

Evaluation of Branch Switching Characteristics in Coupled Flutter through Revised Step-by-Step Analysis

Kyoto University, Bridge and Wind Eng. Lab
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○ Cristiano Augusto Trein (Student Member)
 Masaru Matsumoto (Fellow)
 Yasuaki Ito (Student Member)
 Hisato Matsumiya (Student Member)
 Shinya Fujiwara (Student Member)

1. ABSTRACT – Branch switching characteristics for coupled flutter of structural rectangular sections are analyzed using step-by-step flutter analysis (SBSA). Prior to the appearance of coupled flutter instability, the torsional branch (TB) controls the instability. However, after flutter onset both TB and heaving branch (HB) coexist, with sudden switching in particular velocity ranges. For lower velocity ranges, very good agreement can be obtained between conventional Complex Eigen Value Analysis (CEVA) and SBS method, but for higher velocity ranges this agreement cannot be attained. So SBSA is revised, leading to fairly good convergence between both methods.

2. INTRODUCTION – The advances in the modern Structural Engineering, triggered by the necessity of even longer span bridges, started a new era in the world of bridge constructions; novel design and construction techniques, associated to new girder cross-sections and materials, helped in this progress. The longer the spans become, the closer torsional and heaving natural frequencies of bridges get, making room for the arising of the 2-DOF coupled flutter instability, instead of the more common 1-DOF torsional flutter. In the wake of all this, aerodynamic phenomena not experienced by the bridges of the beginning of the last century became a major issue in the design of the long span bridges of the present days.

Since the famous failure of the old Tacoma Narrows Bridge in 1940, due to a torsional flutter instability in its main span, the investigations on flutter has progressively increased in number and in importance, and with the proposition of the flutter derivatives by Scanlan [1] the studies about the aerodynamic instability phenomena found a new route. Matsumoto et al investigated the inter-dependences between those derivatives [2], showing with the use of Step-by-Step Analysis (SBSA) the important role A_1^* and H_3 play for the occurrence of flutter [3].

Since the role a given aerodynamic derivate plays in the generation mechanism of flutter is dependent on what branch is governing the motion, the identification of the exact point of the branch switch is extremely important for establishing flutter stabilization strategies. So in this work the importance of using SBSA in this context is demonstrated, and a case study showing the differences produced by SBS, a revised SBSA and CEVA is presented, pointing the revised SBSA as an efficient tool for the precise identification of the branch switching point.

3. BRANCH SWITCHING – In the analysis of 2-DOF coupled flutter instability, the commonly used method is the Complex Eigen Value Analysis (CEVA), which provides means for the identification of the logarithmic damping, the flutter frequency, the amplitude ratio and the phase difference between torsional and heaving motions. However, this method is a mathematical approach for a 2-DOF dynamic instability, not based on the generation mechanism of the flutter itself, in a manner that some information is missed in the analysis process, e.g. branch switching. In order to fill this gap SBSA is used, and because this method is based on the flutter generation mechanism, the exact point for the branch switching can be identified.

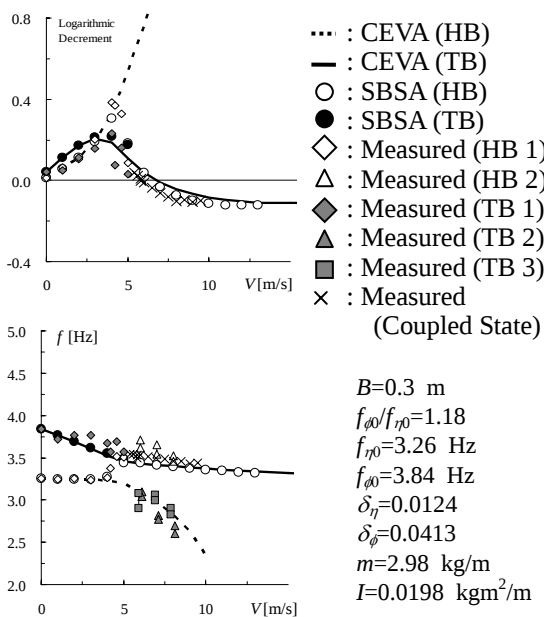


Figure 1 – Coupled flutter characteristics for $B/D = 20$ rectangular cylinder

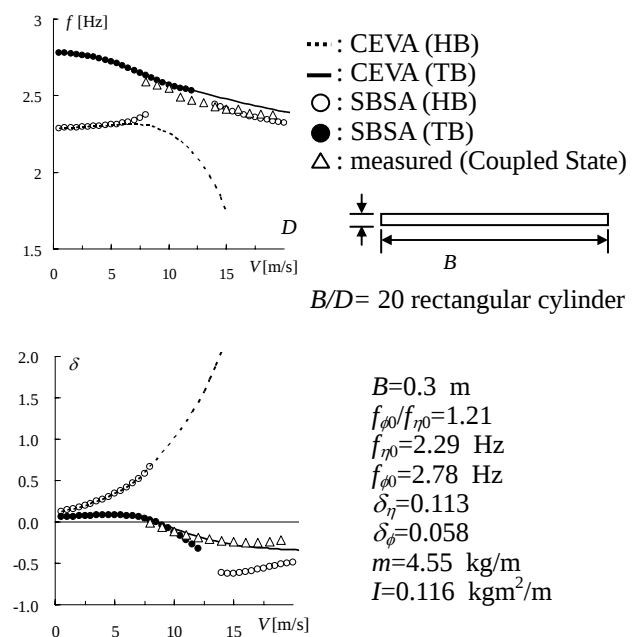


Figure 2 – Coupled flutter characteristics, $V-\delta$ and $V-f$ characteristics of $B/D = 20$ rectangular cylinder

Keywords: Coupled flutter – Step-by-Step Analysis – Branch Switching – Aerodynamic Derivatives

Department of Civil and Earth Resources Engineering, Kyoto University, Kyotodaigaku Katsura, Nishikyoku, Kyoto, Japan

