ID: 570323

Aeroelastic Design of a Highly-Flexible Wing using a Simplified Composite Optimization Approach within cpacs-MONA

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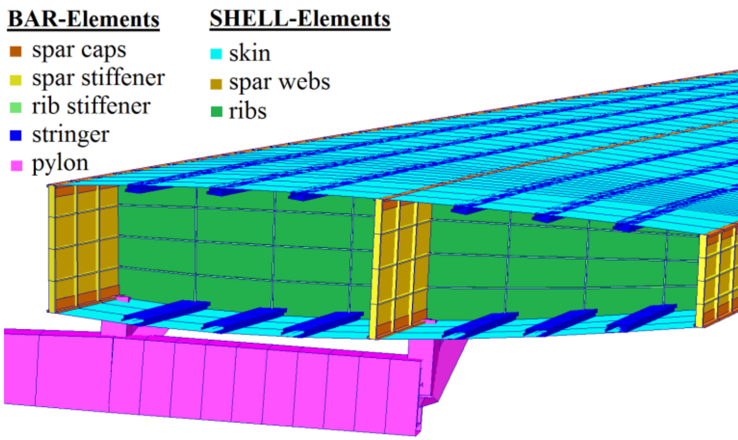
DLR

The different Wing Models

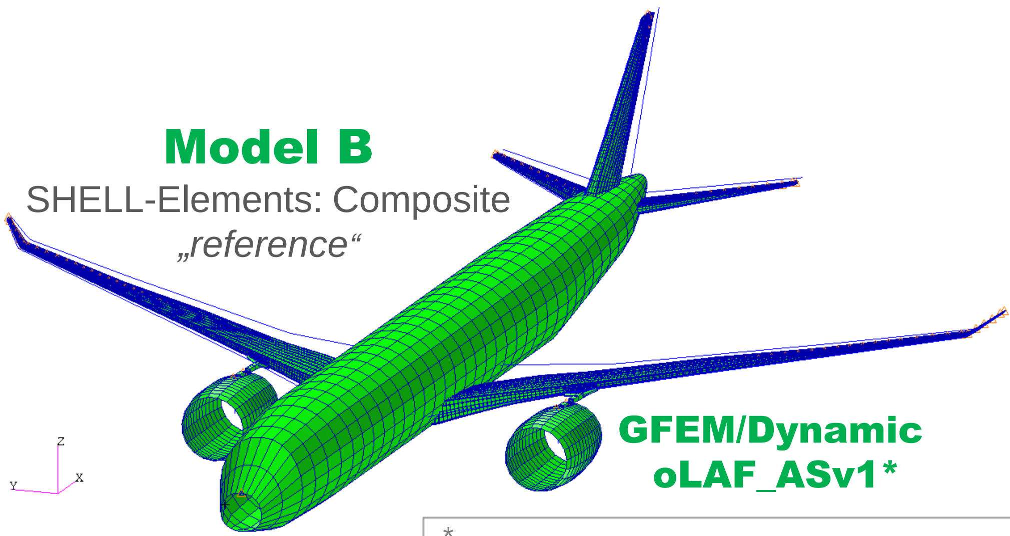


What is the impact on:

- Stiffness?
- Structural mass?
- Eigenfrequencies?
- Aeroelastic stability?
- Loads?

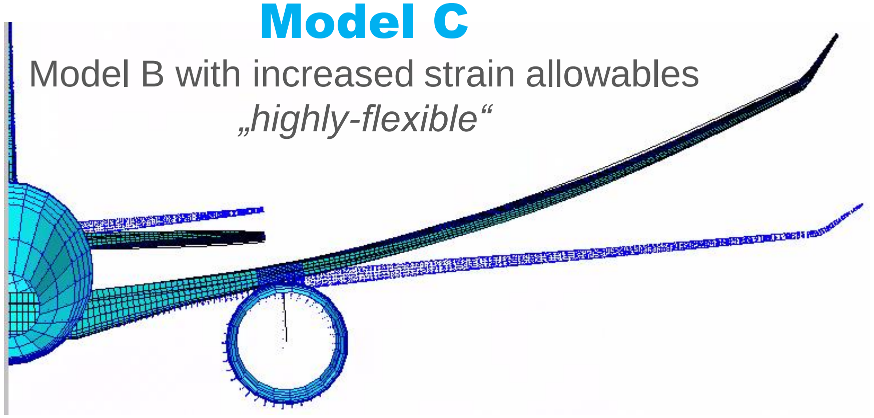
Model A
SHELL-Elements: Aluminum
„aluminum"

Model B
SHELL-Elements: Composite
„reference"



GFEM/Dynamic oLAF_ASv1*

Model C
Model B with increased strain allowables
„highly-flexible"



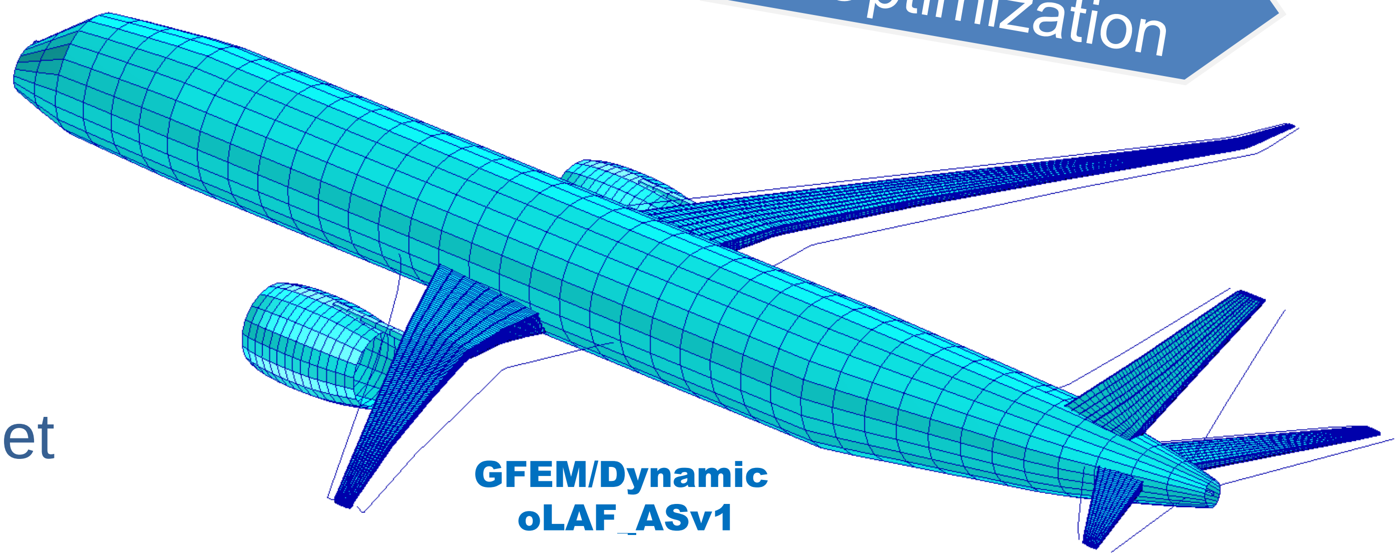
*M. Schulze, T. Klimmek, F. Torrigiani, T. F. Wunderlich: *„Aeroelastic Design of the oLAF Reference Aircraft Configuration"*. DLRK 2021

Aeroelastic Structural Design Tool

cpacs-MONA

Parametric Modelling → Loads Analysis → Structural Optimization

cpacs
A Common Language for Aircraft Design

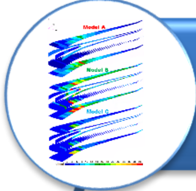


From a **CPACS**-dataset to the **Global Aircraft FEM (GFEM)**

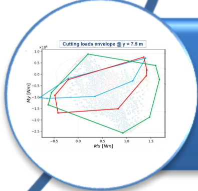
Overview

- Introduction

- Aircraft Configuration



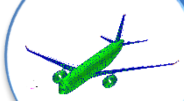
- Results



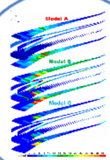
- Conclusion

Overview

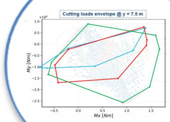
- Introduction



- Aircraft Configuration



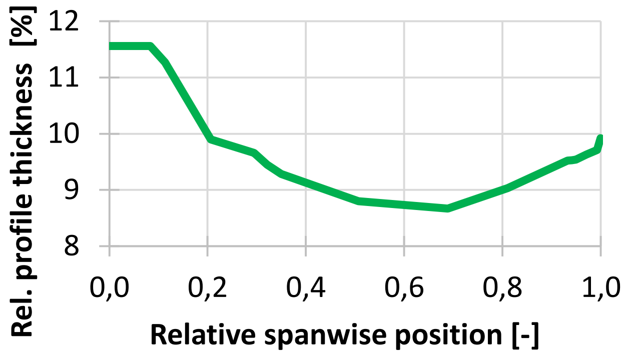
- Results

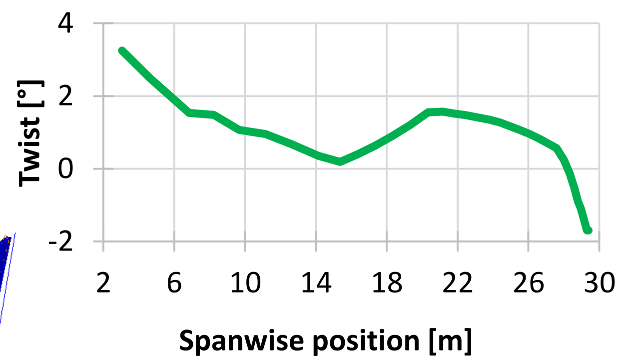


- Conclusion

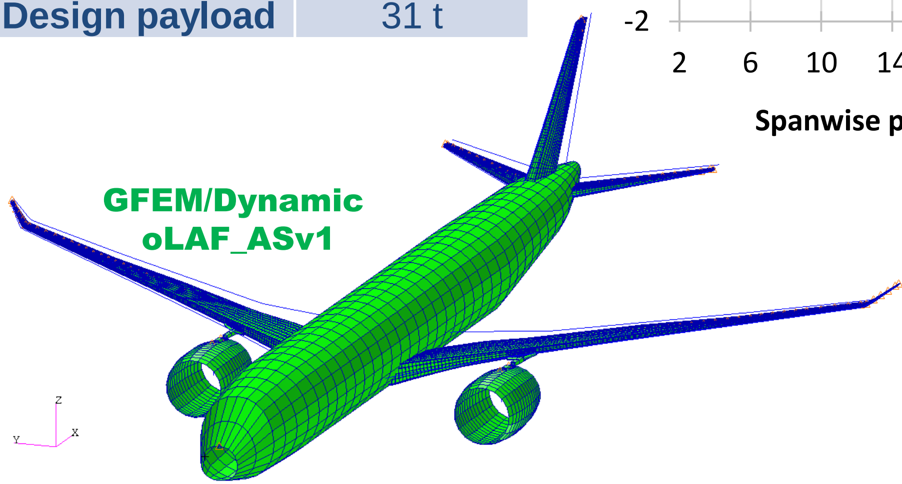
Aircraft Configuration

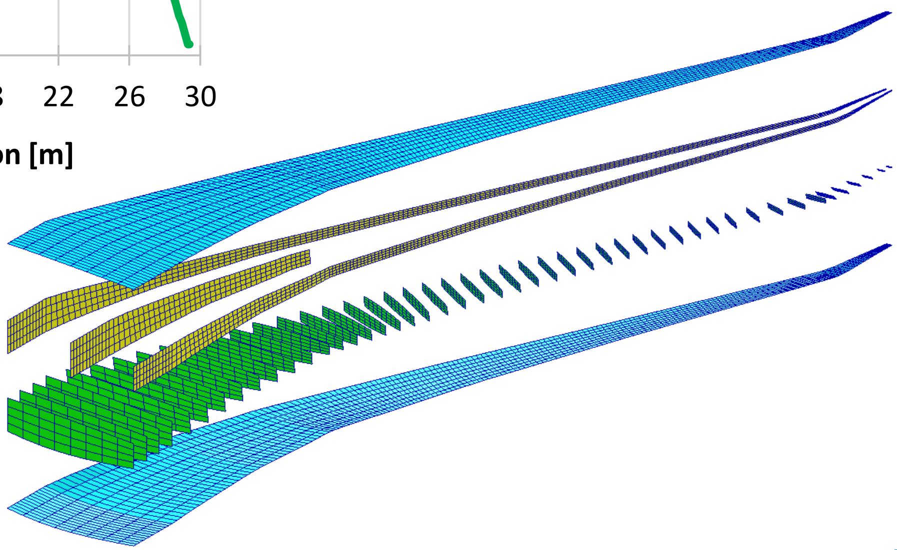
A/C Parameter	oLAF_ASv1
Span	58.9 m
Wing area	338.7 m^2
Aspect ratio	10.2
LE sweep	36.9 deg.
MAC	7.6 m
MTOM	220 t
OEM *(OAD)*	117.0 t
Design range	6000 nm
Design Mach	0.83
Design payload	31 t





Structural Parameters	oLAF_ASv1
Amount of ribs	47
Amount of spars	3
Material	Composite
Engine diameter	4.175 m
Engine mass	17.0 t





Simplified Composite Optimization

„Black Metal Approch“

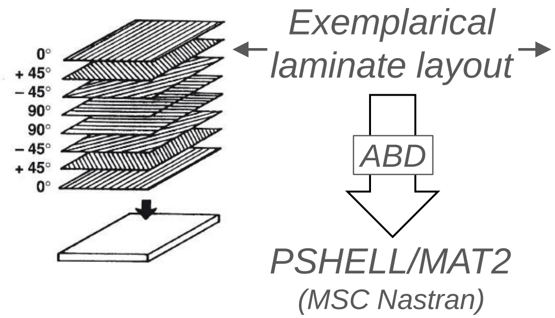
- Read out the laminate layout *(thickness, material, orientation)*
- Convert the layout into 2D-characterisitcs *(ABD-matrix)*
  - PSHELL/MAT2 *(linear anisotropic material)*

Optimization Model

- Design variables: Thickness of the CQUAD4-elements
  - ribs, spar web, skin covers
- Constraints: Strain allowables
- Objective: Minimum weight of wing-box

Allowables	Model B	Model C
Max. strain	4.0e-3	6.0e-3
Min. strain	-3.5e-3	-5.0e-3
Shear strain	8.0e-3	12.0e-3

Quelle: *https://www.r-g.de/wiki/Bauteilkonstruktionen*



cpacs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Simplified:

- *No lamination parameter optimization*
- *No aeroelastic tailoring*

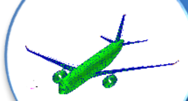
Modelling differences	Aluminum	Composite
Min. element thickness	2 mm	4 mm
Mass penalty factors	1.15	1.25

DLRK DEUTSCHER LUFT- UND RAUMFAHRTKONGRESS

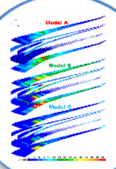
Overview

cpacs-MONA

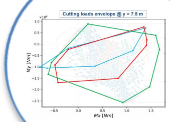
Introduction



Aircraft Configuration



Results

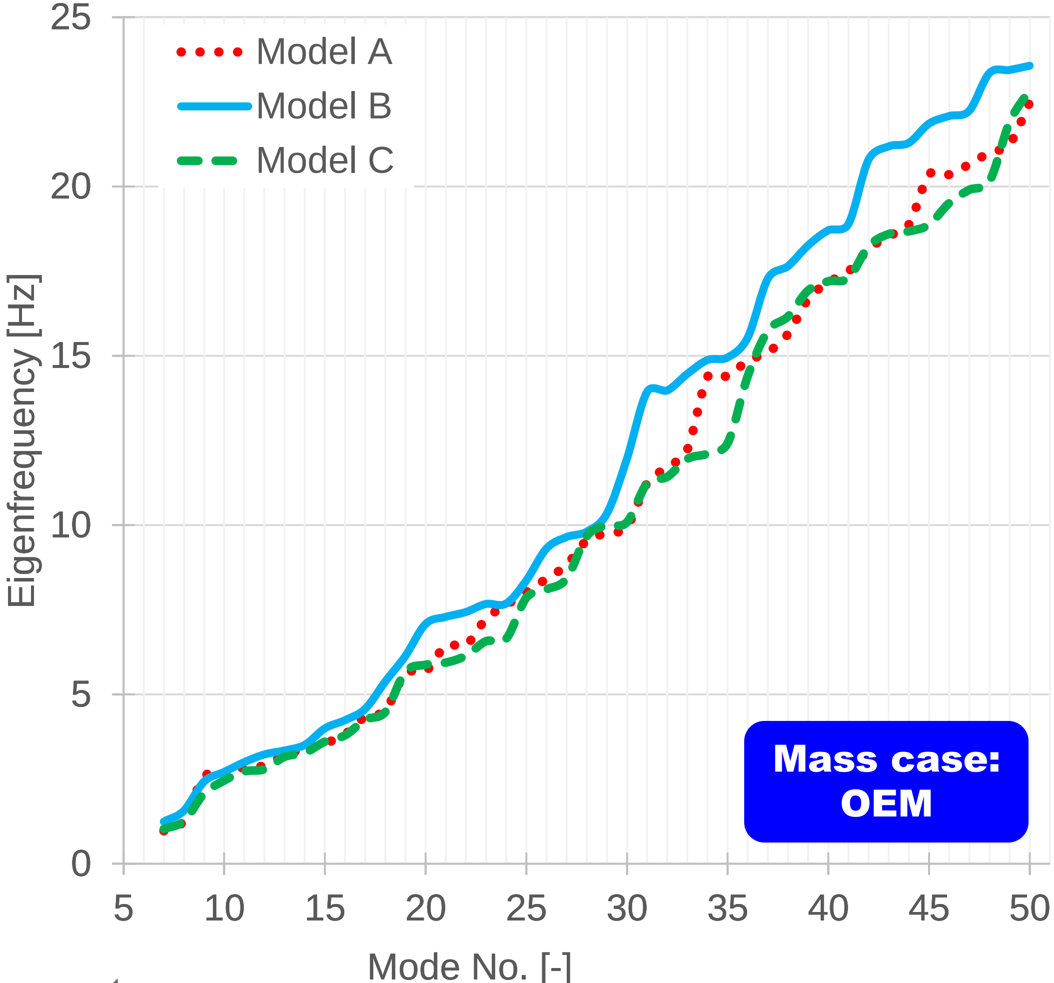


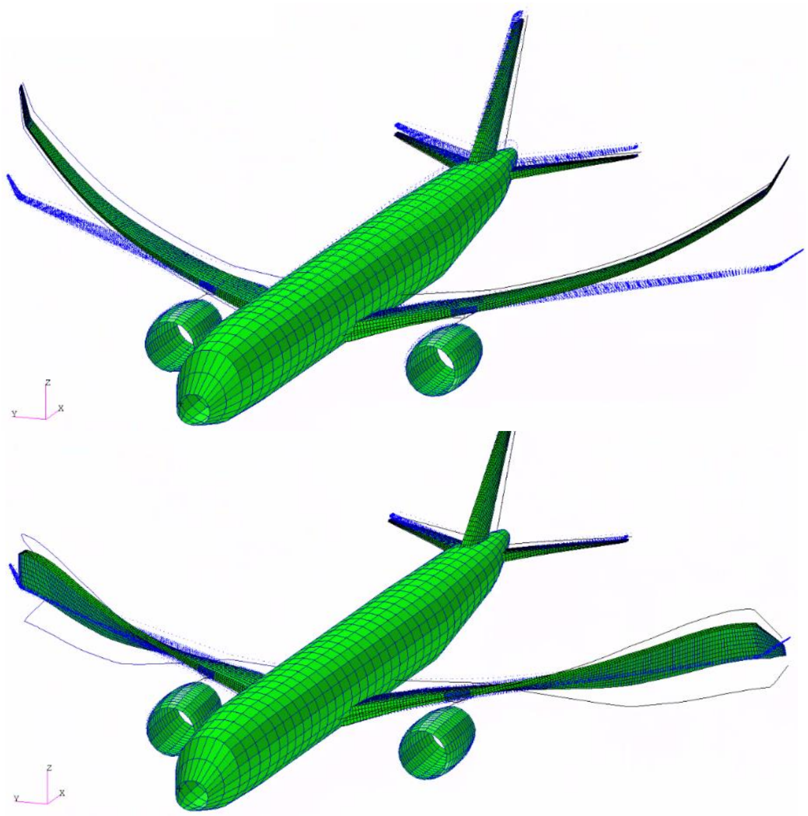
Conclusion

DLR

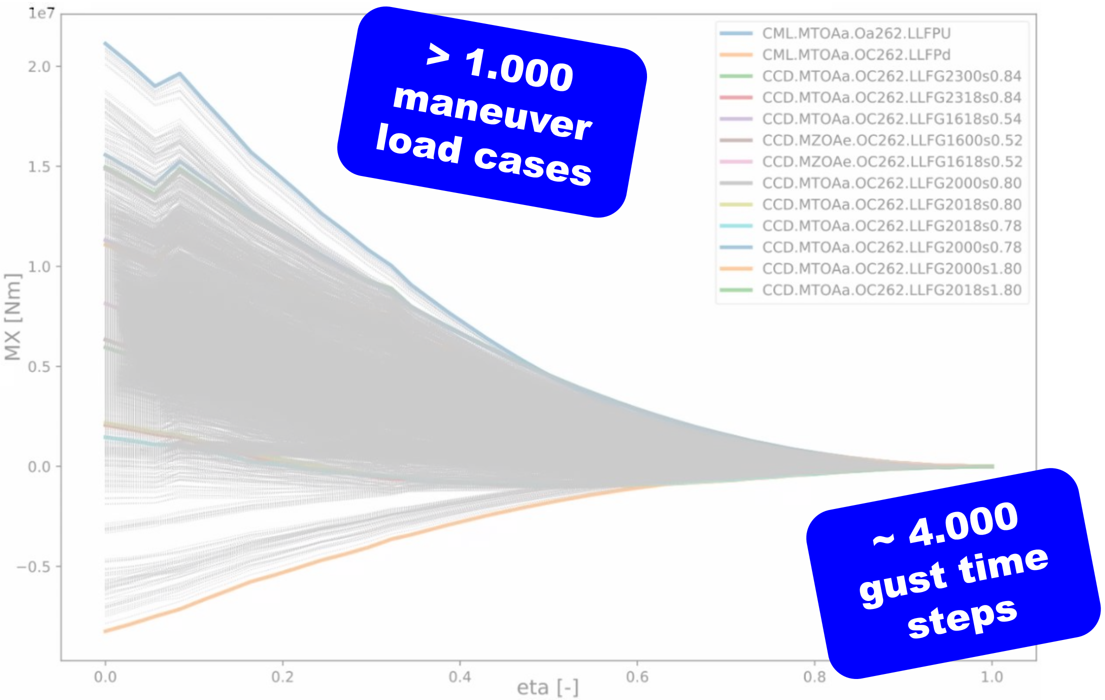
Modal Analysis

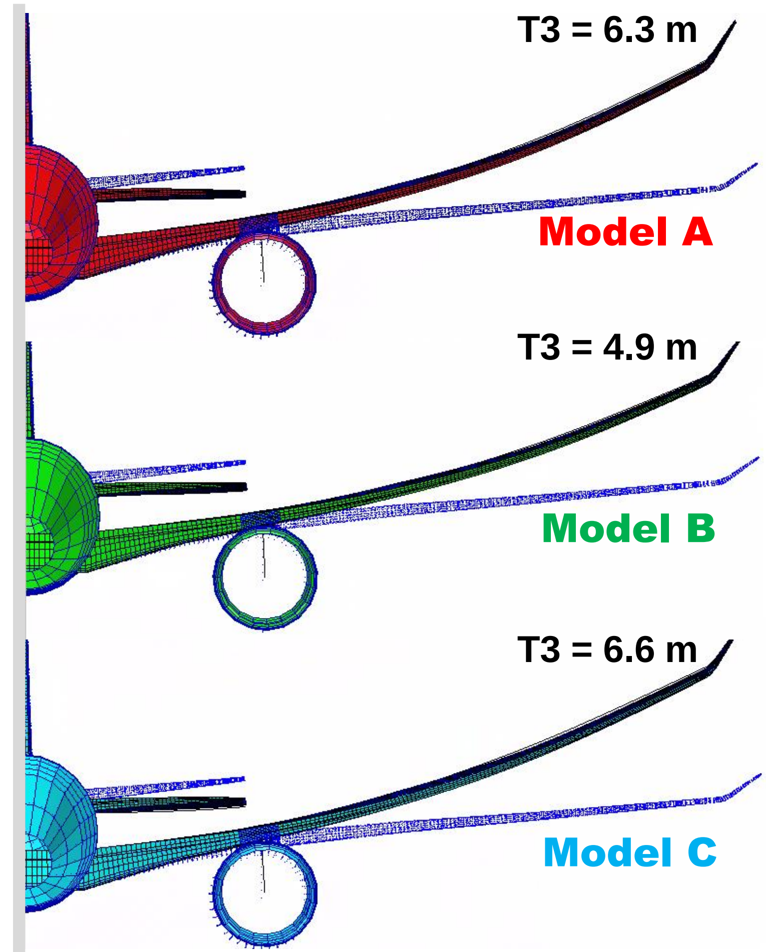
Eigenmode	Model A	Model B	Model C
1st sym. wing bending	-22%	**1.25 Hz**	-17%
1st sym. wing torsion	+10%	**7.68 Hz**	-24%





Displacements / Stiffness

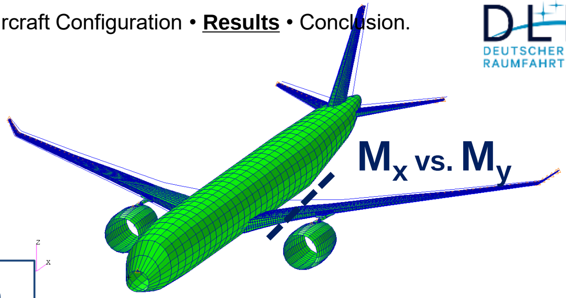




2.5g pull-up maneuver:

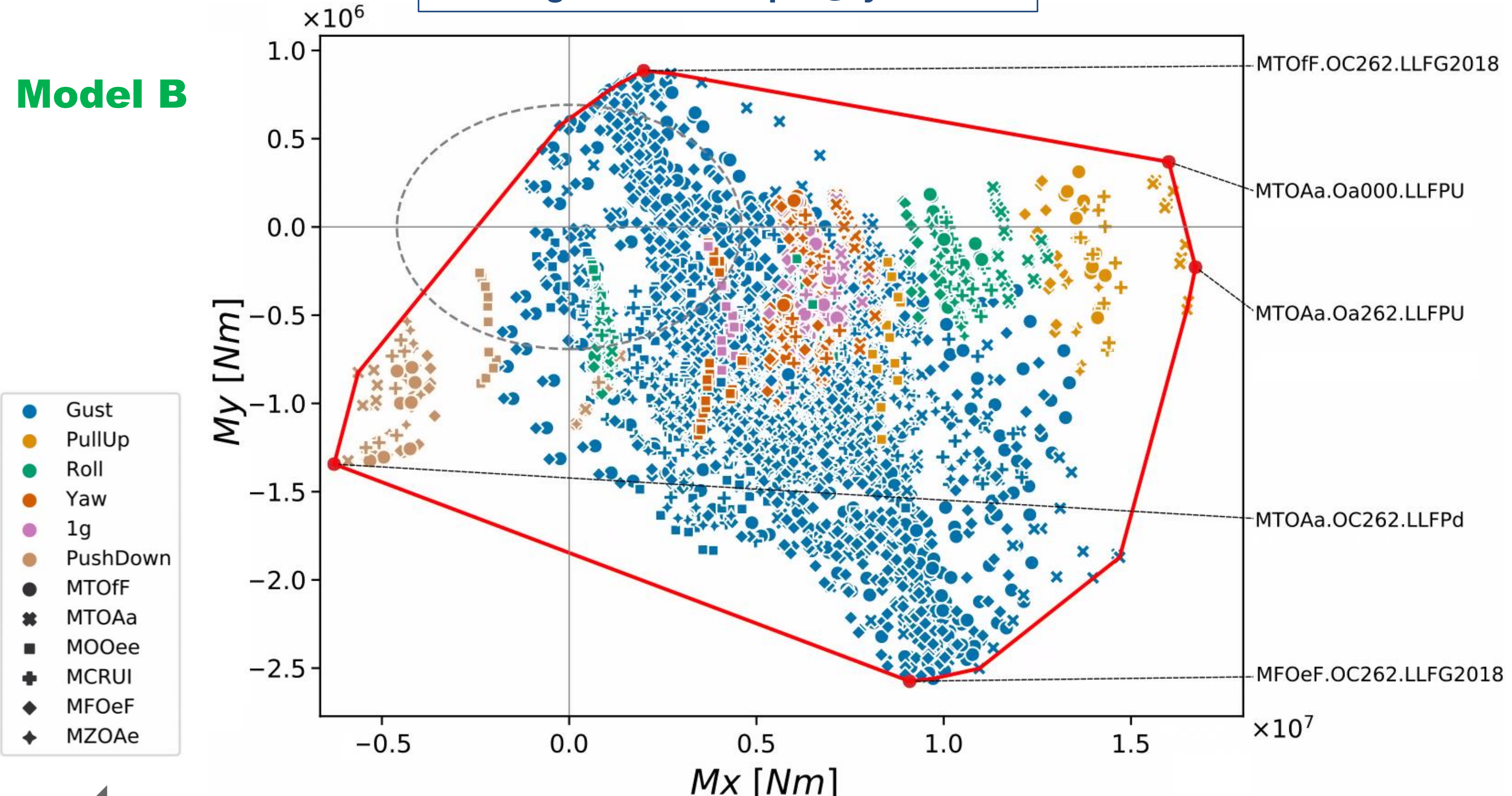
- MassCase: MTOW *(100% payload)*
- X_{CG}: 15 $\%_{MAC}$
- Mach number: 0.51
- Altitude: 8000 m

Cutting Load Envelope – *reference*

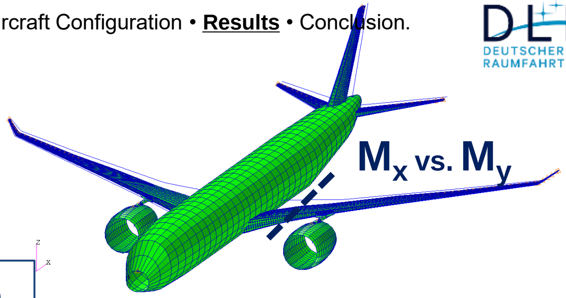


Model B

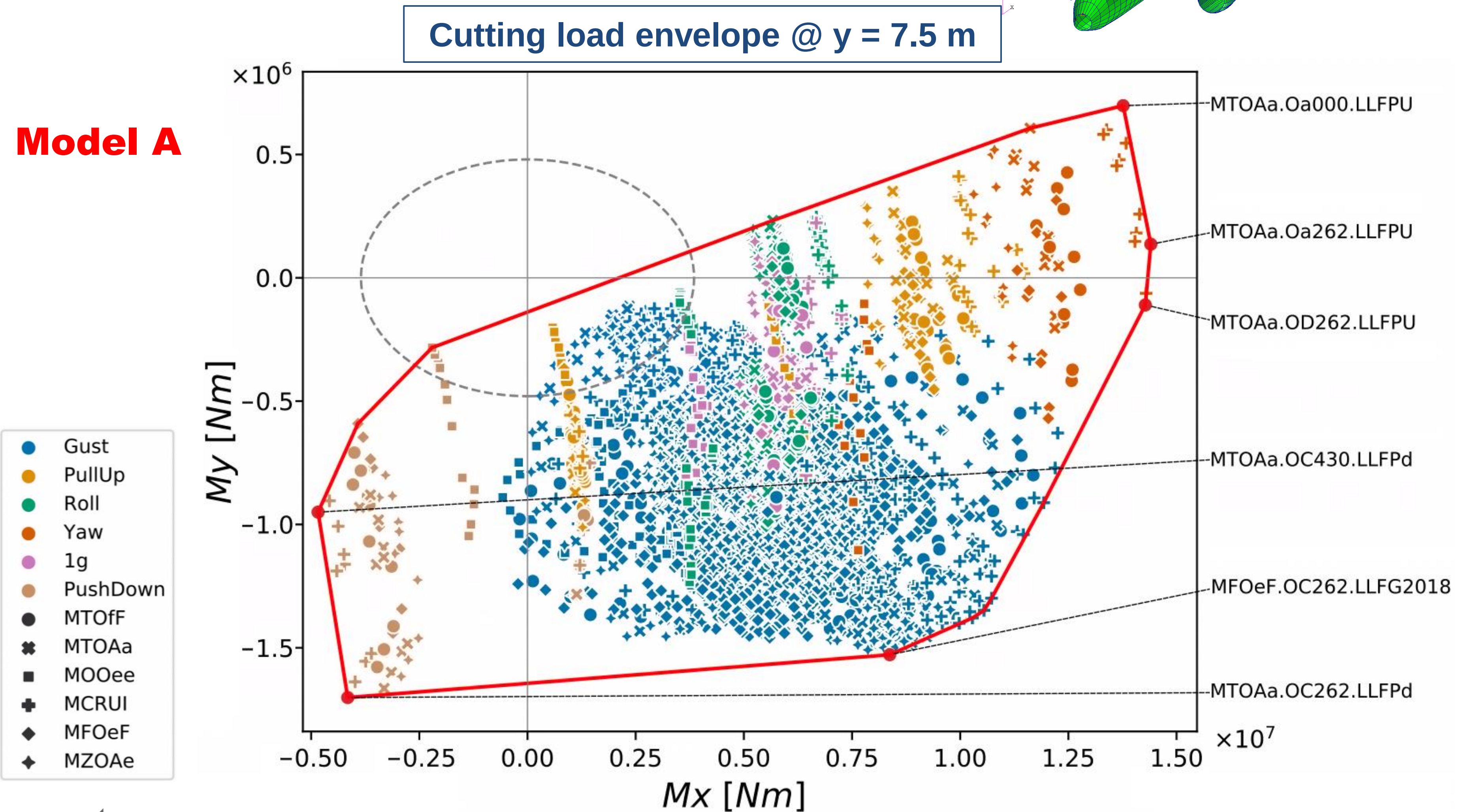
Cutting load envelope @ y = 7.5 m



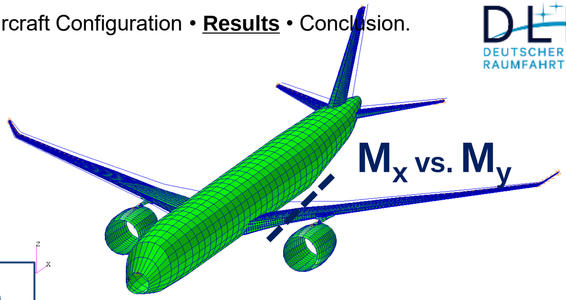
Cutting Load Envelope – *aluminum*



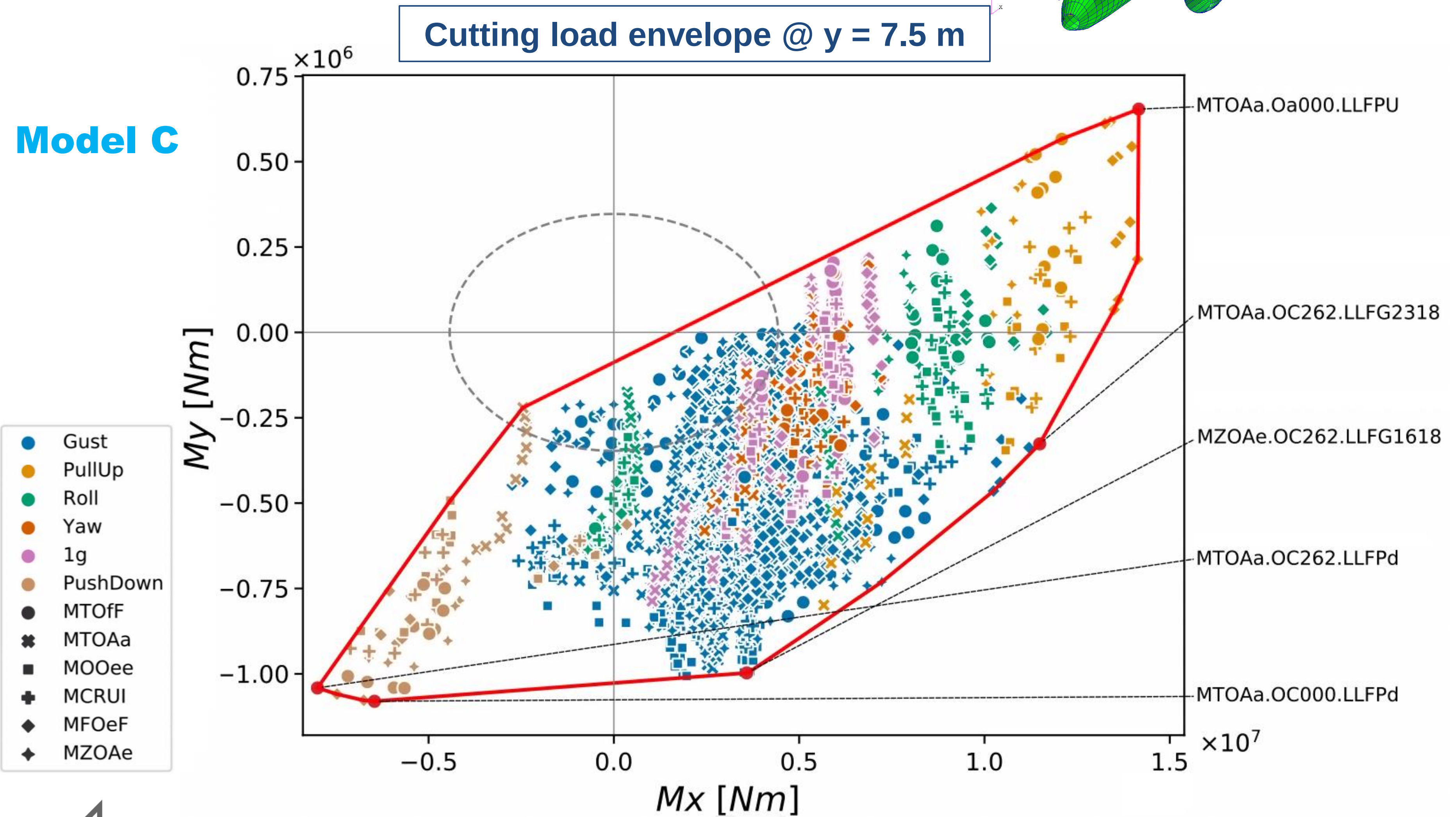
Model A



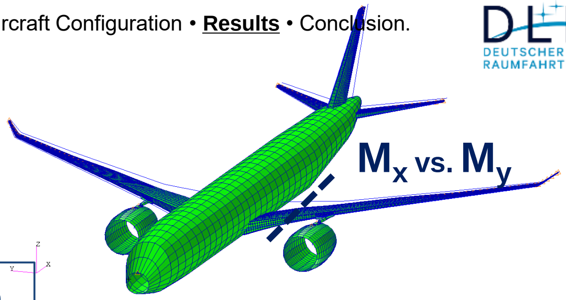
Cutting Load Envelope – *highly-flexible*



Model C



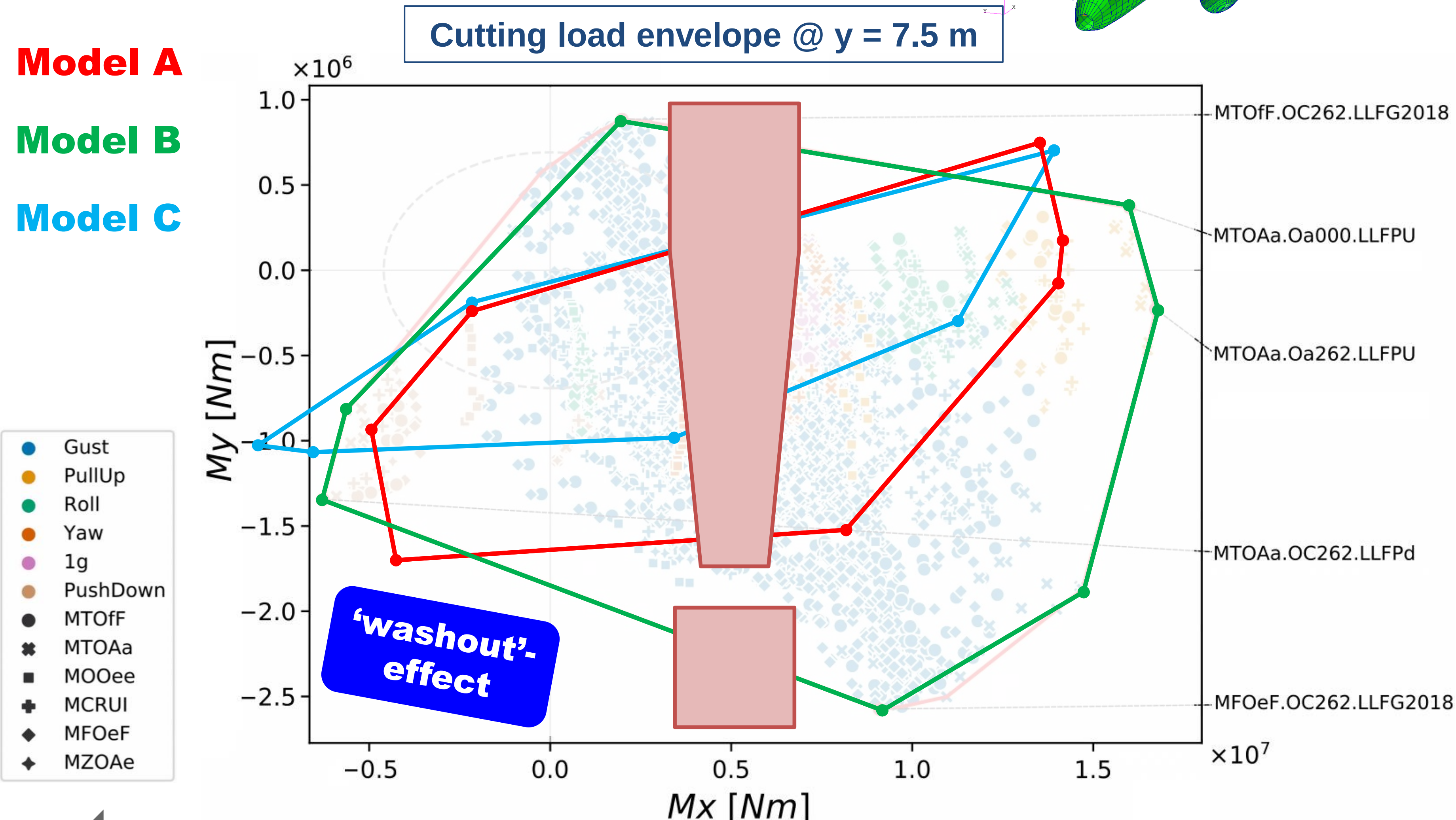
Cutting Load Envelope – Comparison



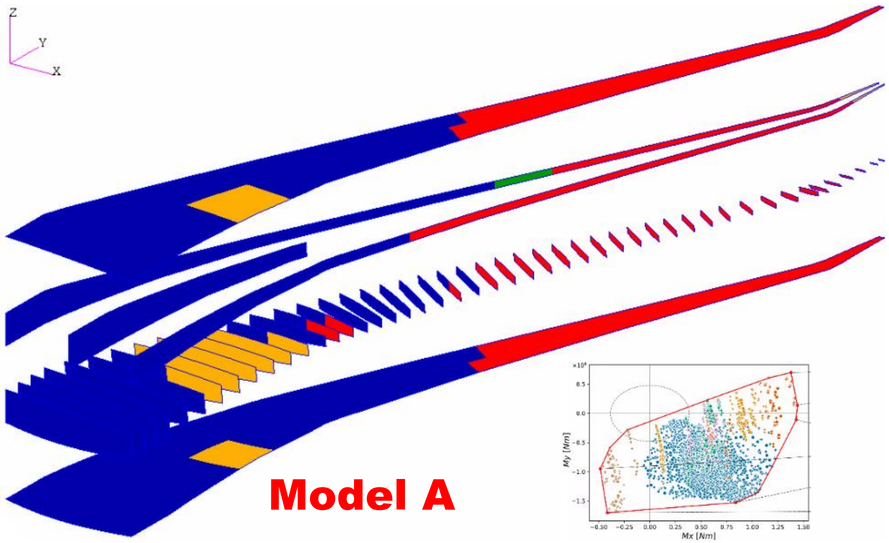
Model A

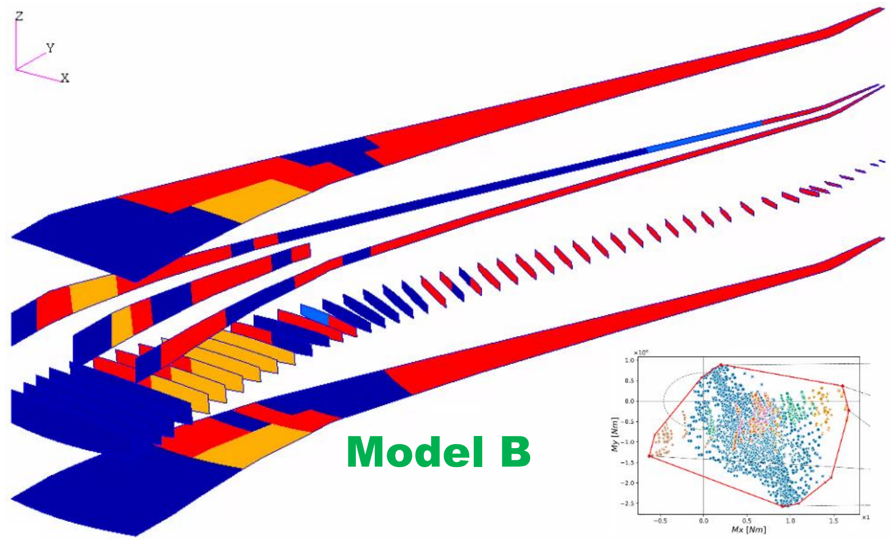
Model B

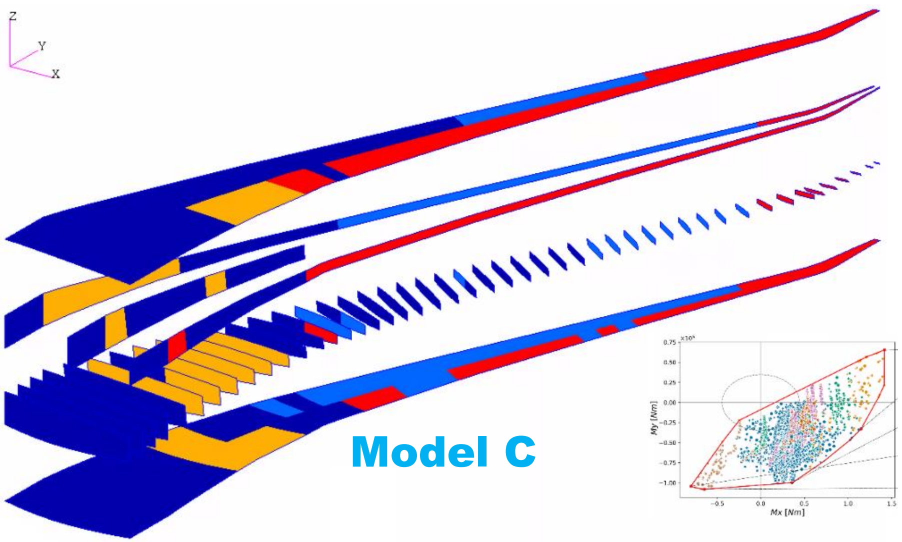
Model C



Dimensioning Load Cases

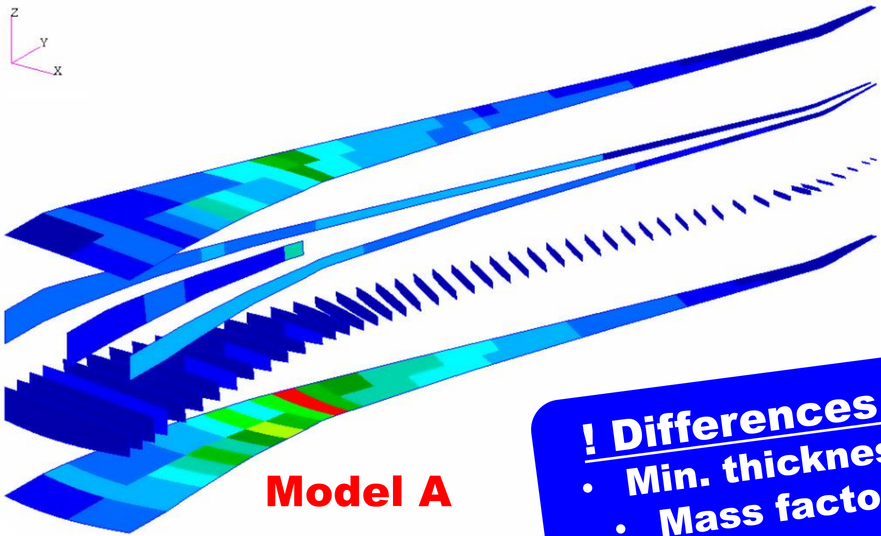




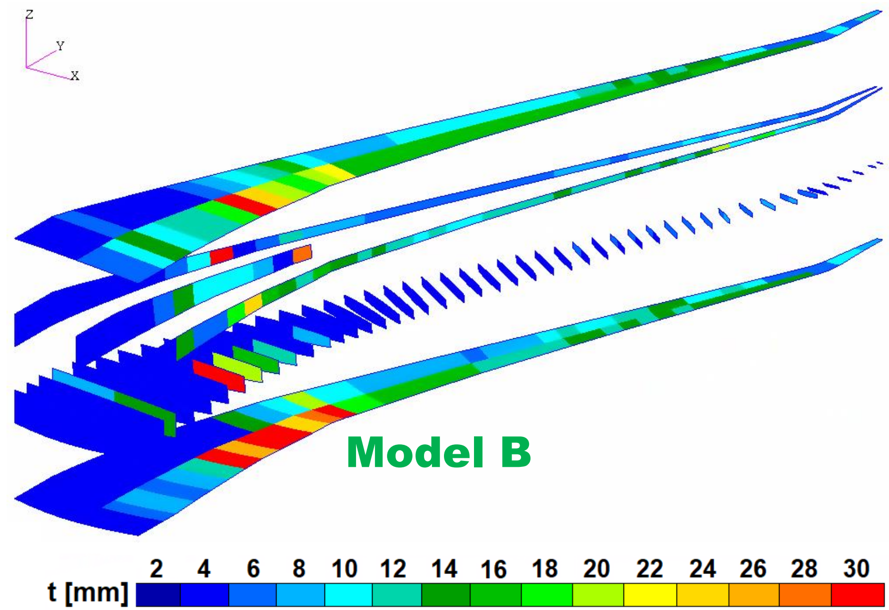


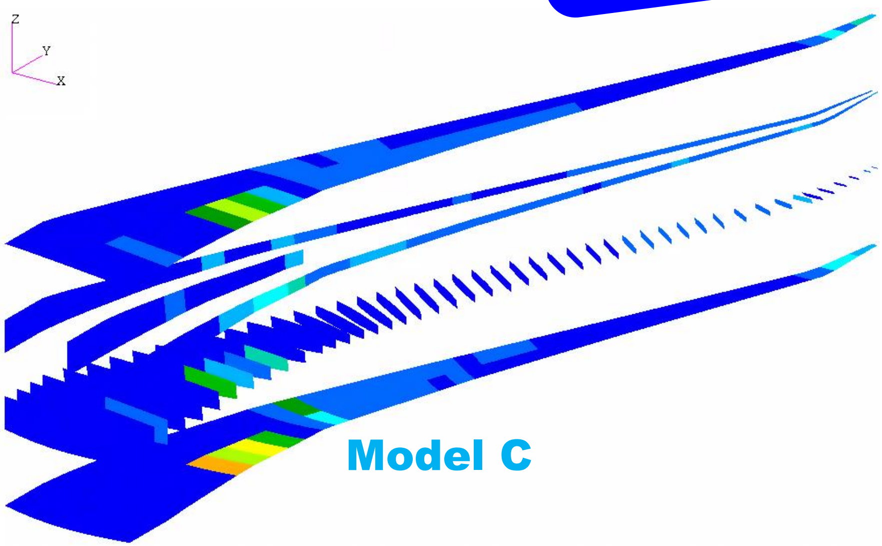
Pull-Up
Push-Down
Roll
Landing
Gust

Thickness Distribution and Masses



! Differences !
- Min. thickness
- Mass factor

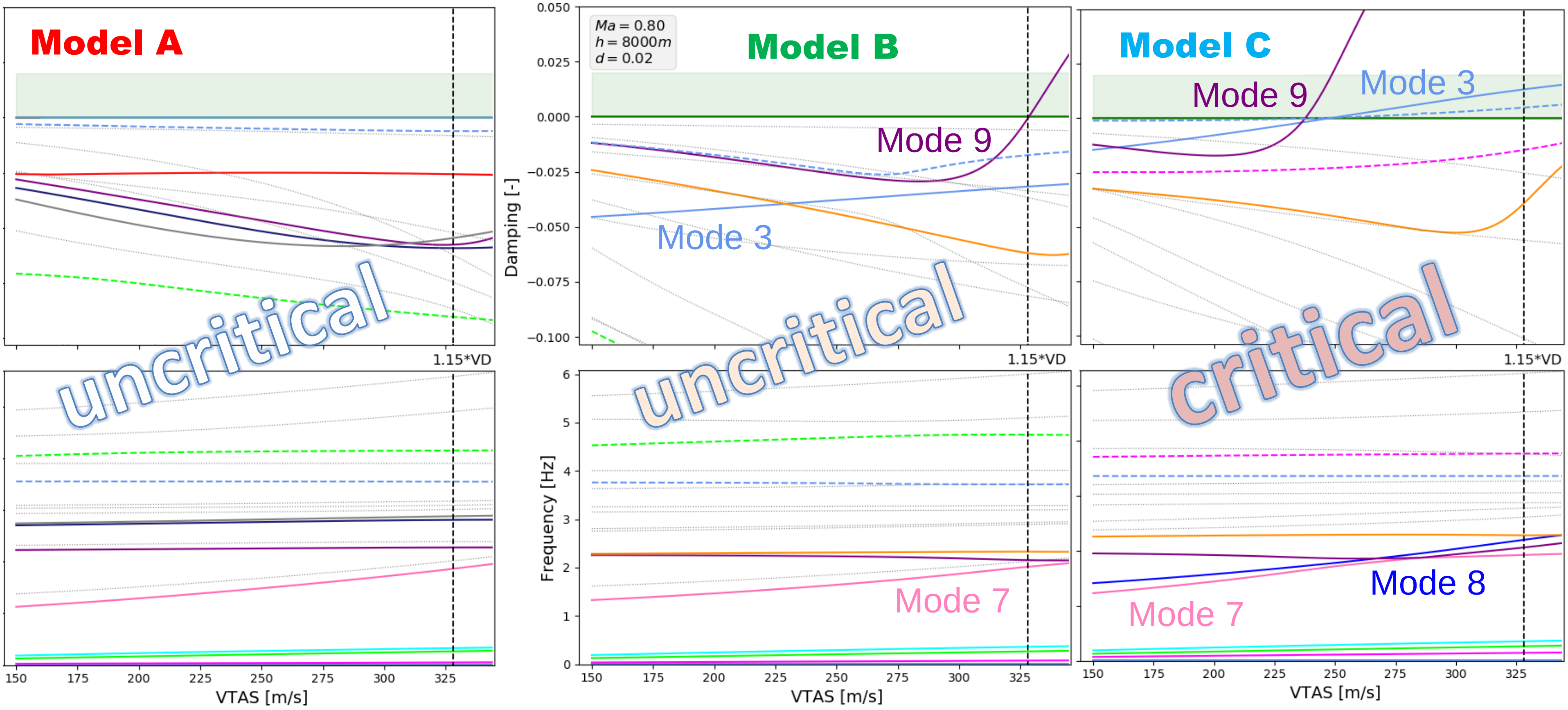




Mass Item	Model A	Model B	Model C
OEM	-1 %	**119.2 t**	-4 %
Main wing primary	-2 %	**20.0 t**	-22 %

Flutter Check – Stability Curves

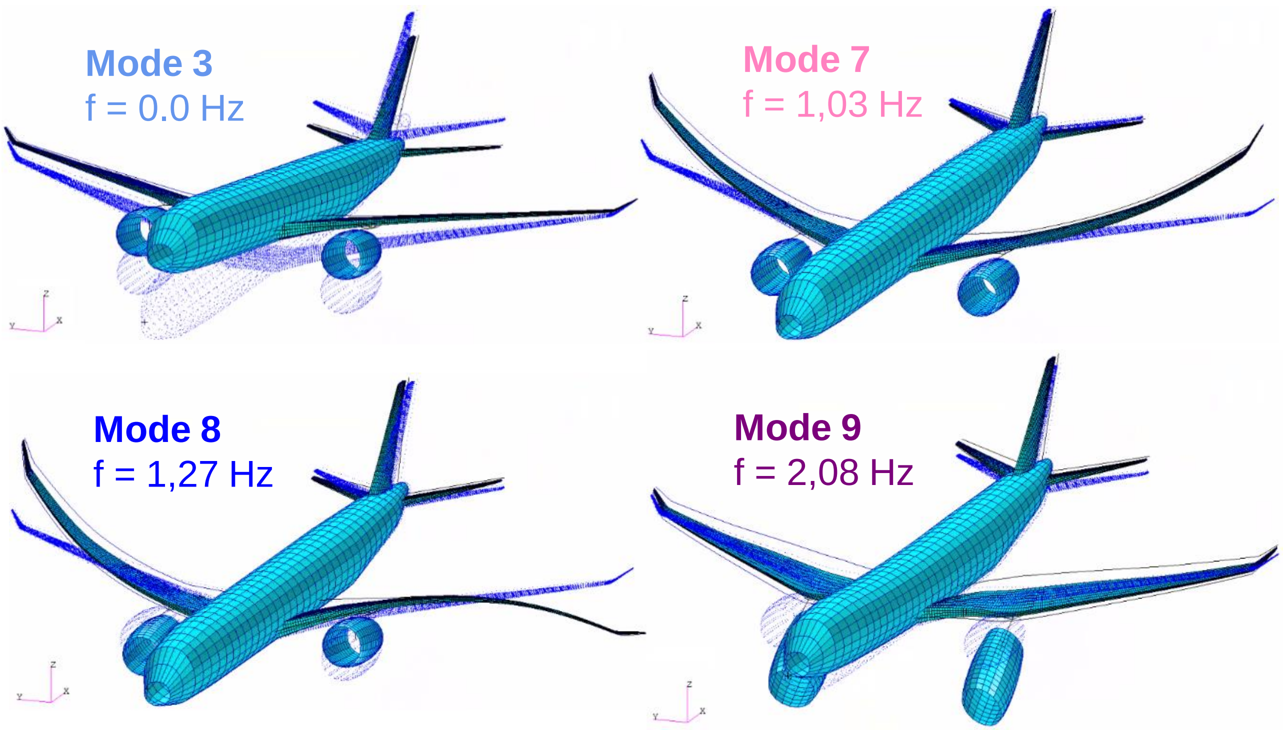
Mass case: MCRUI
Payload: 100%, Fuel: 25%

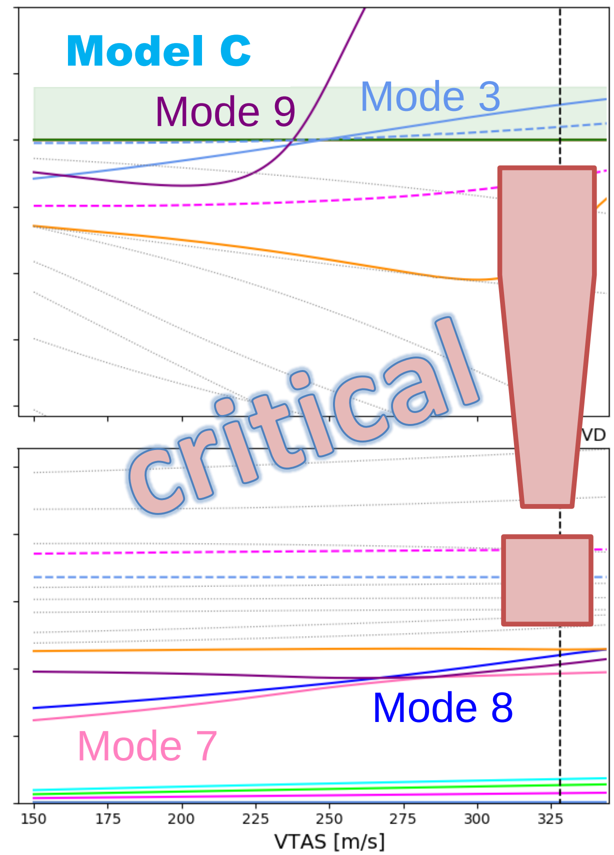


Flutter Modes – *highly-flexible*

Mass case: MCRUI
Payload: 100%, Fuel: 25%

„vacuum modes"





Instabilities
within the flight envelope ($v_{flutter} < v_D$)
influence the gust analysis

MSC Nastran gust analysis – *false friend?*

MSC NASTRAN Solution 146

1. Define gust load in **time domain** (1-cos)
2. Transform gust load into **frequency domain** (FFT)
3. Solve the equation of motion in **modal coordinates** (frequency domain)
4. Transorm the responses into the **time domain** (iFFT)

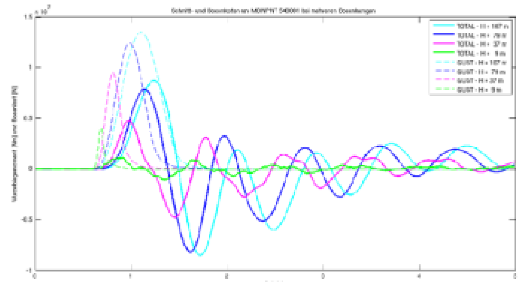
Smoothing instabilities

Without warning messages

FLEXIBLE INCREMENT = f(ω)
+
INERTIAL = f(ω)

+

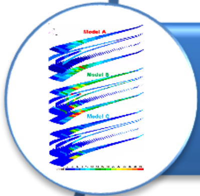
GUST = f(t) → FFT → TOTAL = f(ω) → inv FFT →



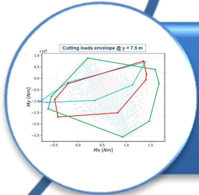
Overview

Introduction

Aircraft Configuration



Results

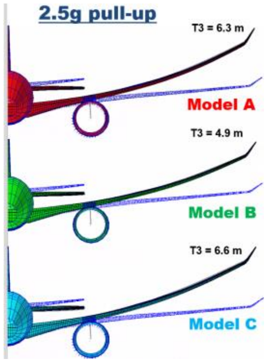


Conclusion

Conclusion

Snapshot

Aeroelastic structural **design** of an aircaft configuration with **three** different **wing charateristics** due to a **change** in **material properties** has been presented**.**

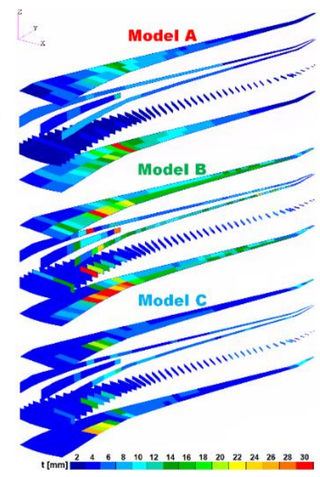


What is the impact on:

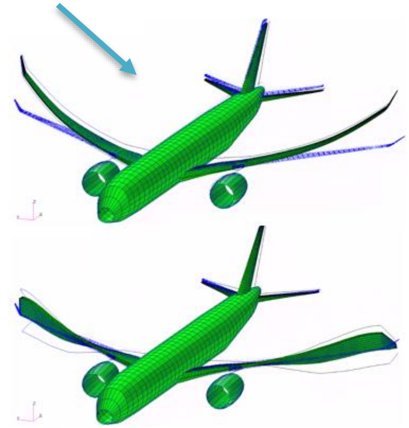
- **Stiffness?**
- **Structural mass?**
- **Eigenfrequencies?**
- **Aeroelastic stability?**
- **Loads?**

Composite wings are not always ‚**more flexible**‘.

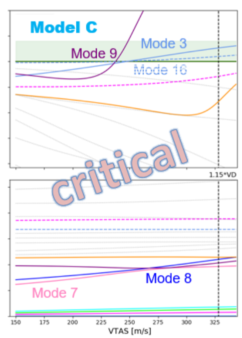
Mass of composite wings depend on **strain allowables**.



Modal parameters depend on **allowable stains**.

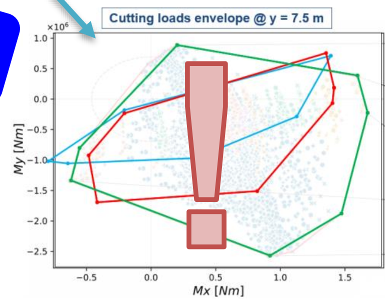


Highly-flexible wings are **prone to flutter**.



Gust loads **not yet reliable** for the higly-flexible wing…

tbc



DLR

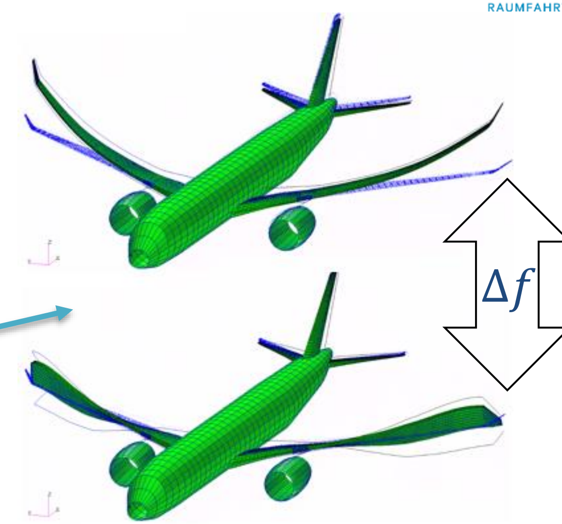
Outlook

Question for the further development of a highly-flexible wing:

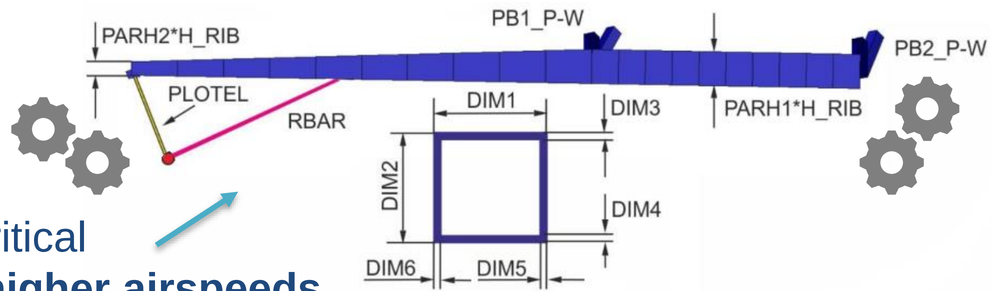
How can we influence the flutter behavior?

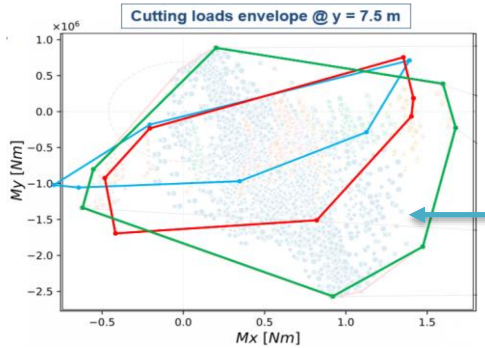
- **Aeroelastic tailoring**
- **Tuning of pylon stiffness**

Increase the **frequency distance** of critical modes



Move the critical Mode 9 to **higher airspeeds**

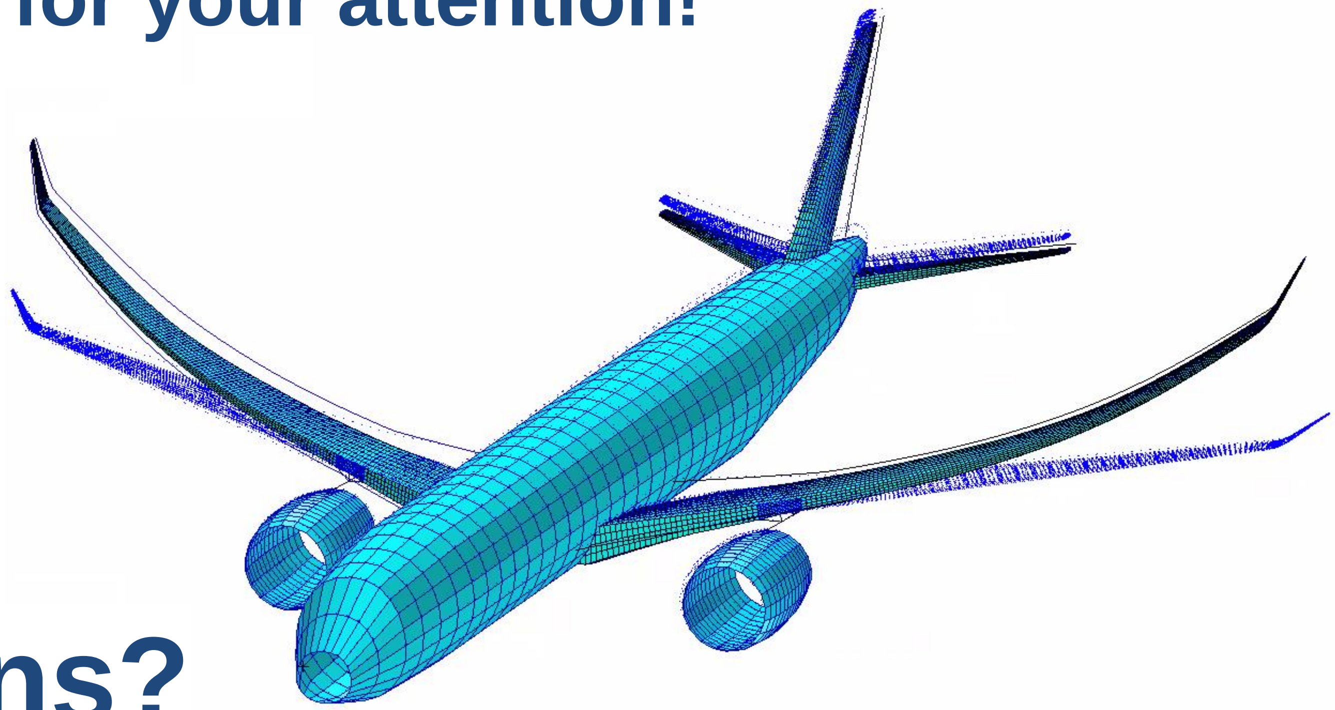




? Do highly-flexible wings strongly **alleviate gust loads** **?**

ID: 570323

Thank you for your attention!



Questions?

AE @ YouTube

Aeroelastik: Warum Flugzeuge elastisch sind

SCAN ME

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cpacs-MONA @

DLRK 2022
DEUTSCHER LUFT- UND RAUMFAHRTKONGRESS
DGLR
27. - 29. SEPTEMBER 2022 – DRESDEN
„Luft- und Raumfahrt - gemeinsam forschen und nachhaltig gestalten"