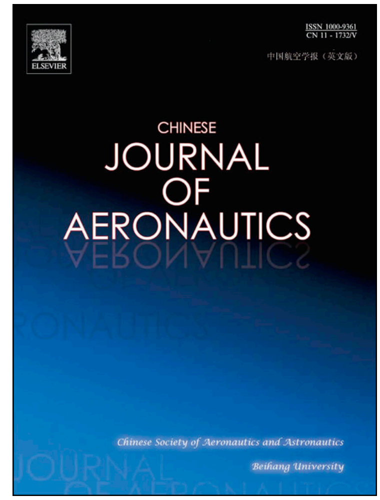
Accepted Manuscript



Full Length Article

Numerical analysis of broadband noise reduction with wavy leading edge

Fan Tong, Weiyang Qiao, Weijie Chen, Haoyi Cheng, Renke Wei, Xunnian Wang

PII: S1000-9361(18)30132-8
DOI: https://doi.org/10.1016/j.cja.2018.03.020
Reference: CJA 1038

To appear in: *Chinese Journal of Aeronautics*

Received Date: 20 June 2017
Revised Date: 7 December 2017
Accepted Date: 23 January 2018

Chinese Journal of Aeronautics 28 (2015) xx-xx

Contents lists available at ScienceDirect

Chinese Journal of Aeronautics

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

Numerical analysis of broadband noise reduction with wavy leading edge

Fan TONG[a], Weiyang QIAO[a,b,*], Weijie CHEN[a], Haoyi CHENG[a], Renke WEI[a], Xunnian WANG[c]

[a] *School of Power and Energy, Northwestern Polytechnical University, Xi'an 710129, China*

[b] *Key Laboratory of Aerodynamic Noise Control, China Aerodynamics Research and Development Center, Mianyang 621000, China*

[c] *State Key Laboratory of Aerodynamics, China Aerodynamics Research and Development Center, Mianyang 621000, China*

Received 20 June 2017 ; revised 7 December 2017 ; accepted 23 January 2018

Abstract

Large Eddy Simulation (LES) is performed to investigate the airfoil broadband noise reduction with wavy leading edge under anisotropic incoming turbulence. The anisotropic incoming turbulence is generated by a rod with a diameter of 10 mm. The incoming flow velocity is 40 m/s and the corresponding Reynolds numbers based on airfoil chord and rod diameter are about 397000 and 26000, respectively. The far-field acoustic field is predicted using an acoustic analogy method which has been validated by the experiment. A straight leading edge airfoil and a wavy leading edge airfoil are simulated. The results show that wavy leading edge increases the airfoil lift and drag whereas the lift and drag fluctuations are substantially reduced. In addition, wavy leading edge can significantly change the flow pattern around the leading edge and a pair of counter-rotating streamwise vortices stemming from each wavy leading edge peak are observed. An averaged noise reduction of 9.5 dB is observed with the wavy leading edge at the azimuthal angle of 90 °. Moreover, the wavy leading edge can mitigate noise radiation at all the azimuthal angles without significantly changing the noise directivity. The underlying noise reduction mechanisms are then analyzed in detail.

Keywords: Aeroacoustics; Broadband noise; Noise control; Large eddy simulation; Wavy leading edge; Rod-airfoil interaction; Noise reduction mechanism

1. Introduction[1]

With the fast development of civil aviation industry, the associated environmental impact of aviation, including both air pollution and noise nuisance, is getting more and more attention. For example, stringent targets have been set in Europe for 2050, which aims at reducing noise emissions by 65% compared to the year of 2000.[1] The aerodynamic noise radiated from the interaction between the oncoming turbulence and the leading edge of an airfoil is one of the commonly encountered types of noise problems and significantly contributes to the noise in many engineering applications, such as turbofan outlet guide vanes, contra-rotating open rotors and contra-rotating fans. The airfoil-turbulence interaction noise, also known as Leading Edge (LE) noise, is often considered to be one of the major noise sources, especially in the presence of significant upstream disturbances.[2]

LE noise has been studied for many years and has been successfully modelled by Amiet[3] and Howe[4-5]. Amiet's model explains the interaction noise by considering that the impinging turbulent eddies will undergo a sudden change in the boundary condition when they encounter the flat plate. The impinging turbulence should satisfy the

* Corresponding author. *E-mail address:* qiaowy@nwpu.edu.cn