Engineering Notes

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Seaplane Takeoff Performance: Using Delta Ratio as a Method of Correlation

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Nomenclature

R_D = delta ratio, D_{wr}/D_t
D_{wr} = takeoff water run distance
D_t = total distance over a 50-ft obstacle

Introduction

SEAPLANE takeoff performance research is notably rare, partly due to the small numbers of seaplanes in the general-aviation fleet and partly due to the difficulty in measuring the takeoff performance (distance) over water. This work presents a method of instrumentation for accomplishing these measurements with currently available technology.

Seaplane takeoff performance information available to pilots in aircraft operating manuals is often inadequate because available takeoff distance for the seaplane is often not known. Also, many other factors affecting takeoff performance, such as engine, propeller, and airframe condition, are not known to the pilot, nor can they be addressed in the performance tables in the operating manual.

A method utilizing the delta ratio was recently published,[1] whereby the pilot can determine, before leaving the water, whether or not the takeoff can be made. Furthermore, this method does not require the pilot to have knowledge of lake length, density altitude, engine and propeller condition, or aircraft weight. The method does, however, assume (and there seems to be a good case[1-3] for the concept) that the delta ratio remains relatively constant over a wide range of flight conditions. If the delta ratio was decreased significantly by any factor unknown to the pilot to a value below that being used by the pilot, use of this concept could become dangerous. This study investigates the effect of aircraft weight and takeoff techniques to determine the consistency of the delta ratio.

Instrumentation and Methodology

The following is a description of the instrumentation and methodology used to determine the actual distance of the takeoff water run (the distance the aircraft is on the water during the takeoff) and the total distance over a "standard" 50-ft-high obstacle (total distance from the beginning of the water run to the point on the surface under the aircraft when the lowest part of the aircraft is 50 ft above the surface).

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A lake large enough to provide more than adequate takeoff distance but not so large as to become excessively rough with windy conditions was selected. Site selection required rising ground near the shore to an elevation of 50 ft above the water, both at the departure end of the takeoff run and at the opposite end of the lake. At the shore nearest the start of the takeoff run, a video camera (with 1/100th-s lapse time capability) was set up so that "height of eye" was 50 ft above water level. An aircraft vhf receiver was set up near the video camera to record on the audio portion of the videotape, the comments and called-out indicated airspeeds from the test pilot. Below the video camera, a narrow-beam traffic radar was set up, with an operator who recorded the radar data verbally onto the audio portion of the videotape. The result was a videotape that contained a photorecord of the takeoff, with elapsed time, audio indications of power application, and indicated airspeeds plus radar-measured ground speed. Since the video camera was at an elevation of 50 ft above the water, and the 50-ft elevation mark on the far shore was known, the video easily showed the time when the aircraft cleared the 50-ft obstacle as well as the time of each significant event of the takeoff.

From the videotapes, time-vs-speed curves were generated. The area under the curve(s) was computed to produce plots of time vs distance. Thus, the distance at any point in the takeoff process became available.

Speed values determined by radar and indicated airspeed, as recorded by the pilot, appeared to agree very well, never varying from each other by more than 4 mph. Apparently, indicated airspeed was very close to actual ground speed due to a slight headwind, which helped compensate for the small difference between indicated and true airspeed.

Experimental Design

To study the effect of aircraft weight and takeoff technique on the delta ratio, three aircraft weights, three takeoff techniques and five replications were utilized. A common twin-float aircraft (Cessna 180 on Edo 2870 floats) was used. Weights chosen were gross weight (2820 lb), gross weight less 14.5%, and gross weight plus 14.5%. The weight was adjusted by adding or removing measured amounts of water from the float chamber most directly under the aircraft's center of gravity.

Takeoff techniques were 1) conventional, where the aircraft was allowed to fly off the water from the step attitude; 2) float lift, where the right float was lifted out of the water as soon as aileron effectiveness permitted (after which the aircraft quickly accelerated and lifted off); and 3) flap change, where the pilot, at the appropriate speed, simultaneously changes the flap setting from the normal takeoff setting of 20–40 deg and pitches up slightly in order to "unstick" the aircraft from the water, after which the flaps are decreased to the normal obstacle clearance climb setting of 20 deg while the aircraft is still near the water.

The day that the experimental data were gathered, the temperature remained between 23 and 24.5° C, the wind varied from 2 to 4.5 knots from 0 to 20 deg left crosswind. Density altitude remained at 1250 ft, ± 50 ft, throughout the day. Forty-seven takeoffs were accomplished while these essentially ideal and constant conditions existed.

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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