FREE TO TUMBLE TECHNIQUE: THEORY

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1. Introduction

The most reliable way to obtain stability parameters for scaled models at realistic Reynolds and Mach numbers is through dynamic experiments in a wind tunnel[1] both with forced and free oscillatory methods. Other experimental techniques may provide the same data on scaled models but limitations apply on test Reynolds number. Furthermore, these techniques focus on the time history of the vehicle and generally do not extract stability parameters in a form suitable for conventional mathematical models (derivatives).

An interesting example among the unconventional experimental methods is the wind tunnel model free testing. The model is dynamically scaled and remotely controlled (control surface deflection). Derivatives can be extracted from free flight measurements with a data reduction procedure derived from flight test techniques. A safety cable is installed to prevent uncontrolled impacts.

X-29 free-flight model in the NASA Langley Full-Scale Tunnel

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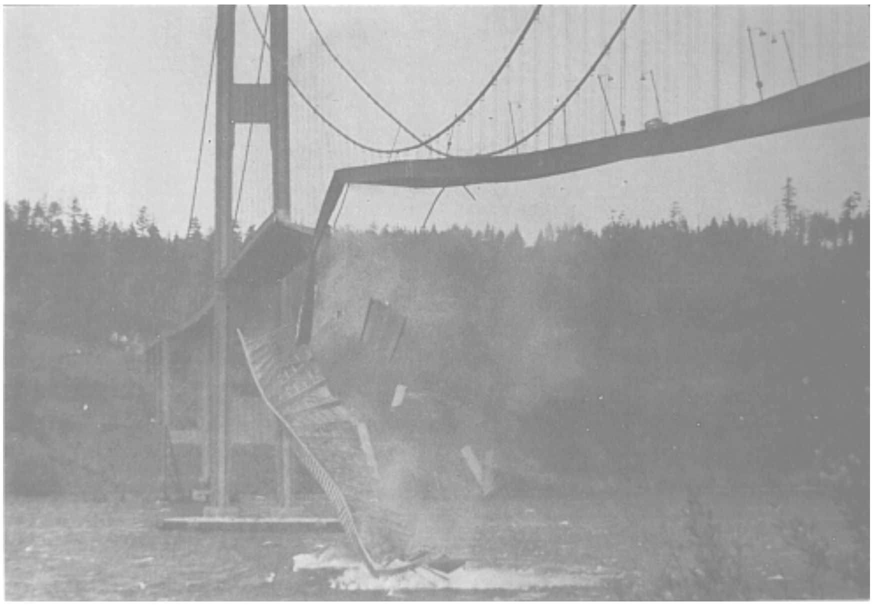
[1] Orlik-Rueckemann, K., "Review of Techniques for Determination of Dynamic Stability Parameters", AGARD-LS-114, 1981

Dynamic stability derivatives are also evaluated using full scale flight experiments for already existing aircraft configurations. Extrapolation of experimental results from aircraft testing is not straightforward and stability parameters may be extrapolated for similar configurations during the design phase only when consistent databases are available.

2. Theory and background

Wind induced oscillations are commonly observed in different fields of engineering. As an example, in the design of long span suspension bridges, notably suspended bridges, the wind action is of primary concern. The aerodynamic effects of wind on bridges are primarily vortex shedding, galloping, torsional divergence, flutter and buffeting.



The Failure of the Tacoma Narrows Bridge (1940)

Differently, wind tunnel free oscillation techniques on aircraft configurations generally provide results in terms of rigid body dynamics. These experiments <u>must not be confused</u> with aeroelastic tests performed on dynamically scaled models.

Wind tunnel free oscillation techniques in aeronautics were widely diffused in the past due to relative simplicity of the test procedure (compared with the other types of wind tunnel dynamic experiments). The main application was a direct validation of system stability in terms of dynamic convergence. As opposed to forced-oscillation testing, in free oscillations the inertia of the body removes energy from the flowfield, reducing the