Surface contribution of a stochastically excited panel to the radiated sound power

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ABSTRACT

In many engineering applcations it is important to identifiy the regions on a vibrating structure which radiate energy to the far field. This work analytically formulates a surface contribution technique based on non-negative intensity in the wavenumber domain to investigate the surface areas on a vibrating planar structure that are contributing to the radiated sound power in the far field. The non-negative intensity is derived in terms of the cross spectrum density function of the stochastic field and the sensitivity functions of either the acoustic pressure or normal fluid particle velocity. A simply-supported baffled panel excited by a turbulent boundary layer or a diffuse acoustic field is considered to illustrate the technique. The region of the panel contributing to the radiated sound power are identified. The non-negative intensity distribution is shown to be dependent on stochastic excitation. It is also observed that the more the non-negative intensity distribution is localised within the panel surface, the more effective the panel radiates sound to the far field.

1 INTRODUCTION

Reconstruction techniques of sound sources such as near-field acoustic holography (NAH), inverse boundary element method and the equivalent sources methods are widely used in industry (Magalhães and Tenenbaum, 2004). Identification of the regions on a vibrating structure which radiate energy to the far field can help design engineers to gain a deeper understanding about the noise generation mechanism, and it also allows targeted mitigation strategies to be explored. For example, noise reduction can be achieved by modifying geometry and structural properties. Acoustic intensity can help with identifying hot spots on the structure. However, intensity is usually highly bipolar and has positive and negative values that correspond to energy sources and sinks on the surface of the radiating structure. Therefore, the near-field cancellation effects occur when integrating the positive and negative components of the normal acoustic intensity over the surface of the structure. Williams, (1995) and (1998) introduced the supersonic intensity (SSI) formulation in the wavenumber domain. The SSI was employed to locate the areas on the source surface which effectively contribute to the far-field pressure. The SSI eliminates the contribution to the pressure and the velocity on the source of the high wavenumber components (subsonic components), which are evanescent and do not contribute to the far field. Williams, (2013) proposed two analytical formulae for the non-negative intensity (NNI) based on the pressure and normal fluid particle velocity for planar structures under deterministic excitation. It was shown that both formulae yield almost identical results in prediction of the regions of a structure that emit sound to the far field.

Stochastic excitations such as turbulent boundary layer (TBL) and diffuse acoustic field (DAF) are widely encountered in transportation systems (Ciappi et al., 2018). In this work, the NNI is analytically formulated for planar structures under stochastic excitation in the wavenumber domain. The proposed formulation is valid for both infinite planar structure and finite plate in an infinite baffle. Two formulae are developed for the NNI which are in terms of the cross spectrum density function of the stochastic field and the sensitivity functions of either the acoustic pressure or normal fluid particle velocity. The technique is implemented to identify the regions of a vibrating simply supported baffled panel contributing to the radiated sound power.

2 The NNI calculation for a flat plate under TBL excitation

A rectangular baffled panel excited by a TBL pressure field is considered here. For more details about NNI formulation and system paramters, see Karimi et al., (2020). To identify the surface contributions of the panel to the radiated sound power under the TBL excitations, the NNI has been computed at four discrete resonance frequencies of 177 Hz, 307 Hz, 691 Hz and 924 Hz as well as at two non-resonance frequencies of 630 Hz and 700 Hz. The maps of S_{vv}(auto spectrum density of velocity), S_{pp} (auto spectrum density of pressure), I_{act} (active intensity) and I^N (NNI) at the selected frequencies are presented in Fig. 1 for the panel under the TBL excitation. It can be observed that at each frequency (particularly at the resonance frequencies) the map of S_{vv} is very similar to that of S_{pp}. Further, it can be seen that the maps of I_{act} at the resonance frequencies are highly dominated by the mode shapes. For the TBL excitation, the NNI shows a distribution where mainly the edges and corners of the panel are significantly contributing to the radiated sound.

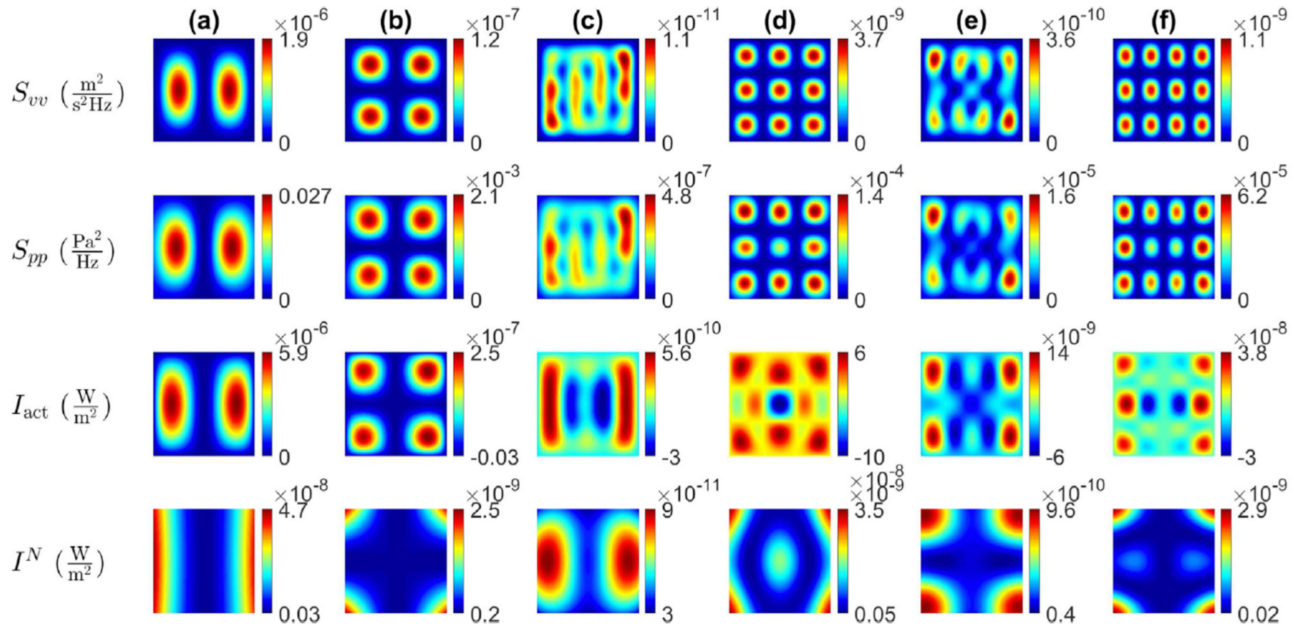

Fig1. Maps of S_{vv}, S_{pp}, I_{act} and I^N for the panel under the TBL excitation at a flow velocity of U_∞= 40 m/s and at selected frequencies of (a) 177 Hz, (b) 307 Hz, (c) 630 Hz, (d) 691 Hz, (e) 700 Hz and (f) 924 Hz.

REFERENCES

Magalhães M.B.S., Tenenbaum R.A., (2004). “Sound sources reconstruction techniques: a review of their evolution and new trends”, *Acta Acustica united with Acustica*. 90 (2) 199–220 .

Williams E.G., (1995). “Supersonic acoustic intensity”, *The Journal of the Acoustical Society of America*. 97 (1) 121–127 .

Williams E.G., (1998). “Supersonic acoustic intensity on planar sources”, *The Journal of the Acoustical Society of America*. 104 (5) 2845–2850.

Williams E.G., (2013) Convolution formulations for non-negative intensity, *The Journal of the Acoustical Society of America*. 134 (2) 1055–1066.

Ciappi E., Rosa S. De, Franco F., Guyader J., Hambric S., Leung R., Hanford A., (2018). “Flinovia-Flow Induced Noise and Vibration Issues and Aspects-II: A Focus on Measurement, Modeling, Simulation and Reproduction of the Flow Excitation and Flow Induced Response”, Springer International Publishing Switzerland,.

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