	372.16	55
55	10	379.28	55
55	10	386.40	55
55	10	393.52	55
55	10	400.64	55
55	10	407.76	55
55	10	414.88	55
55	10	422.00	55
55	10	429.12	55
55	10	436.24	55
55	10	443.36	55
55	10	450.48	55
55	10	457.60	55
55	10	464.72	55
55	10	471.84	55
55	10	478.96	55
55	10	486.08	55
55	10	493.20	55
55	10	500.32	55
55	10	507.44	55
55	10	514.56	55
55	10	521.68	55
55	10	528.80	55
55	10	535.92	55
55	10	543.04	55
55	10	550.16	55
55	10	557.28	55
55	10	564.40	55
55	10	571.52	55
55	10	578.64	55
55	10	585.76	55
55	10	592.88	55
55	10	600.00	55
55	10	607.12	55
55	10	614.24	55
55	10	621.36	55
55	10	628.48	55
55	10	635.60	55
55	10	642.72	55
55	10	649.84	55
55	10	656.96	55
55	10	664.08	55
55	10	671.20	55
55	10	678.32	55
55	10	685.44	55
55	10	692.56	55
55	10	699.68	55
55	10	706.80	55
55	10	713.92	55
55	10	721.04	55
55	10	728.16	55
55	10	735.28	55
55	10	742.40	55
55	10	749.52	55
55	10	756.64	55
55	10	763.76	55
55	10	770.88	55
55	10	778.00	55
55	10	785.12	55
55	10	792.24	55
55	10	799.36	55
55	10	806.48	55
55	10	813.60	55
55	10	820.72	55
55	10	827.84	55
55	10	834.96	55
55	10	842.08	55
55	10	849.20	55
55	10	856.32	55
55	10	863.44	55
55	10	870.56	55
55	10	877.68	55
55	10	884.80	55
55	10	891.92	55
55	10	899.04	55
55	10	906.16	55
55	10	913.28	55
55	10	920.40	55
55	10	927.52	55
55	10	934.64	55
55	10	941.76	55
55	10	948.88	55
55	10	956.00	55
55	10	963.12	55
55	10	970.24	55
55	10	977.36	55
55	10	984.48	55
55	10	991.60	55
55	10	998.72	55
55	10	1005.84	55
55	10	1012.96	55
55	10	1020.08	55
55	10	1027.20	55
55	10	1034.32	55
55	10	1041.44	55
55	10	1048.56	55
55	10	1055.68	55
55	10	1062.80	55
55	10	1069.92	55
55	10	1077.04	55
55	10	1084.16	55
55	10	1091.28	55
55	10	1098.40	55
55	10	1105.52	55
55	10	1112.64	55
55	10	1119.76	55
55	10	1126.88	55
55	10	1134.00	55
55	10	1141.12	55
55	10	1148.24	55
55	10	1155.36	55
55	10	1162.48	55
55	10	1169.60	55
55	10	1176.72	55
55	10	1183.84	55
55	10	1190.96	55
55	10	1198.08	55
55	10	1205.20	55
55	10	1212.32	55
55	10	1219.44	55
55	10	1226.56	55
55	10	1233.68	55
55	10	1240.80	55
55	10	1247.92	55
55	10	1255.04	55
55	10	1262.16	55
55	10	1269.28	55
55	10	1276.40	55
55	10	1283.52	55
55	10	1290.64	55
55	10	1297.76	55
55	10	1304.88	55
55	10	1312.00	55
55	10	1319.12	55
55	10	1326.24	55
55	10	1333.36	55
55	10	1340.48	55
55	10	1347.60	55
55	10	1354.72	55
55	10	1361.84	55
55	10	1368.96	55
55	10	1376.08	55
55	10	1383.20	55
55	10	1390.32	55
55	10	1397.44	55
55	10	1404.56	55
55	10	1411.68	55
55	10	1418.80	55
55	10	1425.92	55
55	10	1433.04	55
55	10	1440.16	55
55	10	1447.28	55
55	10	1454.40	55
55	10	1461.52	55
55	10	1468.64	55
55	10	1475.76	55
55	10	1482.88	55
55	10	1490.00	55
55	10	1497.12	55
55	10	1504.24	55
55	10	1511.36	55
55	10	1518.48	55
55	10	1525.60	55
55	10	1532.72	55
55	10	1539.84	55
55	10	1546.96	55
55	10	1554.08	55
55	10	1561.20	55
55	10	1568.32	55
55	10	1575.44	55
55	10	1582.56	55
55	10	1589.68	55
55	10	1596.80	55
55	10	1603.92	55
55	10	1611.04	55
55	10	1618.16	55
55	10	1625.28	55
55	10	1632.40	55
55	10	1639.52	55
55	10	1646.64	55
55	10	1653.76	55
55	10	1660.88	55
55	10	1668.00	

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 !

akamoulakos@yahoo.com

<http://www.mh370-captio.net/>



AMERICAN INSTITUTE OF
AERONAUTICS AND ASTRONAUTICS