ID: 610369

Aeroelastic Design of the oLAF Configuration using Load Alleviation Techniques within cpacs-MONA

Matthias Schulze & Vega Handojo

German Aerospace Center (DLR)
Institute of Aeroelasticity (AE)
Göttingen, Germany

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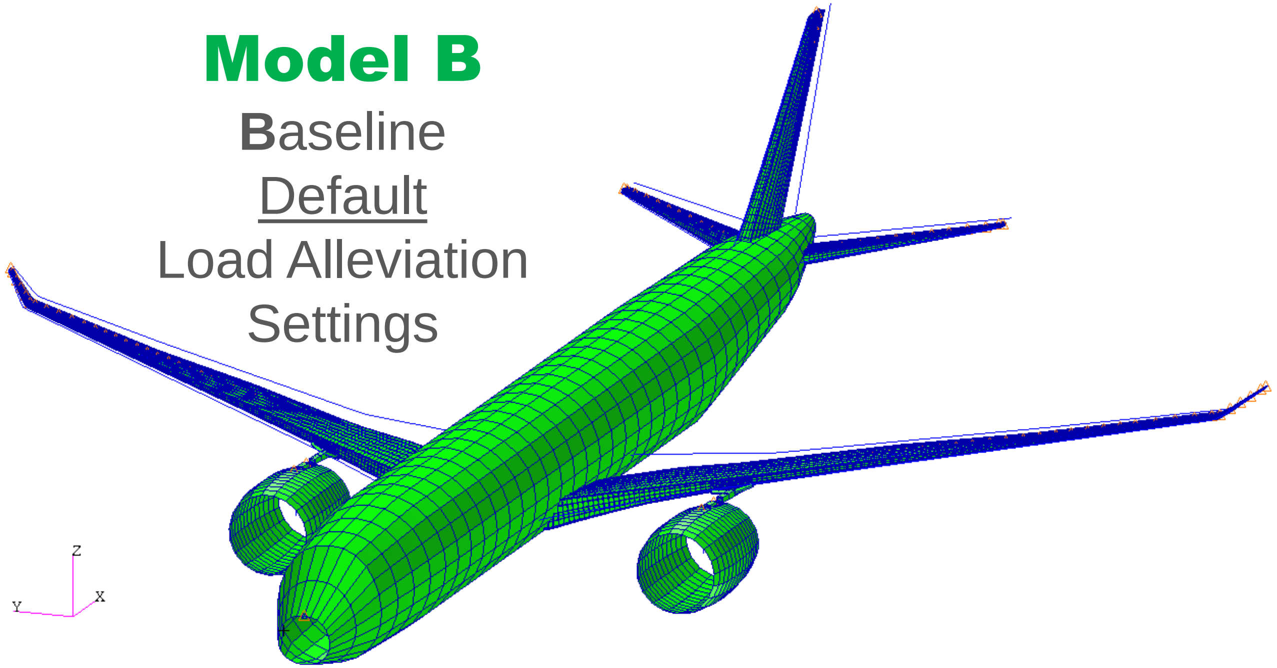
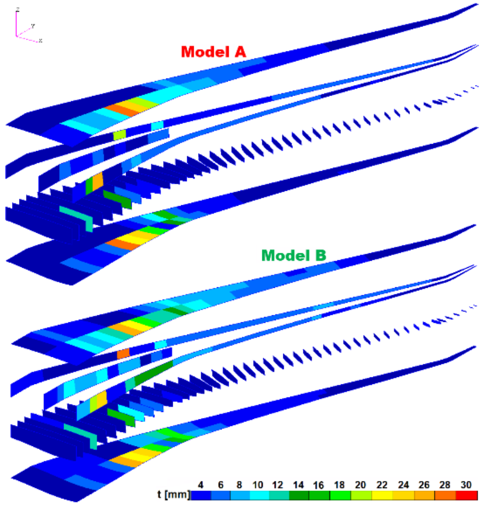
Two Different Load Alleviation Models

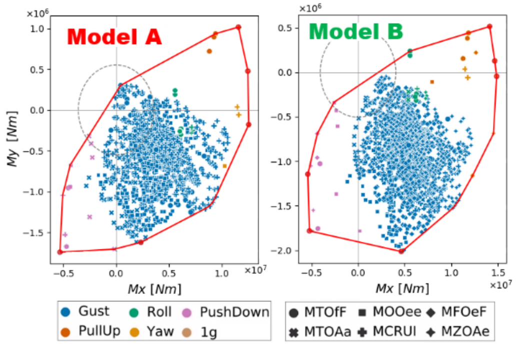
Model A
<u>**A**ggressive</u>
Load Alleviation Settings

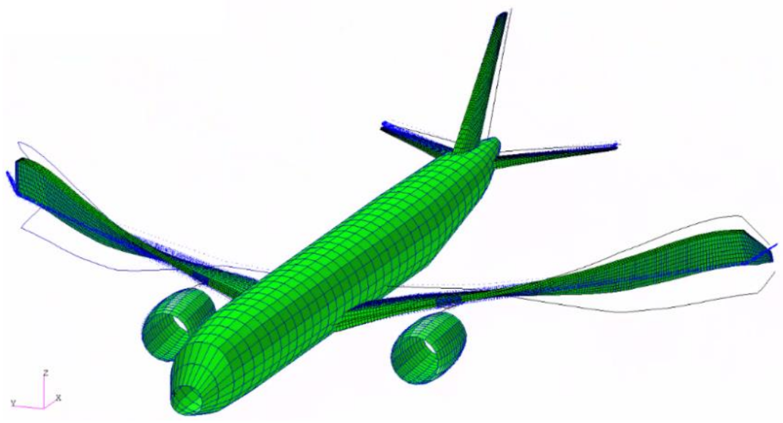
What is the impact on:
- Loads?
- Structure?
- Eigenfrequencies?
- Aeroelastic stability?

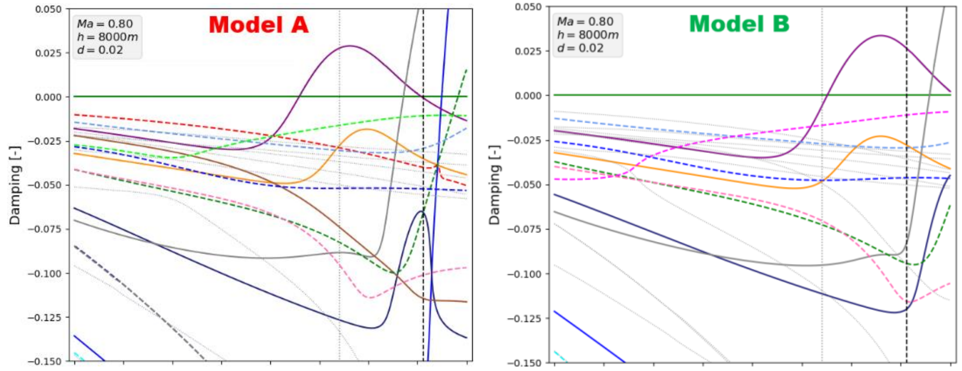
Model B
Baseline
<u>Default</u>
Load Alleviation
Settings











Aeroelastic Structural Design Tool

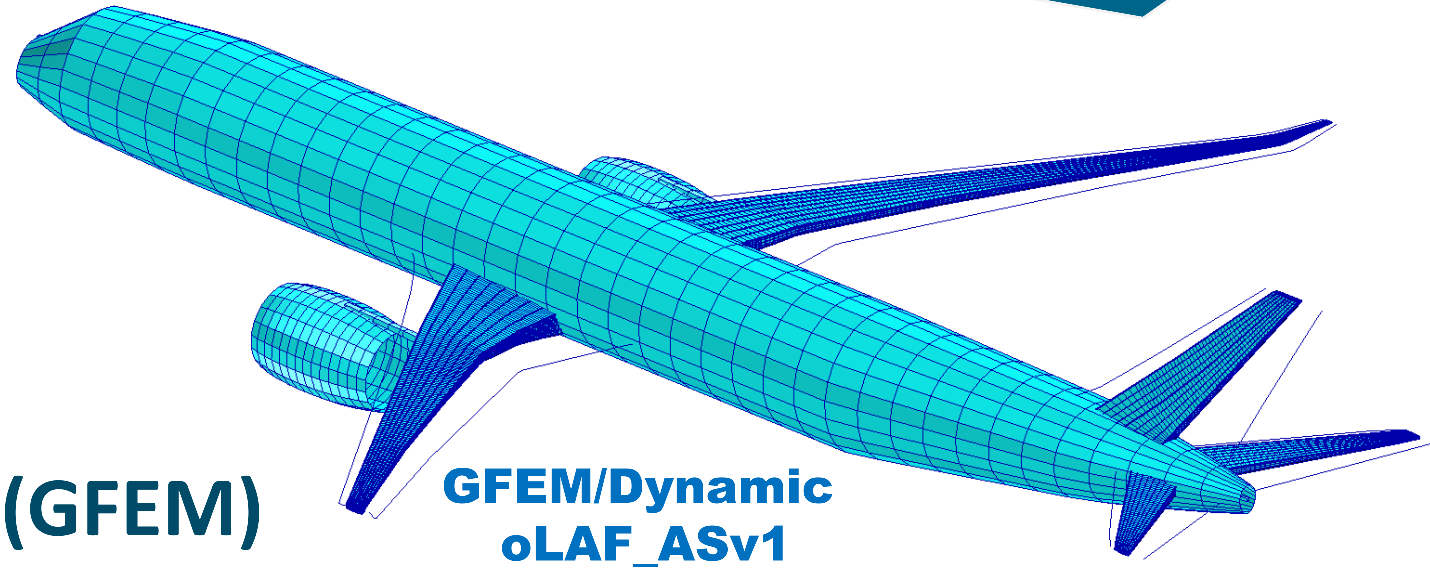
cpacs-MONA

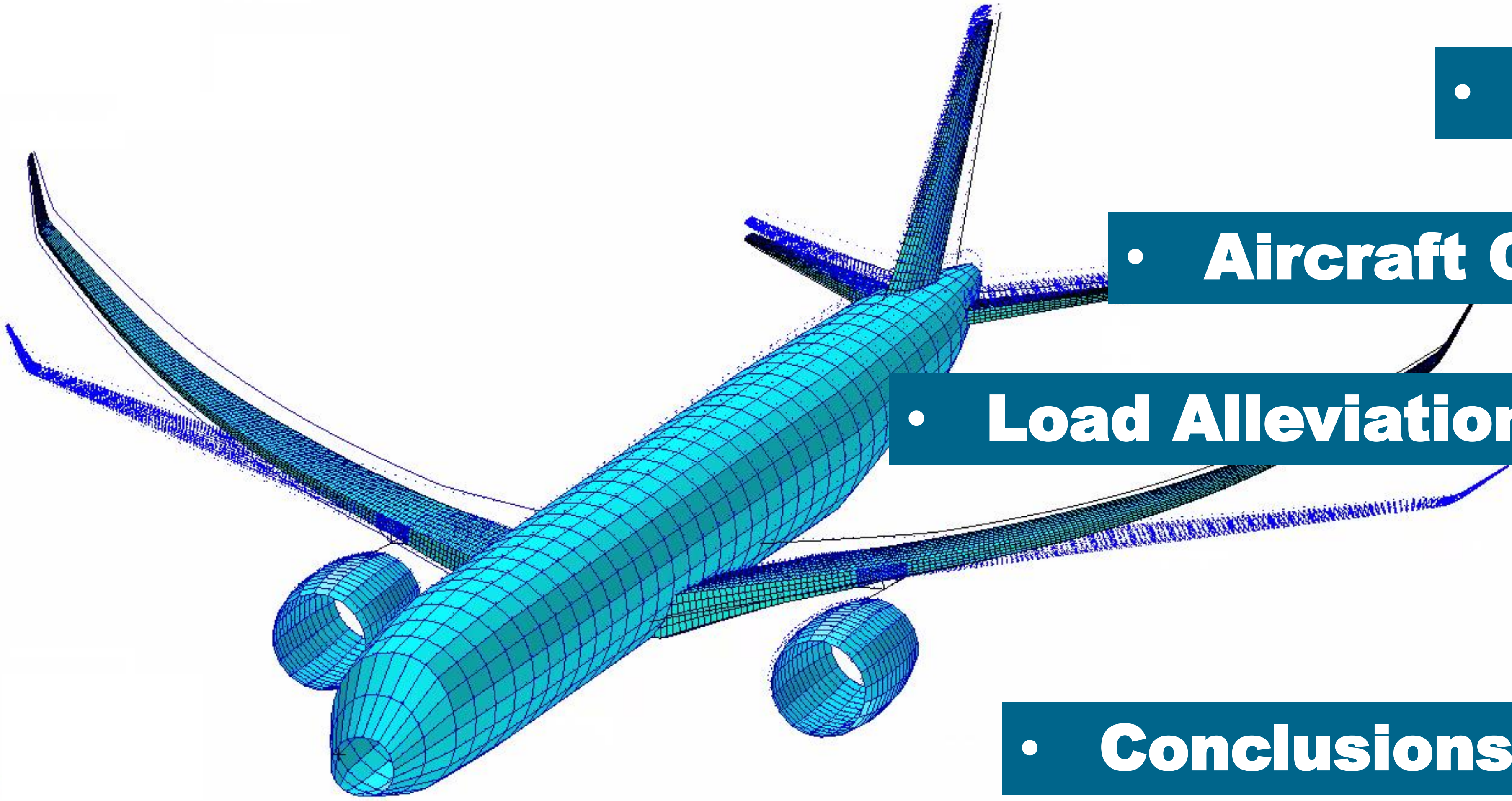
DLR

Parametric Modelling → Loads Analysis → Structural Optimization

cpacs
A Common Language for Aircraft Design

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



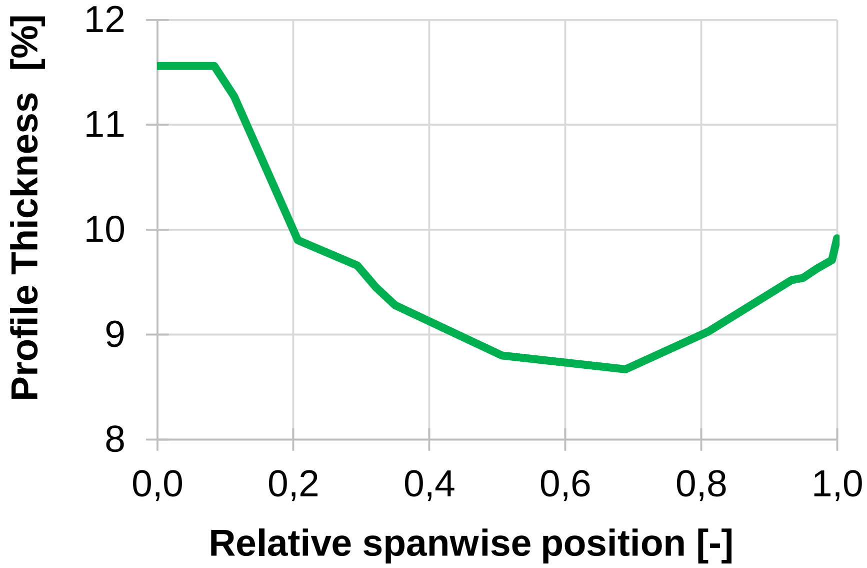


- Introduction
- Aircraft Configuration
- Load Alleviation Techniques
- Results
- Conclusions and Outlook

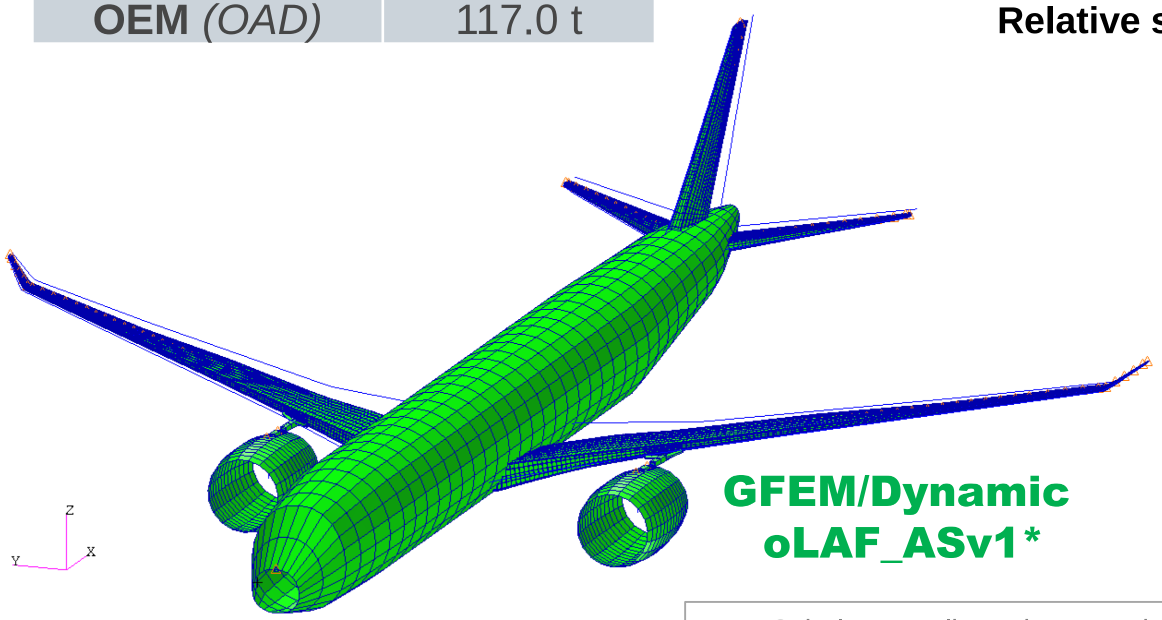
OVERVIEW

The oLAF Reference Aircraft Configuration

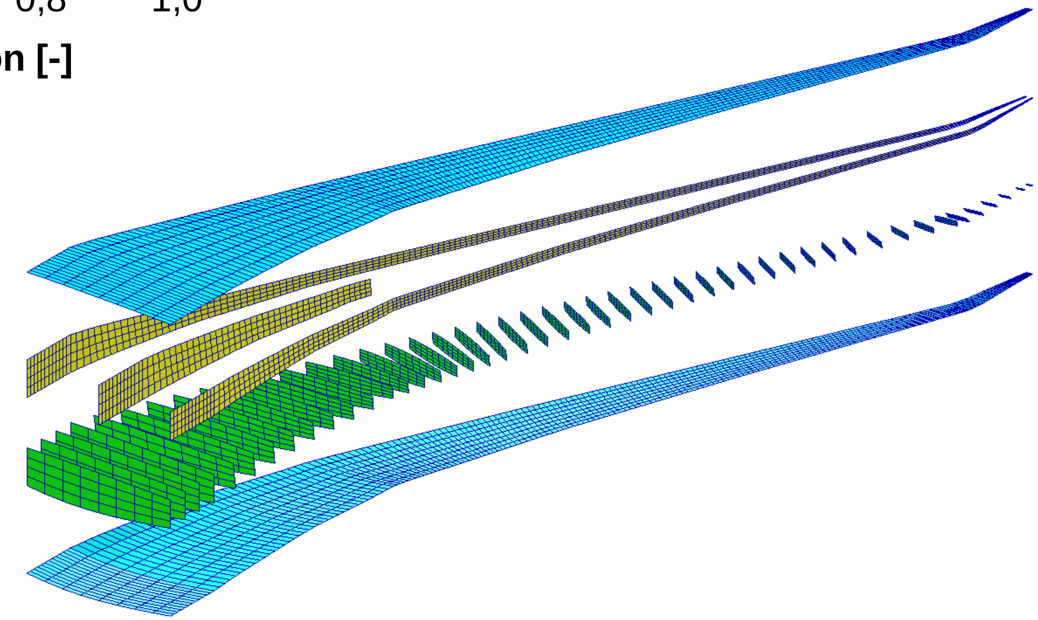
A/C Parameter	oLAF_ASv1
Span	58.9 m
Wing area	338.7 m^2
Aspect ratio	10.2
LE sweep	36.9 deg.
MAC	7.6 m
MTOM	220 t
OEM *(OAD)*	117.0 t



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



GFEM/Dynamic oLAF_ASv1*



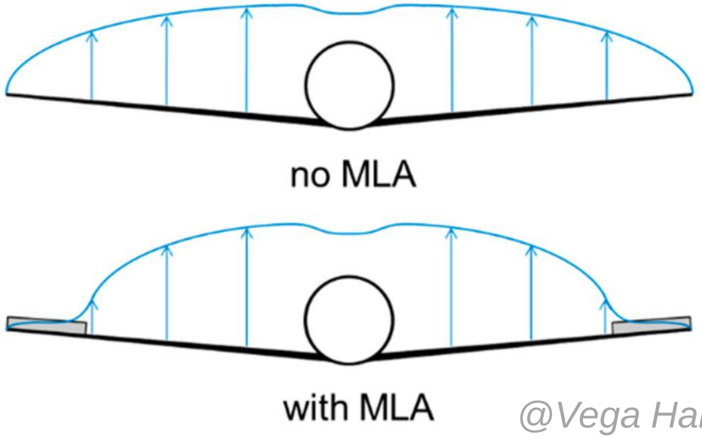
*M. Schulze, T. Klimmek, F. Torrigiani, T. F. Wunderlich: „*Aeroelastic Design of the oLAF Reference Aircraft Configuration*" DLRK 2021

*M. Schulze, K. Bramsiepe, V. Handojo, T. Klimmek: „*Aeroelastic Design of a Highly-Flexible Wing using a Simplified Composite Optimization Approach within cpacs-MONA*" DLRK 2022

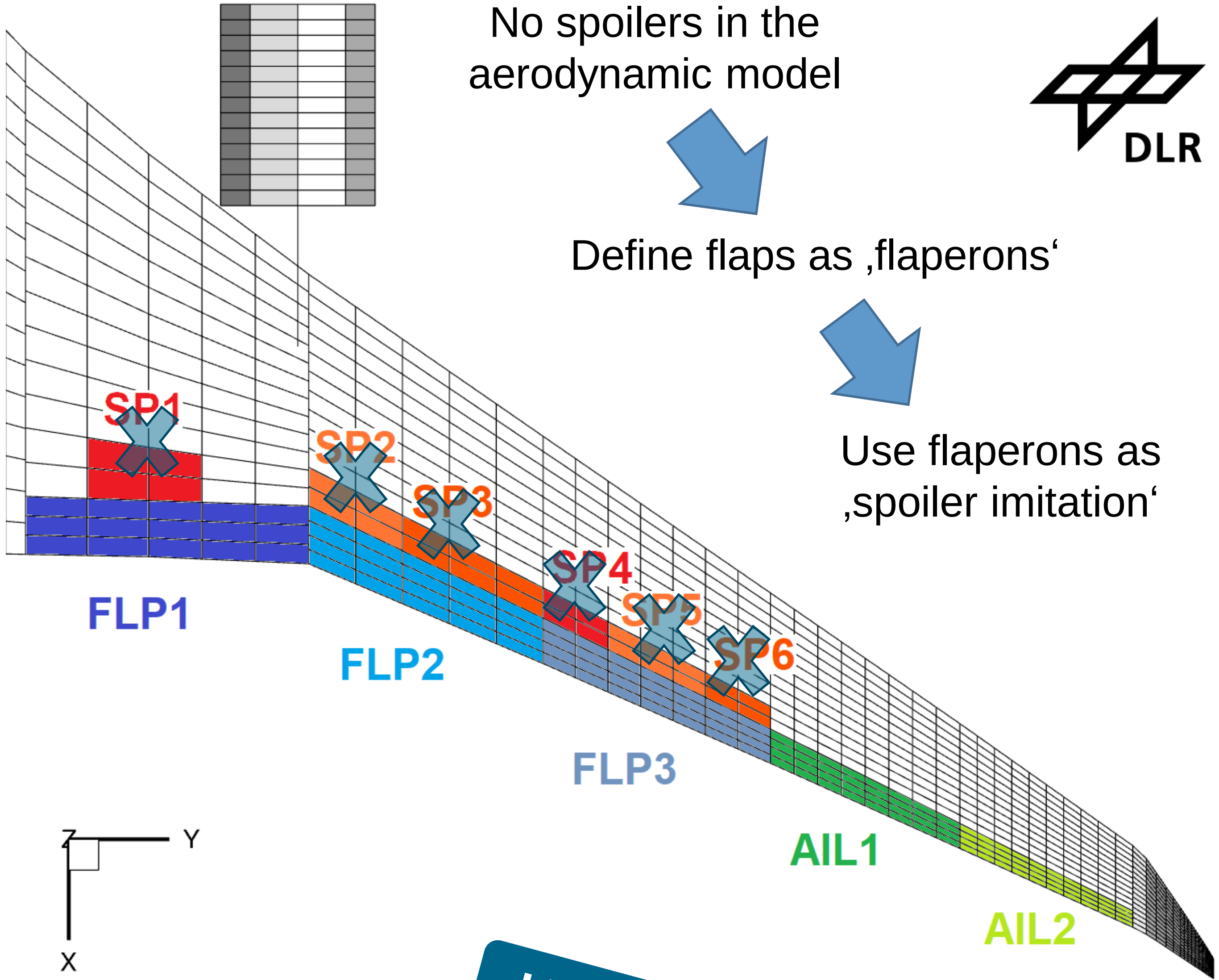
Controlsurface Layout

Main goal:

Inboard shift of the lifting forces



@Vega Handojo



No spoilers in the aerodynamic model

Define flaps as ‚flaperons‘

Use flaperons as ‚spoiler imitation‘

$$defl_{flap} = eff_{area_{spoiler}} * aero_{eff_{flap}} * defl_{spoiler}$$

$$eff_{area_{spoiler}} = 0.5 \qquad aero_{eff_{flap}} = 1.5$$

! Torsional Moments !

Control Surface Settings

Model B

Default LA:

- Use of one aileron for maneuver load alleviation (MLA) for dominant *2.5g* pull-up maneuver
- No gust load alleviation

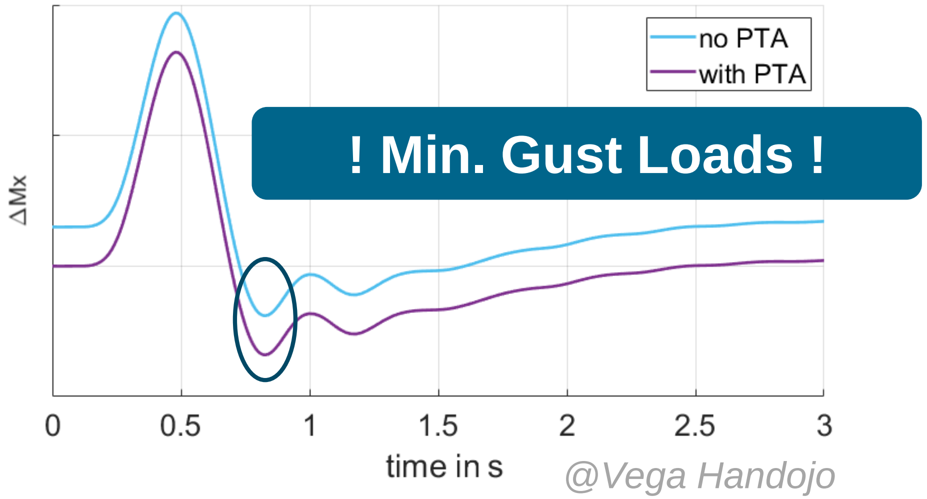
Model A

Push the boundaries

Aggressive LA:

- Use of both ailerons for MLA plus one ‚flaperon' as spoiler imitation
- Use higher control surface deflections for LA
- Increase the aerodynamic efficiency of control surfaces
- Use a passive turbulence alleviation (PTA) for gust loads

Parameter	Model A	Model B
MLA		
FLP3 (SP4-SP6)	15° (20°)	0°
AIL1	30°	20°
AIL2	30°	0°
PTA		
FLP3 (SP4-SP6)	7.5° (10°)	0°
AIL1	20°	0°
AIL2	20°	0°
Control surface efficiency	100 %	75 %



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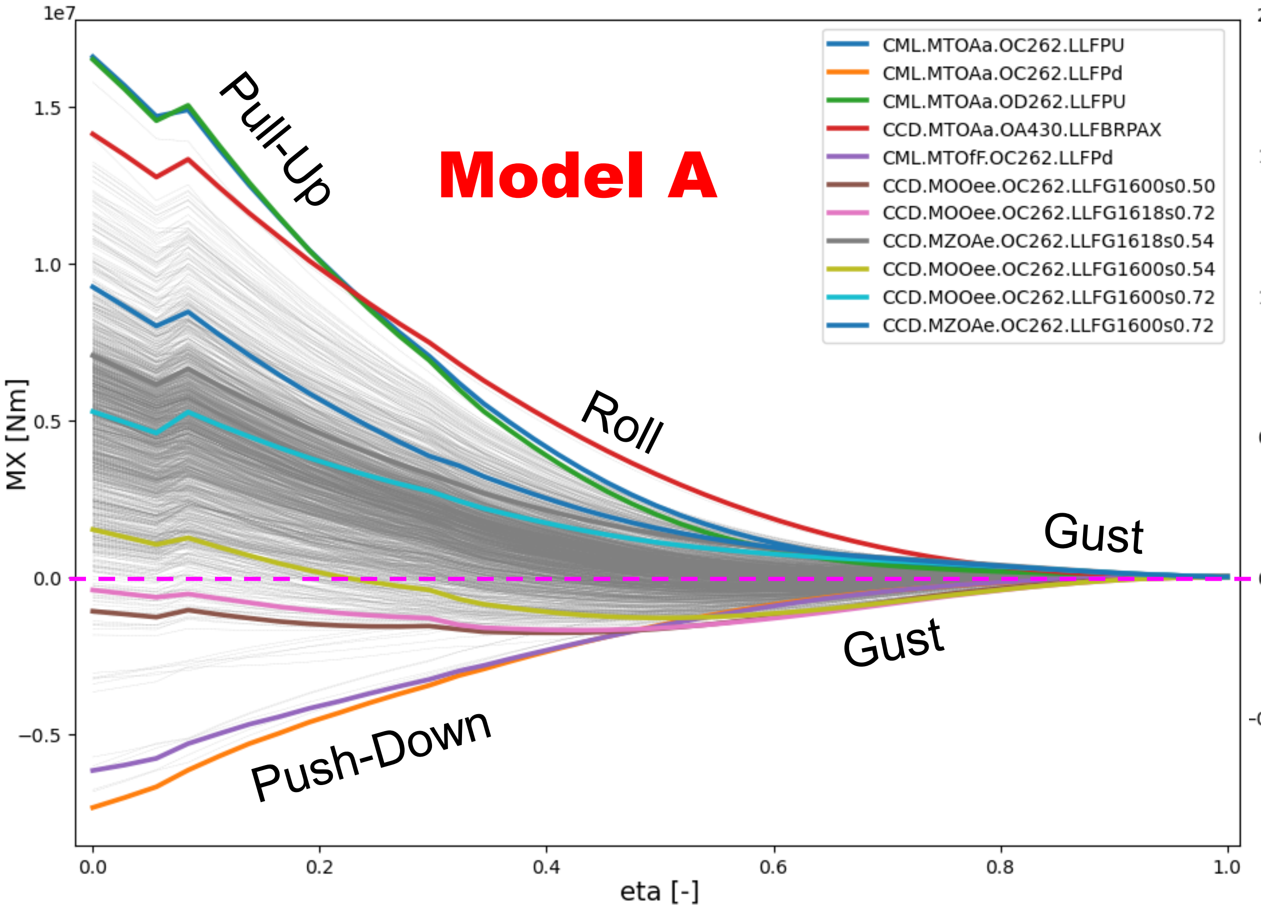
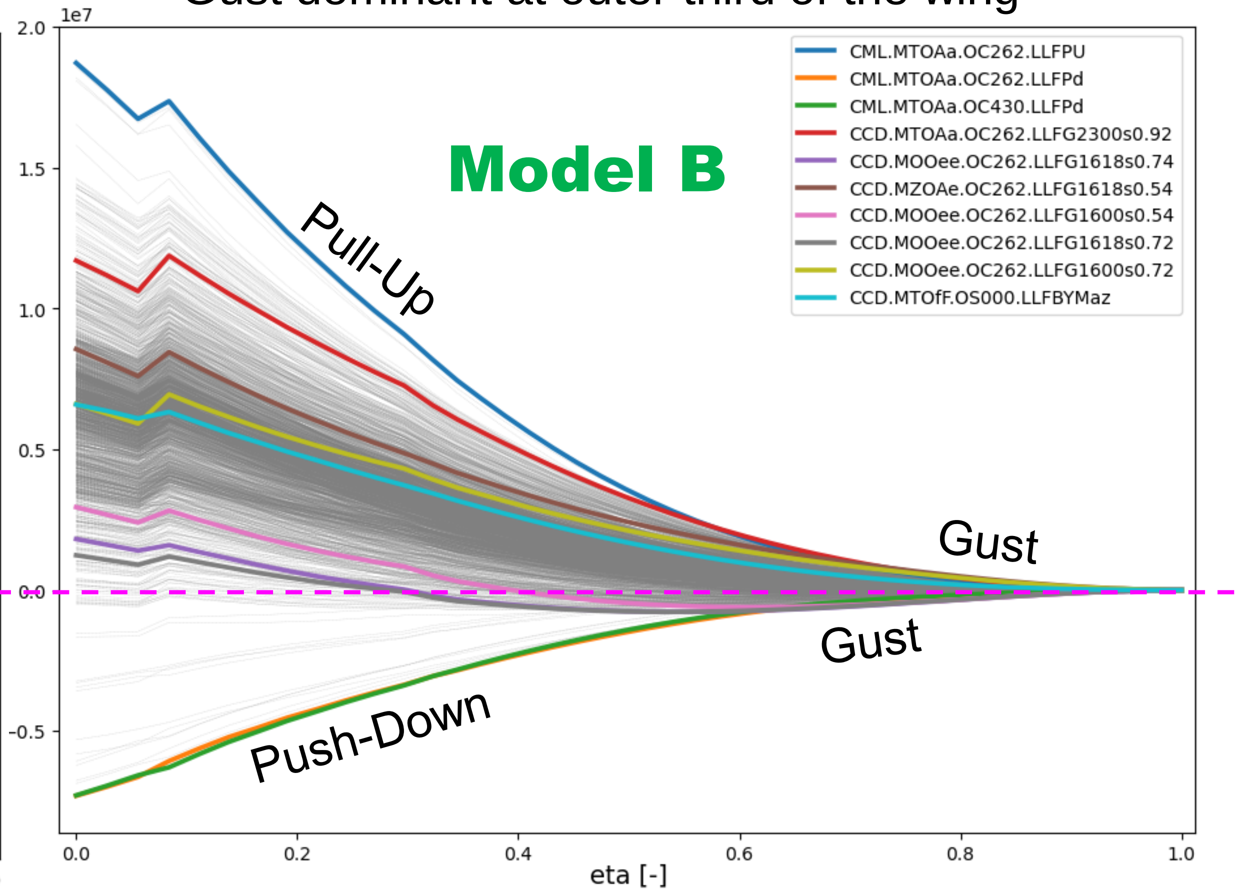
4.1 Loads Analysis
Wing Bending Cutting Moments

- Pull-up dominant up to 20 % span
- Roll maneuver dominant at middle of the wing

- Pull-up dominant up to 50 % span
- Gust dominant at outer third of the wing

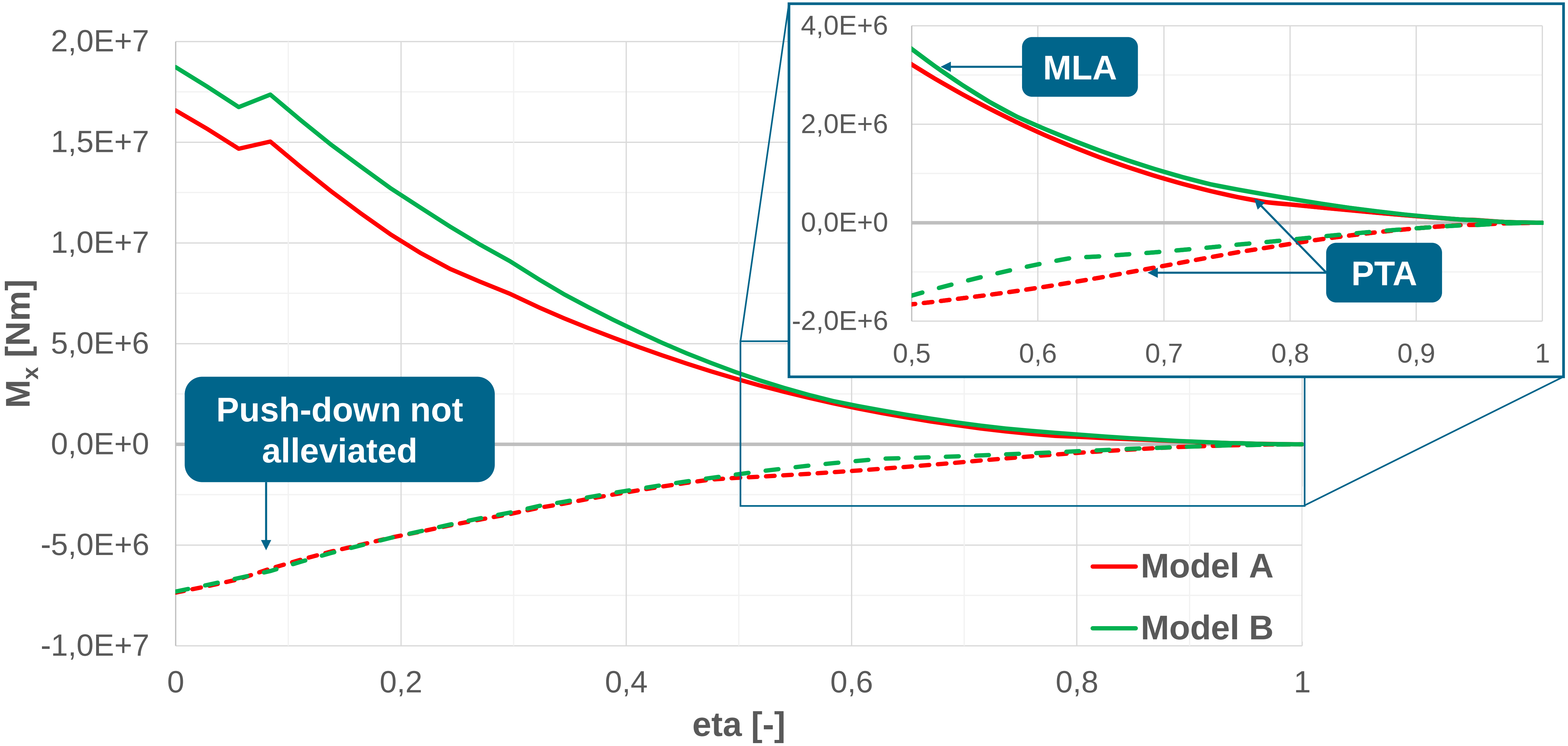




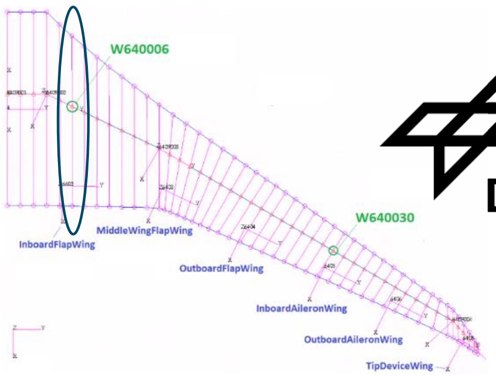
- Push-down dominant up to 50 % span
- Gust dominant at outer half of the wing

- Push-down dominant up to 60 % span
- Gust dominant at outer third of the wing

4.1 Loads Analysis
max./min. Envelope – Wing Bending Cutting Moments

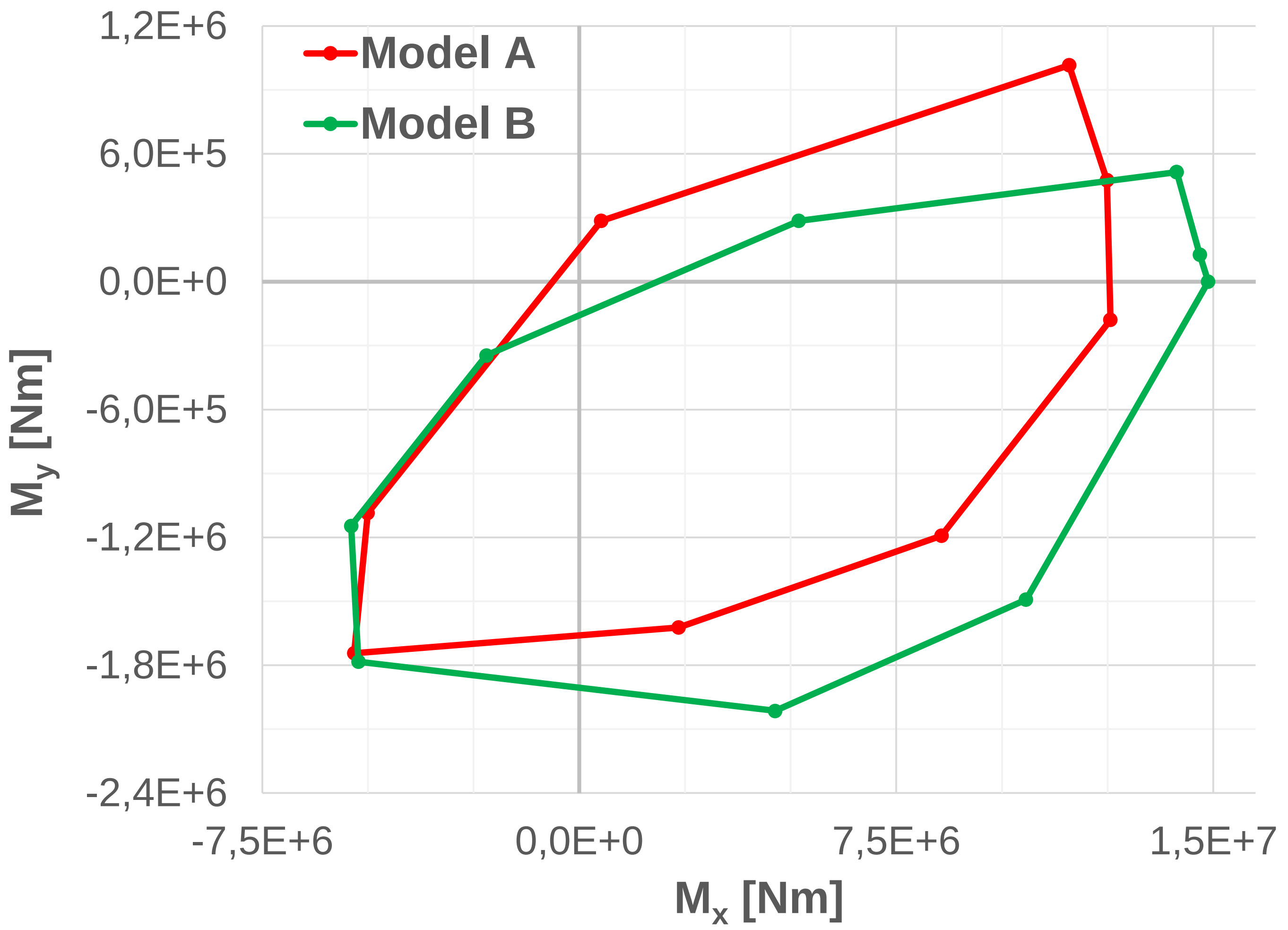


4.1 Loads Analysis
Cutting Loads Envelope @ W640006

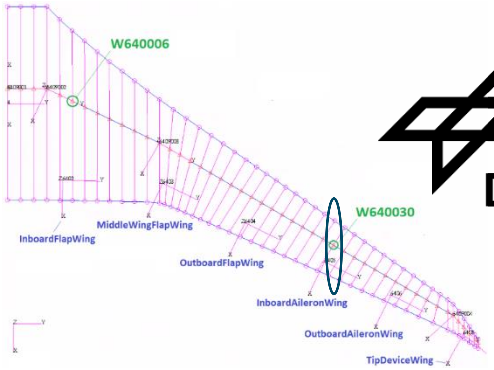


- Envelope shifted upwards to higher maximum torsional (**M_y**) cutting moments
- Reduced maximum wing bending (**M_x**) and minimum torsional (**M_y**) cutting moments

Cutting Load	Model A	Model B
max(**M_x**)	-15 %	$1.5e^{7}$ *[Nm]*
max(**M_y**)	+97 %	$5.1e^{5}$ *[Nm]*
min(**M_x**)	-1 %	$-5.4e^{6}$ *[Nm]*
min(**M_y**)	-13 %	$-2.0e^{6}$ *[Nm]*

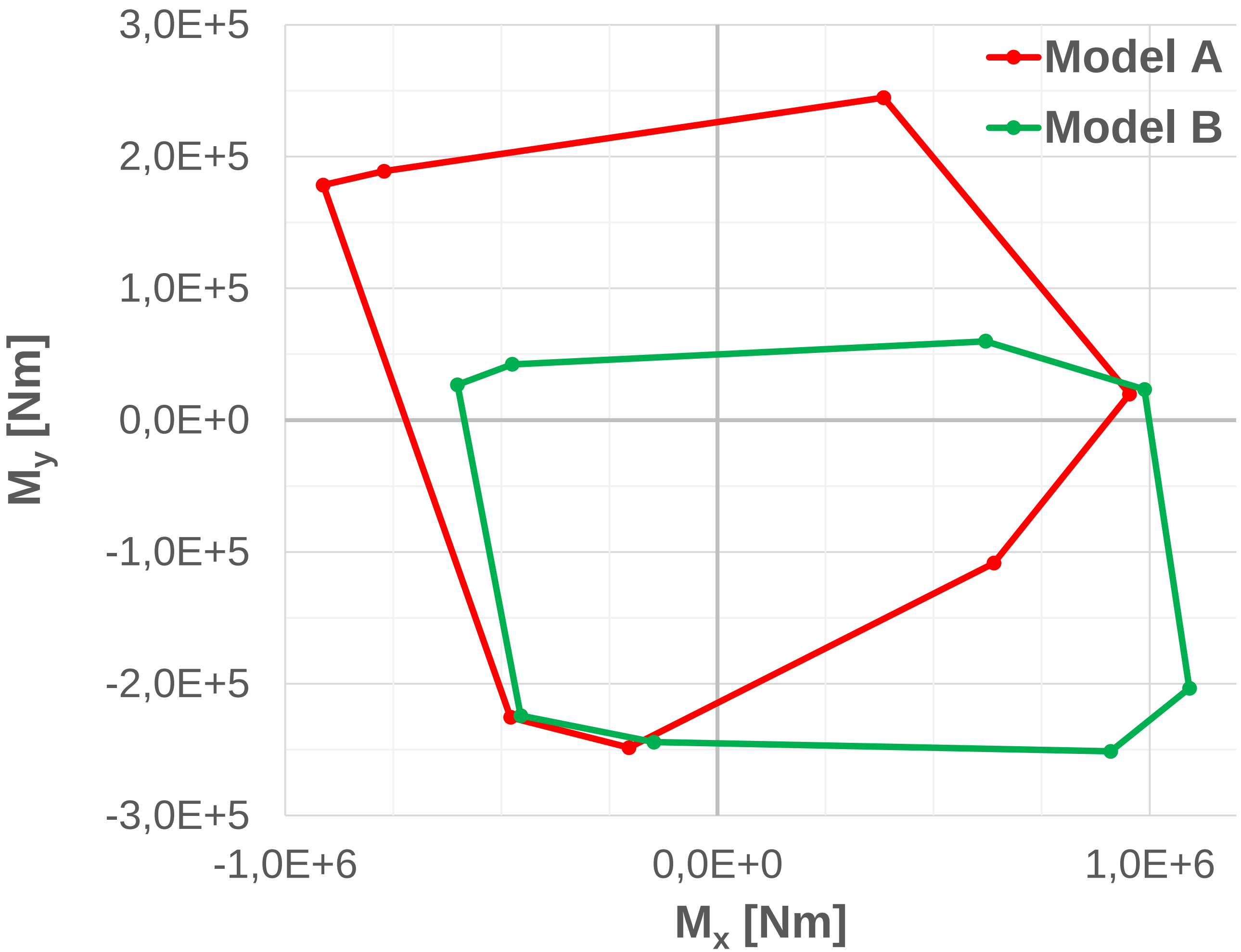


4.1 Loads Analysis
Cutting Loads Envelope @ W640030

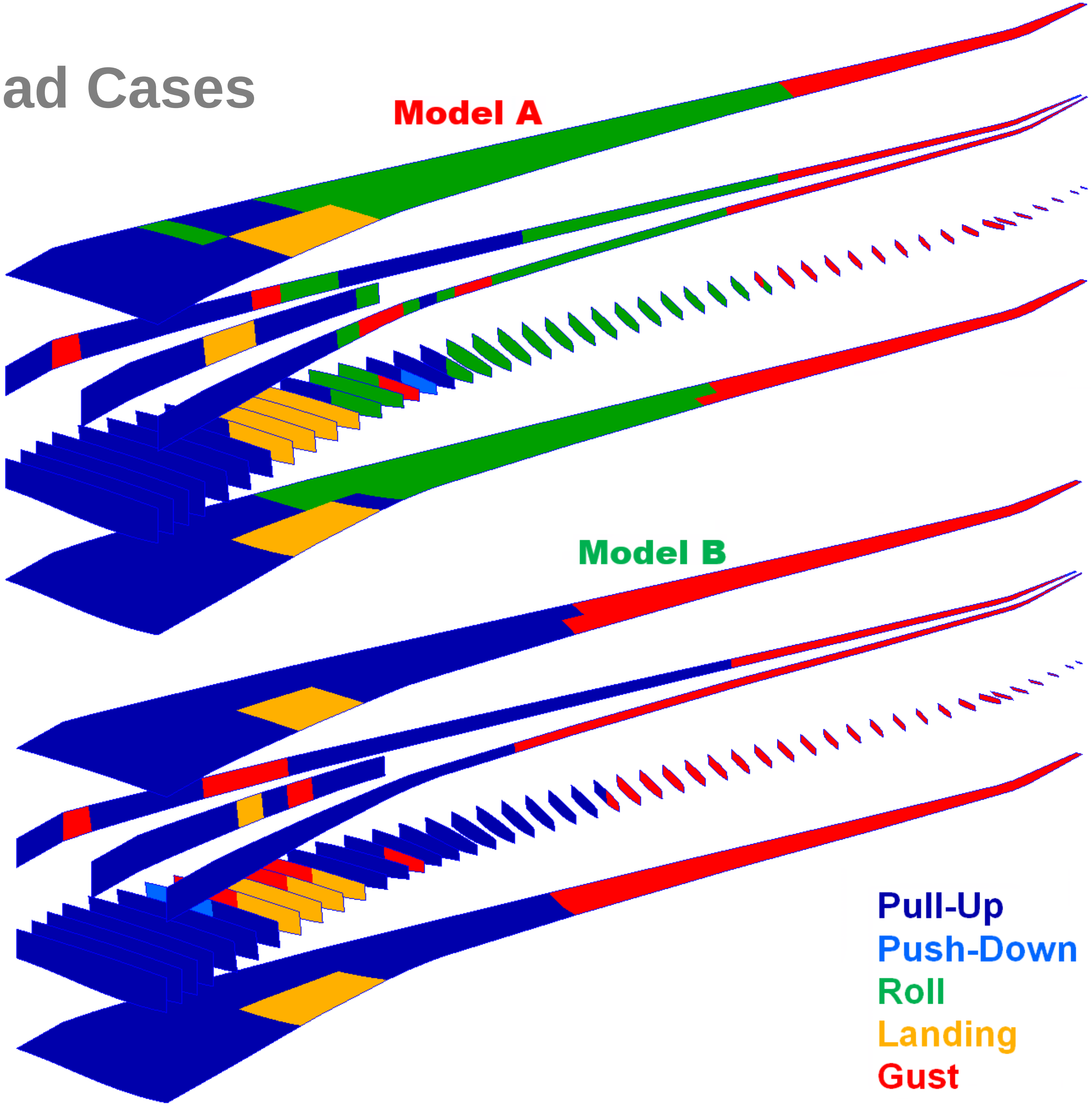


- Envelope significantly shifted upwards to higher maximum torsional (**M_y**) cutting moments
- Minimum wing bending (**M_x**) cutting moments increased due to higher gust loads (PTA)
- Max. wing bending (**M_x**) cutting moments reduced

Cutting Load	Model A	Model B
max(**M_x**)	-13 %	$1.1e^6$ *[Nm]*
max(**M_y**)	+310 %	$6.0e^4$ *[Nm]*
min(**M_x**)	+52 %	$-6.0e^5$ *[Nm]*
min(**M_y**)	-1 %	$-2.5e^6$ *[Nm]*



4.2 Dimensioning Load Cases



Aggressive load alleviation:

Reduces gust and pull-up loads

↓

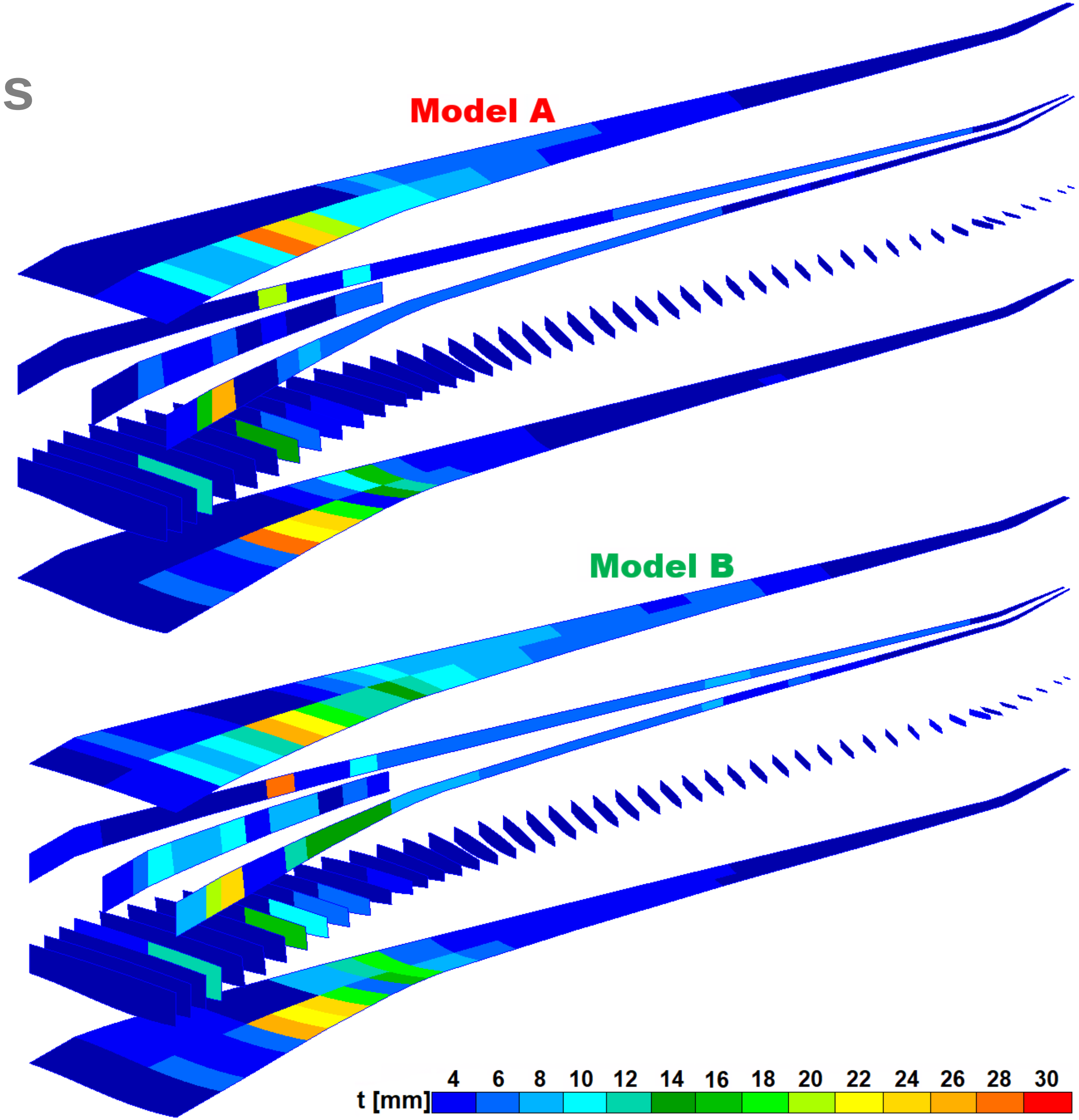
Roll maneuvers *(not alleviated)* become dominant at middle section of the wing

4.3 Wing Primary Mass

Aggressive load alleviation:

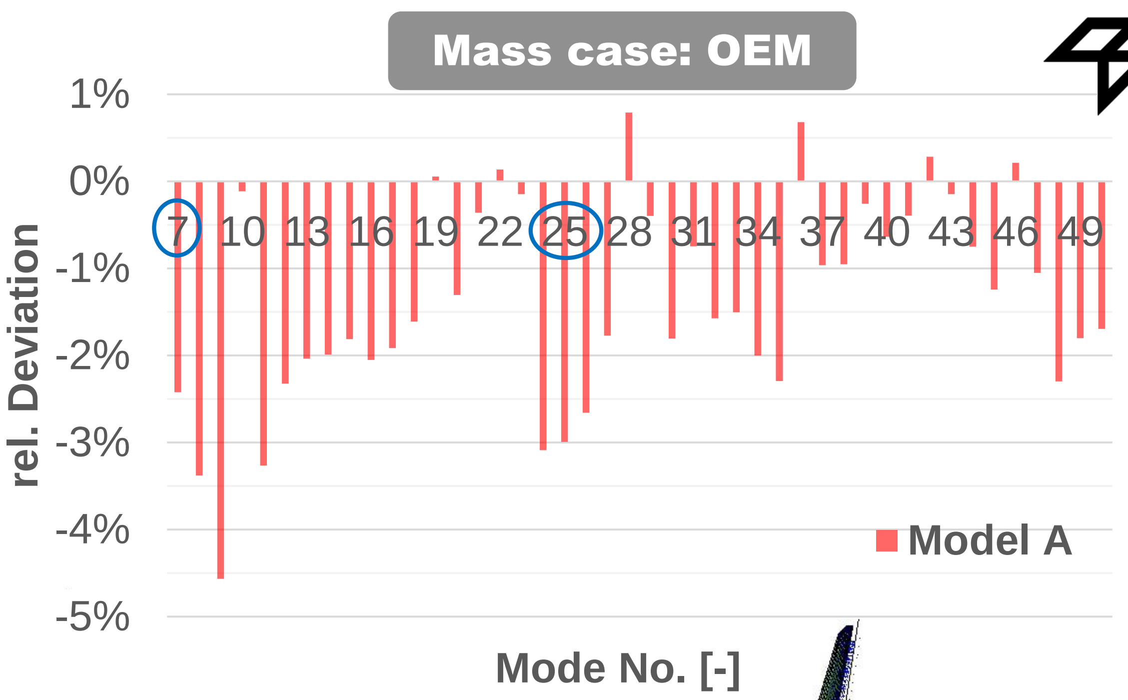
- Reduces spar thickness
- Reduces skin thickness at middle section of the wing
- Reduces skin thickness at the front of the inner section

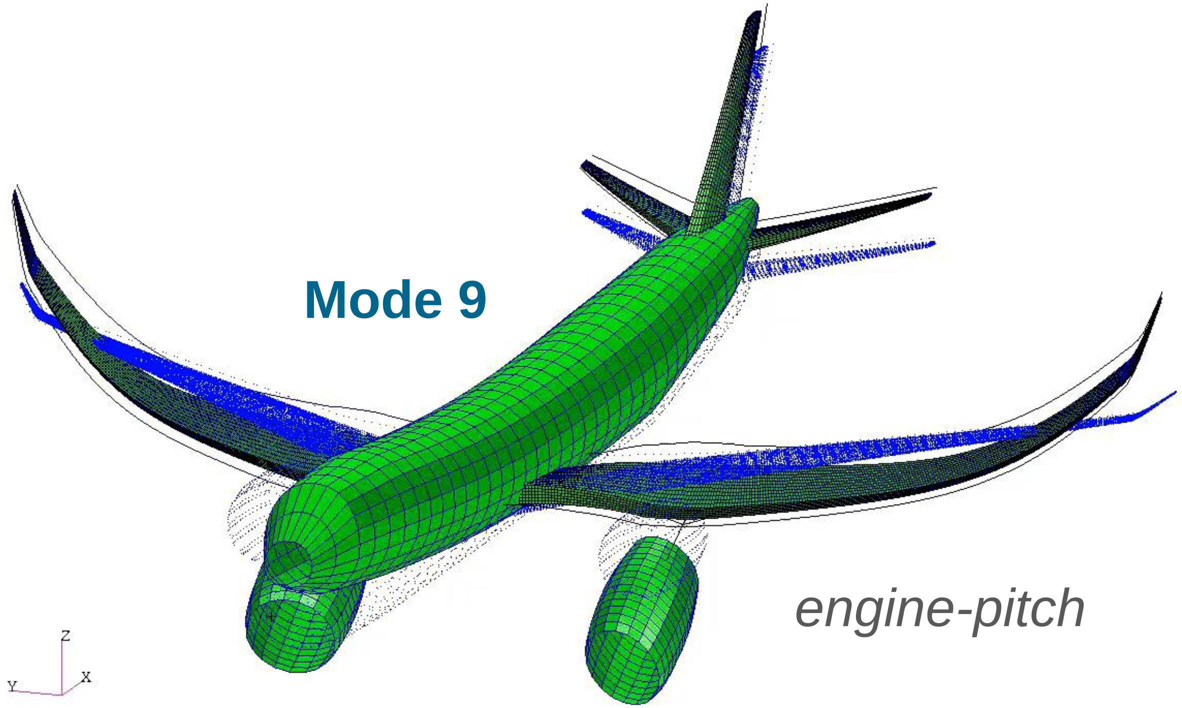
Mass item	Model A	Model B
Operating empty	-1.7 %	116.8 t
Main wings	-11.2 %	17.8 t
Upper skin	-13.8 %	2.32 t
Lower skin	-10.6 %	2.08 t
Ribs	-6.0 %	1.34 t
Spars	-18.0 %	1.22 t

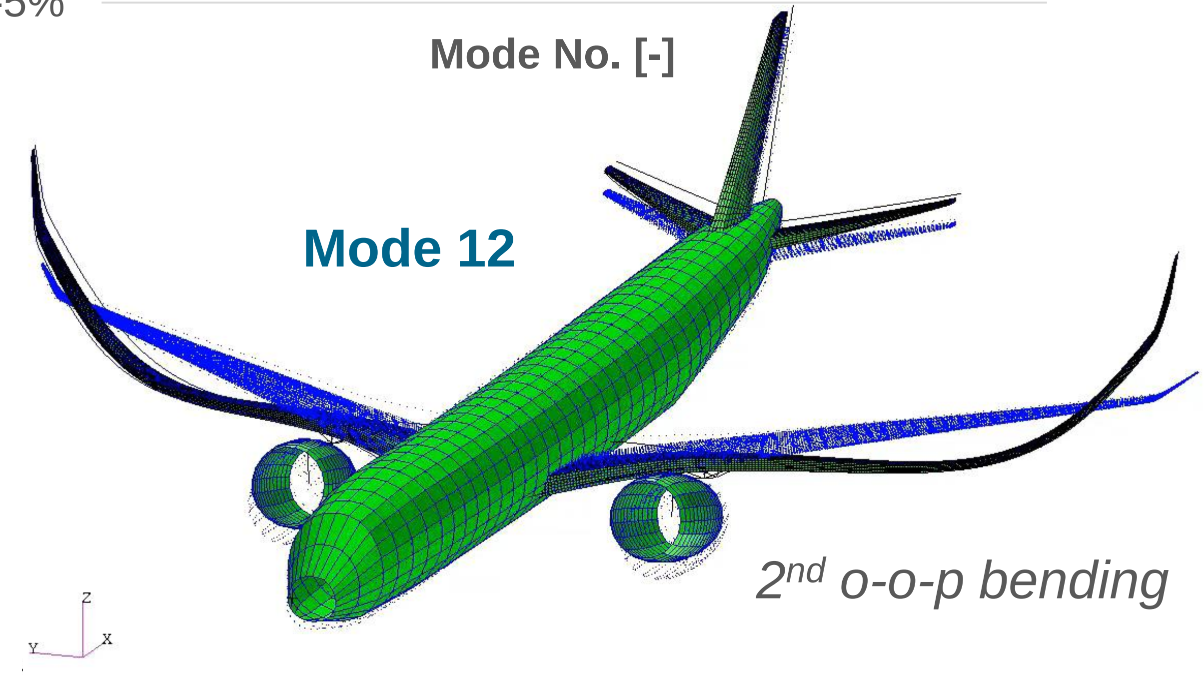


4.4 Modal Analysis

Eigenmode	Model A	Model B
1st sym. wing o-o-p bending	-2.4 %	1.21 Hz
1st sym. wing torsion	- 3.1 %	8.69 Hz







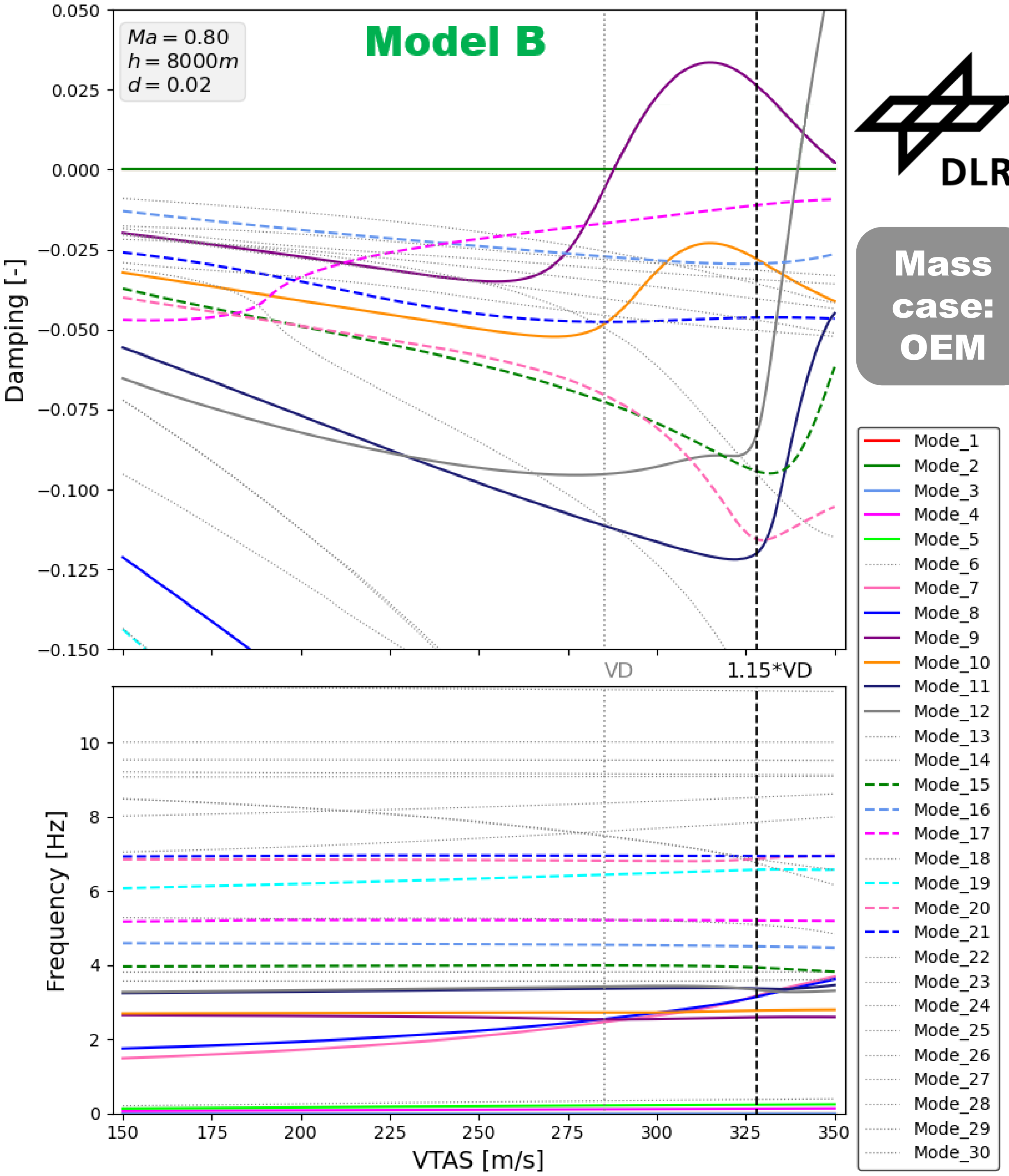
4.5 Subsonic Flutter Check
Default Load Alleviation

- Non-matched p-k flutter method
- Only first 30 modes visualized
  (50 modes used for analysis)

- Hump-mode within the aeroelastic stability envelope for the engine-pitch (***Mode 9***)
- Flutter point for 2nd sym. o-o-p bending (***Mode 12***) outside of the stability envelope

- Lowest flutter speed for Model B:
  - **287 m/s** (Outside the flight envelope)

- Increase of Eigenfrequencies for 1st o-o-p bending (***Mode 7*** and ***Mode 8***) with increased airspeed



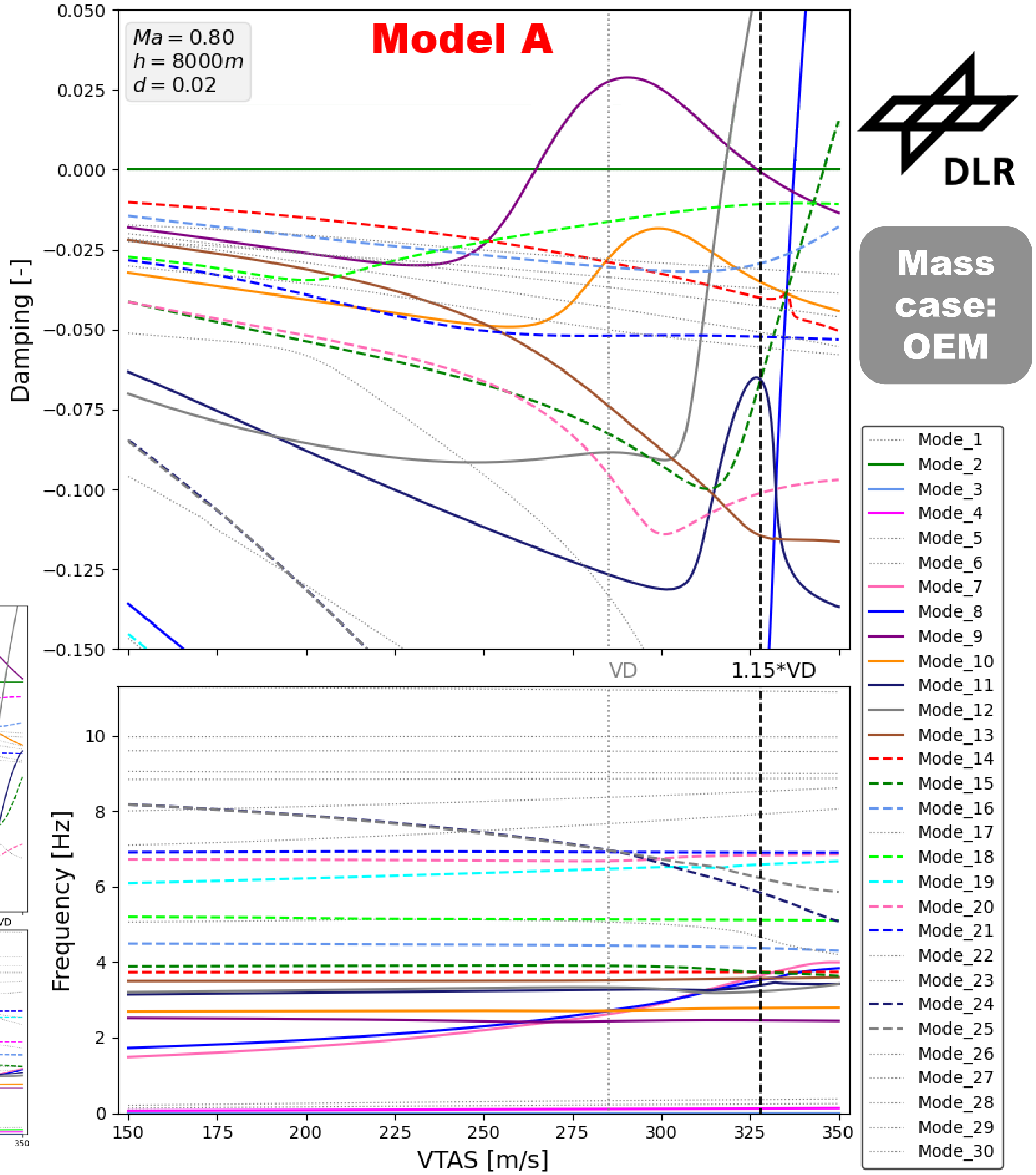
Mass case: OEM

DLR

Results

4.5 Subsonic Flutter Check
Aggressive Load Alleviation

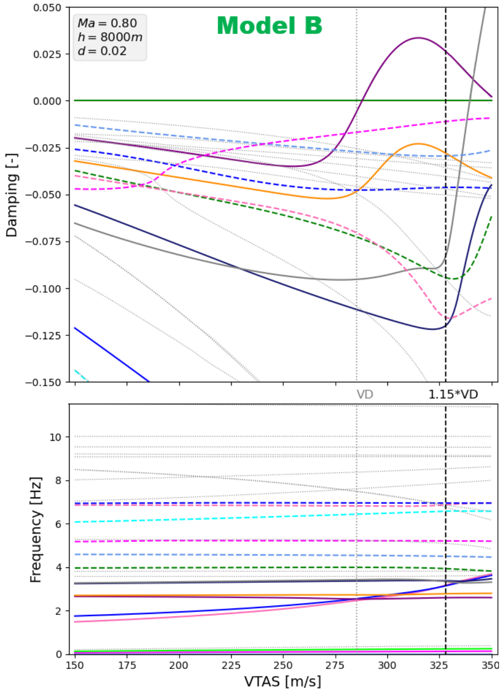
- Hump-mode within the aeroelastic stability envelope for the engine-pitch (***Mode 9***)
- Lowest flutter speed for Model A:
  - **265 m/s** (Inside the flight envelope) ← critical
- Flutter point for ***Mode 12*** inside of the stability envelope



Mass case: OEM

- Eigenfrequencies of wing torsional modes (***Mode 24*** and ***Mode 25***) converge to wing o-o-p bending modes (***Mode 7*** and ***Mode 8***)

  →classical wing bending-torsional flutter phenomenon

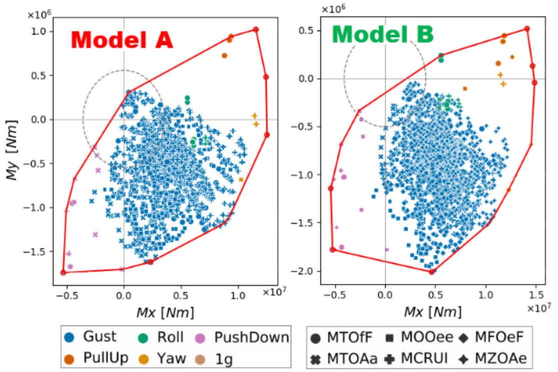


Results

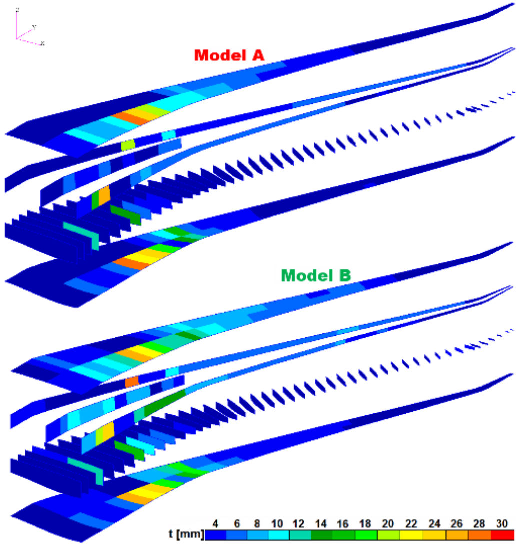
Conclusions

Aggressive Load Alleviation…

… reduces the wing bending cutting moments, but increases the torsional moments!



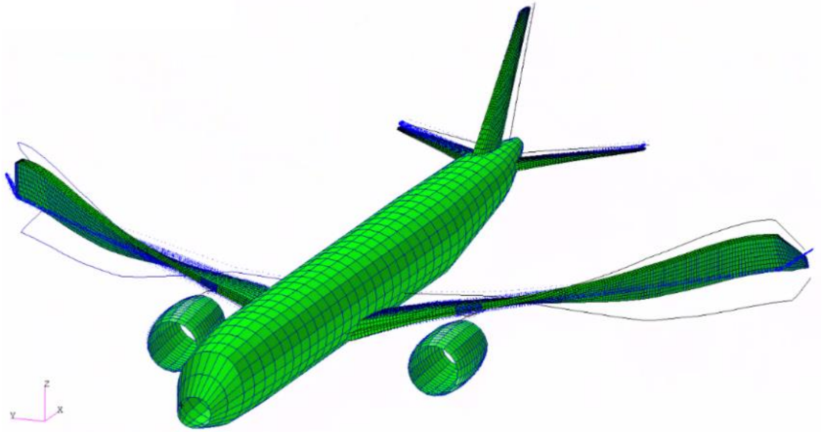
… lowers the wing primary mass!



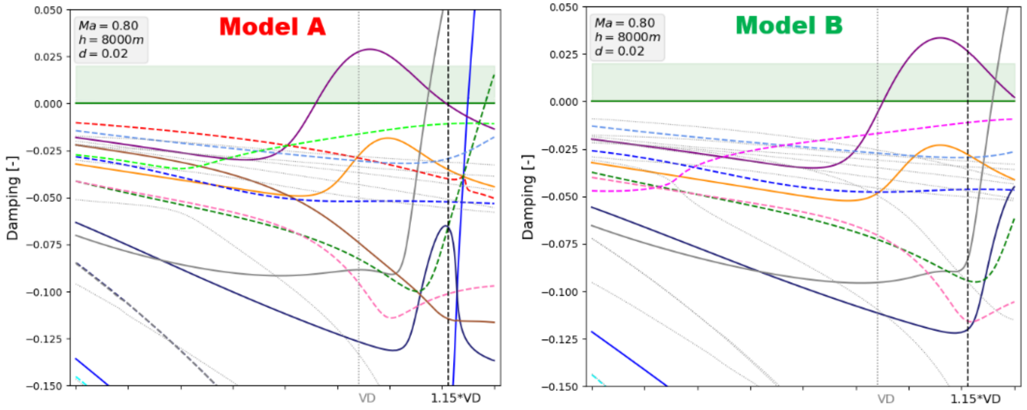
What is the impact on:

- **Loads?**
- **Structure?**
- **Eigenfrequencies?**
- **Aeroelastic stability?**

… influences the wing Eigenfrequencies!

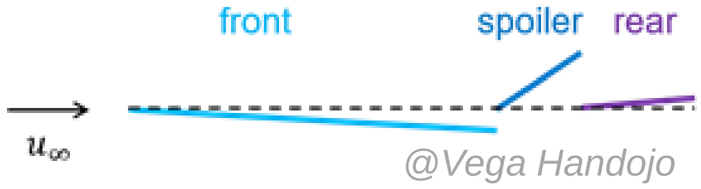


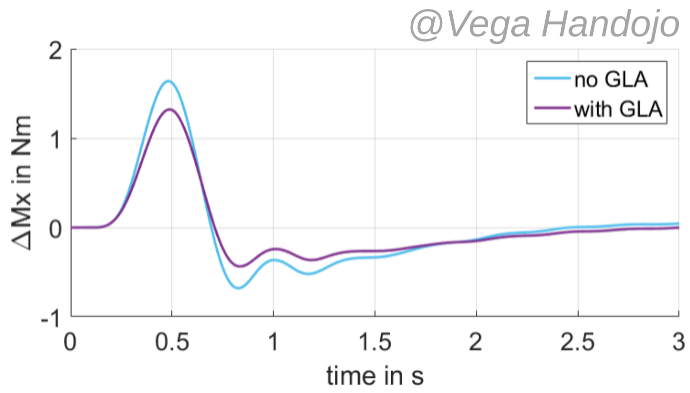
… has a negative impact on aeroelastic stability!



Outlook

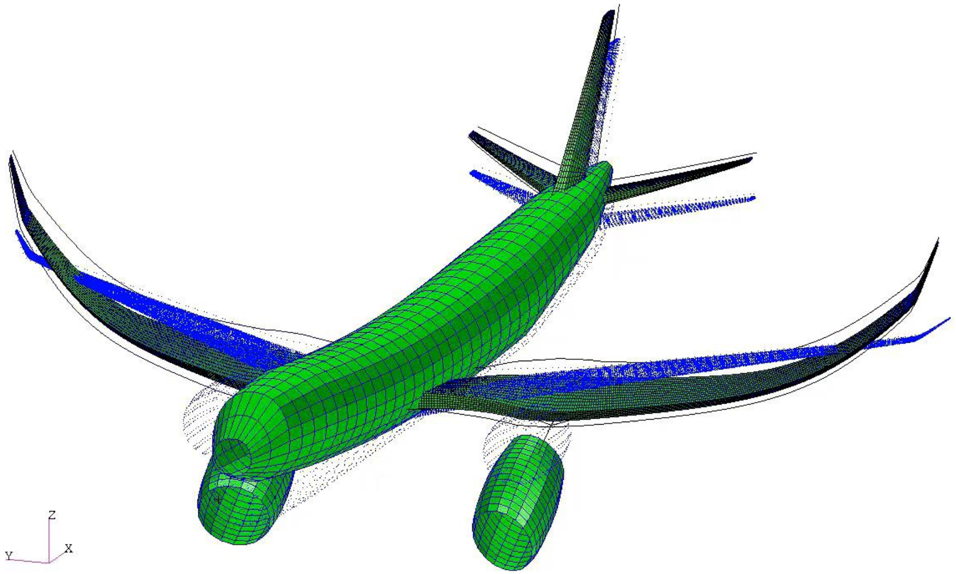
Outlook

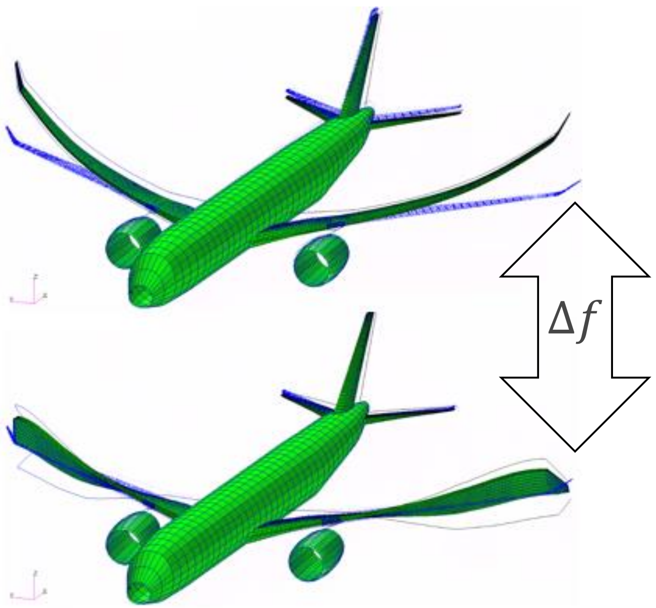




Further Load Alleviation:

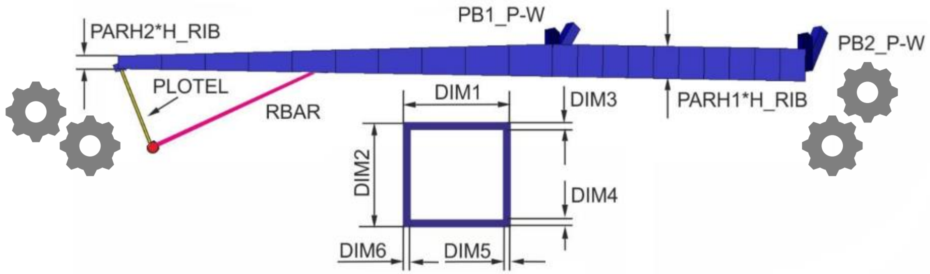
- Use spoiler deflections including CFD-corrections for front and rear panals to avoid high torsional moments
- Use the inner flap to further shift aerodynamic loads
- Use a roll maneuver alleviation
- *Use of active load alleviation**





Avoidance of Flutter:

- Tuning of pylon model
- *Aeroelastic tailoring**



Outside of cpacs-MONA

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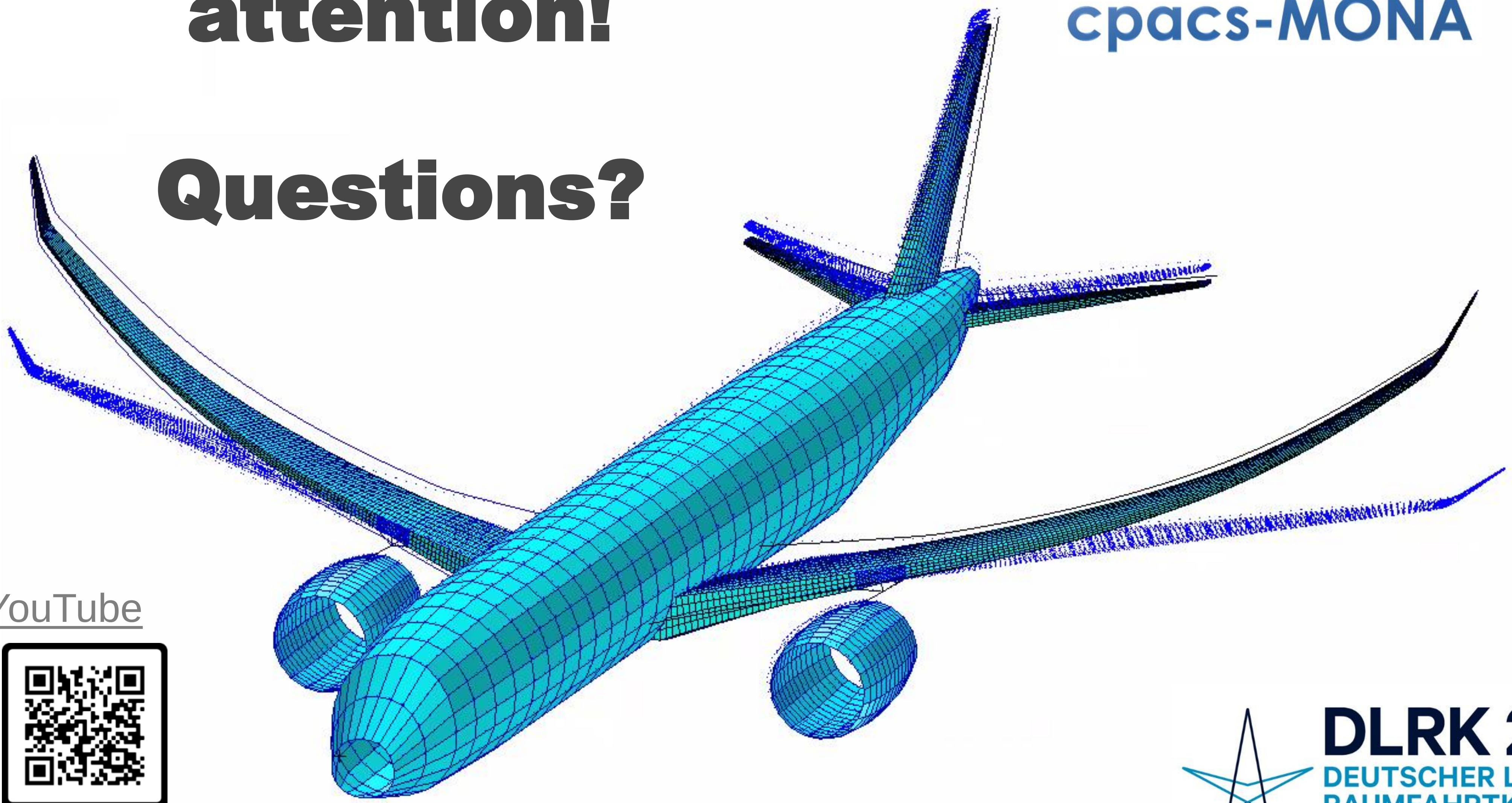
Thank you for your attention!

Questions?



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[AE @ YouTube](#)

Aeroelastik: Warum Flugzeuge elastisch sind

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