Vibration of a cantilever panel due to turbulence ingestion, part II: A virtual experiment

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Abstract - In the first part of this investigation, a semi-analytical approach was presented to predict the vibration response of a cantilever panel due to turbulence ingestion. This study focuses on the practical implementation of numerical experiments using a virtual synthesis of the source scanning technique. This practical framework will serve as a prototype for laboratory investigations. To practically predict the vibration response of a cantilever plate due to turbulence interaction at the leading edge, the problem can be re-framed as synthesising the corresponding response of a structure with an existing pressure field. An array of acoustic compact sources, such as monopoles, can sufficiently excite a structure creating the existing acoustic pressure field. This acoustic pressure field can instead be replicated using the superposition principle, whereby a synthetic array of a single monopole scanning over the structure can replace the array of monopoles. Complex amplitudes are derived from fitting the existing acoustic pressure field to a target pressure field and are subsequently used to scale measured frequency response functions due to the source scanning monopole sources to synthesize the predicted vibration response. It is anticipated that this framework will complement wind tunnel testing as an efficient estimation.

1 VIRTUAL EXPERIMENT

A source scanning technique (SST) based on (Aucejo et al., 2012) and (Pouye et al., 2021) is implemented in a virtual experiment to demonstrate a practical framework for evaluating the vibration of a cantilever panel due to turbulence ingestion. There are four main steps that need to be executed:

1. Characterize the acoustic source. In the virtual experiment, the acoustic monopole source is assumed to have unit strength and can be analytically described accordingly from the Green's function solution of an acoustic free field. In practice, this needs to be performed experimentally by substituting the structure of interest with a rigid replacement, to take measurements of the blocked pressure. For p points of blocked pressure measurements and s locations of the scanning acoustic monopole sources, we create a frequency-dependent matrix $G_{ps}(\omega) = [\boldsymbol{G}]$.

2. Approximation of scaling factors. Using the matrix from the previous step G_{ps} and known target pressures $P_p = [\boldsymbol{P}]$ that we are interested in simulating the vibration due to, we can estimate the complex coefficients $q_s = [\boldsymbol{q}]$ that would scale the s acoustic sources to achieve the target pressure by applying the Moore-Penrose pseudo-inverse $[\boldsymbol{q}] = [\boldsymbol{G}]^{\dagger}[\boldsymbol{P}]$. A schematic is shown in Figure 1.

3. Measurement of frequency response functions (FRFs). For each position of s of the scanning acoustic source, we take the FRF of the structure Γ_s.

4. Evaluation of the sensitivity function. Using the scaling factors from Step 2, we can scale (linearity) and sum (superposition) all the scaled FRFs to obtain the sensitivity function $H_v = \sum_s q_s \Gamma_s$. This sensitivity function can then be inserted into the velocity ASD function (found in part 1).

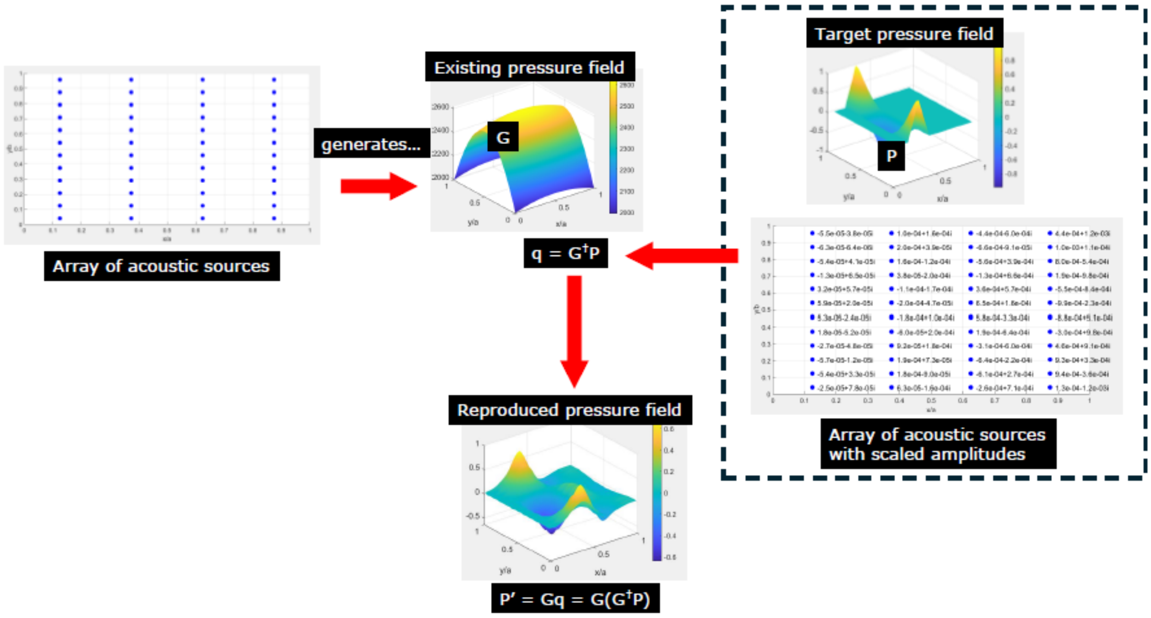

Figure 1: Schematic of Step 2. An array of acoustic sources is scaled by complex coefficients to reproduce the target pressure field.

2 RESULTS

The vibration of a cantilever panel due to turbulence ingestion is evaluated using the semi-analytical (TRM) model provided in part 1. The practical framework of SST is implemented in a virtual experiment. As shown in Figure 2, the SST can re-create the vibration response using acoustic sources and the known target random pressure field. It is envisioned that the SST provides the possibility of efficiently predicting the vibration of structures under specific stochastic loads such as turbulence ingestion and turbulent boundary layer excitations.

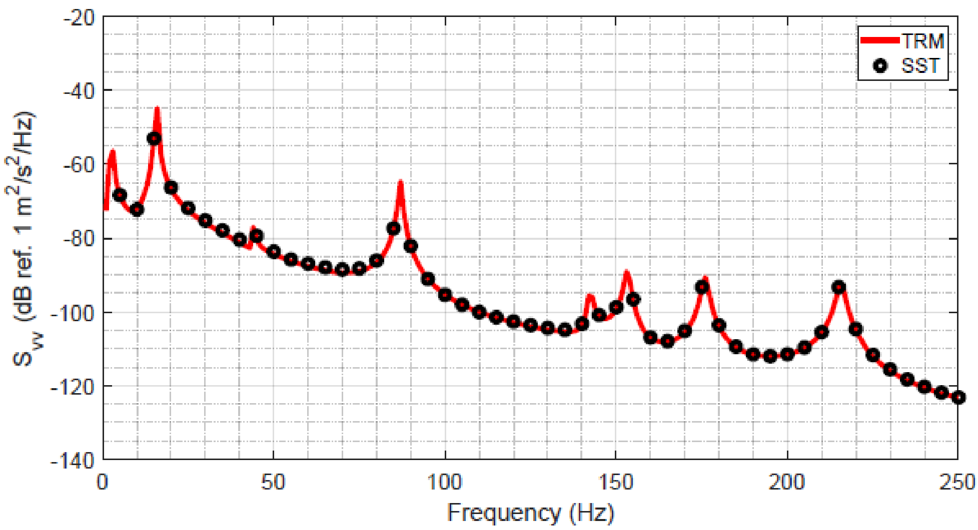

Figure 2: Evaluation of the velocity ASD function at the centre of a cantilever panel due to turbulence ingestion.

REFERENCES

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