A MULTIDISCIPLINARY APPROACH TO DESIGN

A recent issue of the Journal of Aircraft, published by the American Institute of Aeronautics and Astronautics, was devoted to optimization of aeronautical systems through multidisciplinary approaches.

The most interesting article for us was one directed toward actively controlled fiber composite wings[1]. Although the article itself was very heavily mathematics oriented, several charts and diagrams provided basic information of use to model builders. What follows is not a review or condensation of the article, but rather a description of a derived design methodology/philosophy which is suitable for both tailless and conventional RC sailplanes.

CONSTRAINTS

Any design process begins with a determination of the constraints imposed on the eventual design. All of our models must conform to the majority of the FAI regulations for RC sailplanes. From the start, then, we know the wing loading must be over 4 oz/ft^2 and under 24 oz/ft^2. We also know the mass of our completed glider must be below 5 kg (176 oz). Other constraints include the minimum nose radius, a ban on telemetry, and a requirement that all model controls be actuated from the ground, but not all of these are adhered to by AMA regulations. (Thermal sniffers and electrostatic stabilizers can be used in AMA competition.) Additionally, our design may be constrained by certain AMA regulations regarding span, or local rules may define a maximum number or type of control surface.

DESIGN APPROACH

The main thrust of all of the articles in the Journal of Aircraft is the entire design approach needs to be based on a multidisciplinary process in which each segment to be optimized affects all other segments. This implies that while we will of course endeavor to maximize overall sailplane performance, our method of achieving this goal will simultaneously encompass structural, aerodynamic, and control systems, while always remaining within those previously defined restraints. As we explain these systems in detail, through example, we will outline their relationships.

STRUCTURE

Overall size, in our opinion, should be the designer's first consideration. As a pertinent example, we have recently been giving greater thought to winch power versus sailplane size. This came about because our two meter 'wing, the Blackbird, with 1250 in^2 of wing area, can not really take advantage of the power available from our winch. Even very strong zoom launches do not tax its capabilities. At the other extreme, our XC version of the Blackbird (2300 in^2) overloads the winch to an extreme degree. What we need is a 'wing with about 1700 to 1800 in^2 of area. We feel this would allow most efficient use of winch power, while at the same time improve performance compared to the two meter version. If you are designing for contest flying prescribed by AMA regulations, such manipulations of wing area may not be possible to a large extent due to wing span limitations and the desire for optimum aspect ratio. For FAI events, however, such size optimization is both possible and desirable.

Of related interest is flying weight (mass). This is because mass and size are usually positively related and because required lift is directly related to mass. Mass also has an effect on other performance characteristics, such as speed.

Sailplane structure also includes overall planform (tailed vs. tailless, tapered vs. constant chord, sweepback, etc.) The stresses imposed on the wing panels will vary depending on whether or not there is a fuselage, and other distribution-of-mass factors, so spars must be sized for strength and located where strength can be put to best use. It should also be kept in mind the structure may also be influential in drag reduction, as we'll describe in more detail in the next section.

AERODYNAMICS

The portion of the design process devoted to aerodynamics was really introduced in this article when we spoke of the lift necessary to support the mass of the sailplane. Airfoil choice is dependent upon camber, which dictates the amount of lift generated. Lift can be augmented, always with some penalty, through use of various control surface movements. Flaps, as an example, change the camber line and thus influence lift, but with the penalty of higher drag. Local aerodynamics are changed through control surface deflection.

Also influencing the sailplane's aerodynamics is wing shape. Lowest drag is achieved with some small amount of sweepback of the quarter chord line, for instance, and the lift distribution can be tailored to specific requirements through transitioning of airfoils and careful attention to taper.

Consideration must also be given to overall drag. The shape of the lifting surfaces is certainly important, but the wing-fuselage junction, empennage configuration, hinge design, and other factors must also receive careful attention. Of recent interest to modelers is the measurably lower drag of foam core wings when compared with that of open framework structures. The smooth ridge free skin of the foam core wing creates smaller and less numerous vortices.

CONTROL

Velocity, glide angle, and other important variables are easily examined as the sailplane is traveling in a straight line. But our goal when installing RC gear is to have an aircraft capable of turning and having its altitude, attitude, and speed varied according to our input. We wish to have control of the sailplane during its flight, and hopefully with as little degradation of performance as possible. So we install a rudder, elevator, ailerons, flaps, spoilers, air brakes... anything which we feel will allow us some added degree of control and which we hope will allow us to go up more easily, and come down safely and effectively when desired.

Control surface deflection will always have some aerodynamic effect, and this effect will always be transferred to the aircraft's structure. Many of us forget this relationship during the design process. We must not only consider the loads imposed upon the servos and control systems, but also the stresses which are imposed upon the aircraft as a whole. Steeply banked turns place tremendous loads on the conventional tailed sailplane's wing center section. While servos may easily handle the aerodynamic load generated by the deflected control surfaces, the spar and spar-fuselage connection must also remain intact.

INTEGRATION OF THE THREE SYSTEMS

It should be evident from the above that structure, aerodynamics, and control are interwoven to the point of being inseparable, and a change in one aspect of the design process affects all three realms. While our primary design goal is always the maximizing of sailplane performance, it should also be obvious an immense number of design objectives must be met in the process. Improved glide angle, quicker turns, increased roll rate, greater velocity, or better thermal performance may be classed as design goals. But such things as control of wing flex and twist, freedom from flutter within the prescribed speed range, dynamic stability, effective control, maximum lift with minimum increase in drag, and retention of spar integrity under expected g loads are also inherent considerations within the design process. It is the successful integration of the three disciplines - structure, aerodynamics, and control - which produces the optimum sailplane for a particular task.

By developing a more complete understanding of these three disciplines, their interrelationships and the design process, better sailplanes can be produced.

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[1] Livne, E., Schmit, L.A., and Friedman, P.P., "Towards Integrated Multidisciplinary Synthesis of Actively Controlled Fiber Composite Wings," Journal of Aircraft, Vol. 27, No. 12, December 1990, pp. 979-992.

DRAW TAILLESS

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1      REM  **** DRAW TAILLESS ****
10     CALL  - 936
20     PRINT "DRAW TAILLESS will provide a line"
30     PRINT "sketch using input parameters."
40     PRINT : PRINT "What is the sweep ratio? ";: INPUT SR
50     PRINT : PRINT "What is the root chord? ";: INPUT RC
60     PRINT : PRINT "What is the tip chord? ";: INPUT TC
61     PRINT : PRINT "Do you want the vertical fin area on thewing
       tips or on the center line?        ENTER 'W' for Winglets
       'S' for Single fin": INPUT A$
63     IF A$ <  > "W" AND A$ <  > "S" THEN  VTAB (9): GOTO 61
70     REM   ***** RADIANS
80     R = 57.2957795
90     REM  ***** SIN
100    S6 =  SIN (60 / R)
110    S2 =  SIN (240 / R)
120    REM  ***** COS
130    C6 =  COS (60 / R)
140    C2 =  COS (240 / R)
150    H = 88
160    V = 50
170    PRINT : PRINT "Span (150 = Max.)? ";: INPUT SP
171    IF SP > 150 THEN  VTAB (15): GOTO 170
180    HS = SP / 2
190    CH = (RC + TC) / 2
200    SW = SR * CH
210    WS = SW + TC - RC
220    A = (SP * (SW + TC)) - (HS * SW) - (HS * WS)
230    IS =  SQR (((SW + TC / 2 - RC / 2) ^ 2) + (HS ^ 2)) * 2
240    AR = IS / CH
250    HGR : HCOLOR= 3
260    REM H=88, V=50
270    HPLOT H,V
280    REM ***** A
290    HPLOT  TO H + S6 * 100,V + C2 * 100
300    HPLOT H,V
310    REM ***** B
320    HPLOT  TO H + S6 * 100,V + C6 * 100
330    HPLOT H,V
340    REM ***** C
350    HPLOT  TO H + S2 * 100,V + C6 * 100
360    HPLOT H,V
370    REM ***** D
380    HPLOT  TO H + S2 * 100,V + C2 * 100
390    HPLOT H,V
391    REM  CG
392    HC = H + S6 * ((SW + .001) / 2 + CH / 4)
393    VC = V + C6 * ((SW + .001) / 2 + CH / 4)
394    HPLOT HC,VC + 10 TO HC,VC - 10
400    REM ***** RT L.E.
401    HPLOT H,V
410    HO = H + S6 * HS + S6 * SW
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420  VE = V + C2 * HS + C6 * SW
421  HT = HO:VT = VE
430  HPLOT  TO HO,VE
440  REM  ***** RT TIP
450  HO = HO + S6 * TC
460  VE = VE + C6 * TC
470  HPLOT  TO HO,VE
471  REM  RT WINGLET
472  IF A$ <  > "W" THEN  GOTO 480
473  HO = HT + S6 * .3 * TC:VO = VT + C6 * .3 * TC
474  H1 = HO:V1 = VE - .2 * HS
475  H2 = H1 + S6 * .35 * TC:V2 = V1 + C6 * .35 * TC
476  HPLOT HO,VO TO H1,V1 TO H2,V2 TO HO,VE
480  REM ***** RT T.E.
490  HO = H + S6 * RC
500  VE = V + C6 * RC
510  HPLOT  TO HO,VE
520  REM ***** LT L.E.
530  HPLOT H,V
540  HO = H + S2 * HS + S6 * SW
550  VE = V + C6 * HS + C6 * SW
560  HPLOT  TO HO,VE
561  HT = HO:VT = VE
570  REM ***** LT TIP
580  HO = HO + S6 * TC
590  VE = VE + C6 * TC
600  HPLOT  TO HO,VE
601  REM  LT WINGLET
602  IF A$ <  > "W" THEN  GOTO 610
603  HO = HT + S6 * .3 * TC:VO = VT + C6 * .3 * TC
604  H1 = HO:V1 = VE - .2 * HS
605  H2 = H1 + S6 * .35 * TC:V2 = V1 + C6 * .35 * TC
606  HPLOT HO,VO TO H1,V1 TO H2,V2 TO HO,VE
610  REM ***** LT T.E.
620  HO = H + S6 * RC
630  VE = V + C6 * RC
640  HPLOT  TO HO,VE
641  REM  SINGLE TAIL
642  IF A$ <  > "S" GOTO 650
643  TA = A / 10:S =  SQR (TA)
644  HO = HO + S6 * S:VO = VE + C6 * S
645  H1 = HO:V1 = VO - S
646  H2 = H1 + S2 * .4 * S:V2 = V1 + C2 * .4 * S
647  HPLOT HO,VE TO HO,VO TO H1,V1 TO H2,V2 TO HO,VE
650  REM PRINT DATA
660  VTAB 24: PRINT "Area = "; INT (A);"       Aspect Ratio = ";
     INT (AR * 100) / 100
665  PRINT "Root Chord = ";RC;"   Tip Chord = ";TC
668  PRINT "Sweep Ratio = ";SR
670  PRINT "Another design? ";: GET A$: PRINT A$: IF A$ = "N"
     THEN  TEXT : HOME : END
671  IF A$ = "Y" THEN  TEXT : HOME : GOTO 40
672  VTAB 23: GOTO 670
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