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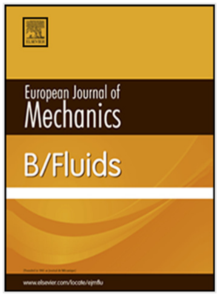

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An improved criterion to select dominant modes from dynamic mode decomposition

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Abstract

Dynamic mode decomposition (DMD) has been extensively utilized to analyze the coherent structures in many complex flows. Although specific flow patterns with dominant frequency and growth rate can be captured, extracting dominant DMD modes for flow reconstruction and dynamic modeling still need a priori knowledge on flow physics, especially for some transient states of unstable flows. In this paper, a criterion to select dominant modes from DMD technique is developed. The unsteady flow can be described by the superposition of each normalized DMD mode multiplied by its time coefficient. The dominance of each DMD mode can be ordered by time integration of its time coefficient. Compared with standard DMD approach, which decides the dominance of DMD modes by the order of amplitude or mode norm, this criterion considers the evolution of each mode within the whole sampling space, and ranks them according to their contribution to all samples. The proposed mode selection strategy is evaluated by test cases including both equilibrium and transient states of a cylinder at Reynolds number of 60 and a transient state of a NACA0012 airfoil buffeting in transonic flow. Results indicate that using this criterion, dominant DMD modes can be identified and flow dynamics in unstable or transient systems can be reconstructed accurately with fewer modes. Besides, this approach has better convergence against mode number and lower sensitivity to the initial condition than standard DMD method.

Key words

dynamic mode decomposition, reduced-order model, unsteady flow, transonic flow, buffet

1 Introduction

Developing reduced-order models (ROMs) for complex fluid flows permits a wide range of engineering applications including mechanism analysis, dynamic modeling, control law design and optimization. Among current investigations in modeling dynamic systems for control and stability analysis, constructing ROM based on input-output data usually provides satisfactory results, which is called system identification. Autoregressive with exogenous input model [1] and neural networks [2-4] are typical identification-based ROMs that have been extensively used in unsteady aerodynamic modeling and aeroelasticity. However, when studying the dynamics of a full-order fluid flow, mode decomposition techniques are more appropriate to be utilized, which decompose the unsteady flow into several dominant coherent structures. Proper orthogonal decomposition (POD) [5,6], dynamic mode decomposition (DMD) [7,8] and global stability analysis [9,10] have all been introduced to extract features on flow dynamics and stabilities, and the selected dominant flow modes are important in constructing low-dimensional dynamic models for flow prediction and control. Based on spatial correlation of flow snapshots, POD decomposes the dataset into an orthogonal set of modes that

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