# Document details





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## Defining Reference Area for Prediction of Aerodynamic Coefficients of a Biologically Inspired Hybrid Buoyant Vehicle (Article)

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### Abstract

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Geometric and volumetric quantities are usually used to define the reference area for the prediction of aerodynamic coefficients of various aquatic mammals, airships and unmanned vehicle. However, reference area does not have a unique definition, especially for a hybrid buoyant aerial vehicle having hybrid lifting hull which resembles a Steller sea lion. The term square cube root of volume is traditionally used as reference area to nondimensionalize the aerodynamic forces for conventional as well as unconventional airships. Published experimental data are usually available for complete configuration at low speed and in nondimensionalized form. So, a generic model of an aircraft's fuselage was first tested in a wind tunnel as a test case to first determine the lift force and then the influence of different choices of reference area on the lift. A hybrid lifting hull was numerically simulated for the prediction of lift as well as drag coefficients and their ratio. It was found that the volumetric term has undefined correlation with aerodynamic forces in both cases. Changes in aerodynamic coefficients are not prominent when using the wetted area as the reference area. Based on the predicted trends of aerodynamic coefficients and a deep literature survey, the projected planform area is proposed as the best option for reference area of a Steller sea lion as well as for hybrid lifting hull of a hybrid buoyant vehicle. © 2017 World Scientific Publishing Company.

### Author keywords

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### References (36)

1 Alexander, D.E.
Drag coefficients of swimming animals: effects of using different reference areas
(1990) *Biological Bulletin*, 179 (2), pp. 186-190. Cited 17 times.
doi: 10.2307/1541768
View at Publisher

2 Batchelor, G.K., Young, A.D.
An introduction to fluid mechanics
(1968) *J. Appl. Mech.*, 35, p. 624. Cited 2 times.

3 Bilo, B.Y.D., Nachtigall, W.
A simple method to determine the drag coeficient of aquatic animals
(1980) *Exp. Biol.*, 87, pp. 357-359. Cited 22 times.

4 Cheneval, O.
(2005) *Biomechanics of Turning Manoeuvers in Steller Sea Loins*. Cited 4 times.
(May). Available at accessed on 15 September 2014
https://circle.ubc.ca/bitstream/id/54541/ubc2005-0397.pdf

5 Pinebrook, Wm.E., Dalton, C.
Drag minimization on a body of revolution through evolution
(1983) *Computer Methods in Applied Mechanics and Engineering*, 39 (2), pp. 179-197. Cited 13 times.
doi: 10.1016/0045-7825(83)90020-8
View at Publisher

6 Lutz, T., Wagner, S.
Drag reduction and shape optimization of airship bodies
(1998) *Journal of Aircraft*, 35 (3), pp. 345-351. Cited 49 times.
http://arc.aiaa.org/loi/ja
doi: 10.2514/2.2313
View at Publisher

7 Vogel, S.
(1987) *Life in Moving Fluids: The Physical Biology of Flow*. Cited 1952 times.
Princeton University Press

8 Vogel, S.
Comparative biomechanics: Life's physical world
(2011) *Comparative Biomechanics: Life's Physical World*. Cited 335 times.
http://press.princeton.edu/titles/7693.html
ISBN: 978-069115566-1

9 Haque, A.U., Asrar, W., Omar, A.A., Sulaeman, E., Ali, J.S.M.
Cambered profile of a California sea lion's body
(2014) *J. Exp. Biol.*, 1, pp. 2-3.

10 Nita, M., Scholz, D.
From peliminary aircraft cabin design to cabin design to cabin optimisation-part I
*Sci. Bull.*, 75. Cited 2 times.
Available at Accessed March 10, 2014
http://www.scientificbulletin.upb.ro/revdocsarhiva/fulld22936656.pdf

11 Vos, R., van Dommelen, J.
A conceptual design and optimization method for blended-wing-body aircraft

(2012) *53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics and Materials Conference 2012*. Cited 6 times.
ISBN: 978-160086937-2

12 Abbas, A., De Vicente, J., Valero, E.
Aerodynamic technologies to improve aircraft performance

(2013) *Aerospace Science and Technology*, 28 (1), pp. 100-132. Cited 55 times.
doi: 10.1016/j.ast.2012.10.008

View at Publisher

13 Bamber, M.J., House, R.O.
*Wind Tunnel Investigation of Effect of Yaw On Lateral-stability Characteristics. II: Rectangular N.A.C.A. 33012 Wing with a Circular Fuselage and a Fin; 1939)*
NACA Technical Note 703, National Advisory Committee for Aeronautics. Langley Aeronautical Lab.; Langley Field, VA, United States

14 Carichner, G.E., Nicolai, L.M.
(2013) *Fundamentals of Aircraft and Airship Design, Airship Design*, 2. Cited 127 times.
(ed. J. A. Schetz ). (American Institute of Aeronautics and Astronautics, AIAA

15 Haque, A.U., Asrar, W., Omar, A.A., Sulaeman, E., Ali, M.J.S.
Conceptual design of a winged hybrid airship

(2014) *21st AIAA Lighter-Than-Air Systems Technology Conference*. Cited 11 times.
ISBN: 978-162410286-8

16 Suzuki, I., Sato, K., Fahlman, A., Naito, Y., Miyazaki, N., Trites, A.W.
Drag, but not buoyancy, affects swim speed in captive Steller sea lions

(2014) *Biology Open*, 3 (5), pp. 379-386. Cited 9 times.
http://bio.biologists.org/content/biolopen/3/5/379.full.pdf
doi: 10.1242/bio.20146130

View at Publisher

17 Ul Haque, A., Asrar, W., Omar, A.A., Sulaeman, E., Mohamed Ali, J.S.
Stability and takeoff ground roll issues of hybrid buoyant aircraft

(2014) *Applied Mechanics and Materials*, 660, pp. 503-507. Cited 5 times.
http://www.scientific.net/AMM
ISBN: 978-303835278-5; 978-303835278-5
doi: 10.4028/www.scientific.net/AMM.660.503

View at Publisher

18 Ilieva, G., Páscoa, J., Dumas, A., Trancossi, M.
MAAT - Promising innovative design and green propulsive concept for future airship's transport

(2014) *Aerospace Science and Technology*, 35 (1), pp. 1-14. Cited 17 times.
doi: 10.1016/j.ast.2014.01.014

View at Publisher

19 Fish, F.E.
Influence of hydrodynamic design and propulsive mode on mammalian swimming energetics

(1994) *Australian Journal of Zoology*, 42 (1), pp. 1-16. Cited 107 times.
doi: 10.1071/ZO9940079

View at Publisher

20 Khoury, G.A.
(2012) *Airship Technology*, 10. Cited 362 times.
Cambridge University Press

21 Khoury, G.A., Gillett, J.D.
(1999) *Airship Technology*. Cited 362 times.
Cambridge Univ. Press

22 Aero Spacelines377 PG Pregnant Guppy Available at Accessed September 7, 2014
http://www.allaboutguppys.com/pg/377pgf.htm

23 Raymer, D.
(2004) *Aircraft Design: A Conceptual Approach, 5th Ed*
Schetz JA, ed.). (American Institute of Aeronautics and Astronautics, Inc., Washington, DC

24 Zhang, K.-S., Han, Z.-H., Song, B.-F.
Flight performance analysis of hybrid airship: Revised analytical formulation

(2010) *Journal of Aircraft*, 47 (4), pp. 1318-1330. Cited 16 times.
http://pdf.aiaa.org/getfile.cfm?
urlX=%2D%3CWI%277D%2FQKS%2B%2FS%40O%40V0%20%20%0A&urla=%26%2A%22L%20%23%20%2AC%0A&urlb=%21%2A%20%20%20%0A&urlc=%
doi: 10.2514/1.47294

View at Publisher

25 Verma, A.R., Sagar, K.K., Priyadarshi, P.
Optimum buoyant and aerodynamic lift for a lifting-body hybrid airship

(2014) *Journal of Aircraft*, 51 (5), pp. 1345-1350. Cited 2 times.
http://arc.aiaa.org/doi/pdf/10.2514/1.C032038
doi: 10.2514/1.C032038

View at Publisher

26 Filippone, A.
Data and performances of selected aircraft and rotorcraft

(2000) *Progress in Aerospace Sciences*, 36 (8), pp. 629-654. Cited 23 times.
doi: 10.1016/S0376-0421(00)00011-7

View at Publisher

27 Qin, N., Vavalle, A., Le Moigne, A., Laban, M., Hackett, K., Weinerfelt, P.
Aerodynamic considerations of blended wing body aircraft

(2004) *Progress in Aerospace Sciences*, 40 (6), pp. 321-343. Cited 122 times.
doi: 10.1016/j.paerosci.2004.08.001

View at Publisher

28 Buerge, B.T.
(2013) *Scalability of Heaviness Fraction for Large Airships in Aerodynamic Decelerator Systems Technology Conferences*
AIAA Lighter-ThamAir Systems Technology (LTA) Conference. Reston: AIAA

29 Torenbeek, E.
Advanced Aircraft Design: Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes

(2013) *Advanced Aircraft Design: Conceptual Design, Analysis and Optimization of Subsonic Civil Airplanes*, pp. 1-410. Cited 74 times.
http://onlinelibrary.wiley.com/book/10.1002/9781118568101
ISBN: 978-111856811-8
doi: 10.1002/9781118568101

View at Publisher

30 Webb, B.Y.P.W.
Is the high cost of body/caudal fin undulatory swiming due to increased friction drag or internal recoil
(1992) *J. Exp. Biol.*, 162, pp. 157-166. Cited 62 times.

31 Stelle, L.L., Blake, R.W., Trites, A.W.
Hydrodynamic drag in Steller sea lions (Eumetopias jubatus)

(2000) *Journal of Experimental Biology*, 203 (12), pp. 1915-1923. Cited 34 times.

View at Publisher

32 Ward, J.
Animal locomotion [2]

(1874) *Nature*, 9 (229), pp. 381-382. Cited 2 times.

View at Publisher

33 Cooper, L.N., Sedano, N., Johansson, S., May, B., Brown, J.D., Holliday, C.M., Kot, B.W., (...), Fish, F.E.
Hydrodynamic performance of the minke whale (Balaenoptera acutorostrata) flipper

(2008) *Journal of Experimental Biology*, 211 (12), pp. 1859-1867. Cited 23 times.
doi: 10.1242/jeb.014134

View at Publisher

34 Weber, P.W., Howie, L.E., Murray, M.M., Fish, F.E.
Lift and drag performance of odontocete cetacean flippers

(2009) *Journal of Experimental Biology*, 212 (14), pp. 2149-2158. Cited 20 times.
http://jeb.biologists.org/cgi/reprint/212/14/2149
doi: 10.1242/jeb.029868

View at Publisher

35 Fish, F.
Imaginative solutions by marine organisms for drag reduction
(1998) *Proc. Int. Symp. Seawater. Drag. Reduct.*, 1, pp. 443-450. Cited 27 times.

36 Levy, D.W., Zickuhr, T., Vassberg, J., Agrawal, S., Wahls, R.A., Pirzadeh, S., Hemsch, M.J.
Data summary from the first AIAA computational fluid dynamics drag prediction workshop

(2003) *Journal of Aircraft*, 40 (5), pp. 875-882. Cited 81 times.
http://arc.aiaa.org/loi/ja
doi: 10.2514/2.6877

View at Publisher