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AUTOMATED OPTIMIZATION WITH THE OPX INTERFACE USING THE EXAMPLE OF VEHICLE STABILIZERS

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Agenda

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1. THE COMPANY “MUBEA”
2. CHASSIS PART STABILIZER BAR
3. (OPTIMIZATION) WORKFLOW
4. XML-BASED INTERFACES IN OPTISLANG

THE COMPANY „MUBEA“

Facts

- Global market leader in development and manufacture of automobile products
- Owner-operated family company since 1916
- Lightweight component design specialist
- Vertical integration from raw material to finished product
- Internal development of products and production processes


Represented worldwide

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North and South America:

- 5 locations
- 2,400 employees

Europe:

- 22 locations
- 8,800 employees

Asia:

- 9 locations
- 1,800 employees

Product portfolio

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Chassis

Body

Powertrain

Industry

Products

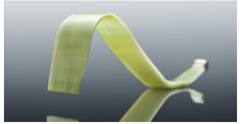
Chassis

Coil Springs

Stabilizer Bars

Stabilizer Bar add-on parts

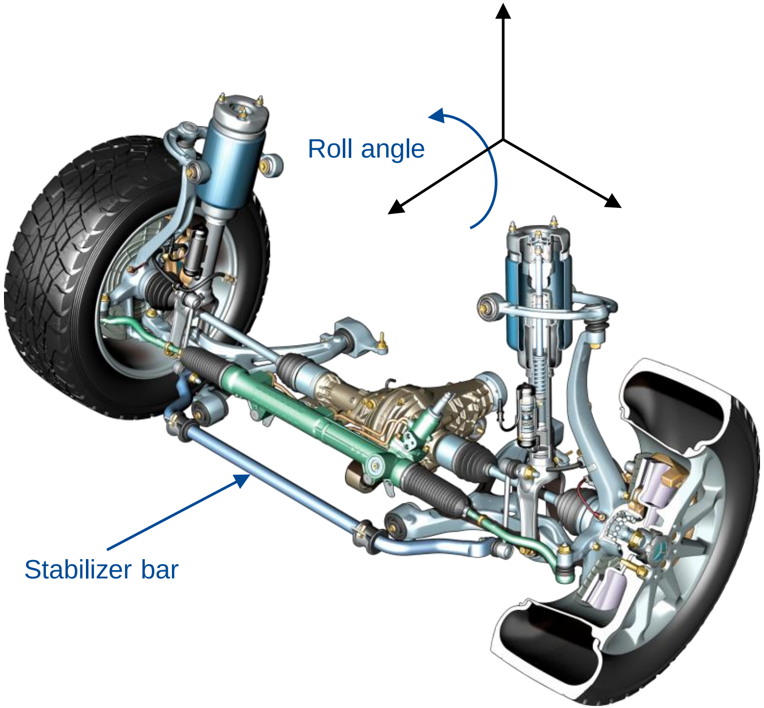
GFRP Leaf Springs



Wheels

CHASSIS PART STABILIZER BAR

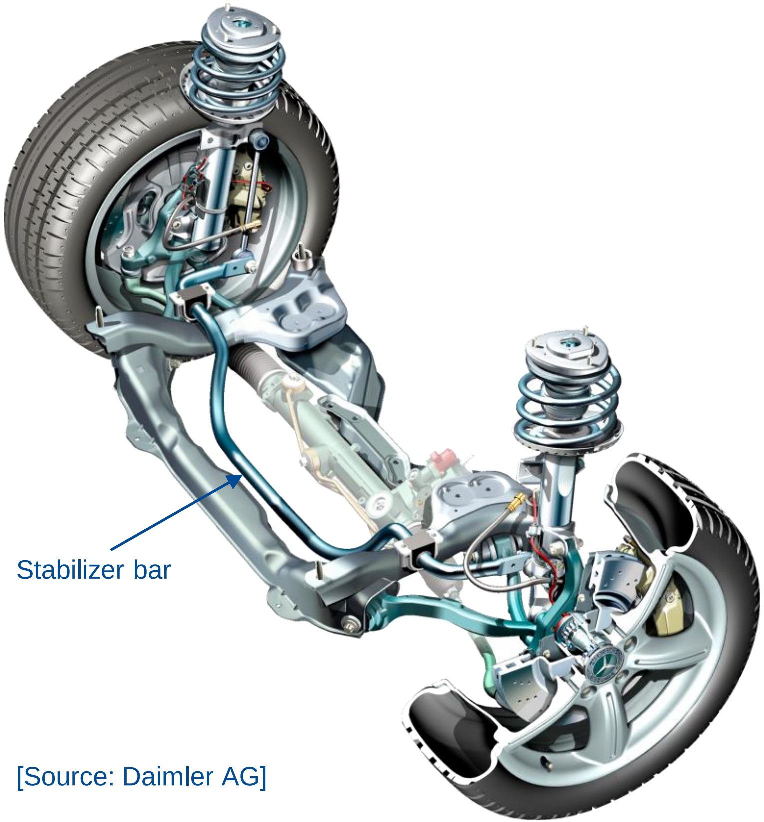
Stabilizer function



[Source: Daimler AG]

- Characteristics of stabilizer bar
  - Links right and left suspension
  - Compensates / decreases roll angle during turning manoeuvres wrt. local body frame
  - Loaded under torsion (and bending)
- Increasing spring rate results in higher compensation of roll moment
- Profile designs
  - Solid
  - Tubular
  - Hammered
  - Multiple wall thicknesses at const. outer diameter (MTT)

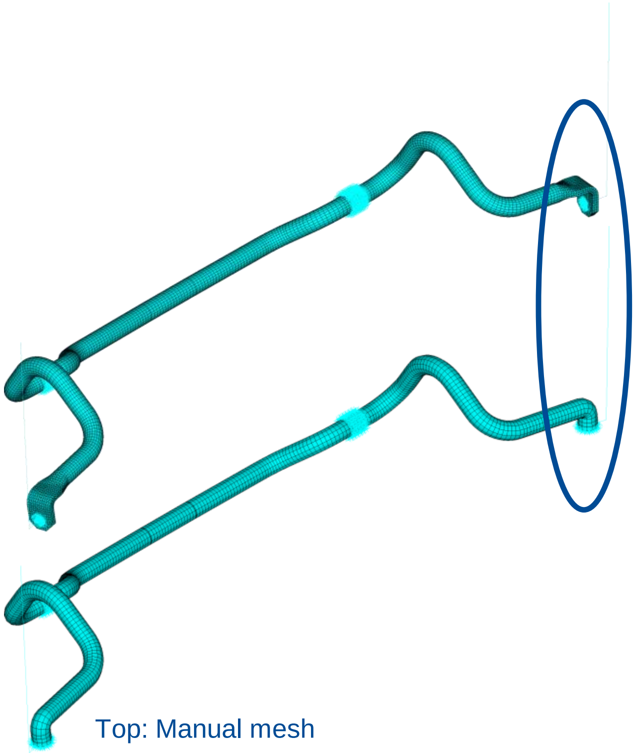
Stabilizer design



[Source: Daimler AG]

- Fixed routing due to limited design space
- Mechanical properties (spring rate) may only be adjusted through stabilizer bar profile
- Profile design is restricted by production-wise feasibility
  - Maximum wall thickness *t*
  - Minimum / maximum wall thickness ratio D_{out}/t
  - Form of crossing depending on raw material
    - Tailor Drawn Tube
    - Tailor Rolled Tube

Stabilizer FEA

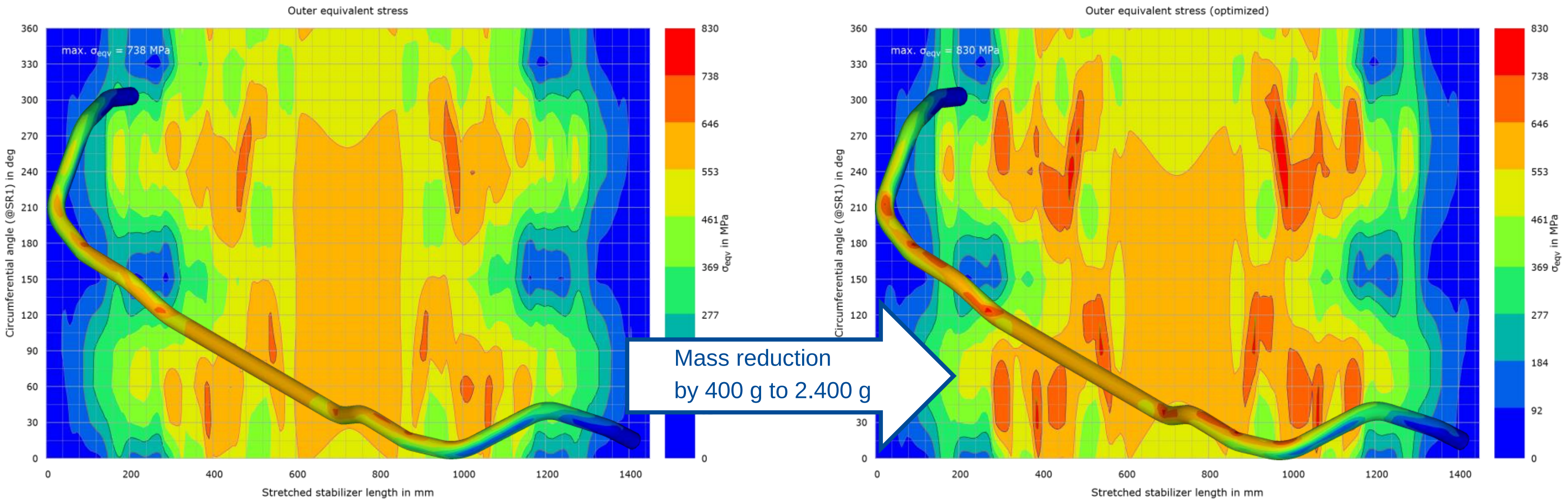


Top: Manual mesh

Bottom: Parametrized mesh (w/o paddles)

- Stabilizer is described via a polyline with circular cross sections
- Stabilizer profile may be separate input detached from routing
- Geometry and boundary conditions are parametrized in APDL
  - Neglecting paddle geometry
  - Using own meshing algorithm
- Static mechanical analysis using implicit solver in ANSYS
- Using quadratic elements
- Design objective is spring rate with minimum stabilizer mass below limit fatigue life

Stabilizer design optimization



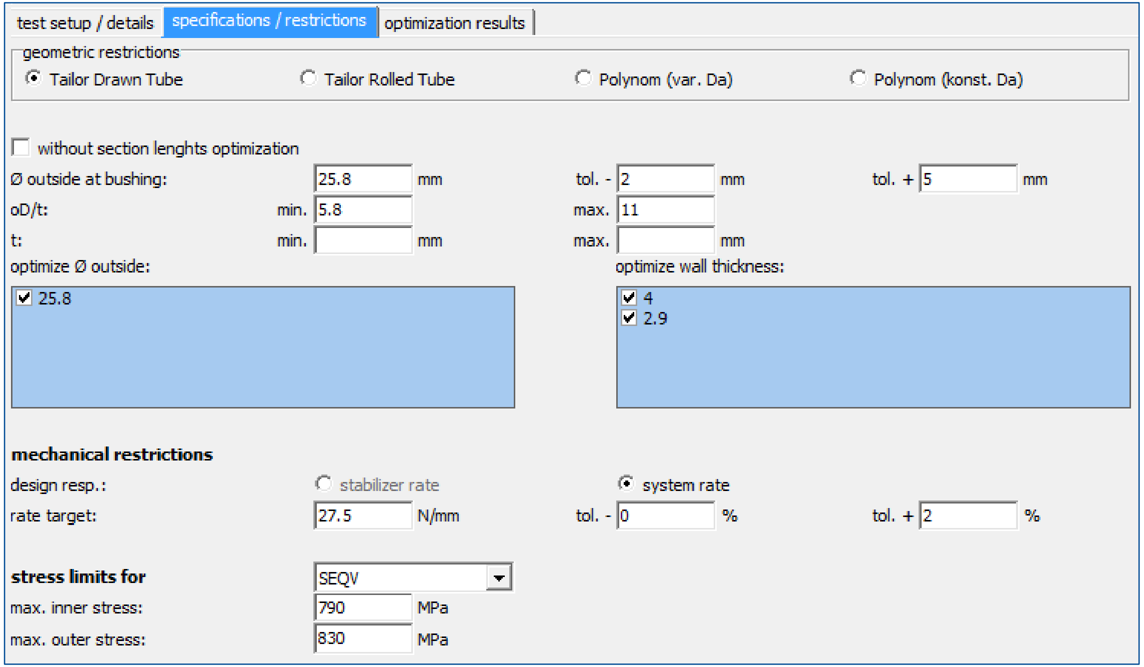
- Example of mass minimization for a stabilizer bar with multiple wall thicknesses
  - Displayed stabilizer bars are equal in spring rate (i.e. same function)
  - Utilizing the stress limits (von Mises) mass could be reduced by ca. 400 g to ca. 2.400 g

(OPTIMIZATION) WORKFLOW

Motivation

- The design process is iterative, where
  - the stabilizer profile is adjusted
  - the FEA is performed
  - the results are compared with target values
- The design process takes a lot of time and experience
- An automatization of this process would relieve the project engineer of this time consuming task and allow him/her to invest his/her time otherwise
- It is expected to find better designs using optimization algorithms

Optimization tasks using PDM



Snippet from the optimization order interface

- Optimization order is created in a PDM system
  - A reference design has to be attached
  - Geometric and FEA restrictions have to be provided with their respective tolerances
  - Input parameters may also be set as constant

Optimization workflow

- A service running on the calculation server checks regularly, if not-processed optimization orders are queued
- The optimization workflow is:
  - Order is loaded and the order‘s status is updated in the database
  - Calculation is performed based on the reference design in ANSYS
  - Input and output is text-based with a variable number of parameters and (geometric) restrictions
  - XML interface files are created for optiSLang and the optimization is performed
  - Best design is loaded and saved to the database
  - The order‘s status is updated in the database and the orderer is informed via email

XML-BASED INTERFACES IN OPTISLANG

XML usage in optiSLang

- The optimization process in optiSLang may be controlled via batch and an XML-file
- The XML-based interface in optiSLang 6.x.x is called OPX
- The XML file for problem description has to be recreated specifically for each project due to variable number of parameters
  - A DTD (Document Type Definition) file may be used to describe the XML file‘s structure
  - DTD files are also used to check XML/HTML files for structural integrity
  - Many computer languages support XML databinding to extract and create object from those DTD files
    - The XML object will contain all elements with their attributes defined in the DTD file
    - Using an XML object elements may be added and edited at run-time as often as needed before the XML (OPX) export is performed

Data Type Definition

```
<?xml version='1.0' encoding='ISO-8859-15' ?>

<!ELEMENT OPX (NODES, EDGES, NODE_ATTRIBUTES)>
  <!ELEMENT NODES (NODE)+>
    <!ELEMENT NODE (NODE)*>
    <!ATTLIST NODE
      ID  CDATA #REQUIRED
    >

  <!ELEMENT EDGES (EDGE)+>
    <!ELEMENT EDGE EMPTY>
    <!ATTLIST EDGE
      FROM      CDATA #REQUIRED
      FROMSLOT  CDATA #REQUIRED
      TO        CDATA #REQUIRED
      TOSLOT    CDATA #REQUIRED
    >

  <!ELEMENT NODE_ATTRIBUTES (ATTRIBUTES)+>
    <!ELEMENT ATTRIBUTES (ID, TYPE, (FILE, SEPARATOR, PARAMETERS, CRIT
      <!ELEMENT ID   (#PCDATA)>
      <!ELEMENT TYPE (#PCDATA)>
      <!ELEMENT FILE (#PCDATA)>
      <!ELEMENT SEPARATOR (#PCDATA)>
      <!ELEMENT PARAMETERS (PARAMETER+)>
        <!ELEMENT PARAMETER (OPTIMIZATIONATTS)>
        <!ATTLIST PARAMETER
          CONSTANT      (true|false)                      #REQUIRED
          NAME          CDATA                             #REQUIRED
          TYPE          (opti|mixed|robust|dependent)     #REQUIRED
          VALUE         CDATA                             #REQUIRED
          VALUETYPE     (real|integer|string|bool)        #REQUIRED
          FORMAT        CDATA                             #REQUIRED
          LINEOFFSET    CDATA                             #REQUIRED
          COLUMNOFFSET  CDATA                             #REQUIRED
          LENGTH        CDATA                             #REQUIRED
          EXPANDABLE    (true|false)                      #REQUIRED
        >
```

Snipped from the manually created DTD file for the OPX interface

- A DTD file consists of a root element:
  - (Sub)elements and attributes are defined top-down
  - Element and attribute names have to be unique
  - Frequency indicators may be used to enforce that certain elements are used (multiple times) or restrict an element to a single occurance
  - Atttributes may be either arbitrary strings or enumerations
- For older optiSLang versions 3.2.x DTD files are located in the installation directory
- For the OPX interface a DTD file may be create manually based on the interface description

OPX example

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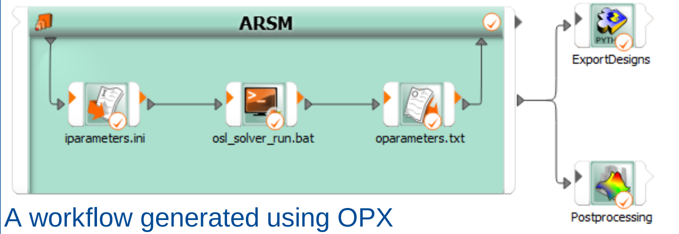
```
<!ELEMENT EDGES (EDGE)+>
  <!ELEMENT EDGE EMPTY>
  <!ATTLIST EDGE
    FROM      CDATA #REQUIRED
    FROMSLOT  CDATA #REQUIRED
    TO        CDATA #REQUIRED
    TOSLOT    CDATA #REQUIRED
  >
```

Snippet from DTD file for the OPX interface for the element EDGES

```
<?xml version="1.0"?>
<OPX>
  <NODES>
    <NODE ID="Scenery">
      <NODE ID="ARSM">
        <NODE ID="iparameters.ini"/>
        <NODE ID="osl_solver_run.bat"/>
        <NODE ID="oparameters.txt"/>
      </NODE>
      <NODE ID="Postprocessing"/>
      <NODE ID="ExportDesigns"/>
    </NODE>
  </NODES>
  <EDGES>
    <EDGE FROM="ARSM" FROMSLOT="IODesign" TO="iparameters.ini" TOSLOT="IDesign"/>
    <EDGE FROM="iparameters.ini" FROMSLOT="ODesign" TO="osl_solver_run.bat" TOSLOT="IDesign"/>
    <EDGE FROM="osl_solver_run.bat" FROMSLOT="ODesign" TO="oparameters.txt" TOSLOT="IDesign"/>
    <EDGE FROM="oparameters.txt" FROMSLOT="ODesign" TO="ARSM" TOSLOT="IIDesign"/>
    <EDGE FROM="ARSM" FROMSLOT="OMDBPath" TO="Postprocessing" TOSLOT="IMDBPath"/>
    <EDGE FROM="ARSM" FROMSLOT="OBestDesigns" TO="ExportDesigns" TOSLOT="IDesigns"/>
  </EDGES>
  <NODE_ATTRIBUTES>
```

Snippet from an OPX file



A workflow generated using OPX

- The OPX file consists of the following elements
  - NODES (input/output files, solver etc.)
  - EDGES (connections between NODES)
  - NODE_ATTRIBUTES (detailed information for all prior defined NODES)
- Example:
  - The element EDGES contains a set of the subelement EDGE
  - The element EDGE has to appear at least once (frequency indicator +)

Conclusion

- ***Optimization algorithms are powerful tools in the design process with regards to light weight products***
- ***Given a parametrized structural element a generally vaild optimization workflow can be defined***
- ***Data bases may be used to administrate optimization tasks and results***
- ***Project specific OPX files may be created automatically and optiSLang may be controlled via batch und OPX files***
- ***Automated processes are more performant and less sensitive to errors than manual processing of optimization tasks***
- ***Automated processes may free bound resources and allow focussing on other tasks***

Thank you very much for your attention!