Table 1 Takeoff performance – mean of five replications

Weight	14.5% under gross weight	Gross weight	14.5% over gross weight
Procedure	Time to liftoff, s		
Conventional*	30.8a	38.5a	48.6a
Float lift**	31.6a	33.9b	43.1b
Flap change***	25.1b	29.8c	39.6c
	Time to 50-ft obstacle at 75 SMIAS		
Conventional	39.9a	48.3a	57.9a
Float lift	41.2b	44.1b	54.7b
Flap change	37.0c	45.7c	57.4c
	Water run distance, ft		
Conventional	1346a	1810a	2724a
Float lift	1392a	1516b	2140b
Flap change	982b	1438b	2027b
	Total distance to 50-ft obstacle		
Conventional	2223a	2767a	3639a
Float lift	2304a	2533b	3314b
Flap change	1897b	2746a	3854c
* V rotate, SMIAS	48	52	62
** V rotate, SMIAS	Fly off	Fly off	Fly off
*** V rotate, SMIAS	43	47	58
Hump to step transition, SMPH	17–20	19–21	24–26

Table Notes: a) Within the column, different lowercase letters following means indicate significant difference at the 0.05 level.

Table 2 Computed delta ratios for three takeoff procedures at three aircraft weights

Takeoff procedure	Aircraft weight: Gross – 14.5%	Gross	Gross + 14.5%
Conventional	0.605	0.654	0.748
Float lift	0.604	0.614	0.646
Flap change	0.518	0.524	0.526

Takeoff performance at three aircraft weights, with time as the measured parameter and distance as the computed parameter is shown in Table 1. Analysis of variance was accomplished on the means. Different lowercase letters following the means indicate significant difference at the 0.05 level. Table 2 indicates values of the delta ratio computed from data in Table 1.

Conclusions

The flap change procedure was an effective technique for reducing water run time and distance at all weights, but is negatively effective for reducing distance over an obstacle when the aircraft is heavy. In that case, the float lift procedure was most effective.

Delta ratio values differ little with weight and the takeoff techniques tested, except when the flap change technique is used. The flap change technique decreases delta ratio sufficiently, such that delta ratios derived from aircraft flight manuals cannot be used safely with the no-go flag technique.[1] However, there is very little change in the delta ratio values for the flap change technique with aircraft weight. The delta ratio for the flap change takeoff technique is consistent and could be used if the pilot knew the correct values.

The delta ratio continues to appear to be consistent over the conditions of weight and takeoff techniques tested, except that delta ratio values are significantly lower when the pilot uses the flap change technique for takeoff. An unsafe condition could exist if the pilot used the flap change takeoff technique in conjunction with delta ratio values derived from the aircraft operating manual and applied them in a departure from an obstacled short lake using the no-go flag method.[1]

References

[1] De Remer, D., "Short Lakes," *Water Flying Annual*, Vol. 9, June 1987, pp. 30–35.
[2] Cessna Aircraft Corp., "Cessna 180 Floatplane Owner's Manual," 1963–67, pp. 1–12.
[3] De Havilland Aircraft of Canada, Ltd., "DHC 2 Beaver Flight Manual," March 31, 1956, pp. A-III–A-IV.

GENMAP: Computer Code for Mission Adaptive Profile Generation

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Nomenclature

$a_{i,j}$ = influence of jth panel on the ith control point
$af_{i,j}$ = influence of jth panel with fixed slopes on ith control point
A = panel elemental area
C_D = induced drag coefficient
D = induced drag
L = lift
M = Mach number
m = total number of panels with fixed slopes
N = total number of panels
$\hat{n}$ = unit normal vector
q = downwash velocity
U = freestream velocity
x, y, z = Cartesian coordinates
ZX = panel chord-wise slopes
α = angle of attack
Γ = vorticity distribution before optimization
γ = vorticity distribution after optimization
ρ = freestream density
$1,2...N$ = panel number
fp = fixed panels

Introduction

MODERN combat aircraft require optimal aerodynamic performance throughout the flight envelope. To achieve this, continuous variation in wing profile with variation in Mach number and angle of attack is essential.[1] Since it is not possible to vary the entire camber of wing in flight, some wing portions, i.e., leading-edge flap (LEF) and trailing-edge flap (TEF), are considered free for deflection. LEF and TEF act as maneuvering flaps for the optimal aerodynamic performance in flight. Optimum LEF and TEF deflections result in a Mission Adaptive Profile (MAP).

Mathematical Modeling

Aerodynamic influence coefficients[2] are used to generate MAP. MAP is essentially an optimization exercise aimed at determining LEF/TEF deflections that will satisfy the condition of minimum drag under the constraints of lift, pitching moment, wing root bending moment, and camber (fixed

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slopes) of the remaining portion of the configuration. Constraint of wing root bending moment is considered undesirable. This is because the loading after optimization tends to be elliptic and reduces[1] the wing root bending moment. A lower structural weight results from such loading. Constraint of pitching moment is also not considered favorable as it shall result in additional reflex in the wing profile. MAP is, therefore, generated under the constraint of lift and camber of the specified portion of the configuration. Figure 1 shows a configuration with specified MAP requirement.

A constant pressure type of singularity is used in the panels to simulate lift effects.[2] Control points are selected at 95% of local panel chords. The condition of flow tangency results in a set of linear simultaneous algebraic equations of the form

$$\sum_{j=1}^{N} a_{ij}\,\Gamma_j = q_i\,\hat{n}, \qquad i = 1, N \tag{1}$$

The matrix of influence coefficients so formed is solved for values of Γ_j. Drag and lift are computed subsequently. The expression for the unoptimized lift and drag for a given profile is given by

$$L = (A_1\Gamma_1 + A_2\Gamma_2 + \cdots A_N\Gamma_N)\,\rho U \tag{2a}$$

$$D = [A_1\Gamma_1\,(\alpha - ZX_1) + \cdots A_N\Gamma_N\,(\alpha - ZX_N)]\rho U \tag{2b}$$

Drag after optimization (D^*) can be expressed as

$$\begin{aligned} D^* = U[&a_{1,1}\,\gamma_1 + \cdots + a_{1,N}\gamma_N)\gamma_1\,A_1 \\ &+ (a_{2,1}\,\gamma_1 + \cdots + a_{2,N}\gamma_N)\gamma_2\,A_2 \\ &+ \cdots \\ &+ (a_{N,1}\,\gamma_1 + \cdots + a_{N,N}\,\gamma_N)\gamma_N\,A_N] \end{aligned} \tag{3}$$

Optimal panel slopes are written in the form of

$$ZX_i = (a_{i,1}\,\gamma_1 + \cdots + a_{i,N}\,\gamma_N)\,A_i \tag{4}$$

The objective function for the constrained lift ($\bar{L}$) and panel slopes ($Z\bar{X}_{fp}$) is written as

$$F = D + \lambda_0\,(L - \bar{L}) + \sum_{\ell=1}^{m} \lambda_\ell\,(ZX_\ell - Z\bar{X}_\ell)_{fp} \tag{5}$$

Largrange multipliers are λ_0, $\lambda_1 \cdots \lambda_m$. A bar indicates the constrained quantities. A minimum-drag condition is applied i.e.,

$$\frac{\partial F}{\partial \gamma_R} = 0,\ R = 1,2\cdots N \qquad \frac{\partial F}{\partial \lambda_\ell} = 0,\ \ell = 0,\ 1\cdots m \tag{6}$$

The matrix of MAP is given below. The matrix is solved for unknown γ (optimal singularity strengths), and new values of the surface slopes are computed through Neumann's boundary condition. The computer code named GENMAP is developed to generate MAP for subsonic and supersonic freestream flow conditions.

The matrix of MAP is as follows:

$$\begin{bmatrix} 2\,A_1\,a_{1,1}\cdots\cdots A_1 a_{1,N} + A_N\,a_{N,1} & A_1 & af_{1,1}\cdots af_{m,1} \\ \vdots & & \\ A_N\,a_{N,1} + A_1\,a_{1,N}\;2\,A_N\,a_{N,N} & A_N & af_{1,N}\cdots af_{m,N} \\ A_1\cdots\cdots\cdots A_N & 0 & 0\ \cdots\ 0 \\ af_{1,1}\cdots\cdots af_{1,N} & 0 & 0\quad\ 0 \\ af_{m,1}\cdots\cdots af_{m,N} & 0 & 0\ \cdots\ 0 \end{bmatrix} \times \begin{bmatrix} \gamma_1 \\ \vdots \\ \gamma_N \\ \lambda_0 \\ \lambda_1 \\ \vdots \\ \lambda_m \end{bmatrix} = \begin{bmatrix} 0 \\ \vdots \\ 0 \\ \bar{L} \\ (Z\bar{X}_1)_{fp} \\ \vdots \\ (Z\bar{X}_m)_{fp} \end{bmatrix} \tag{7}$$

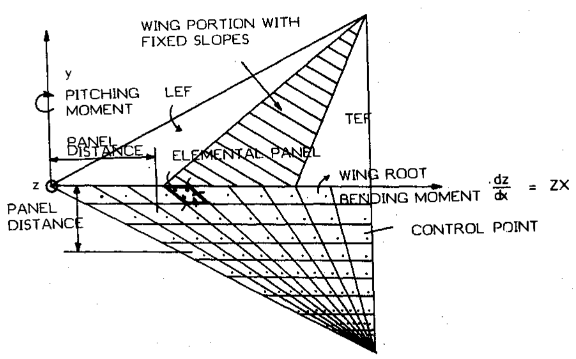

Fig. 1 Paneling scheme.

GENMAP: Capabilities and Validation

GENMAP is developed to produce the required LEF/TEF deflections for minimum drag for a given set of conditions. The code can handle mixed flows so long as a shock wave is not formed. Mixed-flow conditions are seen to occur mainly for subsonic freestream flow. For this, local Mach numbers are calculated without considering their region of influence. Subsequently, the regions of influence are redefined considering Mach waves and Mach cones. The optimization matrix will fail to converge in the presence of a shock wave. The code is developed in Fortran IV.

GENMAP subroutines fall into three categories: equation preparation programs, matrices solution programs, and gross characteristics estimation programs. Matrices without diago-

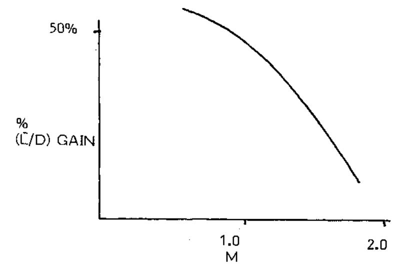

Fig. 2 Influence of compressibility on drag reduction.

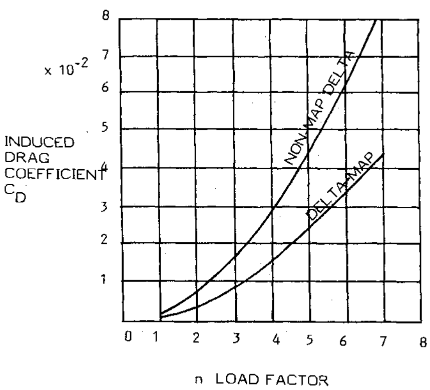

Fig. 3 Influence of MAP on load factor development.

nal discontinuities are solved with a Gauss-Seidel technique. The matrix of MAP has diagonal discontinuities (zeros in the last several rows), and the Gauss-Seidel technique becomes divergent. A Gauss-Jordan numerical technique is, therefore, used for the solution of matrix of MAP.

No data are available for comparison of results from Genmap; therefore, for the validation of GENMAP, the code named WINGER of Ref. 3 is used. WINGER uses method of singularities for estimation of airloads on aerodynamic configurations. Camber resulting from GENMAP is used as input data for WINGER. These slopes are subsequently varied in several forms to see if another minimum drag solution occurs. The camber resulting from GENMAP is seen to be the only solution for the maximum $(\bar{L}/D)$ condition.

Results and Discussion

The code is applied to a flat plate delta wing of 2.5 aspect ratio. LEF and TEF are taken as 22.5% of local wing chord. Local chord of 55% is considered fixed. The results are shown in Fig. 2, exhibiting the influence of compressibility on the improvement of aerodynamics efficiency through MAP. Drag reduction as high as 55% is feasible in the subsonic region. Compressibility deteriorates the optimization effort. In the supersonic region, drag reduction due to MAP falls very rapidly with increasing Mach number. In subsonic maneuvers, the aircraft operates at high angles of attack. Therefore, the MAP application is most useful for the subsonic flow conditions. In supersonic maneuvers, the aircraft operates at low angles of attack. The entire wing planform can be aeroelastically tailored to improve the aerodynamic efficiency for the supersonic flow regime.

The impact of MAP on load factor development is calculated and shown in Fig. 3. Calculations are made for the same MAP conditions as Fig. 2. Sea-level conditions and subsonic Mach number ($M = 0.75$) are considered for load factor calculations. Wing loading of 340 kg/m^2 is taken for sample calculations. MAP application is seen to provide large additional g (i.e., normal acceleration capability) to a nonmap configuration. MAP is required to be programmed as a function of Mach number and angle of attack.

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References

[1]Gupta, S. C., "OPSGER: Computer Code for Multi-Constraint Optimisation at Subsonic and Supersonic Speeds," Institute of Armament/GM/CFD/LCATR2, May 1987.

[2]Woodward, F. A., Tinoco, E. N., and Larsen, J. W., "Analysis and Design of Supersonic Wing-Body Combinations, including Flow Properties in the Near Field, Part 1 – Theory and Application," NASA CR 73106 (Pt. 1), Aug. 1967.

[3]Gupta, S. C., "WINGER: Computer Code for Aerodynamic Coefficient Prediction for 3-D Arbitrary Wing-Body Combination at Subsonic and Supersonic Speeds, including Wake Interrogation and Indirect Design Capability," Aeronautical Development Establishment TR 84-103, April 1984.

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