Swept Pazy Wing Analyses

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Why a swept very flexible wing?

- The modes of the undeformed straight wing were uncoupled and became coupled as the wings deformed. In swept wings, there is bending-torsion coupling even in the undeformed shape.
  - How does this coupling impact the deformation of a very flexible wing?
  - How does it affect the mode shape?
  - How does it affect flutter?

- In the straight Pazy wing, strip theory aero model performed well. This might not be the case in swept deformed wing.

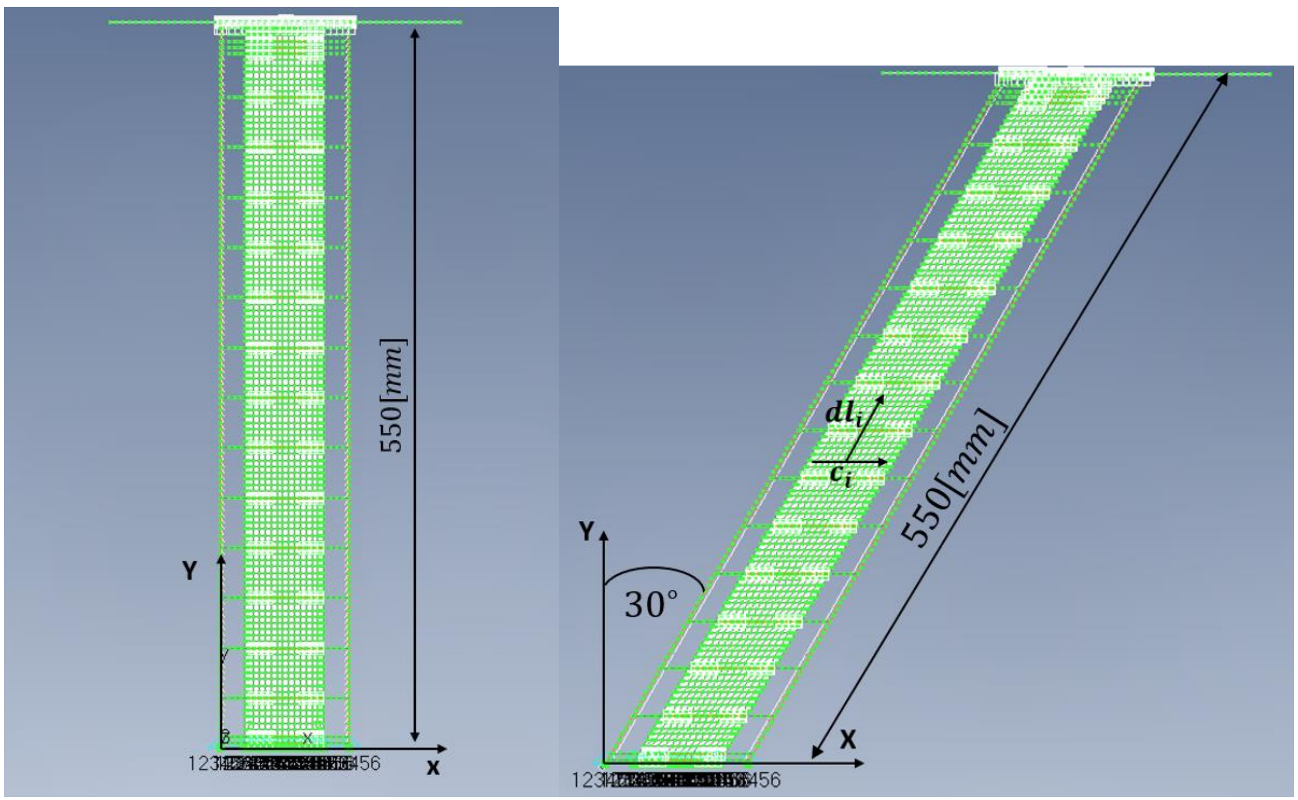
- High-sweep angle wings might not reach large deformations - do we still need to use nonlinear structural models?

In the Presentation

- Structural model
- Natural frequencies and mode shapes of the ***undeformed*** / ***deformed swept*** wings
- Linear flutter analysis of **undeformed** swept wings (0 deg. AoA)
- Nonlinear flutter analysis of **deformed** swept wings (0-10 deg. AoA)
- Static deformations and aerodynamic model
- Very preliminary observations and conclusions

Swept Structural Model

- The straight and swept models have the same length and a different span



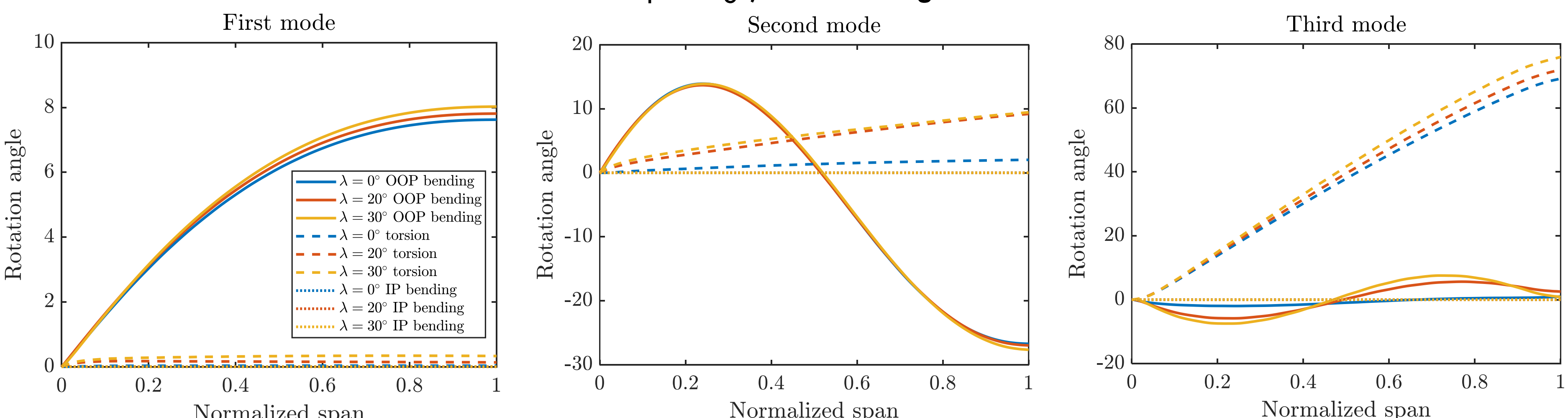
Modes of Swept Wings – Undeformed

Table 1 Natural frequencies of wings of different sweep angles; Zero loading

	$\lambda = 0°$	$\lambda = 20°$	$\lambda = 30°$
Mode 1	$4.2(Hz)$	$4.2(Hz)$	$4.2(Hz)$
Mode 2	$28.2(Hz)$	$27.7(Hz)$	$27.3(Hz)$
Mode 3	$40.4(Hz)$	$43.3(Hz)$	$46.6(Hz)$

- The first and second natural frequencies are independent of sweep
- The swept-wing modes are coupled
- How do the modes vary under load?

OOP bending, torsion, and IP bending components of the first three **curvature modes** of the straight and swept wings; **Zero loading**.



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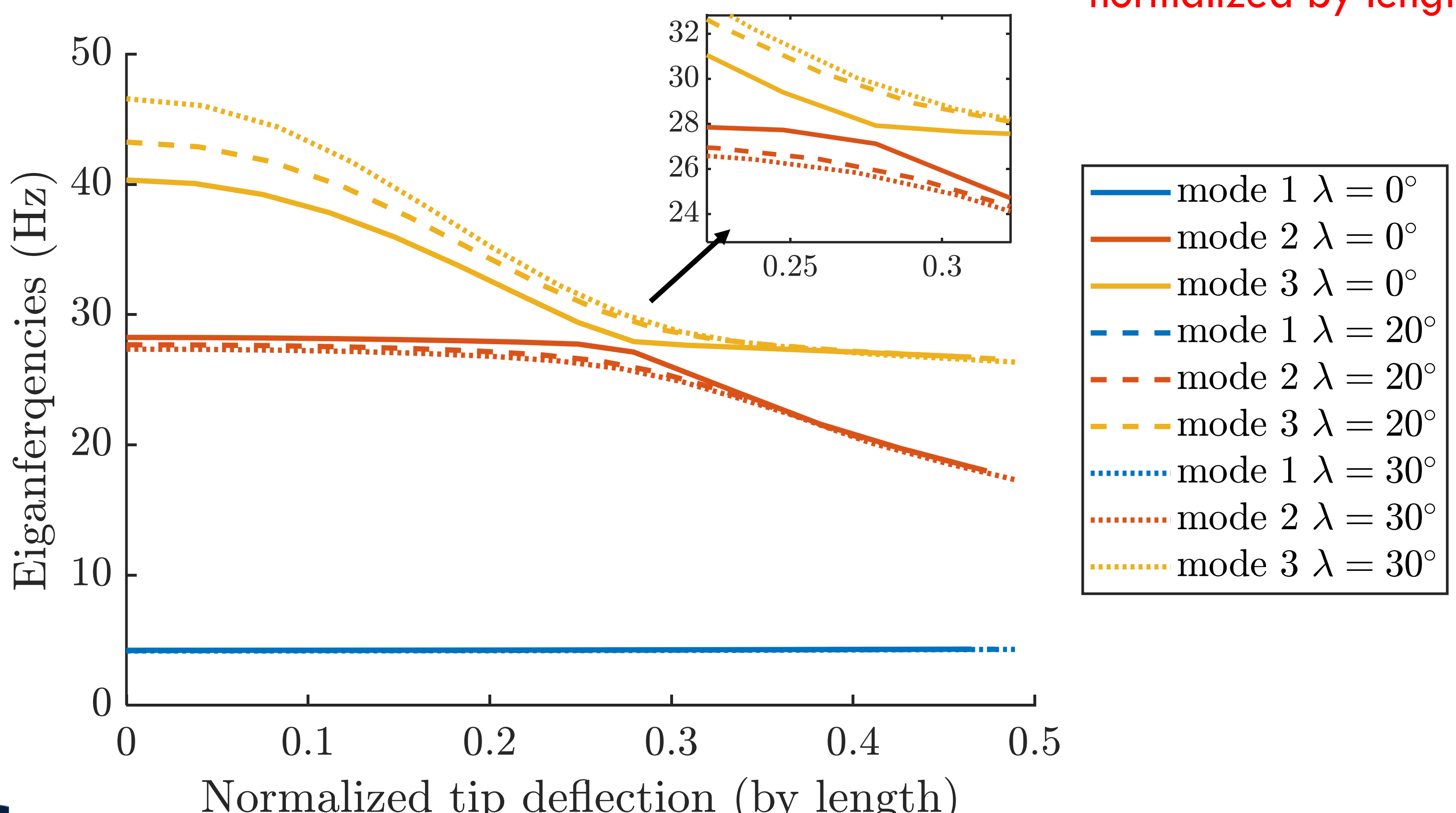
Deformed Wings' Frequencies

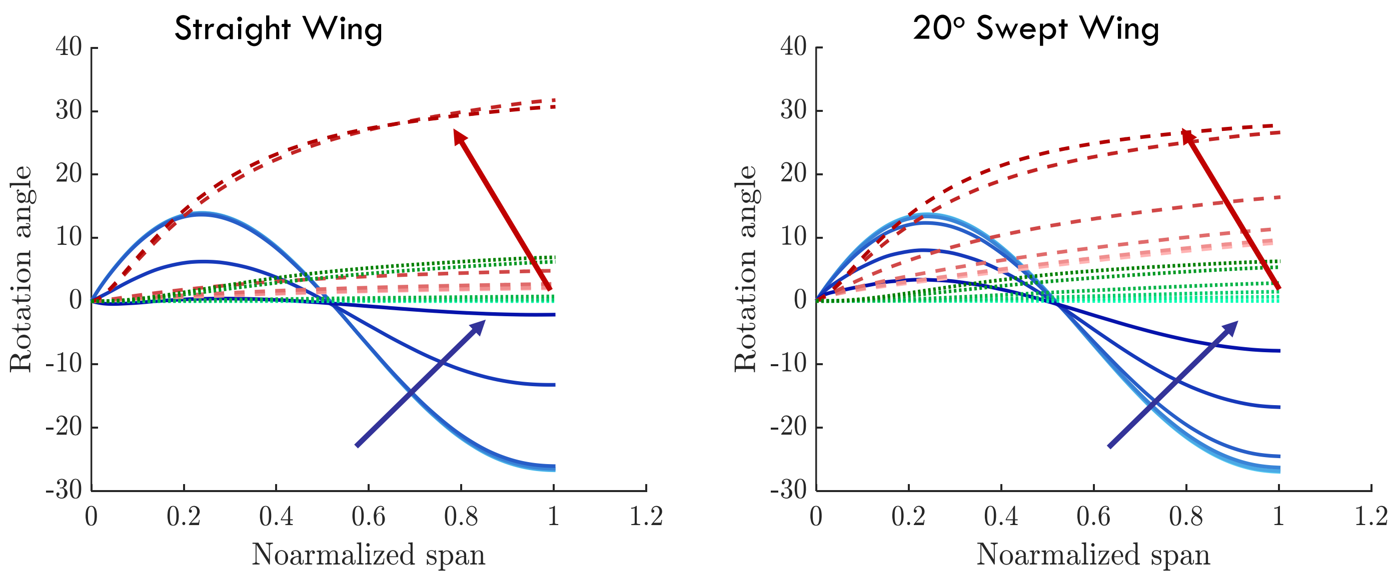
Variation of the first three eigenfrequencies with wing deformation (Nastran nonlinear)



- Similar frequency trends of the straight and swept wings (when normalized by length not span).

Deformed Wings' Modes

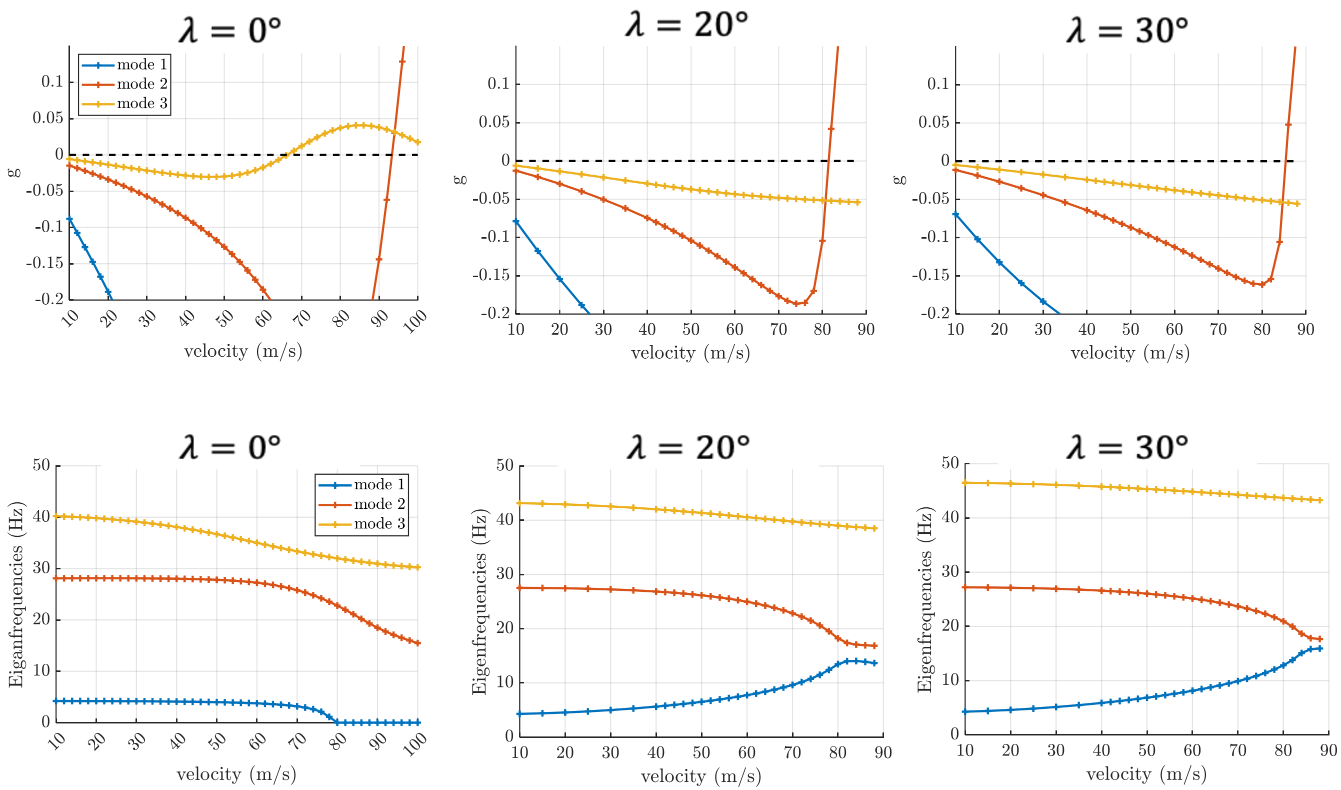
Mode 2 **curvature** components of the deformed wings



- In the swept wings , the mode shapes vary continuously and stay coupled.
- How does it affect flutter?

Flutter of Swept Wings – Undeformed

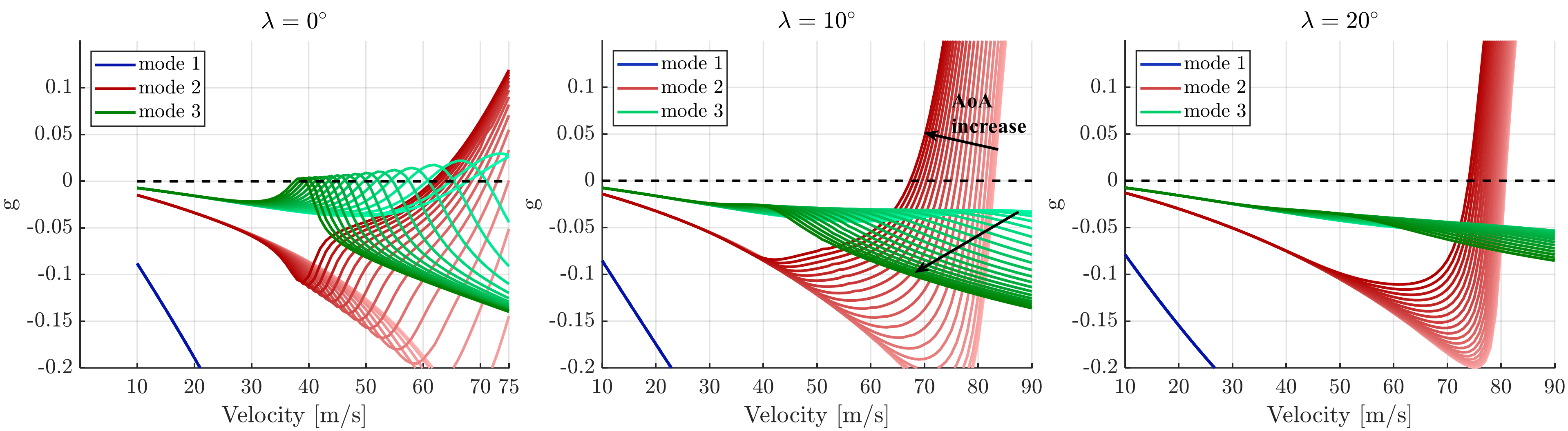
$\omega - V - g$ plots of the undeformed wings (Nastran PK method)



- No hump flutter mode in the swept wings
- The first flutter onset in the swept wings occurs at higher speeds

Deformed Wing Flutter

$\omega - V - g$ plots of deformed wings (different AoA; MRM)



- The hump mode mechanism is still apparent at low-sweep wings, but it is stable.
- The flutter velocity reduces significantly with deformation, especially in the low sweep angle wings.
- Harder flutter mechanism in the swept wings

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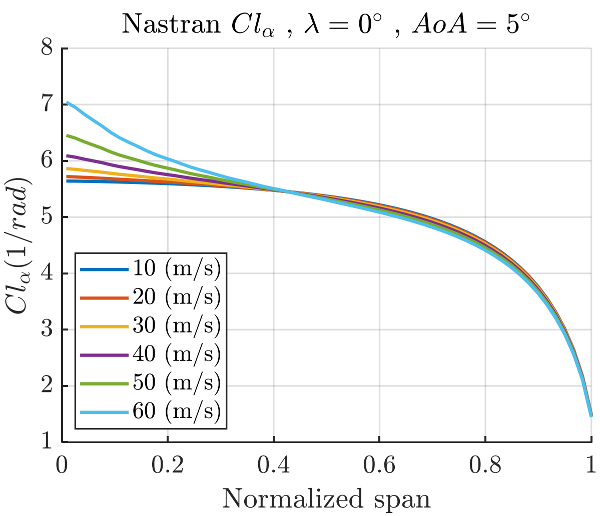
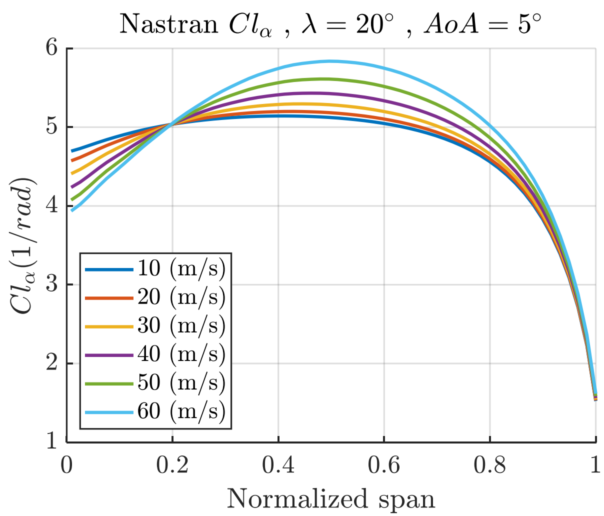
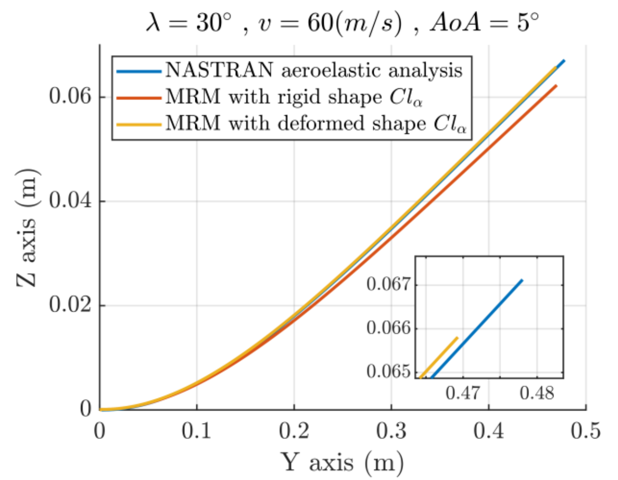
Static Deformations With Strip Theory

- MRM static ae analysis is based on strip theory
- Lift line slope from panel analysis of the undeformed wing
- Yields good results for the straight wing







- The aerodynamic model might have a greater impact in swept wings than in the straight wing.

Observations and Conclusions

- Under load, the coupled modes of swept wings vary but there is no switching of bending and torsion (as in the straight wing)
- The hump flutter mechanism is stable in all swept wings. The first flutter onset is at higher speeds.
- The flutter velocity changes with deformation, more so for the wings of low sweep angle
- The aerodynamic model might have a greated impact on the results