An Aerodynamic Analysis of Current Data for USS Akron Airship

http://en.wikipedia.org/wiki/USS_Akron_(ZRS-4)

1. Introduction

Recently received data from Fred Jackson is the basis of the following analyses. The source of Fred's data was the NACA Report No. 432, titled "Force Measurements on a 1/40 Scale Model of the U.S. Airship Akron" (Ref.3). Here below are the curves and equations that Fred derived from the NACA data. (Ref.1)

http://wiki.titaniumrat.com/wiki/doku.php?id=airships:akron_wind_tunnel_data_curve_fitting

2. Purpose of these analyses

It is my intention to use the newly acquired data (above) plus my own data to develop and display the aerodynamic and aerostatic characteristics of the Akron airship, with a view to exploring its Lift/Drag ratio over a range of airspeeds and angles of attack. All of the data used herein is based upon $Vol^{2/3}$ as the reference area for drag and lift.

Various references were used, as listed on Page 5.

3. Drag coefficient for EQ operations

From a short report that was completed recently by the Author, using the data of Ref.2 (Hoerner), the following drag coefficients were developed based upon actual R_N's.

Table 1 – Drag coefficients for Akron ($Vol^{2/3}$) at EQ

Airspeed-knots		25	50	75	80	Comments
Altitude - ft						
S.L.		0.0105	0.0103	0.0102	0.0102	minimum
5,000		0.0106	0.0104	0.0102	0.0102	-
10,000		0.0106	0.0104	0.0103	0.0103	-
15,000		0.0107	0.0105	0.0103	0.0103	maximum

For the purposes of these analyses, C_{Do} is taken to be equal to 0.0107 (constant).

4. Induced drag

For a body-of-revolution such as an airship, lift induced drag is generated whenever the hull is inclined to the velocity vector, so as to generate vertical lift (in pitch) or a turning moment (in yaw). This induced drag is developed due to cross-flow on the hull plus the generation of vortices from the regions of flow separation.

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The following table of data points, based upon $Vol^{2/3}$, was obtained by interpolation of the graph "cdi-equation.png" from Ref.1.

Table 2 – Lift induced drag coefficient vs angle of attack

Angle of attack	0	3	6	9	12	15	18	20	deg.
C_{Di}	0.0	0.0025	0.0075	0.019	0.038	0.066	0.102	0.130	

(Credit: Fred Jackson)

5. Aerodynamic lift

Also from Ref.1, the following tabulation of lift coefficients (based upon $Vol^{2/3}$) was obtained by interpolation of the graph "cl-equation.png".

Table 3 – Lift coefficient vs angle of attack

Angle of attack	0	3	6	9	12	15	18	20	deg.
C_L	0.0	0.033	0.075	0.127	0.184	0.262	0.338	0.400	

(Credit: Fred Jackson)

6. Total drag coefficient

The total drag coefficients of the airship are found by summing C_{Do} (i.e. 0.0107 from Table 1) and the data of Table 2 (C_{Di}).

Table 4 – Total drag coefficient vs angle of attack

Angle of attack	0	3	6	9	12	15	18	20	deg.
Total C_D	0.0107	0.0132	0.0182	0.0297	0.0487	0.0767	0.113	0.141	

7. Lift to drag ratio (aerodynamic)

Now by using the data of Tables 3 and 4, the following tabulation was obtained (by dividing C_L by C_D)

Table 5 – Lift to drag ratio vs angle of attack

Angle of attack	0	3	6	9	12	15	18	20	deg.
L/D	0.0	2.50	4.12	4.28	3.78	3.42	2.99	2.84	

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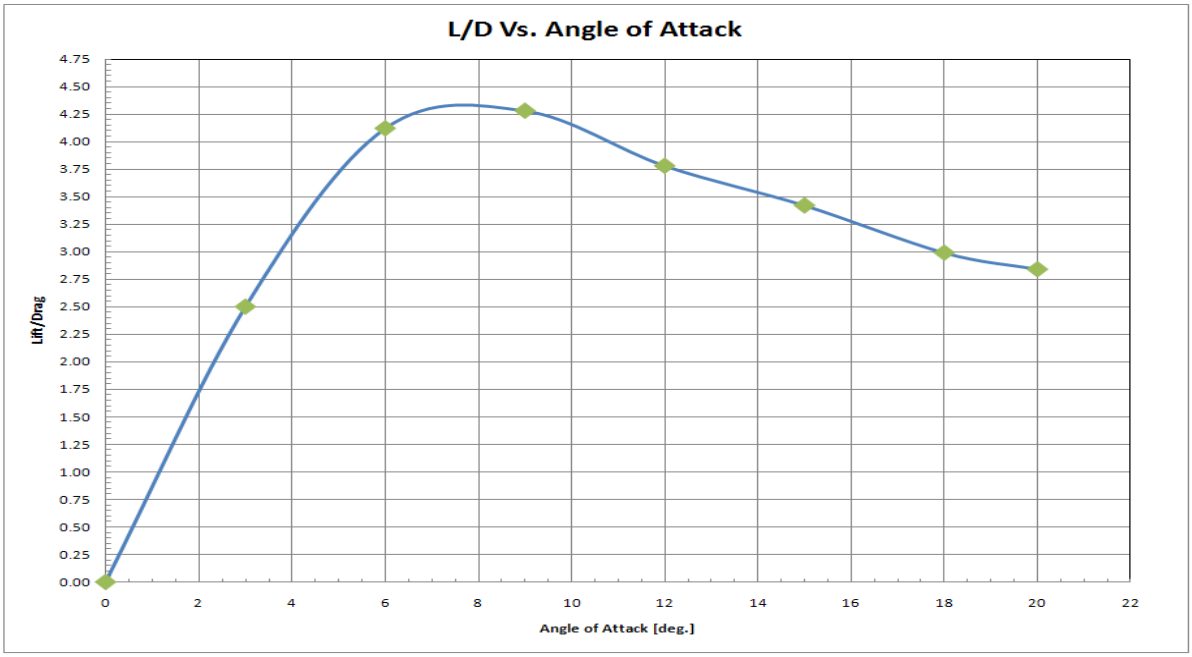
7. Lift to drag ratio (aerodynamic) continued

Fig. 1 – Graph showing L/D vs Angle of attack for USS Akron



(Thanks to Donald. P. Horkheimer for the graph)

8. Inclusion of aerostatic lift

Ref.4 (Wikipedia) lists the volume of the USS Akron airship as 6,500,000 cubic feet, and a useful load of 182,000 lb (83 ton). [Author: 81.25 Imperial ton @ 2,240 lb/ton]

When this useful aerostatic lift, as distinct from the gross aerostatic lift (~412,000 lb), is considered in the L/D relationship, then a much different outcome from the above can be shown.

For the purposes of these analyses I have coined the symbol C_A which is defined as the coefficient of aerostatic lift, based upon $Vol^{2/3}$ and treated in the same way as the aerodynamic coefficients. This fictitious coefficient enables an interesting comparison to be shown.

Using the familiar equation :- $L = \frac{1}{2} \rho V^2 S C_A$

Where we arbitrarily define :- Altitude = 5,000 ft

$\rho = 0.002048$ slug/ft^3

$V = 50$ knots, 84.44 ft/sec

$S = Vol^{2/3}$, 34,829 ft^2

and $L = 182{,}000$ lb

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8. Inclusion of aerostatic lift continued

Therefore :- $C_A = L/½\ \rho V^2 S$

Evaluate using data above :- $C_A = 0.7157$ based upon $Vol^{2/3}$

Now by summing C_A and C_L of Table 3, we obtain the combined lift coefficient.

Table 6 – Combined lift coefficient vs angle of attack

Angle of attack	0	3	6	9	12	15	18	20	deg.
C_L	0.7157	0.7487	0.7907	0.8427	0.8997	0.9777	1.054	1.116	

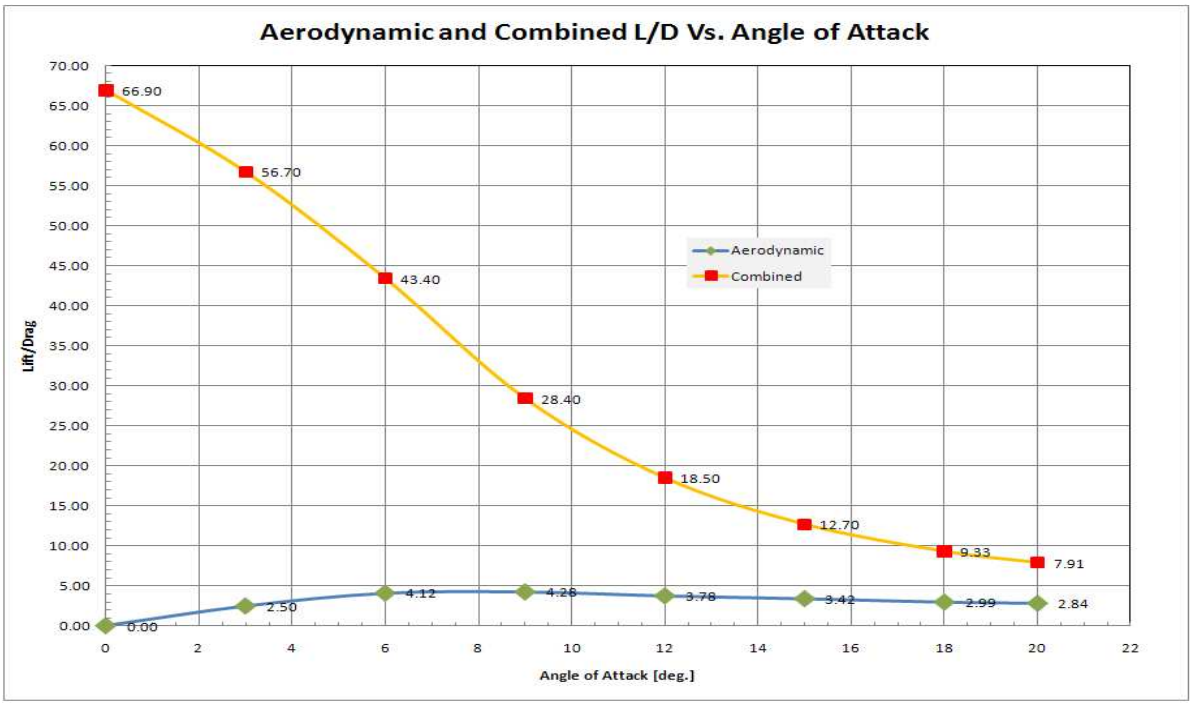
9. Lift to drag ratio, with combined aerodynamic and aerostatic lift

From the results of Tables 6 and 4, by dividing C_L by C_D, we arrive at the following set of data.

Table 7 – Lift to drag ratio vs angle of attack (combined lift)

Angle of attack	0	3	6	9	12	15	18	20	deg.
L/D	66.9	56.7	43.4	28.4	18.5	12.7	9.33	7.91	

Fig. 2 – Graph showing L/D vs Angle of attack for USS Akron (combined lift)



(Thanks to Donald. P. Horkheimer for the graph)

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10. Comparison with NASA lifting-bodies



NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/gallery/photo/index.html
NASA Photo: ECN-1107 Date: 1966 Photo by: NASA photo

M2-F1 and M2-F2 lifting bodies on ramp

From Ref.6, the following data was obtained for the L/D ratios of various lifting-bodies tested during the 1960's under NASA contracts.

Table 8 – L/D performance of Lifting-bodies

Designation	X-24B	X-24A	HL-10	M2-F3
Glide L/D	4.5	4.0	3.6	3.1

11. Conclusions

In this brief report I have shown that the L/D performance of the USS Akron, and by similarity other airship types, is aerodynamically low, but not less than the capabilities of the NASA lifting bodies.

When the lift of helium is included, the L/D is shown to increase by an order of magnitude (>x10), per Fig.2.

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References

1. Fred Jackson's analysis of NACA Report No. 432.
   http://wiki.titaniumrat.com/wiki/doku.php?id=airships:akron_wind_tunnel_data_curve_fitting
2. Fluid Dynamic Drag, Hoerner.
3. NACA Technical Report No. 432
   http://naca.central.cranfield.ac.uk:80/report.php?NID=1079
4. USS Akron http://en.wikipedia.org/wiki/USS_Akron_(ZRS-4)
5. http://www.dfrc.nasa.gov/Gallery/Photo/Fleet/HTML/ECN-1107.html
6. Wingless Flight, R. Dale Reed, Foreword by Chuck Yeager. Page 175.

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