Mechanical Systems and Signal Processing 118 (2019) 781–807

Contents lists available at ScienceDirect

Mechanical Systems and Signal Processing

journal homepage: www.elsevier.com/locate/ymssp

Characterization of a 3DOF aeroelastic system with freeplay and aerodynamic nonlinearities – Part I: Higher-order spectra

Michael Candon [a,*], Robert Carrese [a], Hideaki Ogawa [a], Pier Marzocca [a], Carl Mouser [b], Oleg Levinski [b], Walter A. Silva [c]

[a] School of Engineering (Aerospace and Aviation), RMIT University, Melbourne, Victoria, Australia
[b] Defence Science and Technology Group, Fishermans Bend, Victoria, Australia
[c] NASA Langley Research Center, Hampton, Virginia, USA

ARTICLE INFO

Article history:
Received 18 October 2017
Received in revised form 21 April 2018
Accepted 27 May 2018

Keywords:
Nonlinear aeroelasticity
System identification
Higher-order spectra
Structural freeplay
Aerodynamic nonlinearity
Transonic flow
LCO
Chaotic response

ABSTRACT

The identification of nonlinear systems in aeroelasticity poses a significant challenge for practitioners, often hampered by the complex nature of aeroelastic response data which may contain multiple forms of nonlinearity. Characterizing and quantifying nonlinearities is further hampered when the response is obtained at a location which is away from the nonlinear source and/or the response is contaminated by noise. In the present paper, a three-degree-of-freedom airfoil with a freeplay nonlinearity located in the control surface and exposed to transonic flow is investigated. In this Part I paper the main form of analysis is via higher-order spectra techniques to unveil features of the nonlinear mechanism which result from i) structural nonlinearities (freeplay) in isolation and ii) freeplay with Euler derived nonlinear inviscid aerodynamic phenomena (transition between Tijdeman Type-A and Type-B shock motion). It is shown that the control surface structural freeplay nonlinearity is characterized by strong cubic phase-coupling between linear and nonlinear modes. On the other hand, nonlinear inviscid flow phenomena are shown to be characterized by quadratic phase-coupling between linear and nonlinear modular modes, the strength of which is related to the strength of the aerodynamic nonlinearity (amplitude of the shock motion). The nonlinear inviscid flow phenomena do not appear to affect the identification of the freeplay nonlinearity. Conjectures are made which address the transition between aperiodic, quasi-periodic and periodic behavior (pre-flutter), further physical support towards these conjectures is provided in Part II [1]. The limitations of the higher-order spectra approach are assessed, in particular, the analysis demonstrates the difficulty in extracting natural frequencies with this approach.
© 2018 Elsevier Ltd. All rights reserved.

1. Introduction

Within the body of knowledge surrounding aeroelasticity for aircraft it is well documented in the literature that both aerodynamic and structural nonlinearity can induce undesirable nonlinear aeroelastic phenomena. In particular, limit cycle

* Corresponding author.
E-mail addresses: s3329364@student.rmit.edu.au (M. Candon), robert.carrese@rmit.edu.au (R. Carrese), hideaki.ogawa@rmit.edu.au (H. Ogawa), pier.marzocca@rmit.edu.au (P. Marzocca), Carl.Mouser@dsto.defence.gov.au (C. Mouser), Oleg.Levinski@dsto.defence.gov.au (O. Levinski), walter.a.silva@nasa.gov (W.A. Silva).

https://doi.org/10.1016/j.ymssp.2018.05.053
0888-3270/© 2018 Elsevier Ltd. All rights reserved.

Nomenclature

Nomenclature

α	pitching displacement
β	control surface displacement
β_s	control surface freeplay margin
μ	structural-to-fluid mass ratio
ω_α	pitch natural frequency (coupled)
ω_β	control surface natural frequency (coupled)
ω_h	plunge natural frequency (coupled)
ω_{NL}	nonlinear mode
Φ	phase
τ	tricoherence
a	normalized distance from the elastic axis to mid-chord
A_r	asymptotic range calculated for the grid convergence index
b	semi-chord
$\hat{b}$	bicoherence
B	bispectrum
C_l	lift coefficient
$C_{m\alpha}$	moment coefficient of the airfoil
$C_{m\beta}$	moment coefficient of the control surface
$\mathbf{C}$	damping matrix
d	normalized distance from the mid-chord to hinge
f	frequency
$\mathbf{F}$	nonlinear internal forces
$\mathcal{F}$	fourier transform
F_s	safety factor used in the grid convergence index calculations
g	damping ratio
$GCI_{12,23}$	grid convergence index between refinement levels 1 and 2, and, 2 and 3 respectively
h	plunging displacement
I_α	non-dimensional airfoil moment of inertia
I_β	non-dimensional control surface moment of inertia
$j_{1,2,3}$	general terms used for the physical solutions to each grid in the grid convergence index
k_h	plunge longitudinal stiffness
k_α	pitch torsional stiffness
k_β	control surface torsional stiffness
$\mathbf{K}$	stiffness matrix
L	lift
m	airfoil mass per-unit-span
M	higher-order spectra number of data segments
M_α	airfoil pitching moment
M_β	control surface pitching moment
M_∞	freestream Mach number
$\mathbf{M}$	mass matrix
N	total number of data points
q_∞	freestream dynamic pressure
r_α	normalized radius of gyration of the airfoil about the elastic axis
r_β	normalized radius of gyration of the control surface about the control surface hinge axis
P	order of convergence for the grid convergence index
S_α	non-dimensional airfoil static moment
S_β	non-dimensional control surface static moment
SP_{NL}	general nonlinear spectra term
$SP_{NL,norm}$	general normalized nonlinear spectra term
t	time
Δt	time-step size
T	trispectrum
$\mathbf{u}$	displacement vector
$\dot{\mathbf{u}}$	velocity vector (first derivative of $\mathbf{u}$ with respect to time)
$\ddot{\mathbf{u}}$	acceleration vector (second derivative of $\mathbf{u}$ with respect to time)
V^*	velocity index
x_{aft}	maximum aft location of the shock
x_{for}	maximum forward location of the shock

Download English Version:

https://daneshyari.com/en/article/11032456

Download Persian Version:

https://daneshyari.com/article/11032456

Daneshyari.com