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# Aeroacoustic source contributions to sound power

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**ABSTRACT**

A technique to investigate the contributions of aeroacoustic sources to the sound power is presented. The method combines the Lighthill source distribution with an acoustic impedance matrix constructed from radiation kernels of the free-field Green's function. By calculating the contributions of aeroacoustic sources to sound power, the location and nature of the dominant flow noise sources are identified. To demonstrate the technique, the flow noise produced by a pair of co-rotating vortices is examined. The aeroacoustic contribution of each component of the Lighthill tensor is determined for a range of wavenumbers, with key findings discussed.

## 1 INTRODUCTION

A non-negative surface contribution which can be interpreted as a non-negative intensity was proposed by Marburg et al. (2013) for the identification of surface areas of a vibrating structure contributing to far-field sound radiation. The approach uses the acoustic impedance matrix of a vibrating structure to compute acoustic power based on the summation of positive-only sound power contributions. The non-negative intensity technique was combined with the boundary element method to address acoustic problems associated with large-scale fluid-solid interaction (Wilkes et al., 2017). The non-negative intensity method for vibro-acoustic applications is well established. This work extends the technique to identify the non-negative contribution of aeroacoustic sources to sound power. To demonstrate the technique, flow noise generated by a pair of co-rotating vortices is examined. The non-negative contributions of each component of the Lighthill tensor to the sound power are identified. The technique is applied to acoustically compact and non-compact sources arising from a range of wavenumbers and vortex separation distances.

## 2 METHODOLOGY

The acoustic pressure $p_q(\mathbf{x})$ at a far-field location $\mathbf{x}$ due to a small volumetric quadrupole source $\Omega$ can be expressed as (Croaker et al., 2013):

$$p_q(\mathbf{x}) = \int T_{ij} \frac{\partial^2 G(\mathbf{x},\mathbf{y})}{\partial \mathbf{y}_i \partial \mathbf{y}_j} \mathrm{d}\Omega \tag{1}$$

where $\mathbf{x}$ and $\mathbf{y}$ are the locations of field and source points, respectively. $T_{ij}$ is the Lighthill tensor and $G(\mathbf{x},\mathbf{y})$ is the 2-D harmonic free-field Green's function. For $M$ number of acoustic sources, the acoustic pressure at a field point can be expressed as:

$$p(\mathbf{x}) = \sum_{q=1}^{M} p_q(\mathbf{x}) \tag{2}$$

The acoustic intensity at a far-field location can be expressed in terms of acoustic pressure using

$$I = \frac{1}{2\rho c} \mathrm{Re}\{p(\mathbf{x}) p^*(\mathbf{x})\} \tag{3}$$

where $\rho$ is the density of the fluid and $c$ is the speed of sound in the fluid at rest. The sound power can be obtained from the integration of acoustic intensity over a far-field surface enclosing the sources through which the sound is propagating.

## 3 RESULTS AND DISCUSSION

To demonstrate the non-negative contribution technique, flow noise from co-rotating vortices is examined. Two identical vortices are rotating counter-clockwise with a radius of 1 m about a coordinate system located at the centre of a square computational domain with a side dimension of 60 m. To compute the velocity distribution, the computational domain was divided into 3600 square elements. A total of 3600 quadrupole sources in the computational domain were considered. Figure 1 shows the contribution of each Lighthill tensor component to the sound power for an acoustically compact case arising from acoustic wave number of $k = \pi/16$ (top row) and a non-acoustically compact case arising from $k = \pi/2$ (bottom row). For the acoustically compact case, the contribution of the aeroacoustic source distribution for the first and third components of the Lighthill tensor corresponding to $T_{11}$ and $T_{22}$ are respectively similar to sound maps for longitudinal quadruples, as described previously by Croaker et al. (2018) using a time-reversal technique. The contribution of the acoustic source distribution for the second component of the Lighthill tensor denoted by $T_{12}$ shows a central focal point. The trend of sound maps can also be observed in the acoustically non-compact case for $T_{11}$ and $T_{22}$ in the same orientation as the corresponding aeroacoustic source distribution for the acoustically compact case.

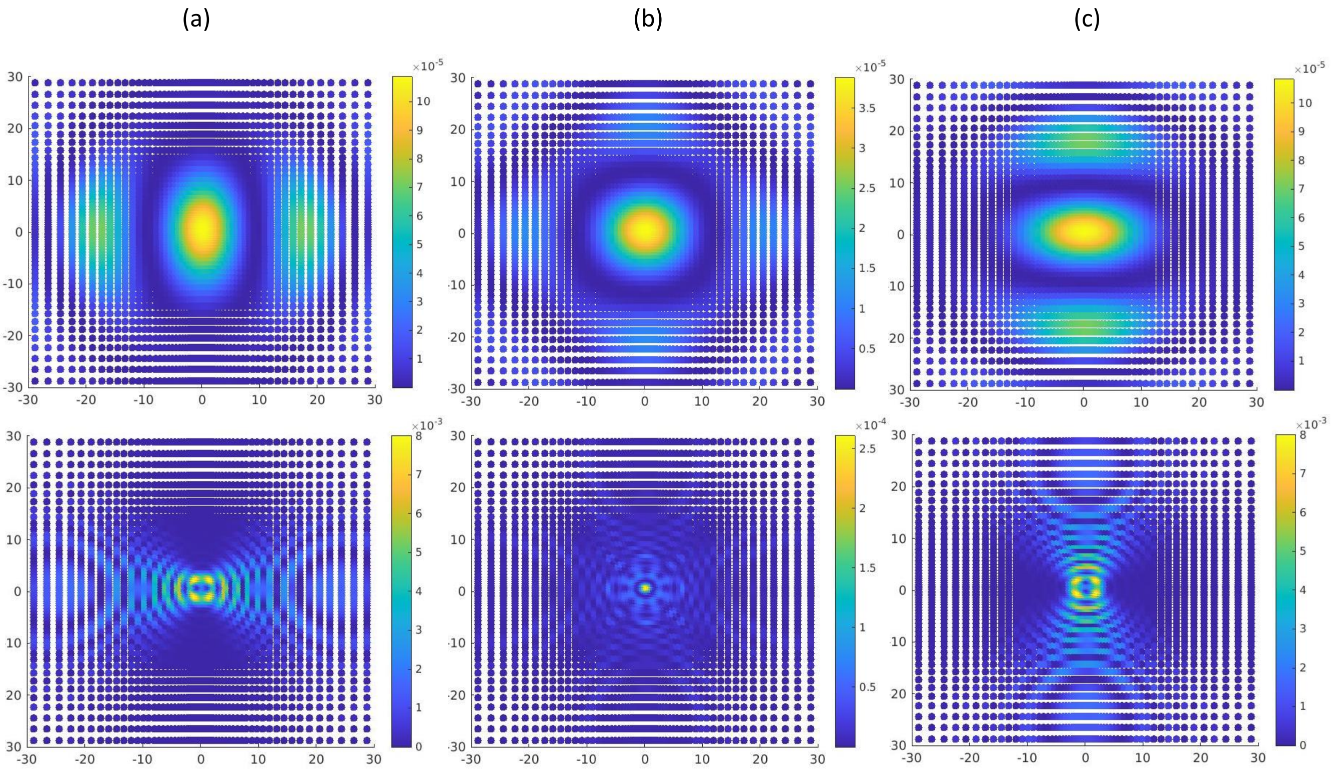


Figure 1. Non-negative contribution to sound power from (a) $T_{11}$, (b) $T_{12}$, (c) $T_{22}$ for an acoustically compact vortex pair ($k = \pi/16$) (top row) and (b) a non-acoustically compact vortex pair ($k = \pi/2$) (bottom row)

## 4 CONCLUSION

In this study, a new method to determine the non-negative contribution of aeroacoustic sources of co-rotating vortices was described. Results were presented for the non-negative contributions resulting from different components of the Lighthill tensor under both acoustically compact and non-compact conditions. Identification of dominant flow noise sources that have the greatest contribution to far-field sound can facilitate the design of targeted noise mitigation strategies.

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