# FREQUENCY AND AMPLITUDE EFFECTS ON PRESSURE LOADING ON AN OSCILLATING TURBINEBLADE

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## ABSTRACT

The tip of a blade oscillating at high frequencies is subjected to huge acceleration forces that result in blade flexing, thus increasing the blade-tip incidence above the level corresponding to a stiff blade. The consequence of the blade flexing is that it is difficult to distinguish between the effects of the blade's oscillation frequency and of the instantaneous incidence angle, as they act concurrently. A new computational procedure for reducing experimental data was devised that allows distinguishing the effects of blade tip amplitude and blade oscillation frequency on blade pressure loading. The new procedure, analogous to a “stroboscopic motion freezing” method, “stops” the blade motion at selected incidence angles, thereby allowing inspection of the blade loading at selected blade amplitudes for a constant blade oscillation frequency.

## INTRODUCTION

A new generation of steam turbines for electric plants must have a wide operating range to compensate for the fluctuating output of alternative electricity sources, given the constraints imposed by the electric network's maximum capacity. Variations in turbine power output force the last turbine stages into off- design conditions, intensify flow instabilities, and trigger flutter behavior of the long, slender blades in these stages. An increase in flow instability is particularly dangerous for blades with transonic or low-supersonic flow at their tips.

Experimental research on blade flutter aerodynamics is conducted in dedicated, simplified test facilities rather than on large, actual turbomachines for technological and, primarily, economic reasons. A five-bladed linear cascade module, equipped with a driver to oscillate up to three blades and simulate blade flutter, was built and used in the High-Speed Laboratory of the Institute of Thermomechanics of the Czech Academy of Sciences.

The flutter module is placed in the flow channel of a large suction-type wind tunnel, allowing up to 30 seconds of continuous test time at prescribed transonic flow and blade oscillation frequencies up to 200 Hz. The flat test blades, 160 mm long, are the tip sections of the last-stage turbine blades. The blade chord is 120 mm, and the thickness is 6 mm. One blade is instrumented with 8 high-frequency transducers (Kulite) along its chord on the blade suction side.

## RESULTS AND DISCUSSION

The amplitude of blade tip oscillations is not generally reported in publicly available reports on forcedly induced blade flutter; it is based on the angular amplitude of the blade driver. In the reported work, however, the blade-tip instantaneous amplitude of the oscillation was measured using a laser triangulation sensor. Data sampling frequency was 40 kHz. This is an important innovation because it reveals that at high oscillation frequencies, the blade does not behave as a rigid body. Due to the acceleration loading, which reached up to 100 g in the reported case, the blade flexes, and the maximum instantaneous blade tip incidence angle exceeds that based on the driver angular amplitude and the blade half-chord length.

Blade flexing poses a problem during the data reduction process because the effects of the blade oscillation frequency and the blade's instantaneous incidence angle act concurrently and cannot be readily distinguished, except by costly rerunning of the entire series of experiments with drivers repeatedly set to different angular amplitudes.

An alternative approach for data reduction was devised. Each recorded data segment, about 4 sec long, was divided into intervals based on the blade oscillation period, revealing the dependence of the measured instantaneous pressures on the instantaneous blade incidence angle. All such hysteresis loops of instantaneous pressure as functions of instantaneous incidence angle were averaged into a single hysteresis loop characteristic of the particular flow and frequency state. Then, a computational procedure analogous to a “stroboscopic motion freezing" method was applied to "stop" the blade motion at selected incidence angles, thereby distinguishing the effects of blade tip amplitude and blade oscillation frequency on blade pressure loading.

The effects of the blade-tip amplitude were determined by comparing the computationally "frozen" blade pressure distributions at selected blade-tip amplitude levels, or phases of the hysteresis loop, at the same oscillation frequency. An example of such pressure distributions is shown in the plots in the attached figure for incidence angles of -1.0 and -2.5 deg, compared with the static distribution at the same incidence angle.

Preliminary results indicate that, for the transonic flow regime in the cascade, the effects of blade-tip amplitude are more pronounced than those of blade oscillation frequency. A detailed analysis of these effects will be presented in the paper for three distinct flow regimes in the cascade: subsonic, critical, and transonic.

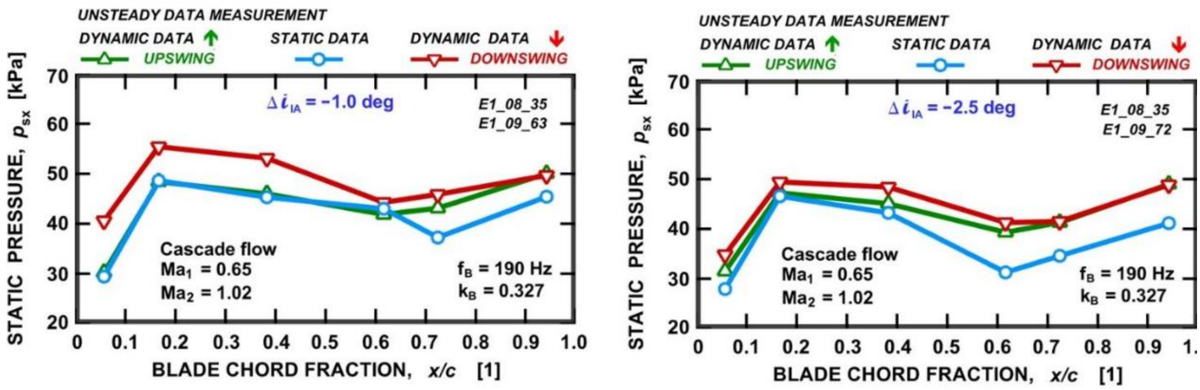


**Figure 1. Effects of blade amplitude at constant oscillation frequency for a transonic flow regime.**

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