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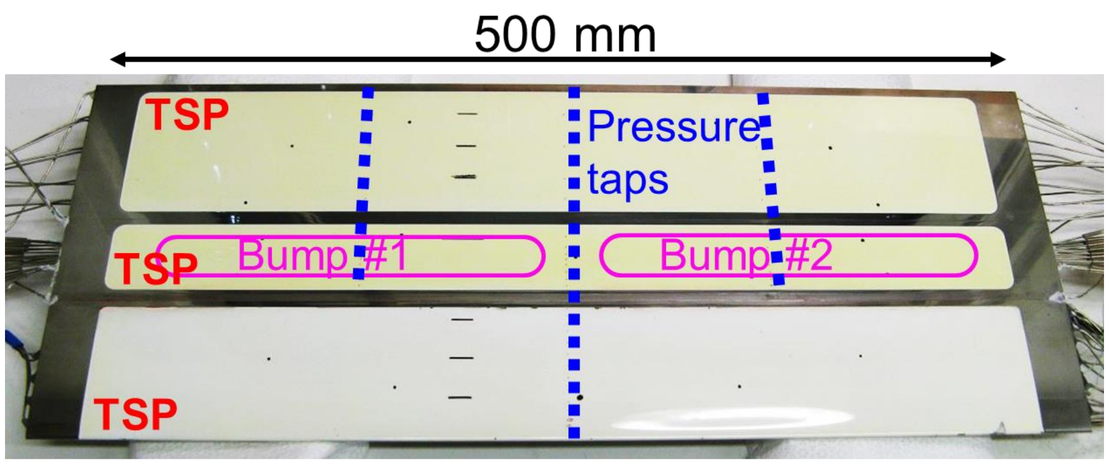
Bump-Induced Transition in Compressible High Reynolds Number Flow: Experimental Results and Correlation with Linear Stability Analysis

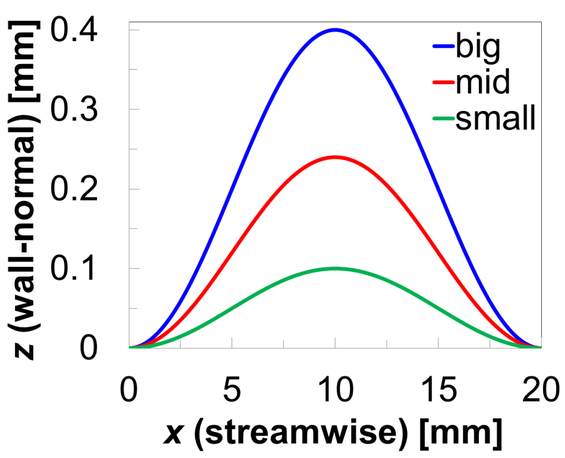
Introduction Surface bumps can occur on aircraft components (e.g., at or between structural joints, ribs and stringers) and can induce a marked amplification of boundary-layer instabilities, thus leading to premature transition to turbulence. The influence of bumps on boundary-layer transition was systematically studied in combination with the effect of variations in the following parameters: streamwise (global) pressure gradient, freestream Mach number (up to **M = 0.77**) and chord Reynolds number (up to **Re = 10 · 10^6**). The experimental investigations were conducted in a (quasi-) two-dimensional flow in the Cryogenic Ludwieg-Tube Göttingen (DNW-KRG).

Wind-tunnel model *BuLASTra*



- Leading edge at the bottom of the image
- Model chord ***c* = 200 mm**, bump crest at *x*/*c* = 45 %
- Temperature-Sensitive Paint (**TSP**) for transition detection

Bump shape



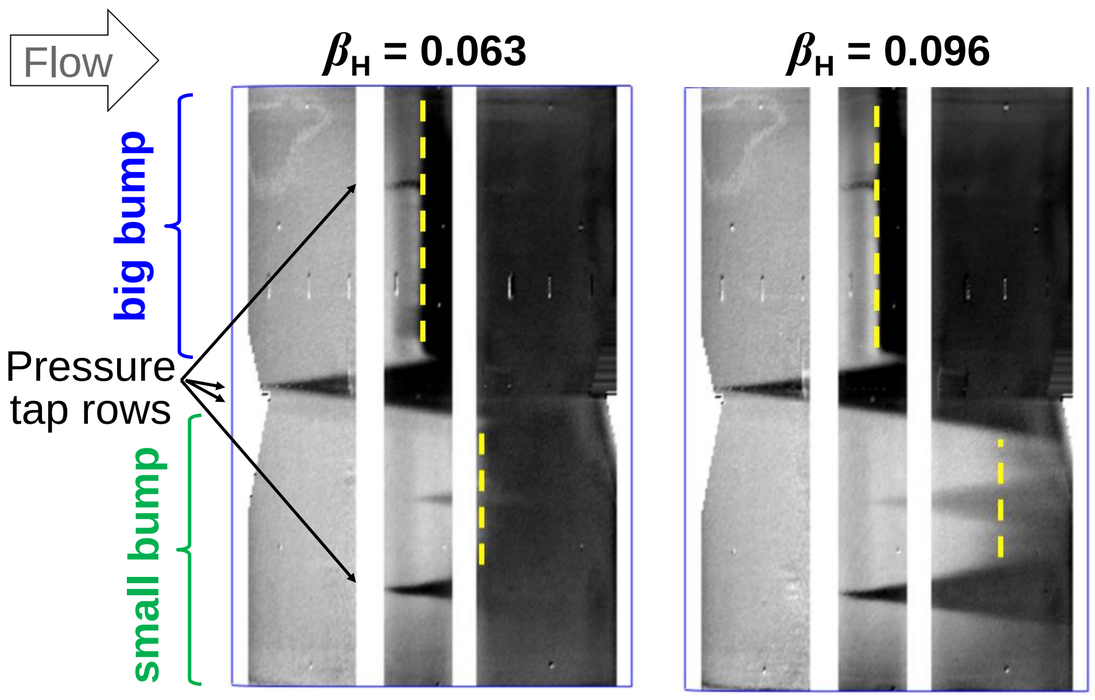
Three sinusoidal bumps (quasi-2D) investigated

Numerical setup

- Laminar basic flow computed with boundary-layer code COCO using the experimental pressure distributions and considering an isothermal wall.
- Approach applicable only for cases without separation, i.e. mostly the reference and small bump configurations.
- Compressible linear local stability analyses (LST) using both LILO and NOLOT.

Effect of the variation of the streamwise (global) pressure gradient (Hartree parameter β_H)

Experimental results (*TSP*)

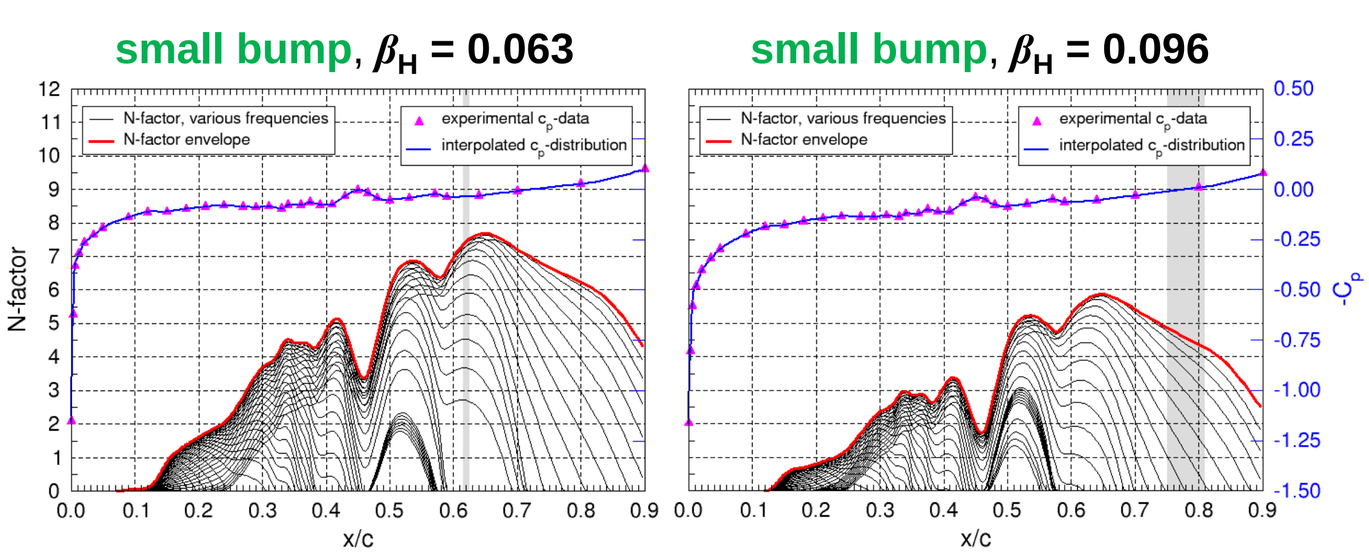


x_T/c (small) ~ 62 %
x_T/c (big) ~ 48 %

x_T/c (small) ~ 78 %
x_T/c (big) ~ 49 %

Transition location x_T/c shown by dashed yellow lines

Numerical results (*N-factors*)



Results of LST obtained using NOLOT
Transition location x_T/c and its uncertainty shown by gray bars

- Boundary-layer transition location moved upstream with increasing bump height.
- In the case of the small bump, transition was very sensitive to the global pressure gradient β_H.
- With the mid bump, the transition sensitivity on β_H depended on Mach and Reynolds numbers.
- Transition induced by the big bump was essentially unaffected by β_H.

- Correlation of the experimental data with results from LST for the small bump configuration:
  - Transition N-factors N_T decreased with increasing M and increasing β_H.
  - The decrease of N_T with increasing M may be related to the increasing level of total pressure fluctuations in DNW-KRG.
  - In some cases, the transition locations found in the experiments could not be explained via the adopted e^N-methodology.