

FLOW DECOMPOSITION ANALYSIS OF THE AEROACOUSTIC WALL PRESSURE GENERATED BY AUTOMOBILE SIDE MIRROR

S. Julisson^{1,2}, E. Gaudard^{1,2}, R. Marchiano² and Ph. Druault^{*2}

¹ PSA, Case Courrier VV1405, Route de Gisy, 78140 Velizy-Villacoublay, France

² UPMC-Paris 6, Institut Jean Le Rond d'Alembert-Case 162, 75252 Paris cedex 5-France

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Car manufacturers are now facing new challenges as the development of quieter electric and hybrid vehicles modifies the interior wind noise. In such a context, the noise caused by the complex three-dimensional flow field in the wake of the side car window becomes one of a major wind noise source and especially during high speed driving. It is now well known that Wall Pressure Fluctuations (WPF) developing over side windows is composed of 1) an acoustic component that propagates at sound velocity and 2) a hydrodynamic component convected at the flow velocities. Both contributions which also differ by several orders of magnitude have been already well identified thanks to the representation of the Power Spectral Density [1, 2, 5]. In this work, a WPF database previously obtained [6] thanks to the resolution of the filtered Navier-Stokes equations related to the wake flow of a side car window is retained. Details about the numerical code solver (called Safari) used in this study can be found in [3, 6]. One then proposes to pursue the analysis of the numerical WPF database by comparing two WPF flow decompositions: the classical Fourier Decomposition and an energetic filtering procedure: the Proper Orthogonal Decomposition [4]. Figure 1 displays instantaneous fluctuating pressure fields in the whole 3D computational domain and also over the 2D flat plate. A Fourier analysis is first applied to the WPF field obtained on the 2D flat plate. As a representative result, figure 1 represents the wavenumber-frequency ($k_x - f$) along the dash-line (see figure 1- left-bottom) and the wavenumber representation at $f = 2000\text{Hz}$. One then observes both contributions (acoustic and hydrodynamic) because of the difference in convection velocities. To discriminate the two contributions, a filtering procedure is implemented in the spectral space. Figure 2 illustrates it with an instantaneous WPF representation and with a phase analysis like in [2]. This last one proposes to compute the phase relation between two wall pressure signals stored at two points along the dash-line and distant of 1cm. It is confirmed the effectiveness of the Fourier filtering technique in well separating both contributions, especially for frequencies higher than 300Hz. Similar analyses are performed thanks to the POD energetic filtering procedure. Based on POD application, the WPF field are successively projected onto the first POD modes and onto the POD mode remainder. A PSD analysis as well as a phase analysis are presented in figure 3. Even if POD seems to act as a wavenumber filtering procedure, such application can not enable to well discriminate both contributions. However, numerous parameters (WPF database: near wake or whole 2D flat plate domain, space resolution, ...) influence notably the flow decomposition. This will be presented in the final version of the paper.

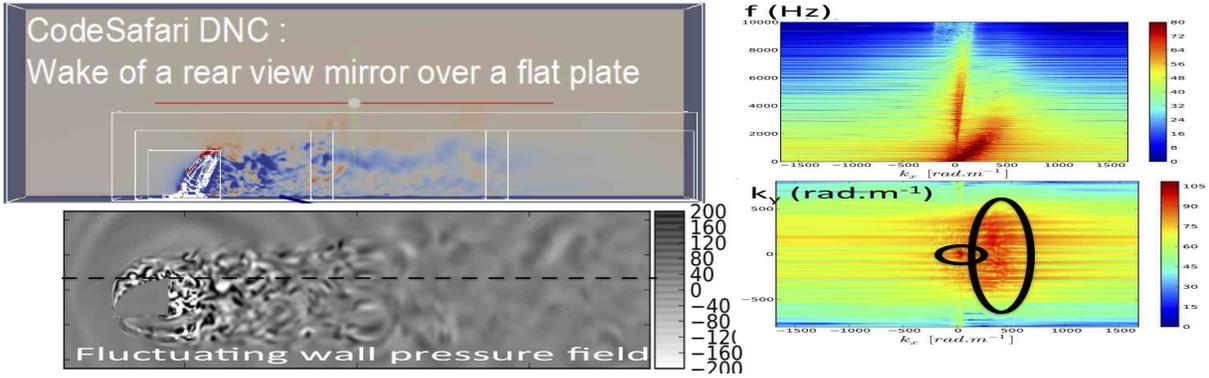


Figure 1: Left-Top: Instantaneous fluctuating pressure field in the whole 3D computational domain. Left-Bottom: Snapshot of the wall fluctuating pressure field. Right-Top: Wavenumber (k_x)-frequency (f) representation of the WPF field along the dash line. Right-Bottom: Wavenumber (k_x, k_y) representation of the WPF field at $f = 2000$ Hz. Each PSD representation is given in dB scale.

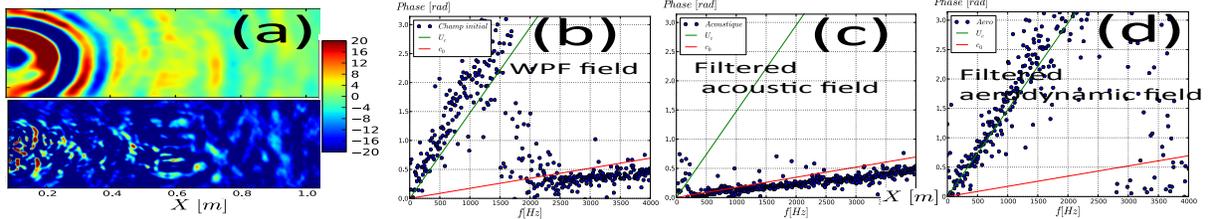


Figure 2: Fourier filtering application. (a) Instantaneous filtered (acoustic-top and aerodynamic-bottom) WPF field. (b-c-d) Phase analysis computed for two WPF signals extracted along the dashed line and distant of 1cm: reference WPF field (b), filtered acoustic field (c) and filtered aerodynamic field (d). The theoretical phases related to plane waves propagated at sound velocity (red) and convection velocity (green) are also plotted for comparison.

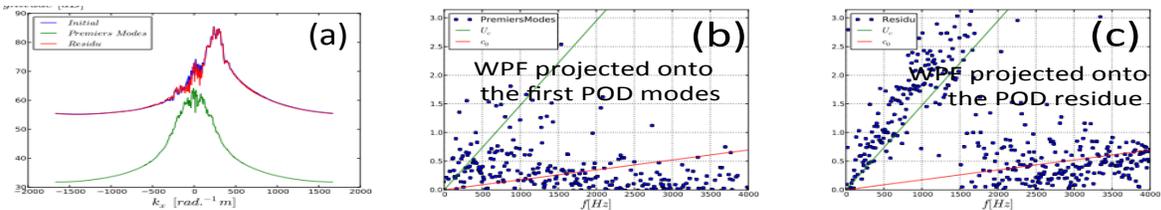


Figure 3: POD filtering application. (a) PSD computed along the dashed line ($f = 1300$ Hz) of the reference WPF (blue), its projection onto the first POD modes (green), its projection onto the POD mode remainder (red). (b-c): Phase analysis of the WPF projected onto the first POD modes (b) and of the WPF projected onto the POD mode remainder (c).

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