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# Reduction of aerodynamic noise from square bars by introducing spanwise waviness

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**Abstract**

This paper presents an investigation, using both numerical and experimental methods, of the application of spanwise waviness to reduce aerodynamic noise from square bars. The numerical simulations are performed using the Delayed Detached-Eddy Simulation approach to obtain the near-field unsteady flow properties, which are then used to calculate the equivalent source terms in the Ffowcs Williams-Hawkings equation for far-field noise prediction. For a straight square bar in cross-flow, which produces strong tonal noise associated with the vortex shedding, a benchmark study showed good agreement between numerical simulations and measurements in terms of far-field noise spectra. Waviness is then introduced along the bar span and the influence of the amplitude and wavelength of the waviness is studied. When the wave amplitude is nearly half the bar width, a large noise reduction of as much as 30 dB is found from both numerical simulations and measurements, including a 10 dB reduction in the broadband level. The influence of the wavelength is much smaller. Analysis of the flow features showed that, with increased wave amplitudes, the spanwise flow becomes significant and strong crossflow vortices develop in the near wake which effectively suppress the primary vortex shedding. This reduces the noise level significantly, especially the tonal noise associated with the vortex shedding.

*Keywords:*
aerodynamic noise reduction, square bars, spanwise waviness, pantograph, vortex shedding

## 1. Introduction

Flow around bluff bodies, such as circular cylinders and rectangular or square bars, is of great practical importance in many industrial applications and environmental situations, e.g. structural design, flow-induced vibration, and flow-induced noise. The aerodynamic noise emission from bluff bodies has been an important research topic with many practical applications including components of aircraft landing gear [1] and high speed train pantographs [2]. Most research on the fundamentals of aerodynamic noise, its prediction and reduction have been carried out for circular cylinders. Structures with rectangular or square cross-sections are also common in these applications including, for example, the contact strip of a pantograph. The aim of the present study is to investigate the mechanisms of aerodynamic noise from square bars, and measures for noise reduction.

Measurements have been conducted on the aerodynamic noise radiated from square bars although not as extensively as for circular cylinders. King and Barsikow [3] measured and compared the acoustic properties of square, circular and elliptical cylinders. The effects of the incoming flow speed and bar aspect ratio ($L/D$, where $L$ is the cylinder spanwise length and $D$ is the width of the cross-section) were also assessed in the measurements. It was found that the noise level at the spectral peak, which is associated with the vortex shedding phenomenon, is $5-7$ dB higher for the square bar than for a circular cylinder. The effect of the aspect ratio on the vortex shedding frequency, measured by the non-dimensional Strouhal number ($St = fD/U_\infty$, where $f$ is the vortex shedding frequency and $U_\infty$

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