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Computation of flow separations from bridge girders and effects on flutter derivatives

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1 INTRODUCTION

The widely used formulation of aeroelastic forces presented in the work of Scanlan and Tomko (1971) relies on the frequency dependent coefficients - flutter derivatives and wind tunnel experiments as their identification tool. The lack of analytical solution for flutter phenomena at bridges is related to the complexity of flow separations from a typical bridge deck. Numerical approaches can be considered for identification of aeroelastic forces. Nevertheless, it has to be kept in mind that numerical simulations are often jeopardized by the limitations related to poor detection of separation regions. In order to estimate the influence of these limitations over the computed flutter derivatives, this study employs 3D Large Eddy Simulation (LES) and 2D Unsteady Reynolds-Averaged Navier-Stokes (URANS) approaches.

2 METHODOLOGY

2.1 Different representations of flutter derivatives

The discretized pressure measurements allow another representation of flutter derivatives. Namely, total aeroelastic force can be treated as the sum of the contributions of the forces associated to each pressure tap, as presented in Argentini et al. (2012). This way global (integral) value of flutter derivative can be treated as the sum of its distributed values, for example:

$$\mathrm{H}^*_{2/3} = \sum_{j=1}^{N_{taps}} \mathrm{H}^*_{2/3,\mathrm{j}} \tag{1}$$

Further, these distributed flutter derivatives can be linked with the distributed unsteady pressure amplitude - $\hat{\mathrm{C}}_{\mathrm{p,j}}$ and the phase shift related to the forced motion - φ_{j}. As an example:

$$\mathrm{H}^*_{2,\mathrm{j}} \sim \hat{\mathrm{C}}_{\mathrm{p,j}} \sin\varphi_{\mathrm{j}} \qquad \mathrm{H}^*_{3,\mathrm{j}} \sim \hat{\mathrm{C}}_{\mathrm{p,j}} \cos\varphi_{\mathrm{j}} \tag{2}$$

These different representations of flutter derivatives provide additional information about distributions around the cross-section.

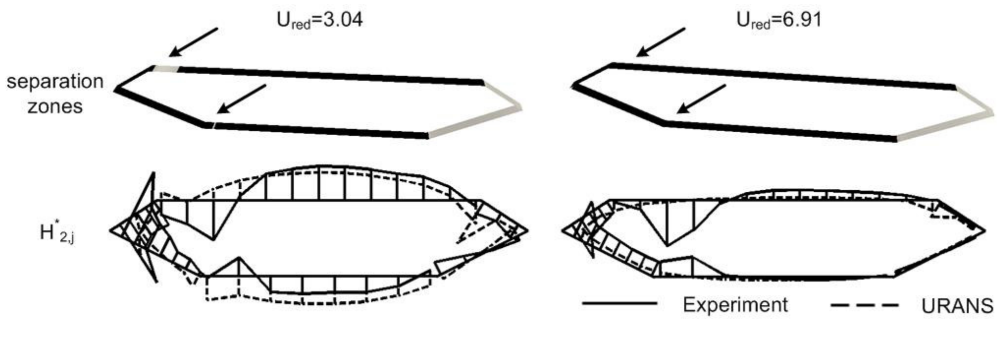

Figure 1: URANS simulated positive wall shear stresses indicating upstream separation zones and distributed representation of the H_2^* flutter derivative for reduced velocities: U_{red}=3.04 and U_{red}=6.91.

2.2 Experimental approach

To provide validation data, wind tunnel tests are performed in the boundary layer wind tunnel of the Ruhr-Universität Bochum using the forced vibration mechanism. Two independent sensor systems are used, namely the force balance and pressure sensor system (with 40 pressure taps), Šarkić et al. (2012).

2.3 Numerical methods

3D LES approach is applied with the dynamic Smagorinsky model to predict aeroelasic forces, Šarkić and Höffer (2013). In addition, the LES simulations are going to be compared to the results related to the 2D URANS with k-ω-SST closure model, Šarkić et al. (2012).

3 AIM OF THE WORK

Besides treating integrated values of flutter derivatives, this paper will use distributive representations of unsteady pressure amplitude, phase and flutter derivatives. In addition of gaining a deeper insight into phenomenology of the unsteady aerodynamics, also more detailed validation of numerical results is accomplished. Based on adopted validation procedure the impact of the numerical limitations related to separation region is going to be estimated. One example of the impact of the upstream separation zones related to URANS simulations is shown in Figure 1 for two reduced velocities. Simulation related to the smaller reduced velocity, associated with small but existing separation zones, shows better agreement of distributed H_2^* pattern compared to the measured results.

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