FLIGHT TEST TECHNIQUES, SIMULATION, AND DATA ANALYSES DURING A HIGH ANGLE-OF-ATTACK VORTEX FLOW CONTROL FLIGHT TEST PROGRAM

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Abstract

Flight testing a vortex flow control system at high angle of attack is discussed in this paper. Vortex flow control provides a means of directional control at high angle of attack. General considerations, simulation modeling techniques, and data analysis techniques are addressed.

Nomenclature

ADFRF	Ames-Dryden Flight Research Facility
AOA	angle of attack
ARI	aileron to rudder interconnect
A_{noz}	VFC nozzle reference area (in^2)
C_d	nozzle discharge coefficient
Cl	body axis rolling moment coefficient
$Cl_{c\mu}$	body axis rolling moment coefficient due to VFC mass flow coefficient
Cm	body axis pitching moment coefficient
$Cm_{c\mu}$	body axis pitching moment coefficient due to VFC mass flow coefficient
Cn	body axis yawing moment coefficient
$Cn_{c\mu}$	body axis yawing moment coefficient due to VFC mass flow coefficient
$C\mu$	VFC mass flow coefficient $=m_{vfc}V_{vfc}/qS$ $=.7396C_dP_{noz}A_{noz}/qS$
DOF	degree of freedom
FCS	flight control system
INS	inertial navigation system
m_{vfc}	VFC jet mass flow (lbm/sec)
NASA	National Aeronautics and Space Administration
p	body axis roll rate
pEst	parameter estimation program
P_{noz}	VFC nozzle total pressure (psi)
q	dynamic pressure (lbf/ft^2)
r	body axis yaw rate
RAV	remote augmented vehicle
S	reference area (185 ft^2)
VFC	vortex flow control
V_{vfc}	VFC jet velocity (ft/sec)
WPAFB	Wright Patterson Air Force Base
α	angle of attack
β	angle of sideslip

Introduction

The second X-29A aircraft (Figure 1) completed eighty-five flights during its high angle-of-attack (AOA) envelope expansion program, and another thirty-five flights during a follow-on aerodynamic characterization program in the summer of 1991. These programs successfully expanded the useful angle-of-attack envelope of the X-29A from 20 degrees to greater than 50 degrees, with a maximum recorded angle of attack of approximately 67 degrees. Aircraft flying qualities in the 20- to 40-degree AOA range were excellent, with very well-coordinated 360-degree rolls demonstrated up to 35-degrees AOA using lateral stick alone.

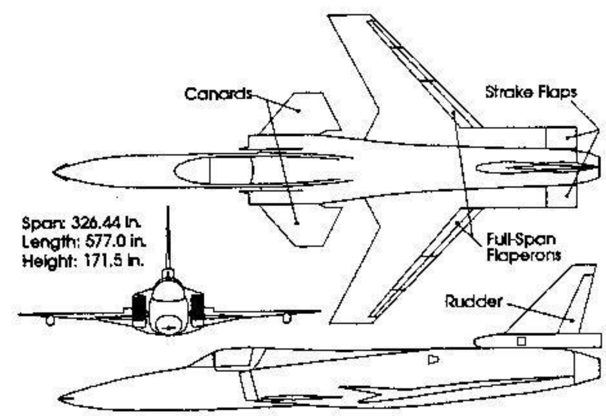

Fig. 1. X-29A Aircraft

Correlation of flight-derived aerodynamic parameters with wind tunnel predictions was generally very good, although there were some significant differences. Roll damping at nonzero sideslip and higher than predicted aileron effectiveness at large deflections caused flight wing rock amplitudes to be considerably lower than predicted (1). Total nose down pitching moment was lower than predicted, which increased the susceptibility to nose-up inertial coupling. These, and other less significant changes, were added to the simulation aerodynamic model, as simulator-to-flight data correlation was required for all test points before further envelope expansion could occur. Methods developed for aerodynamic data extraction and simulator updates allowed the envelope expansion to continue on schedule.