Technical Comments

Comment on "Experimental Determination of Improved Aerodynamic Characteristics Utilizing Biplane Wing Configurations"

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IN Ref. 1, Olson and Selberg have presented very interesting data relating to lift and drag of biplane wing combinations. They find that, over a wide range of lift coefficients, there are combinations of biplane gap, stagger, and decalage which give a significantly higher lift to drag ratio than a comparable monoplane. They also find that the biplane combinations they tested had significantly lower maximum lift coefficient than the monoplane.

1) As was pointed out recently in Ref. 2, a lower maximum lift coefficient is not an inevitable result of a biplane configuration, nor have Olson and Selberg said that it is.

2) One wonders how much of the observed improvement in aerodynamic characteristics was due to the biplane arrangement, and how much was due to the specific wing-fuselage-Reynolds number combinations tested. A study of Fig. 9 of Ref. 1 reveals that almost all of the improvement in L/D for the biplane was a result of a reduction in zero lift drag. It is hard to see how any change in inviscid flow distribution, as postulated in Ref. 1, could produce a change in drag at zero lift. The efficiency factor, "e," measured for both monoplane and biplane was significantly lower than what is normally observed for commercial or general aviation aircraft. This indicates a possibility that viscous effects, perhaps due to wing-fuselage interference, may be playing an important part in the increase of drag as lift is increased. It would be interesting to see what the drag comparison would look like if the monoplane airfoil had occupied the same forward, high wing position relative to the fuselage as the upper wing of the biplane combination, and/or if the comparison had been made at Reynolds numbers more nearly representative of those that are encountered in commmercial and general aviation aircraft.

3) As was pointed out in Ref. 2, there are important points relating to biplane aerodynamics other than lift/drag ratio. One of these is handling characteristics at or near stall. Figure 13 of Ref. 1 shows a sharp increase in pitching moment coefficient for angles of attack above 16°, which is just slightly below the angle of attack for maximum lift coefficient. This indicates that perhaps the trailing wing is stalling first. This could cause a quite unpleasant pitch up near stall in a real airplane. As is pointed out in Ref. 3, and as is shown by the performance of the Grumman Ag-Cat, biplanes can be designed which have quite docile and safe stalling characteristics.

4) It is hoped that the results presented in Ref. 1 will not obscure an advantage of the biplane configuration which used to be quite well known to designers: with proper choice of gap and stagger, the biplane structure can be braced so that the wing weight is much less than for a monoplane. Reference 3 indicates that the biplane wing weight per unit area can be made approximately half that for a comparable cantilever monoplane. This, combined with the shorter wing span of the biplane, makes it possible to design a biplane with handling characteristics that one would normally find only in a monoplane with a much smaller payload. The high stagger configurations tested in Ref. 1 might be difficult to brace.

5) The authors of Ref. 1 are acheiving their low drags with approximately the same configurations that Nenadovitch,[4] tested as two-dimensional configurations. This would indicate that perhaps the low drags which are being measured are due to some two-dimensional inviscid-flow-boundary-layer interaction. If so, analytical tools exist for investigating this effect. In fact, Ref. 3 describes how the problem might be investigated analytically even for finite span biplane wing systems.

In short, Olson and Selberg have experimentally demonstrated a very interesting effect. It could be very worth while to investigate the configurations they have tested further, both analytically and experimentally, to see if more can be learned about the causes behind the effects they have demonstrated.

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References

[1]Olson, E.C. and Selberg, B.P. "Experimental Determination of Improved Aerodynamic Characteristics Utilizing Biplane Wing Configurations," *Journal of Aircraft*, Vol. 13, April 1976, pp. 256-261.

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[3]Addoms, R.B., "Aerodynamic and Structural Design Considerations for High Lift Biplane Wing Systems," Ph.D. Thesis, Dept. of Mechanics and Structures, University of California, Los Angeles, Cal., Nov. 1971.

[4]Nenadovitch, M. "Recherches sur les Cellules Biplane Rigides d'Envergure Infine," Publications Scientifiques et Techniques du Ministere de L'Air, Institut Aerotechnique de Saint-Cyr, Paris, 1936.

Reply by Author to R.B. Addoms

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I WISH to thank R. B. Addoms for his comments on our paper. While many of Addoms' comments apply to biplane configurations with the conventional wing placement, our paper specifically investigated, in detail, only those configurations that would result in less energy usage, increased payload capacity, and increased range through reductions in C_D over the monoplane configuration. Our tests indicated that for particular biplane wing gap, wing stagger, and decalage angle significant C_D reductions, C_L/C_D increases, and $C_L^{3/2}/C_D$ increases for a large variation of lift conditions occurred. The range of gap, stagger, and decalage angle in which these improvements occurred was quite narrow. As was indicated in our article[1] and with the original complete date,[2] our tests agreed with Nenadovitch's[3] complete work in that

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they showed this C_L and C_D improvement both for the same values of gap, stagger, and decalage angle and only in a narrow range of gap, stagger, and decalage angle. Nenadovitch[3] and our tests used different airfoil sections and were conducted at different test Reynolds numbers. In addition, our tests were conducted with and without a fuselage without any loss of data consistency.

In Addom's comment, he noted that almost all of the L/D improvement occurred at zero lift, and he did not understand how our postulated change in the inviscid flow distribution could occur at zero lift. In all our tests that showed improvement of C_L and C_D, there was a negative decalage angle, i.e., the angle of attack between the chords of the upper and lower wings was negative. Thus, even when the total lift is zero, the upper forward wing will be producing a negative lift while the lower rearward wing will be producing a positive lift. Thus, the two lift-producing wings will indeed produce a change in the inviscid flow distribution about the wing-fuselage-tail system even at zero total lift. Moreover, at all angles of attack, at least one of the two wings will always be producing lift.

Addoms called attention to our low efficiency factor. This occurred because all our tests were conducted with a constant chord and constant thickness wing with square lateral edges. The models were constructed in this manner for ease of fabrication. Square lateral edges tend to raise C_D and lower $dC_D/dC_L{}^2$, hence lowering the efficiency factor.[4] As pointed out by Addoms, a more streamlined fuselage would probably have lowered C_D further, making the aerodynamic improvements even larger and more significant. As also suggested, tests at higher Reynolds number,[5] with the same configuration, would have decreased C_D, caused C_L to stay the same, and increased $C_{L\max}$. Each of these changes would have improved the results we reported in our paper.[1]

Addoms also noted our studies showed a pitching up tendency at stall. While this tendency does present handling problems, it was the intent of the paper of investigate the gap, stagger, and decalage angle of the biplane configurations to maximize C_L and minimize C_D over a wide angle of attack range. Reverting to the conventional biplane wing placement, as suggested to alleviate this problem, will not give the aerodynamic improvements that lead to reduced energy usage and increased payload capacity.

In summary, while some of Addoms' comments pertain to our specific biplane configurations, others, because of wing placement, do not relate to our paper or our results.

References

[1] Olson, E.C. and Selberg, B. P., "Experimental Determination of Improved Aerodynamic Characteristics Utilizing Biplane Wing Configurations," *Journal of Aircraft*, Vol. 13, April 1976, pp. 256-261.

[2] Olson, E.C., "Experimental Determination of Improved Aerodynamic Characteristics Utilizing Biplane Wing Configurations," M.S. Thesis, Mechanical and Aerospace Engineering Dept., University of Missouri-Rolla, Rolla, Mo. 1974.

[3] Nenadovitch, M., "Recherches sur les Cellules Biplane Rigides d'Envergure Infine," Publications Scientifiques at Tecniques du Ministere de L'Air, Institute Aerotechnique de Saint-Cyr, Paris, 1936.

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[5] Abbott, I.H.and Von Doenhoff, A.E., *Theory of Wing Sections*, Dover Publications Inc., New York, 1959.