# Broadband aerodynamic noise simulation using synthetic turbulence

Xin Zhang
Department of Mechanical and Aerospace Engineering
The Hong Kong University of Science and Technology
Clear Water Bay, Kowloon
Hong Kong, SAR China
Website: aantc.ust.hk; Email: aexzhang@ust.hk

The turbulence-airfoil interaction noise is a major source of broadband noise. The high computational cost incurred in Direct Numerical Simulation or Large Eddy Simulation make them prohibitively expensive for industrial applications where repeated computations are required. Alternatively, synthetic turbulence methods that reproduce the turbulence statistics coupled with full/linearised Equations are a highly efficiency approach to simulate sound generation and propagation. The Aerodynamics and Aeroacoustics & Noise Control Technology Centre (AANTC) has conducted various studies into broadband noise using the synthetic turbulence methods.

Early studies using Fourier modes summation and digital filter methods were conducted at Airbus Noise Technology Centre at University of Southampton, UK. By using the Fourier modes methods that are a superposition of the weighed sinusoidal functions, one-, two-, and three-component turbulent fields are reproduced, which can be used to study the effects of real airfoil geometries on broadband leading edge noise (Gill, Zhang, & Joseph, 2013).

In a digital filter approach, the turbulent field with given velocity and energy spectra is expressed as the curl of a stream function determined by the convolution of a spatial filter and a white noise signal. For noise simulations, there are two ways to realize non-Gaussian energy spectra. One is the superposition of several Gaussian eddies with different integral length scales and amplitudes (Gea-Aguilera, Gill, & Zhang, 2017). The other method is the direct use of non-Gaussian filters by rigorously figuring out the integral of the given function. An advance of the proposed direct filter method is the velocity-spectrum tensor of the anisotropic turbulent field could be directly achieved, which can accelerate the initialization of the fluctuating velocity field and get rid of the troubles in determining different sets of eddy parameters (see Figure 1). Both 2D and 3D turbulences can be realized by the direct anisotropic filter method. The various synthetic turbulence methods have been used for broadband noise problems at AANTC. Those include airfoil geometry effect, wavy leading edge, heaving motion of airfoil, and aero-engine cascade noise (see Figure 2), *etc*.

For cases involving high speed rotating blades the flow around the airfoil could be transonic and shock waves are formed. Various aeroacoustic mechanisms are involved such as turbulence-leading edge interaction, turbulence-shock interaction, sound scattering by shocks and the shock oscillation due to the nonlinear impacts (see Figure 3). Different numerical experiments based on the synthetic turbulence methods are designed to identify the physics (Zhong , Zhang , Gill, & Fattah, 2018). Geometry effects such as angle of attack, thickness and camber are also studied at transonic speeds.

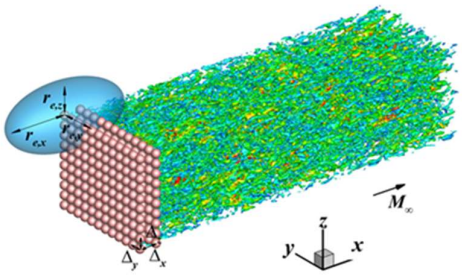

**Figure 1. The vorticity field of the synthetic turbulence based on the direct anisotropic turbulence method.**

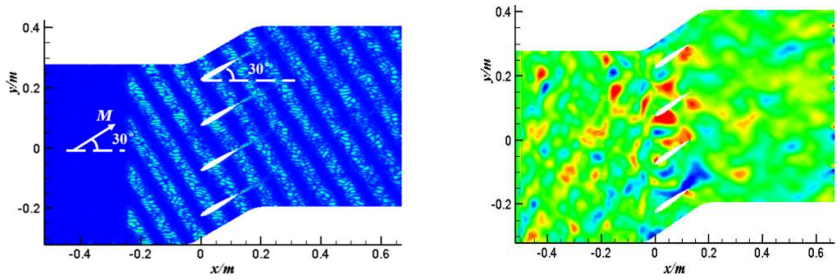


**Figure 2. Simulation of the turbulence-cascade interaction noise. Left, the vorticity field; Right, the sound field.**

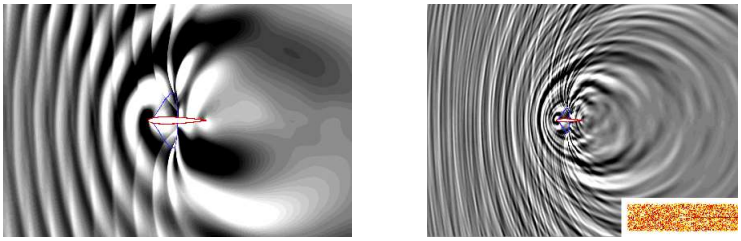

**Figure 3. Simulation of the turbulence-airfoil interaction in transonic flows with shocks. Left, single frequency with shock oscillation. Right, broadband simulation with various acoustic mechanisms.**

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The results highlighted in the abstract were obtained by Siyang Zhong, Zhen Shen and Wei Yi at AANTC.

## References

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