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An extended unsteady aerodynamic model at high angles of attack

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Abstract: In this paper, an extended unsteady aerodynamic model for aircraft oscillations at a high angle of attack is developed and modified based on the traditional state space model. With an analysis of the nonlinear flow field in the dynamic process, three influencing factors, the pitching angular velocity, the reduced frequency and the amplitude, are determined and added to the original state space equation to provide a more comprehensive description of the dynamic flow field. The particle swarm optimization (PSO) algorithm is used to identify unknown parameters in the extended model based on Computational Fluid Dynamics (CFD) results or wind tunnel experimental data. The identifiability of the parameters and the performance of the extended model are validated with a 70°sharp leading-edge delta wing and a scaling geometry of an F-18 aircraft. The results show that the extended model can achieve more accurate aerodynamic loads than the original model. Moreover, the aerodynamic forces and moments of various configurations at different reduced frequencies and amplitudes can be predicted with the model. The extended state space model is demonstrated to be a more efficient and widely applicable approach for unsteady aerodynamics modeling.

Keywords: high angle of attack; unsteady aerodynamics modeling; state space equation; reduced frequency; amplitude; Computational Fluid Dynamics (CFD)

Nomenclature

C_i ($i = L, D, my$)	=	lift, drag and pitching moment coefficient
C_r	=	root chord length, m
c	=	reference chord length, m
k	=	reduced frequency, $k=\omega c/2V$
l	=	span, m
Ma	=	Mach number
q	=	pitching angular velocity, rad/s
Re_{C_r}	=	Reynolds number based on root chord length
t	=	time
V	=	airspeed, m/s
$x, \bar{x}$	=	state-space internal dynamic variable and its non-dimensional value
α	=	instantaneous angle of attack, °