WOST
optiSLang - easy and safe to use

FEM und Sensitivitätsanalysen unter Berücksichtigung von in Grenzen zulässiger Formtoleranzen zufällig deformierter Körper

FEA and Sensitivity Analysis Taking Into Account Allowable Tolerances from Randomly Deformed Bodies

Peter Gust und Christoph Schluer

Weimar, 24.11.2011

dynamic software & engineering

Lehrstuhl Konstruktion (Engineering Design)

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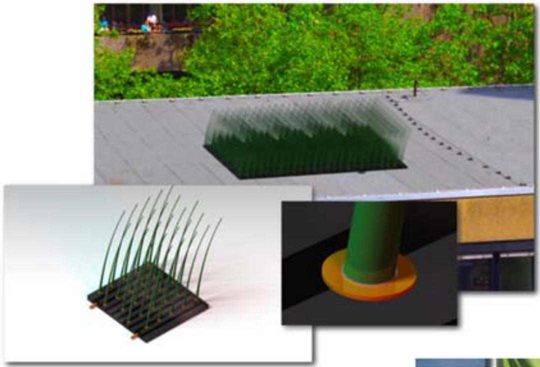
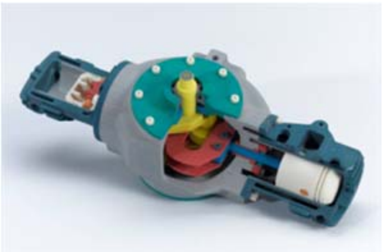
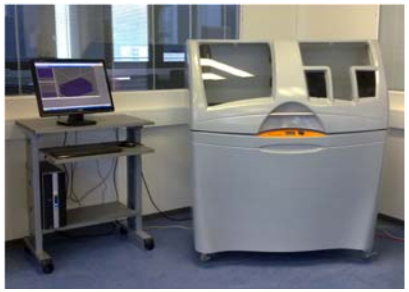
Introduction

- Founded 1972, students > 16.000 from 90 nations
- 250 Professors, 27 institutes and 280 labortories
- 7 Faculties and 91 study paths
- Mechanical Engineering positive trend
  +110% Beginners
- Chair of Engineering Design
  - 3D CAD Design(CATIA), FEM: Catopo, ANSYS, Abaqus
  - MBS SAM, Recurdyn, Enventive, 3D Tolerancing VisVSA
  - Robust Design optiSLang
  - Prototyping: colored 3D Printing

Prize Money
25.000€







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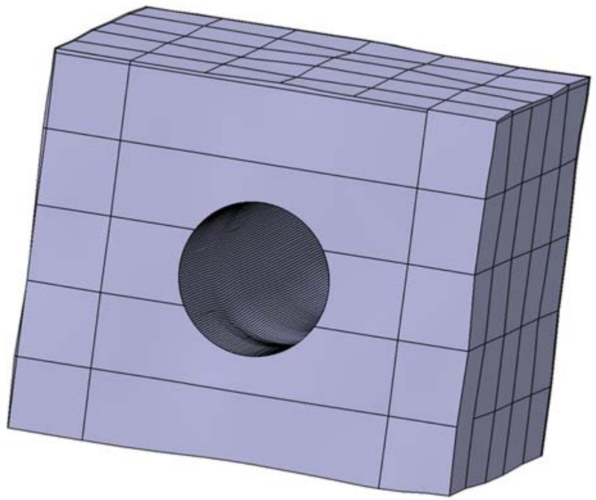
Overview:
Parametrik für Robust Design Optimierung

Sensitivity study to optimize the stiffness of automotive hinge systems (Bachelorthesis)



Randomly deformed bodies (Masterthesis, Research)

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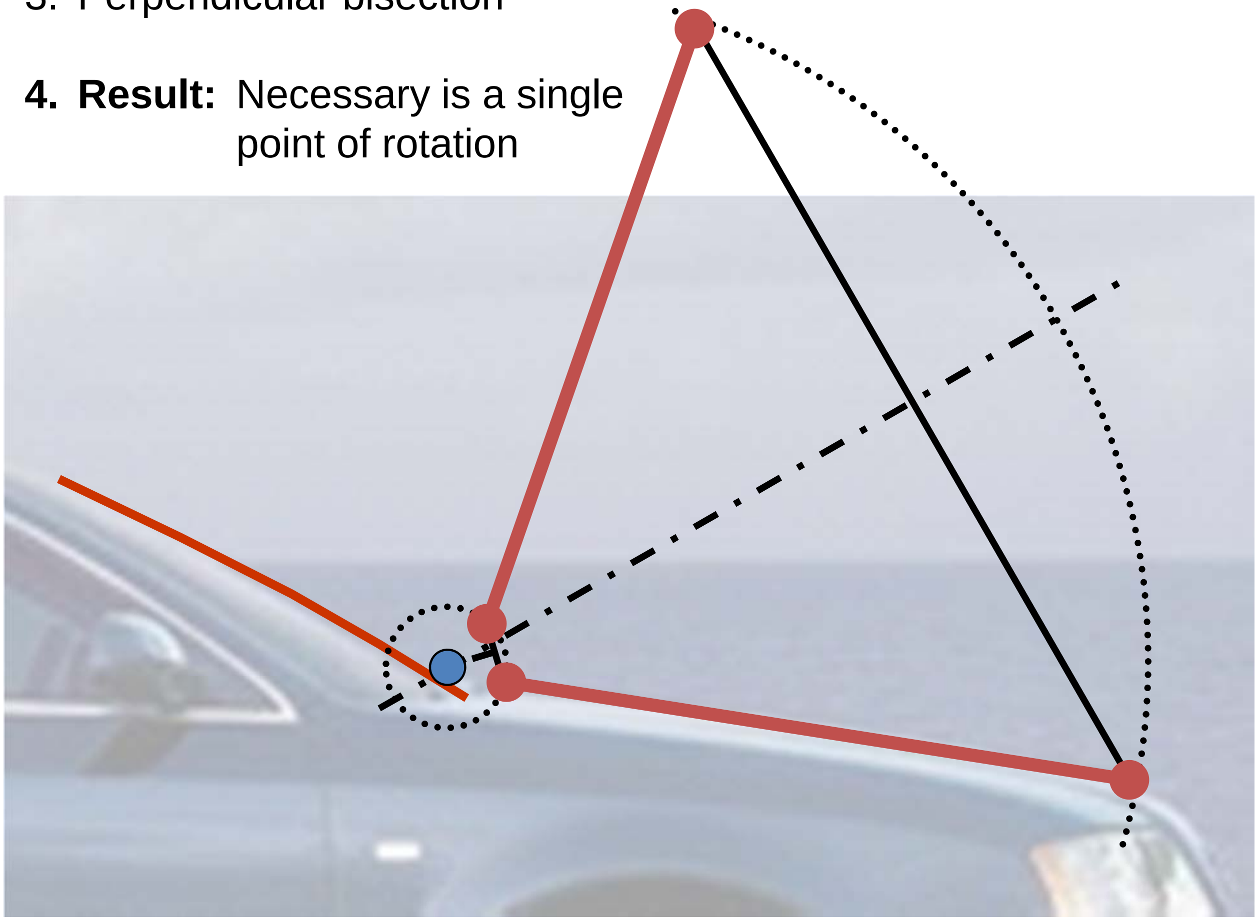
Because of the collision with the **front shield** a four joint hinge is necessary

1. Mark the closed and open position
2. Interconnection
3. Perpendicular bisection

4. **Result:** Necessary is a single point of rotation



4 Joint Hinge*

1 Joint Hinge*

*Source Kirchhoff GmbH, Halver

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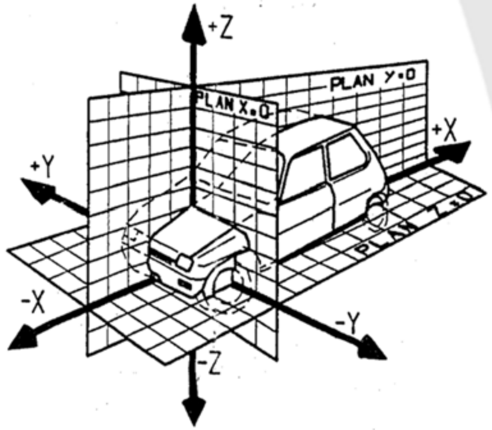
Requirements for hinge systems for hoods and flaps

„ The hinge system must be supported free of slackness and rattle and easily used“



Guidance requirements

Safe Keep of the hood from closed to open state

Wind Stiffness

200N Load max. 2mm z-deformation

Side Stiffness

200N max. 7mm y-deformation

and again

„Easy to use“

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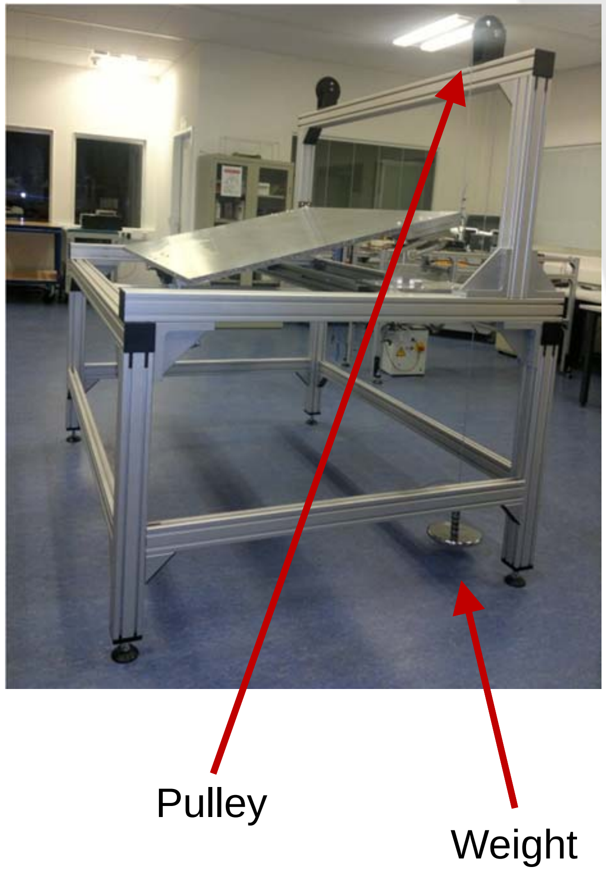
Experimental setup to verify the modeling and calculation results

Aluminium Foam Sandwich is nearly equal to the original hood and is available in prototype phase for the automotive supplier!

$F_G = 200N$
+Friction
(Weight)



The results have an accuracy of ± 5%: FEM-Model, Alu-Hood and Real Hood includes

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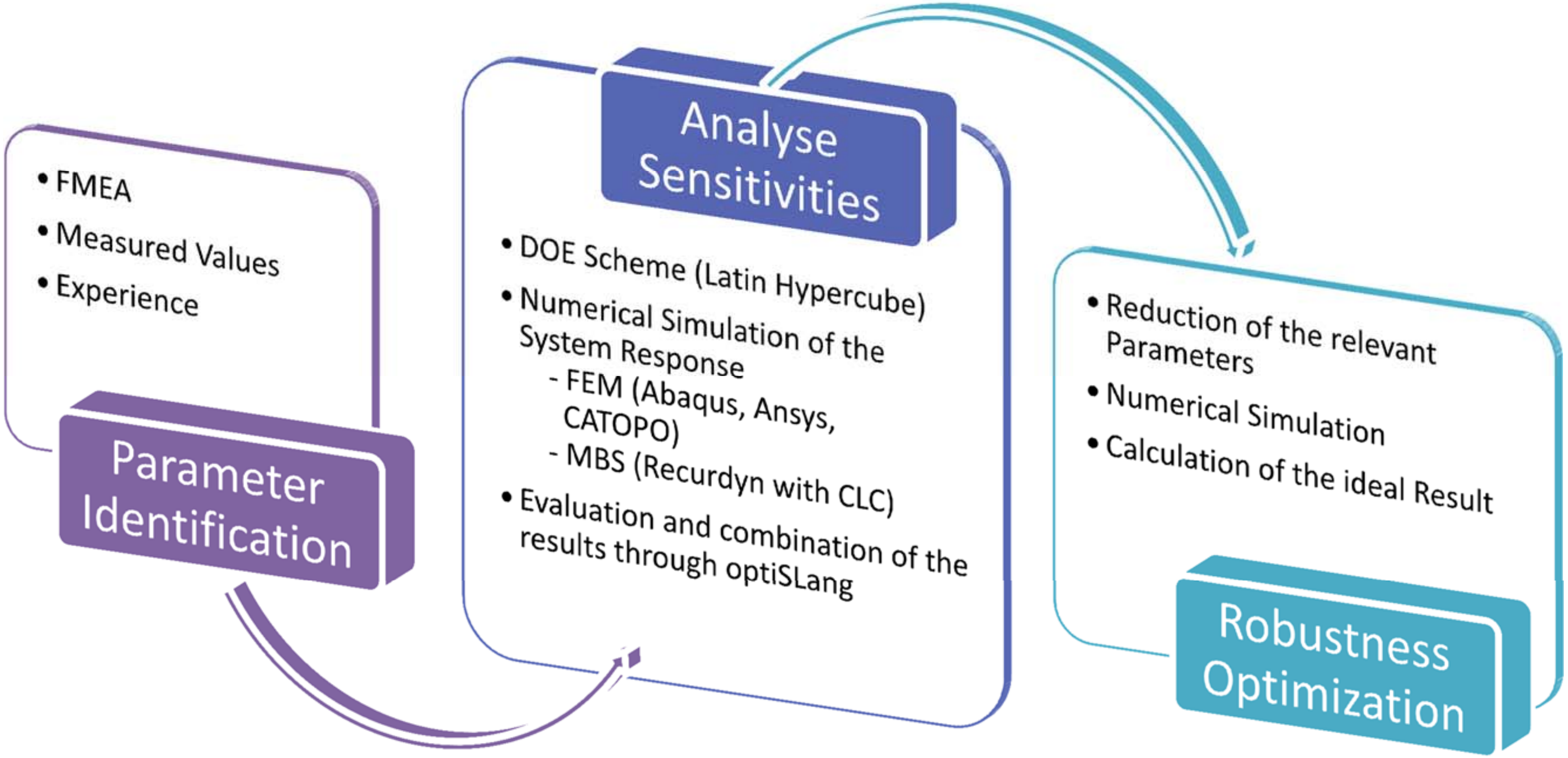
Methodical robust Design



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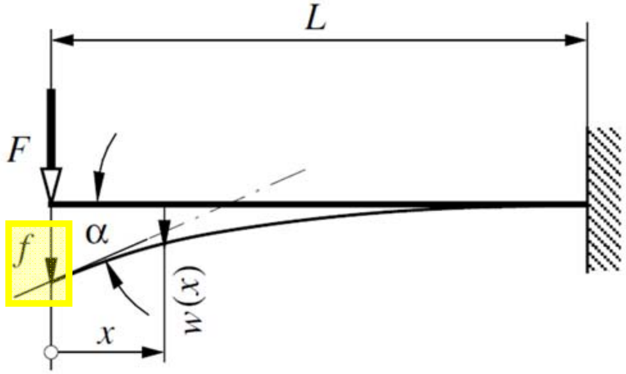
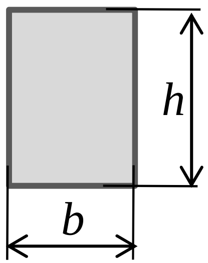
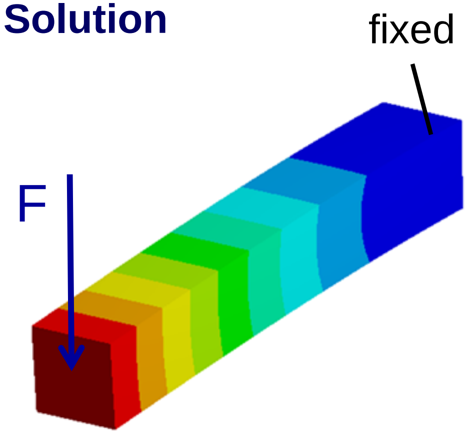
Single Beam / Motivation

Analytical Solution





Numerical Solution



Input Parameter

Name
breite_DS
hoehe_DS
laenge_DS
youngs_modulus
force_y_component

Which Parameter is the **important** One?

Name
total_deformation_maximum

Output Parameter

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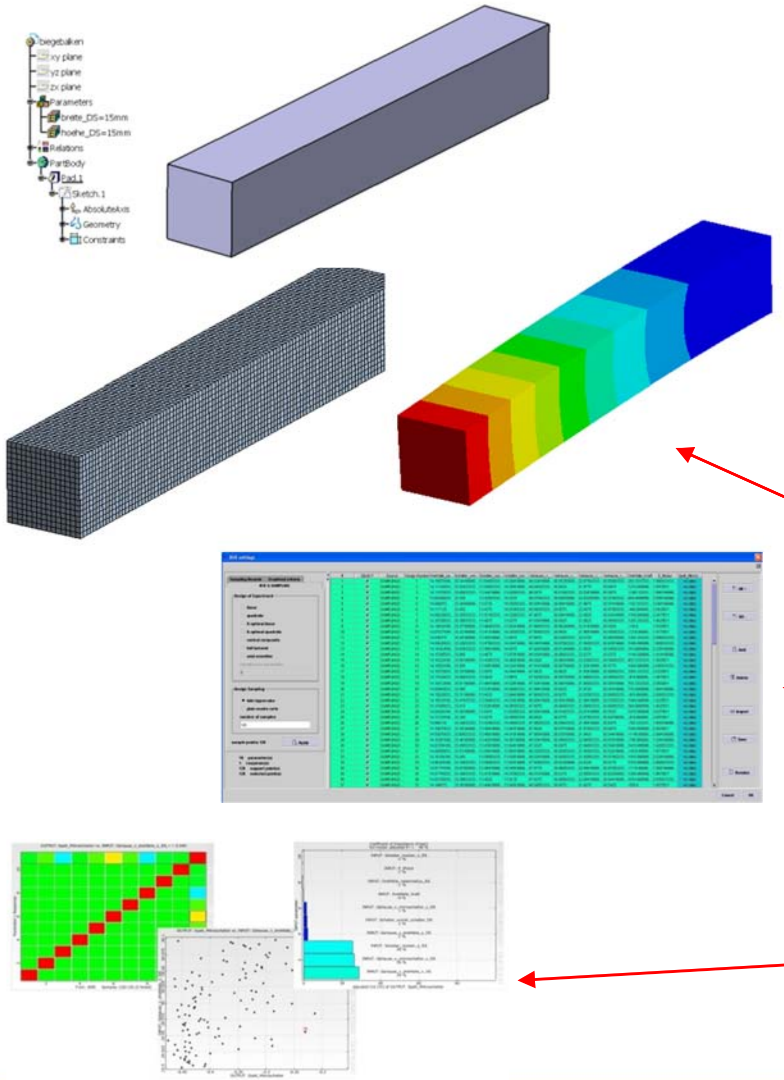
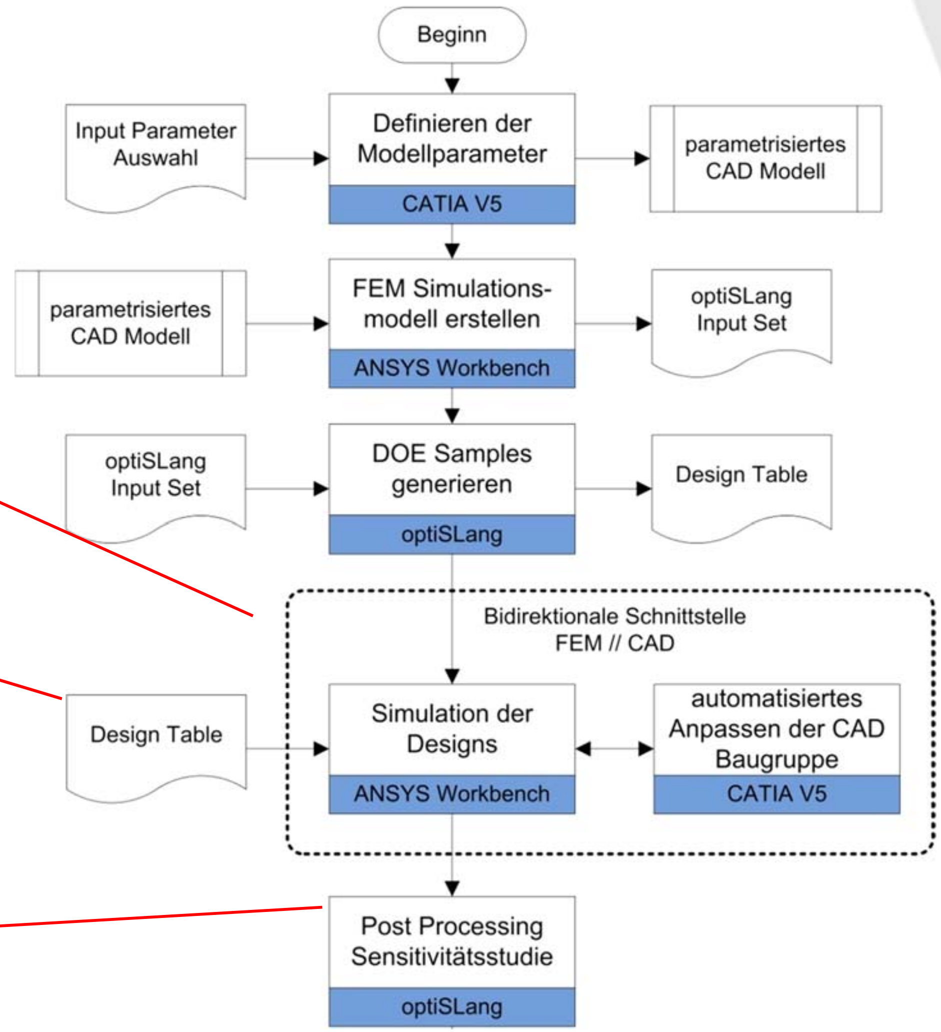
Coppling between Catia V5, ANSYS Workbench and optiSLang





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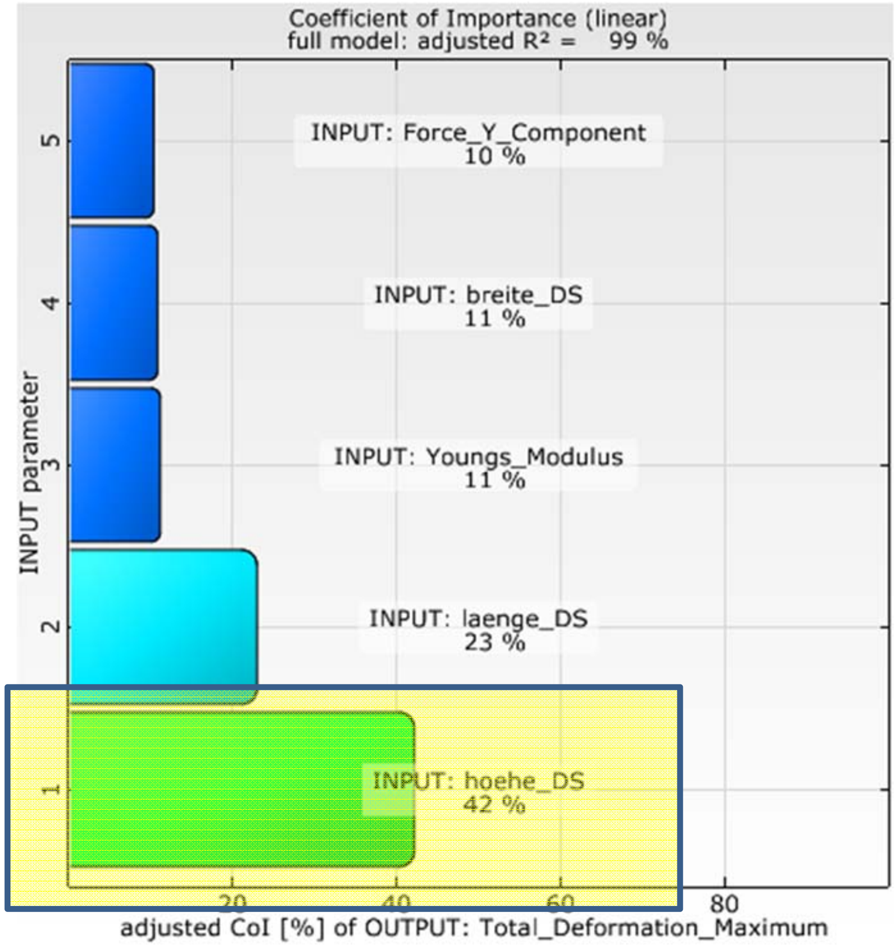
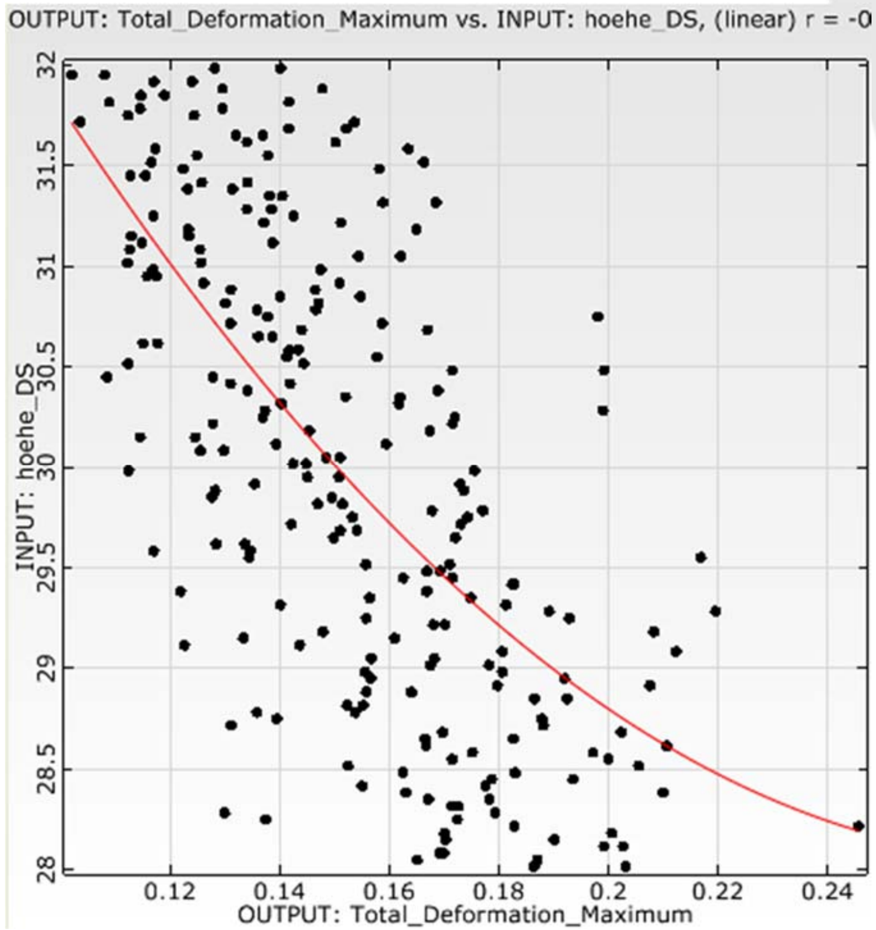
Statistical Results
Postprocessing after DOE (LHS;120 Designs)





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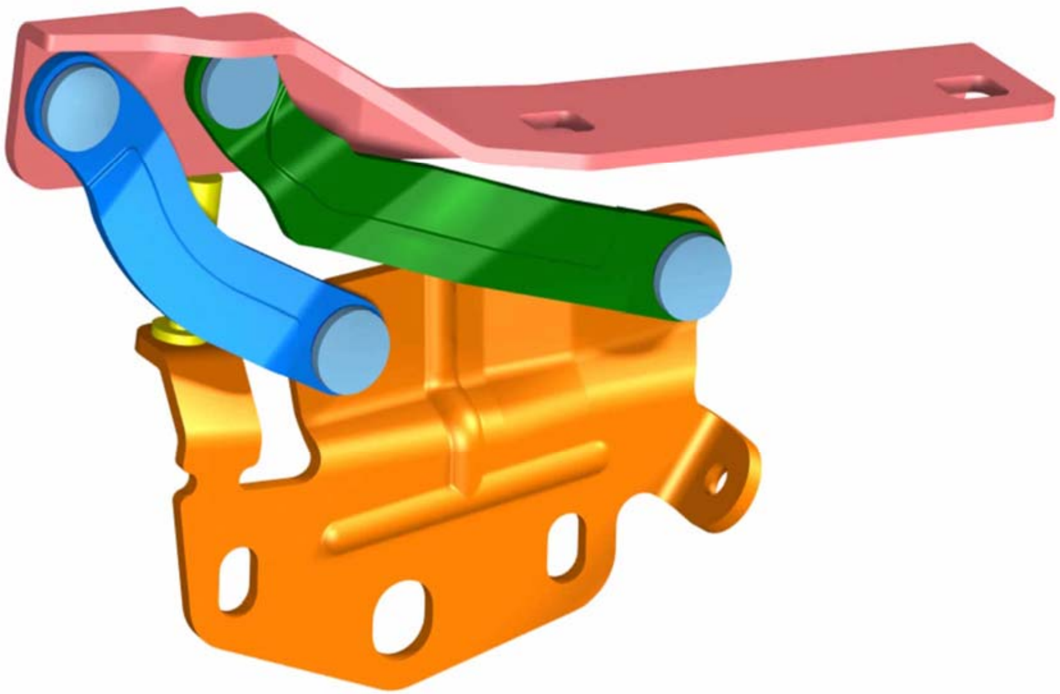
Sensitivity Study - Hinge Parameters



Parameterliste für Viergelenkscharnier

Modell: viergelenkscharnier.CATProduct
Referenz: 911.512.151.01. CATProduct
Datum: 02. Jan 11
System: CATIA V5 R19
Erstellt durch: Christoph Schluer

			Toleranzbereich	
Parameterbezeichnung	**Einheit**	**Istmaß**	**max**	**min**
`_koppel_blechdicke_DS`	mm	3	4	2
`_koppel_laenge_umschlag_anlenkstelle_DS`	mm	114	120	60
`_koppel_laenge_umschlag_kugelzapfen_DS`	mm	40	45	35
`_koppel_haubenaufnahme_sprung_DS`	mm	6,5	>6,5	6,5
`_koppel_breite_aufnahmeseite_haube_DS`	mm	28	33	23
`_koppel_verpraegung_aufnahme_kugelzapfen_DS`	mm	2	6	1
`_koppel_verpraegung_aufnahme_lenker_DS`	mm	2	2	1,6
`_koppel_d_konturausschnitt_biegung_DS`	mm	1,5	2	1
`_koppel_breite_aufnahme_anschlagpuffer_DS`	mm	15	20	10
`_koppel_uebergangsradius_anlenkstelle_DS`	mm	5	50	5
`_koppel_hoehe_umschlag_anlenkstellen_DS`	[illegible]	11,5	17	7
`_gestell_blechdicke_DS`	[illegible]	3	4	2
`_gestell_skalierung_tasche_DS`	[illegible]	1	1,3	0,6
`_gestell_uebergangsradius_aufnahmepl[illegible]rne_DS`	[illegible]	8	8	1
`_gestell_laenge_aufnahmeplatte_DS`	[illegible]	123,771	130	119
`_gestell_hohe_aufnahmeplatte_hinten_DS`	[illegible]	10,5	13,5	6
`_gestell_uebergangsradius_aufnahmeplatte_hinten_DS`	[illegible]	15	30	15
`_gestell_breite_auflageflaeche_1_DS`	[illegible]	27,265	33	24
`_gestell_breite_auflageflaeche_2_DS`	mm	45	50	45
`_gestell_breite_auflageflaeche_3_DS`	mm	34,735	35	30
`_gestell_aufnahmeplatte_breite_1_DS`	mm	34	35	30
`_gestell_aufnahmeplatte_breite_2_DS`	mm	34	35	30
`_langer_lenker_blechdicke_DS`	mm	3	3	2,20
`_langer_lenker_winkel_verpraegung_DS`	deg	45	88	45
`_langer_lenker_breite_DS`	mm	18	21	16
`_langer_lenker_winkel_links_DS`	deg	4,205	5	3,5
`_langer_lenker_winkel_rechts_DS`	deg	4,205	5	3,5
`_langer_lenker_breite_verprägung_DS`	mm	5,151	5,152	5,151
`_langer_lenker_absatzhoehe_DS`	mm	3	4	3
`_kurzer_lenker_blechdicke_DS`	mm	3	3,2	2
`_kurzer_lenker_sickenhoehe_DS`	mm	1	1,5	1.0
`_kurzer_lenker_breite_gestellseite_DS`	mm	9	11	9
`_kurzer_lenker_breite_koppelseite_DS`	mm	9	11	9
`_kurzer_lenker_schraegungswinkel_versteifung_DS`	deg	45	50	10
`_kurzer_lenker_sprung_DS`	mm	4	7	4
`_kurzer_lenker_breite_verpraegung_DS`	mm	21	21,5	20
`_kurzer_lenker_position_versteifung_DS`	mm	17,5	17,5	15
`_koppel_anschraubbohrung_vorne_x_DS`	mm	40,8	32,8	48,8
`_koppel_anschraubbohrung_hinten_x_DS`	mm	195,828	203	187
`_koppel_stichmass_DS`	mm	31,58	31,53	31,63
`_langer_lenker_stichmass_DS`	mm	115,35	115,3	115,4
`_kurzer_lenker_stichmass_DS`	mm	60,614	60,564	60,664
`_gestell_stichmass_DS`	mm	86,45	86,4	86,5
`_gestell_stich_in_x_DS`	mm	86,15	86,1	86,2
`_koppel_verspannschraube_in_x_DS`	mm	3	0,5	10

?

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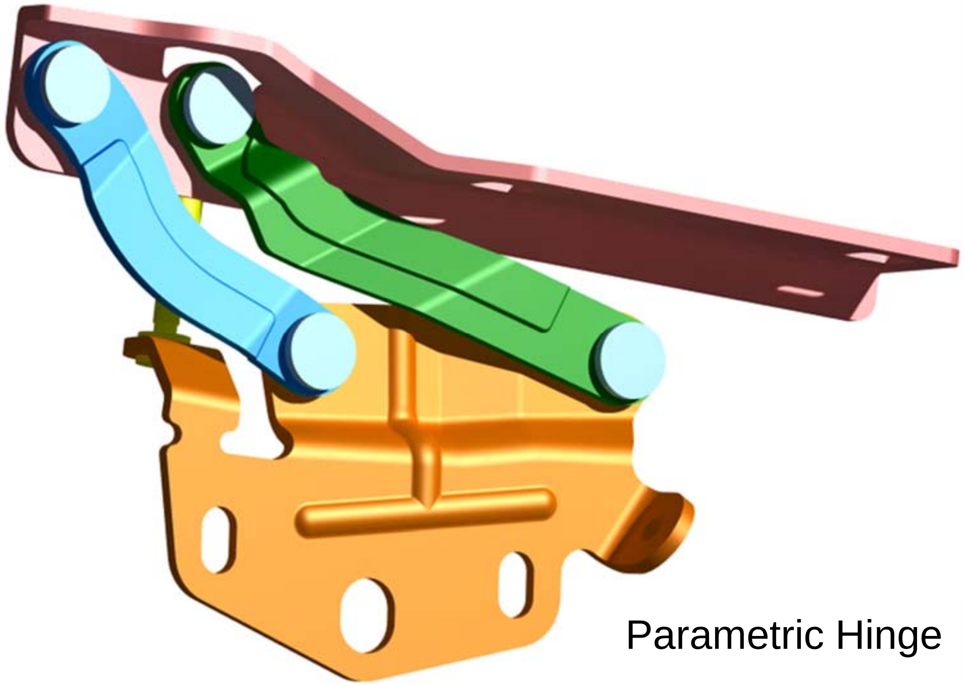
Parametric CAD Model

- All CAD Data is fully parametric designed
- The CAD Modell must react robust against parametric automatic changes
- The model includes 38 control parameters
- The assembly consists of 60 Parts

Hood



Parametric Hinge

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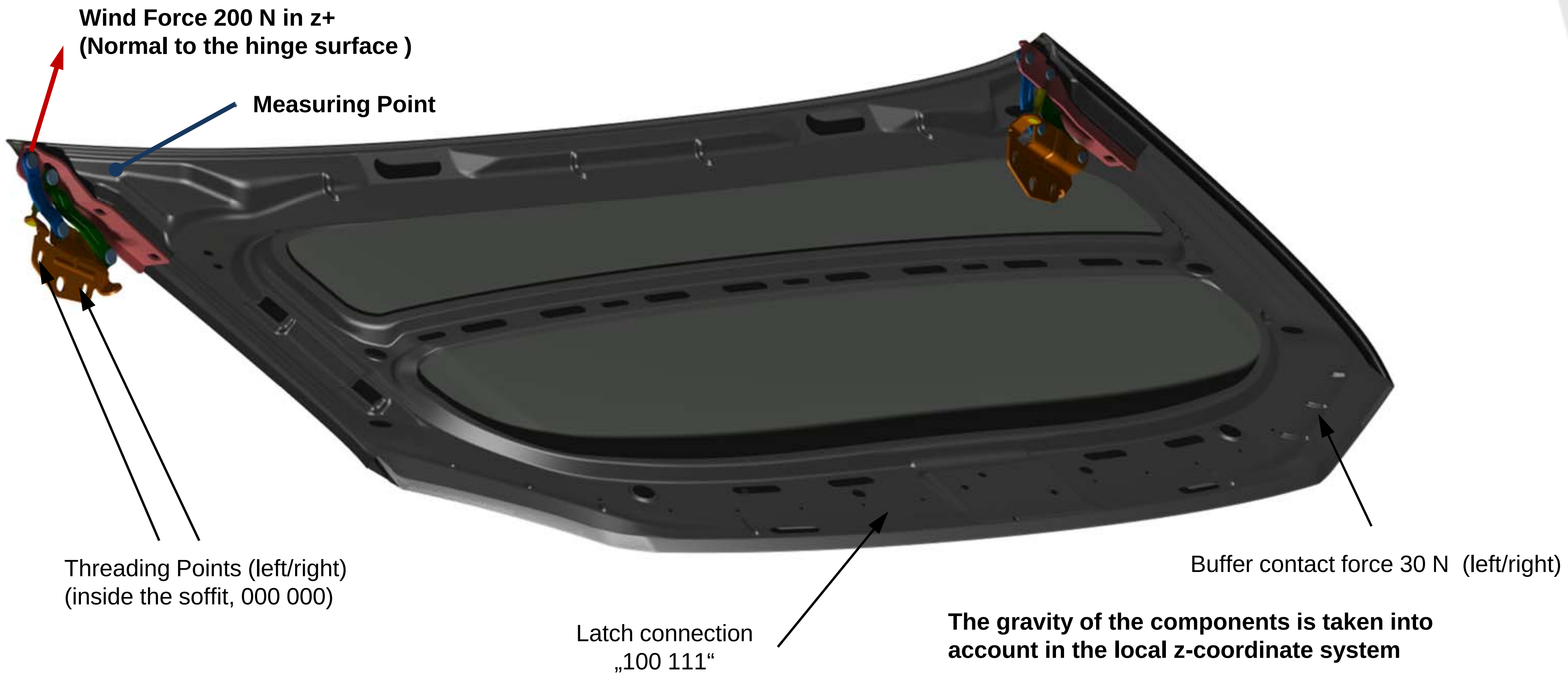
Build up a Simulation Model for the calculation of the hinge wind stiffness

Boundary Conditions and Load:

- The bushings in the connecting rods are discretizised with a single solid.
- Between the bushes and the other components is one involving friction contact condition.
- The buffers are mapped using a spring-replacement model.



The gravity of the components is taken into account in the local z-coordinate system

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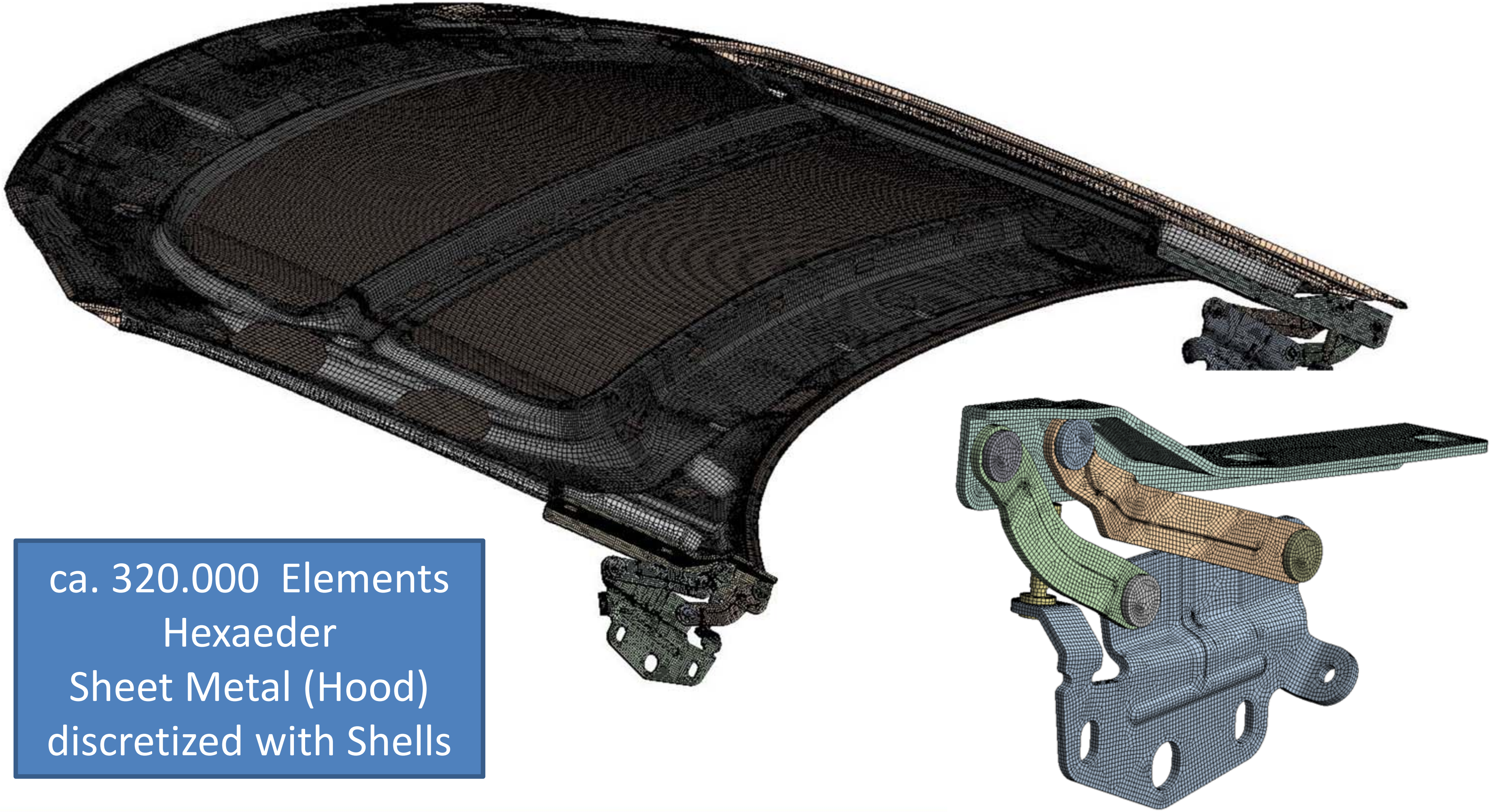
FEM-Model: Discretization



ca. 320.000 Elements
Hexaeder
Sheet Metal (Hood)
discretized with Shells

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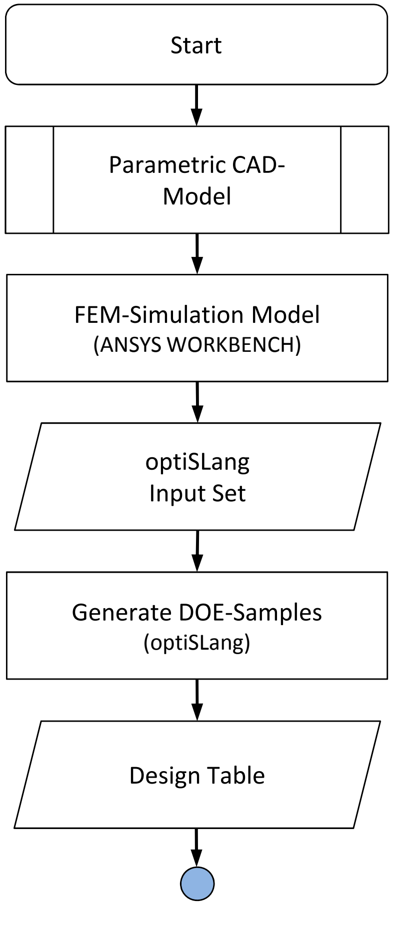
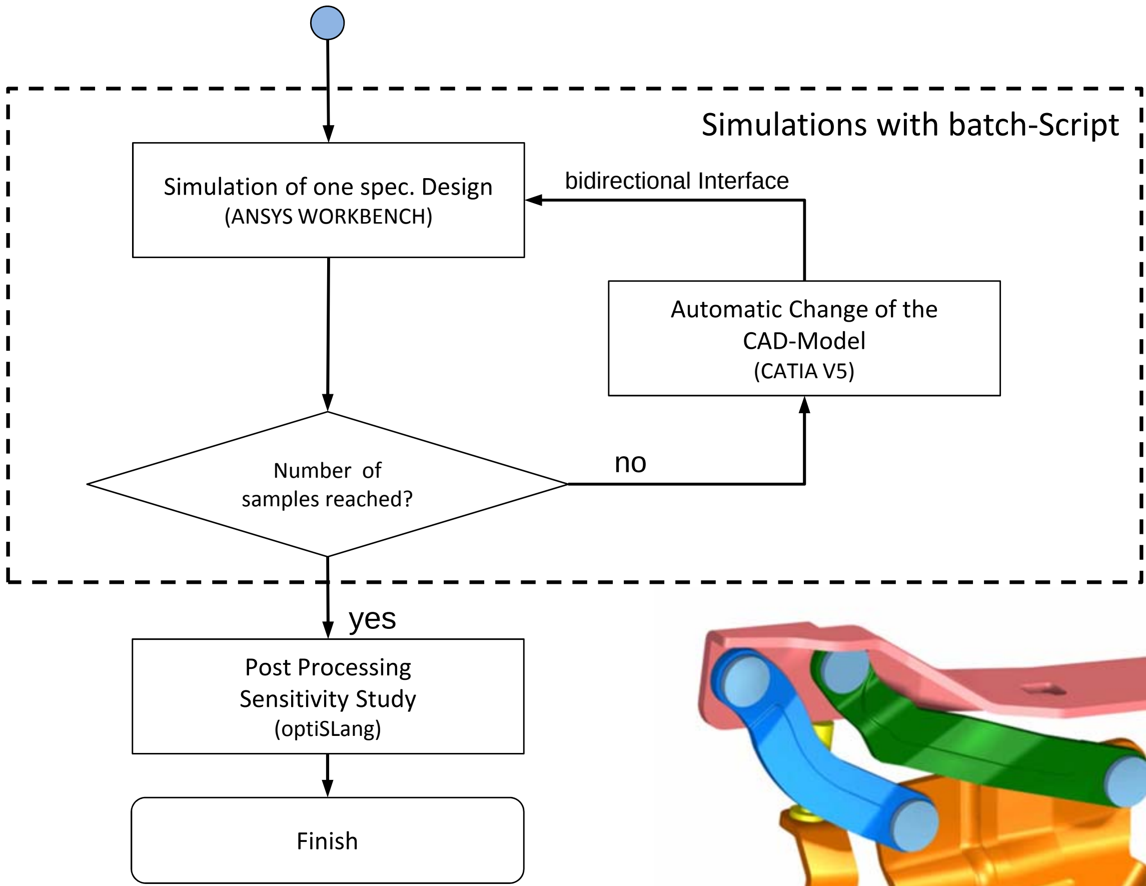
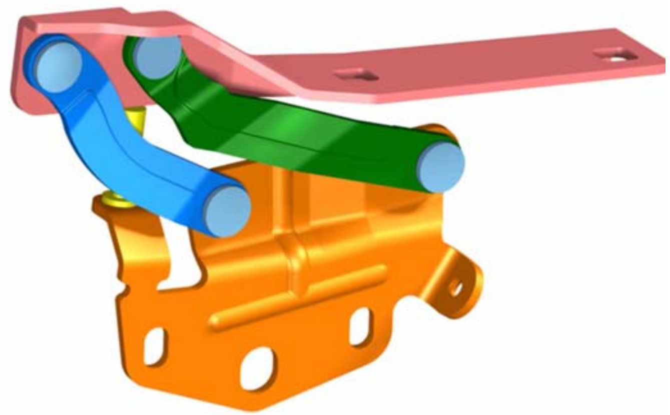
Workflow







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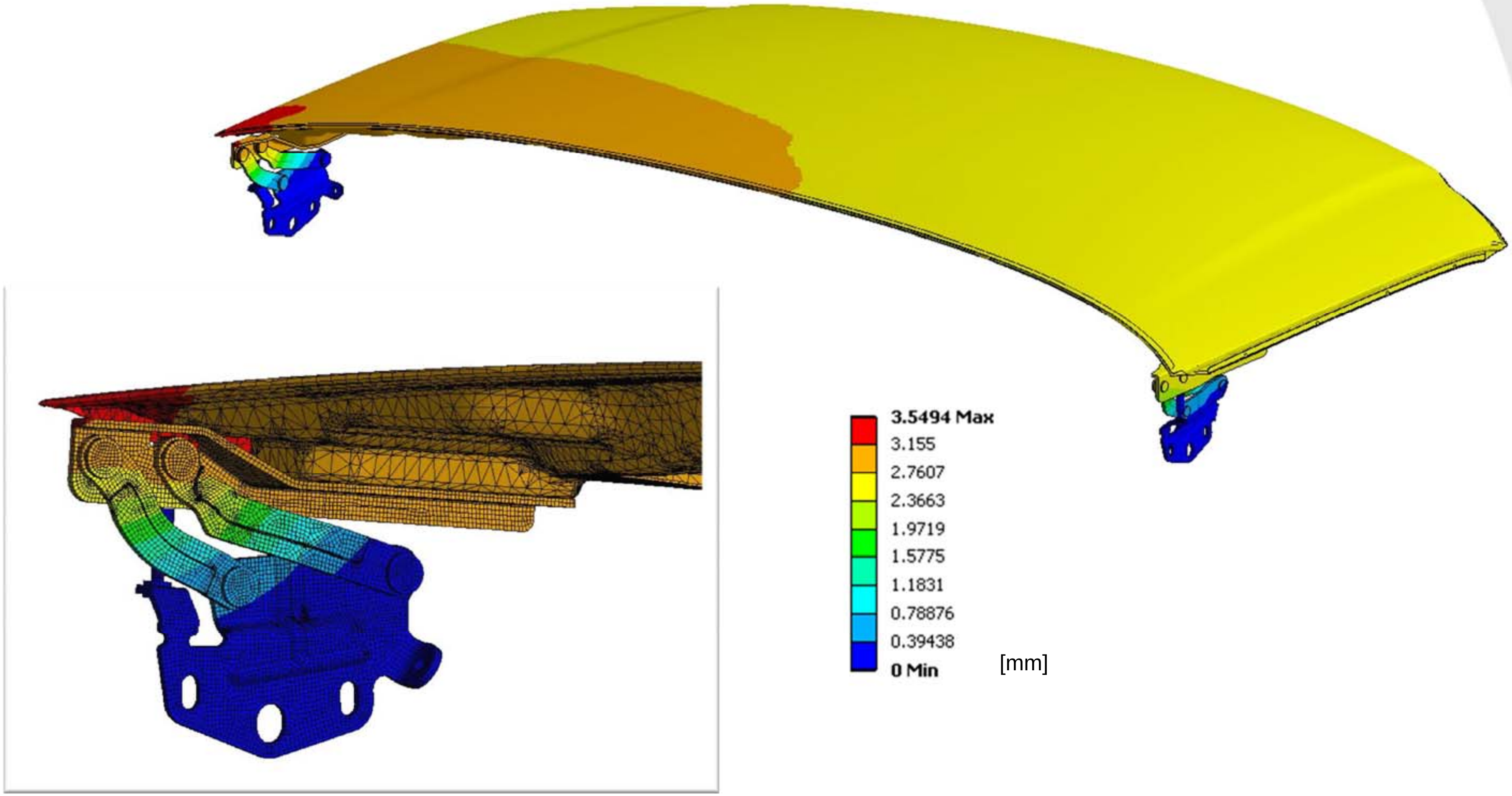
Results: Deformation under 200N wind load



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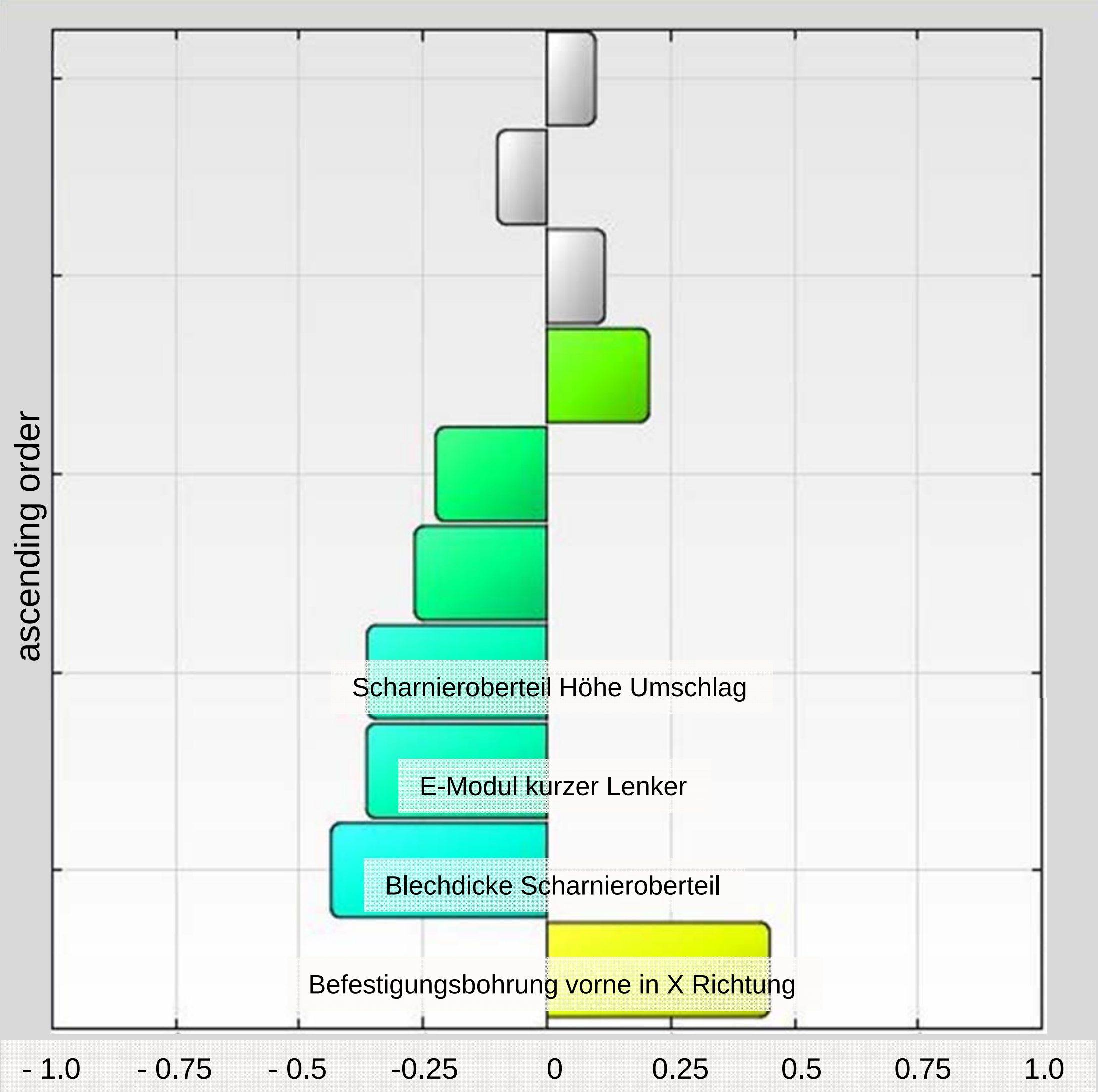
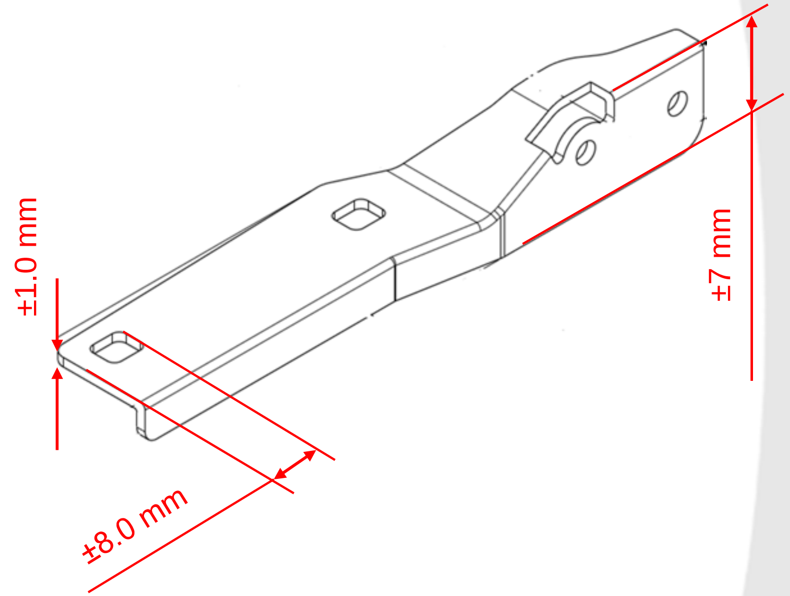
Tolerance analysis of a four bar hinge
PostProcessing with optiSLang – Correlation coefficient





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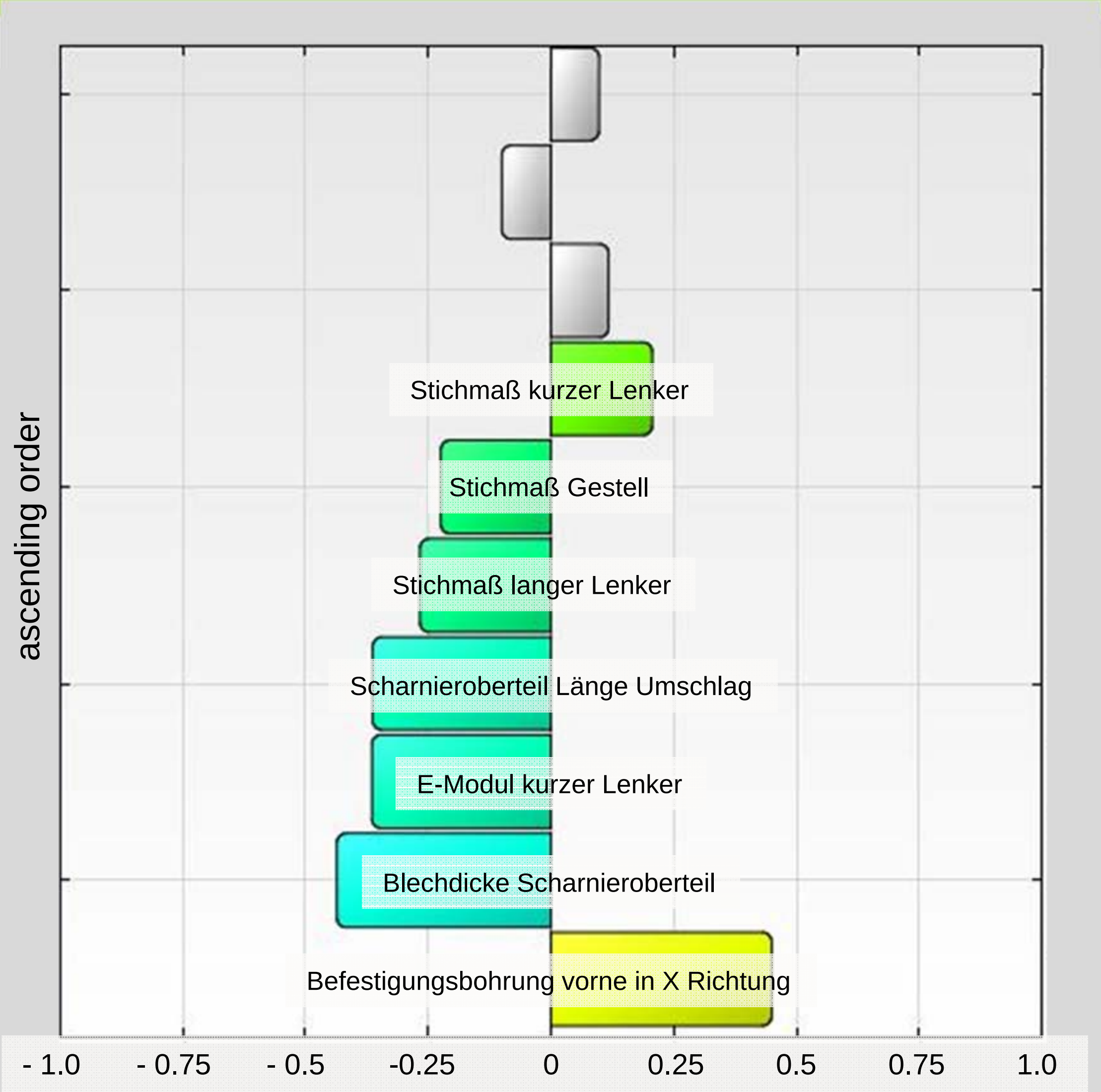
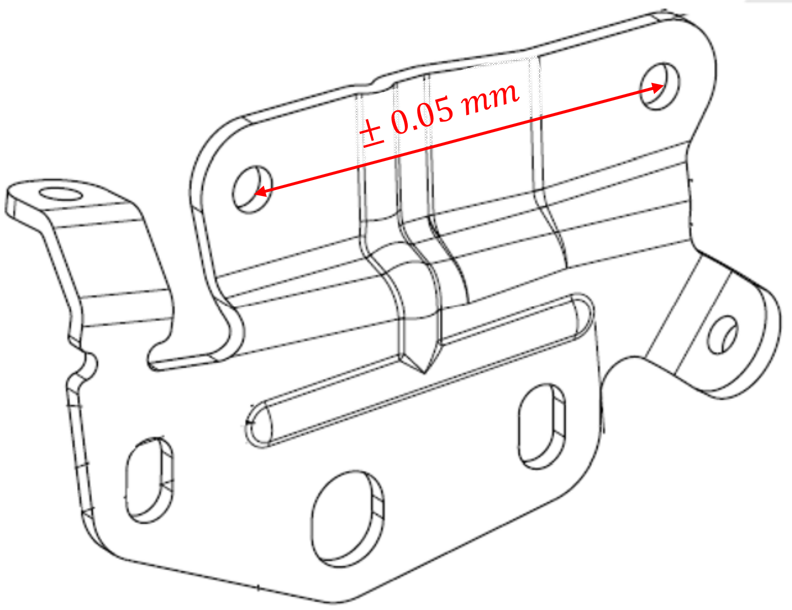
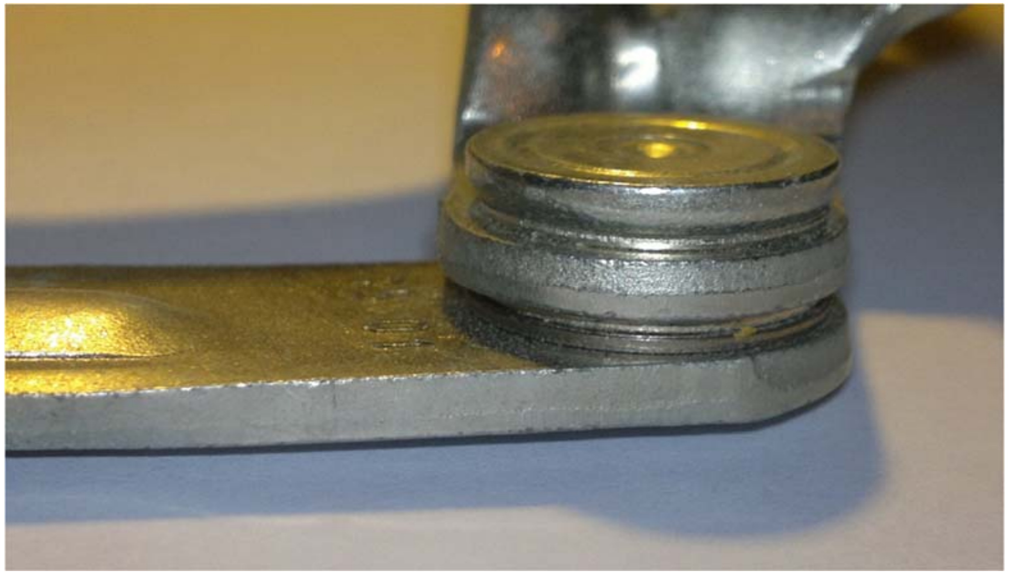




Conclusion and Outlook „Hinge Design“

1. Methods Sensitivity Study is a suitable base for the optimization of sheet metal mechanism like automotive hinge systems.
2. The mechanism become more and more complex like hinge systems for pedestrian safety!



3. We still have unsolved problems!
   – Lifetime safety (durability)
   – Uncontrolled opening torques at -40°C

Idea: Influence of the Surface Shape Tolerance

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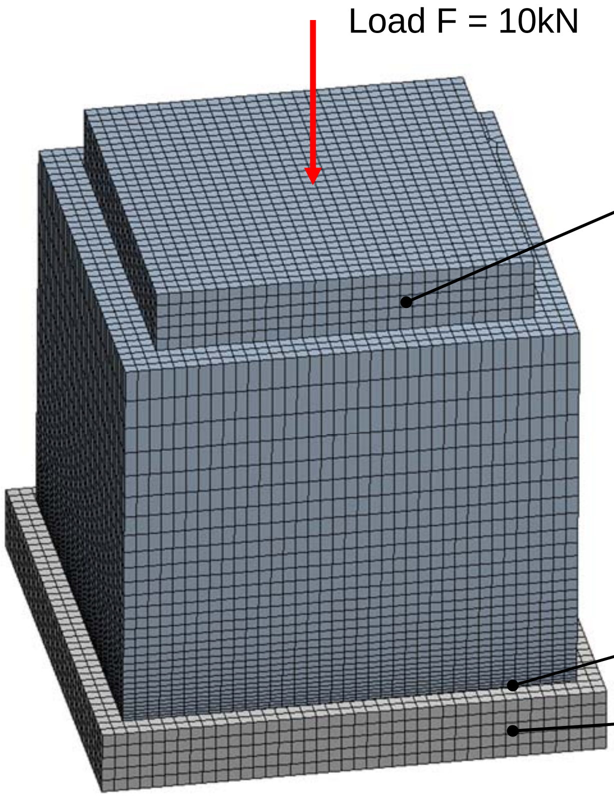
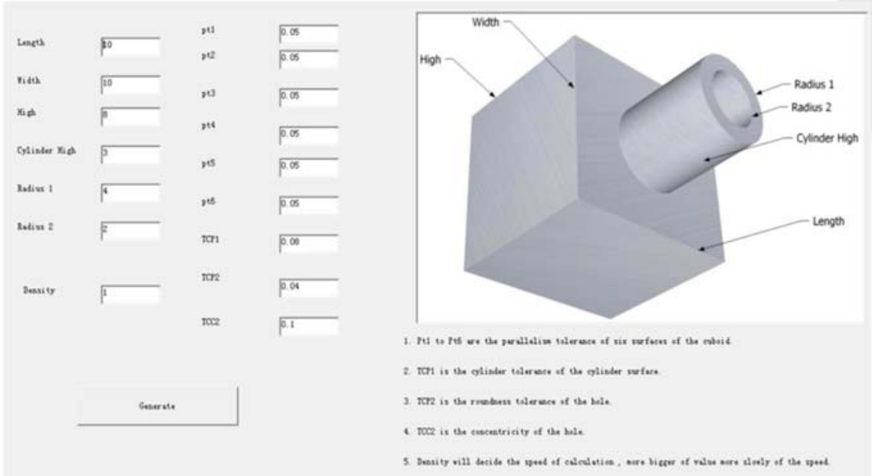
Randomly Deformed Bodies

For the reference case is shown below FE analysis is performed to evaluate the influence of the shape and dimensional tolerances of parts on the stress distribution under load





LK Catia Module

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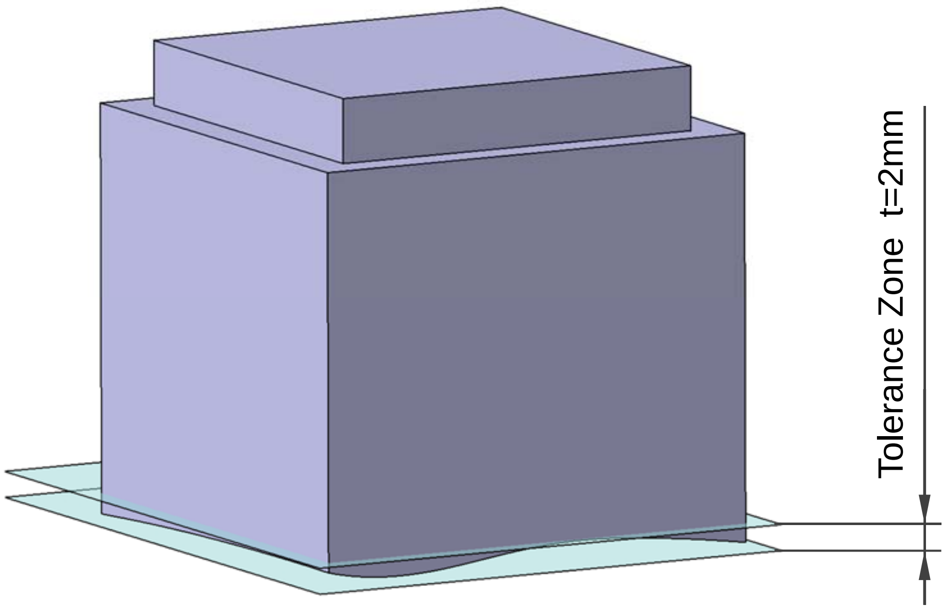
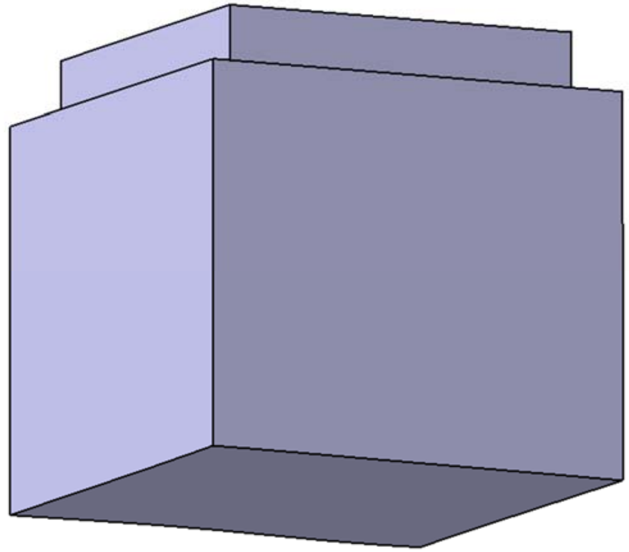
Randomly deformed bodies

Contact surface with randomly deformed shape (inside the given tolerance!)



Surface Profile Tolerance (SPT) = 2mm



SPT = 0,2mm

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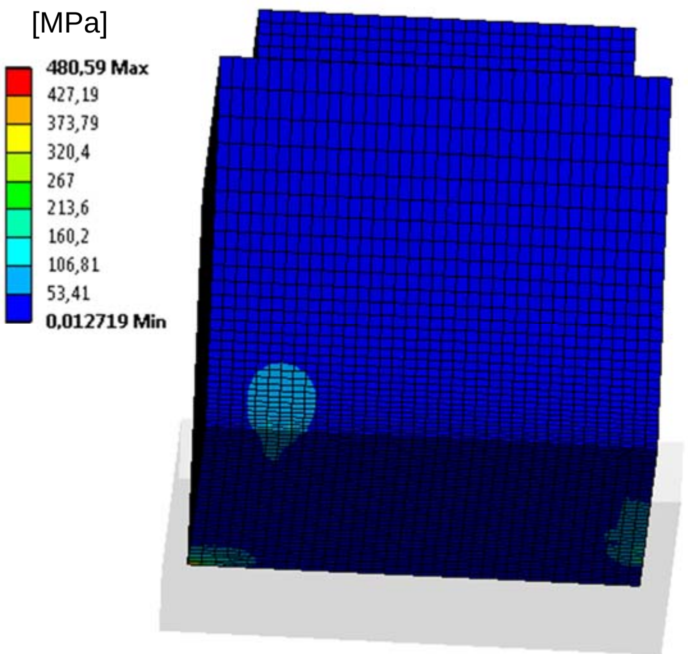
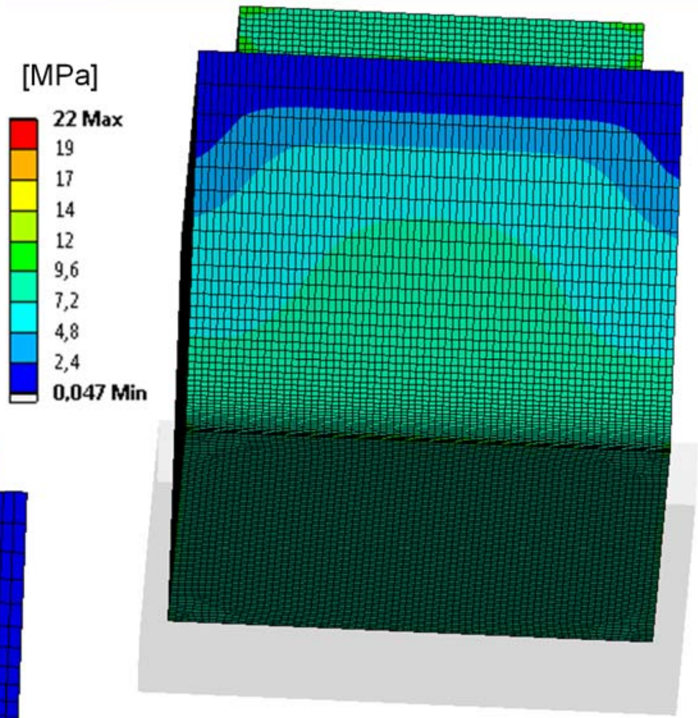
Randomly deformed bodies

First Result

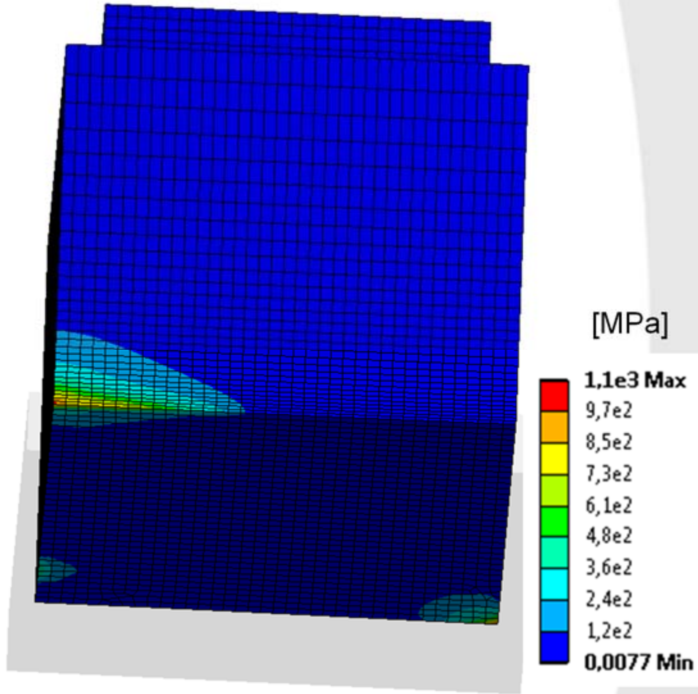
SPT = 0,1mm





SPT = 0,0mm
“Nominal Value”

SPT = 0,2mm



Lehrstuhl Konstruktion
(Engineering Design)

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Conclusion

- The results of the sensitivity study are very useful for the optimization of the hinge in relation to the wind stiffness
- The influence of surface shape tolerance is significant and will be further examined at the chair of engineering design
  - Calculation of the opening torque, hinge at f(T=-40°C)
  - Influence on fatigue calculation
  - Influence on slide bearings
  - Shrink and Press Fits