Contact Update in Gear Box Simulation

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- Gear Box – ERC

02 Model Description and Motivation

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- Contact Geometry Update (CAU)

03 Contact Update Simulation

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- Customizing of Contacts for CAU
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01

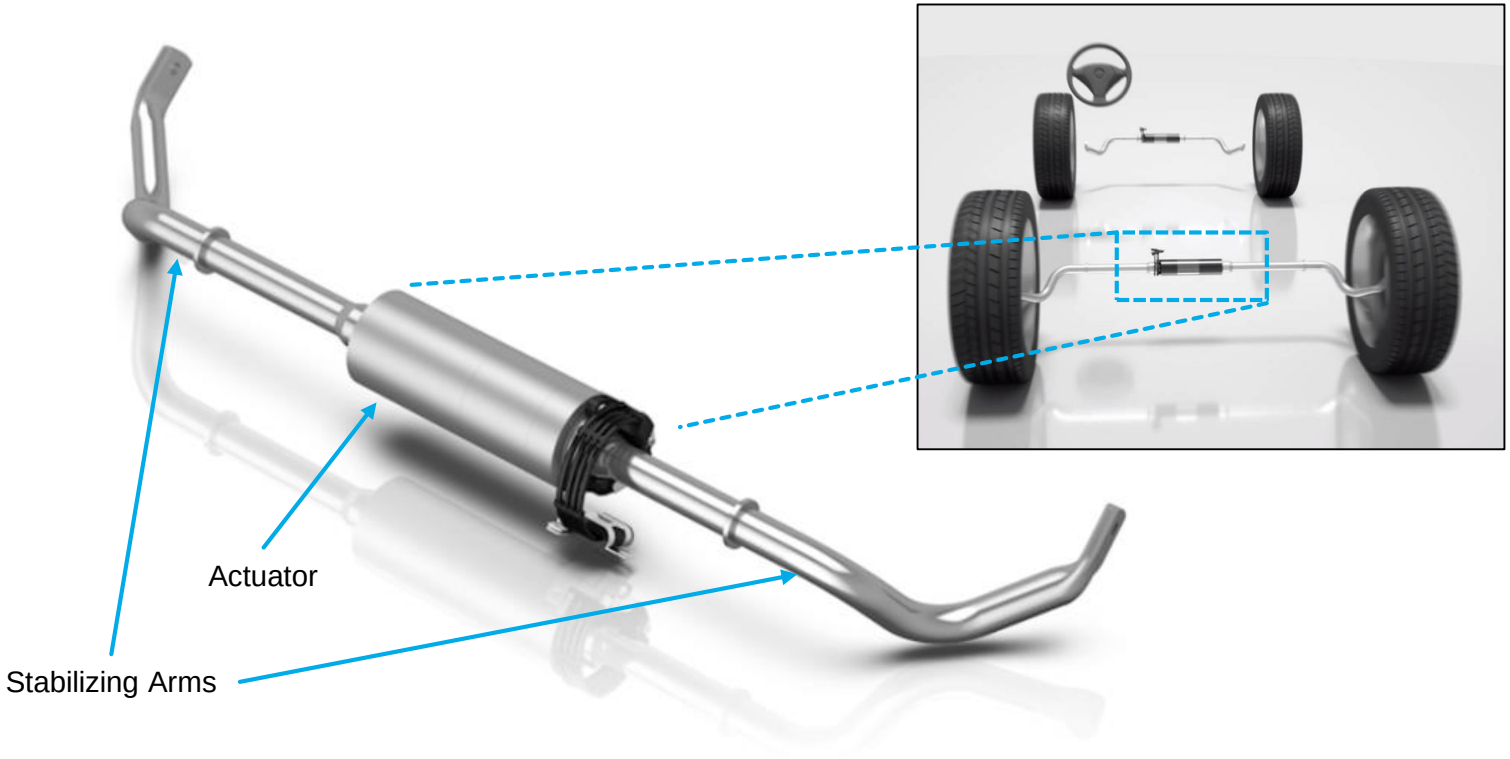
Introduction and Background

ZF Group [1]

- The leading global technology group in driveline and chassis technology as well as active and passive safety technology
- The second largest automotive supplier in the world
- Founded: 1915

- The headquarters: Friedrichshafen, Germany
- 230 locations in 40 countries and 20 main development locations

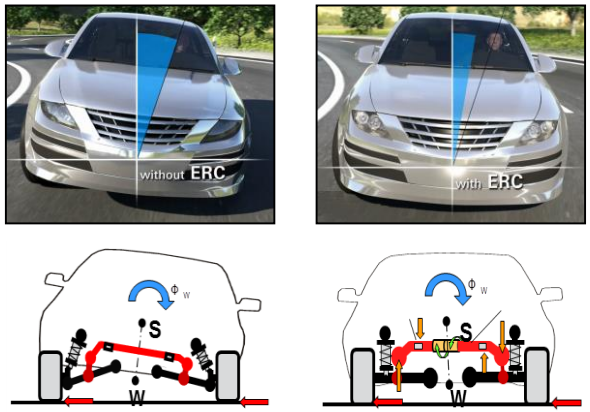
Gear Box – Electromechanical Roll Control – ERC



Gear Box – Electromechanical Roll Control – ERC

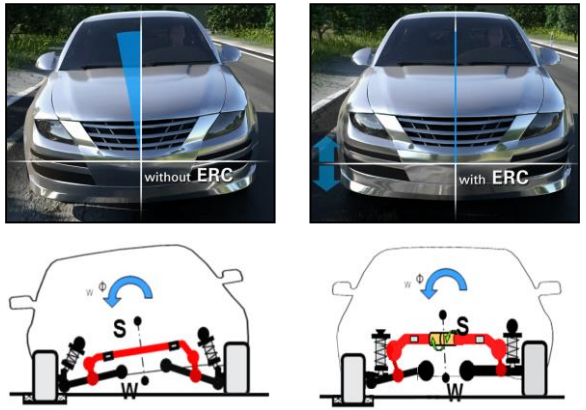
- ERC is an electromechanical active roll bar
- The system works against vehicle rolling motions (torque – applied to the stabilizing arms)
- Major components: an electric motor, a planetary gear and the integrated Electronic Control Unit (ECU)
- ERC provides additional safety functions, comfort features and improvement of vehicle dynamics

Safety and dynamics in a curve



without ERC | with ERC

Safety and comfort under unilateral stimulation



without ERC | with ERC

Cooperation ZF Friedrichshafen and ZF Engineering Pilsen

ERC Design
ZF Dielingen

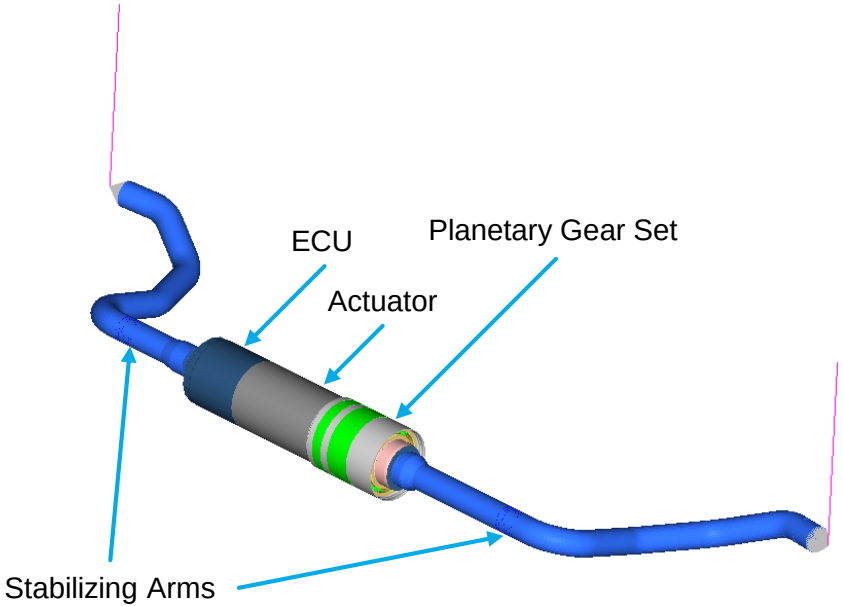
Simulations
ZF Friedrichshafen
Lars Schories

Simulations
ZF Pilsen
Karel Dráždil

02

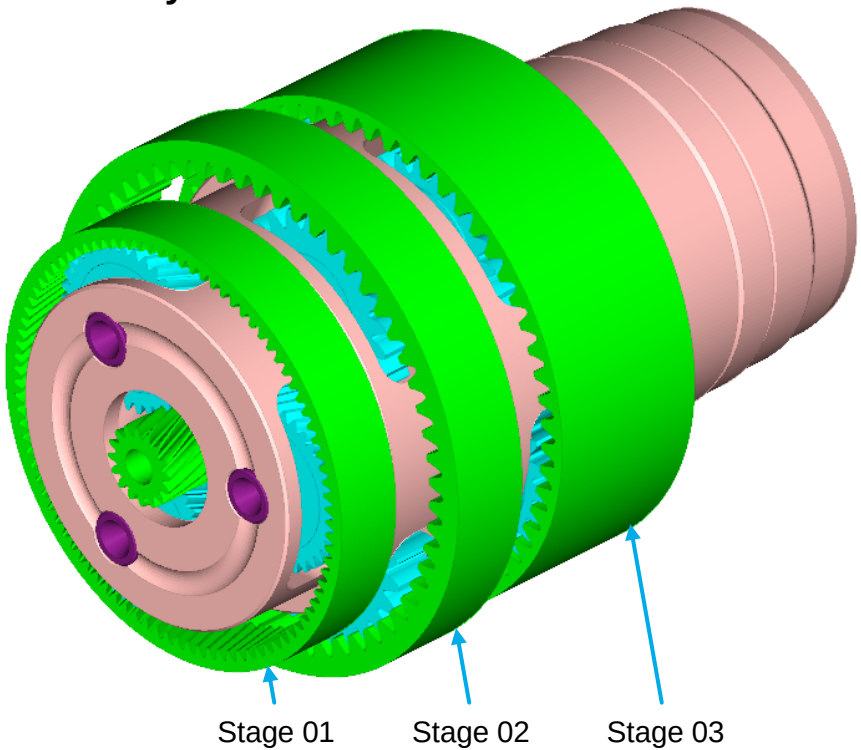
Model Description and Motivation

Model Description



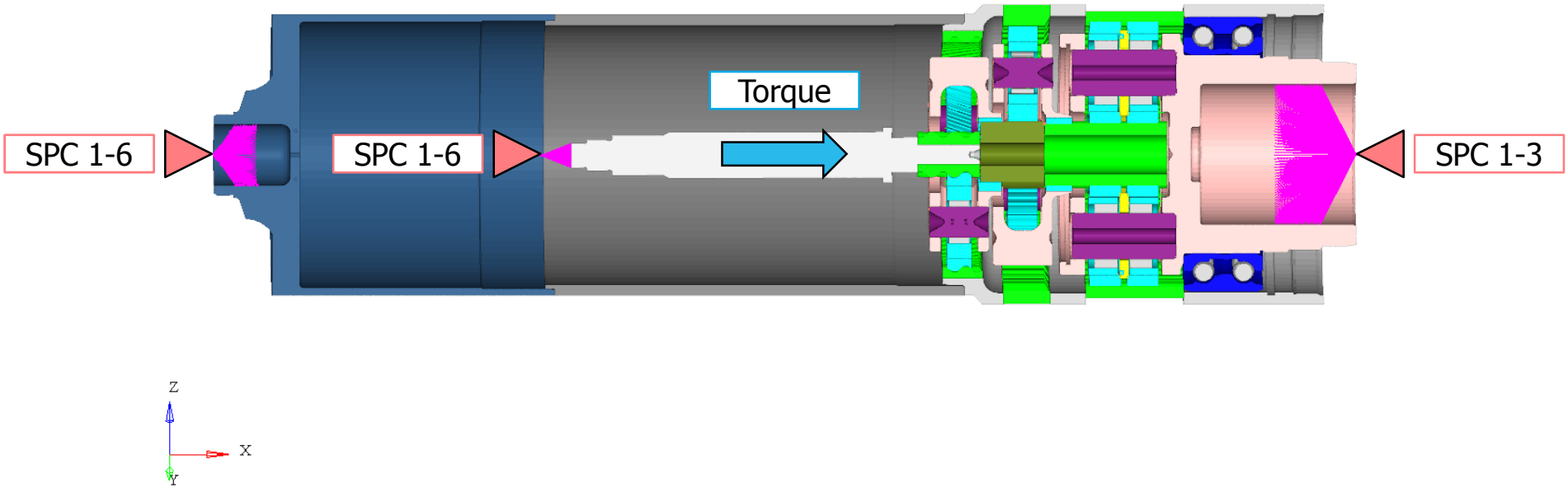
Number of Elements: ~ 3.4 million
Number of Nodes: ~ 4.5 million

Planetary Gear Set



SubModel

Boundary conditions and application of Torque



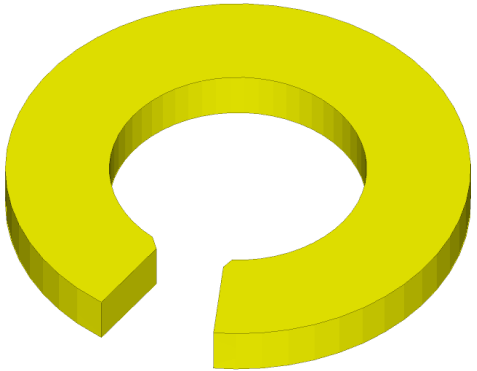
Stage 03 and Split Gear

- 4 Planets with Needle Roller Bearing

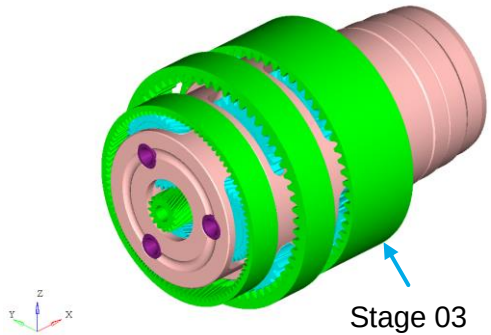
- The implementation of Springs between Planets

- Split Gear

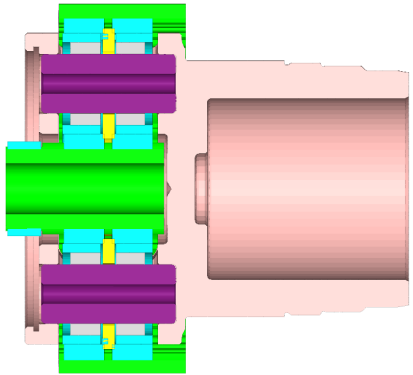
Spring (the 1st version)



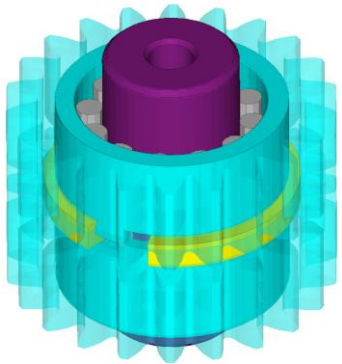
Planetary Gear Set



Stage 03



Split Gear



Split Gear functionality and Motivation

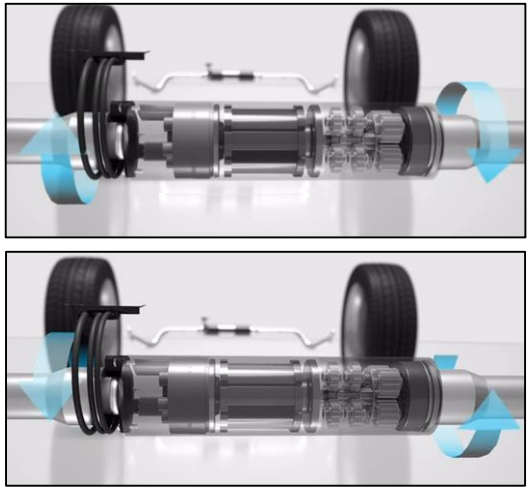
- **Stage 03 without Split Gears**
  - Changing of torque direction (very often)
  - Clearances on teeth

  } **Clicking Noise**

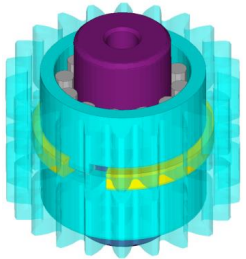
- **Stage 03 with Split Gears**
  - The implementation of Springs between Planets
  - Contact forces on both sides of teeth
  - No clearances on teeth

  } **Less Noise**

- **Motivation of using CAU**
  - The application of Split Gears with Springs
  - Assembly process should be considered (Pretension of Springs)
  - **Contact Geometry Update (CAU)**



Split Gear



Contact Geometry Update (CAU) [3]

- **Without contact geometry update**
  - The contact pairs are:
    - Determined once in the initial undeformed state
    - Kept constant over all time steps

- **With contact geometry update**
  - The contact geometry is updated at each time step according to the observed deformation
  - The final displacement status of previous time step is used as a reference displacement status for next time step → **CA Geometry Update Loop** (Core contact iteration)

- **When to use contact geometry update**
  - If the change of the contact direction appears
  - If the different contact pairing in deformed state is considered (**the pretension of the Springs between Split Gears**)

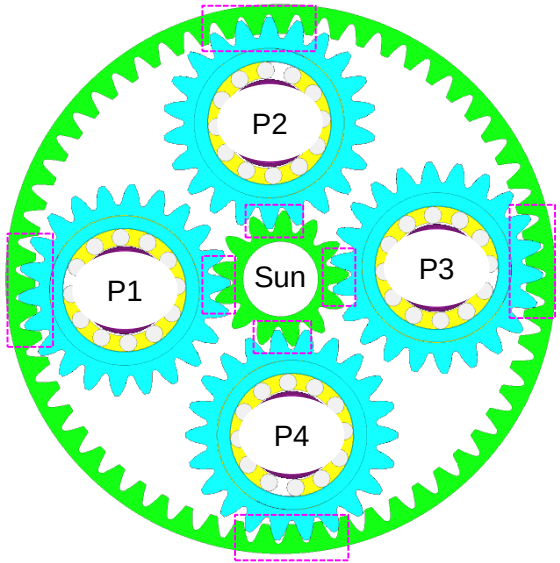
03

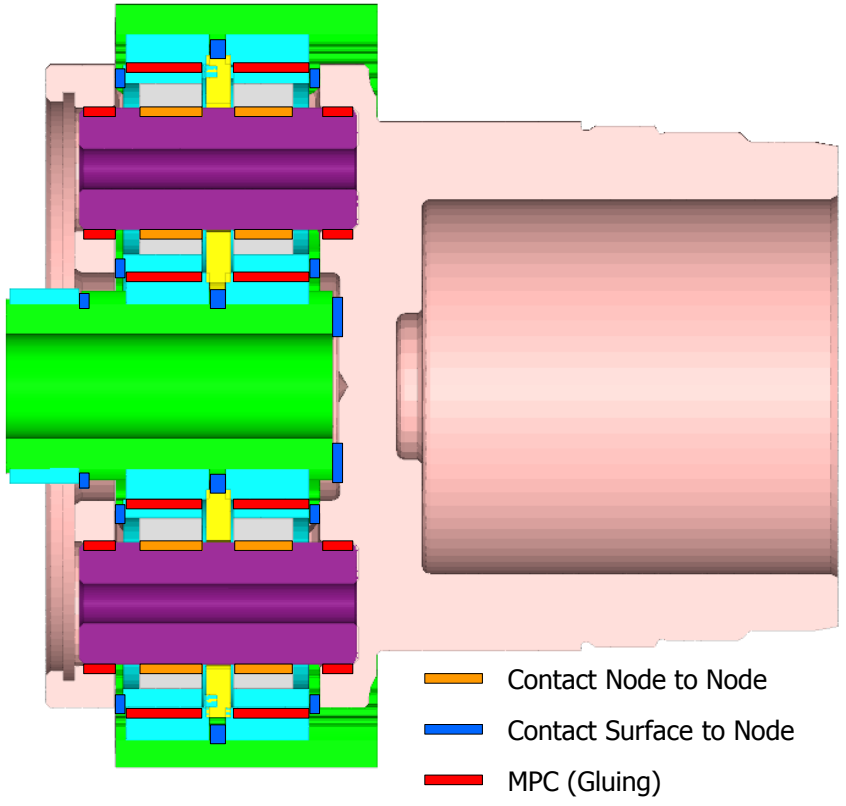
Contact Update Simulation

Contact Update Simulation

Contacts in Stage 3 without modification for CAU

Contact Surface to Surface is used on contact flanks of the teeth

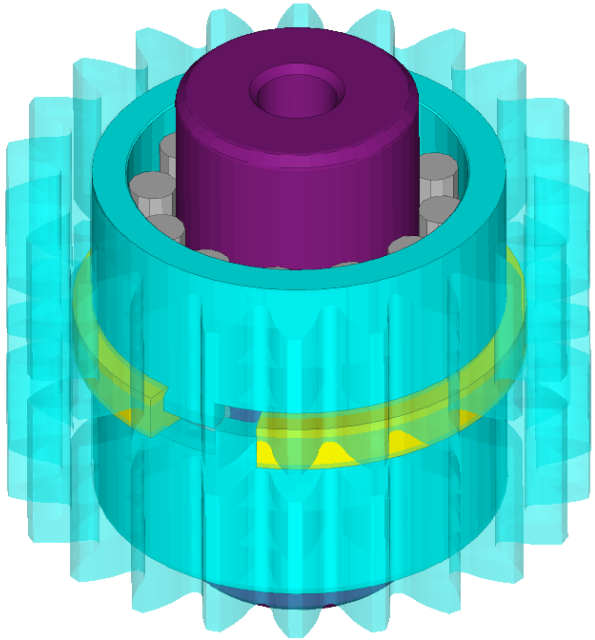




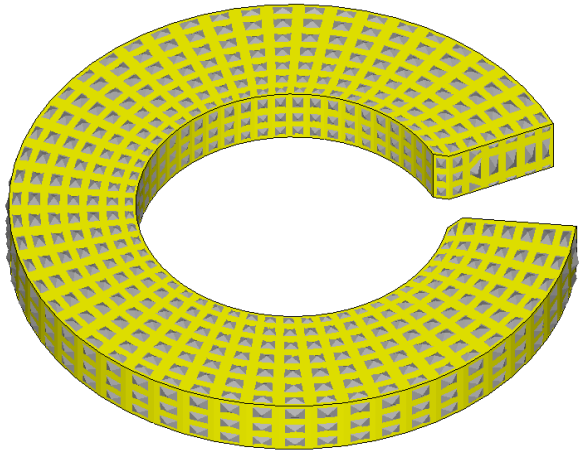
Contact Update Simulation

Contacts in Stage 3 without modification for CAU

Split Gear



The spring inside of the Split Gear is in contact on the whole surface with surroundings parts (Contact **Surface to Surface**)



Contact Update Simulation
Modification for CAU

- **What is updated [3]**
  - Contact pairs in contact definition **Surface to Surface / Node / etc.**
  - Contact system (components of contact forces) of contact definition **Surface to Surface / Node / etc.**
- **What is NOT updated [3]**
  - Contact pairs in contact definitions **Node to Node**

- **Additional information of CAU simulation [3]**
  - New search of neighboring contact pairs and contact consolidation
  - Rebuilding flexibility matrix
  - Repetition of contact iteration

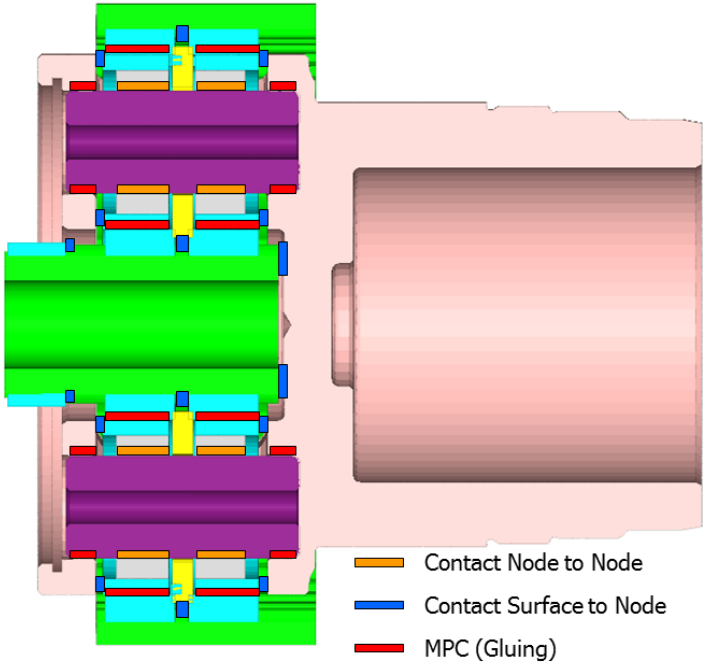
Target

- To reduce the type of contact **Surface to Surface / Node** to the type of contact **Node to Node**

Contact Update Simulation

Customizing of Contacts for CAU

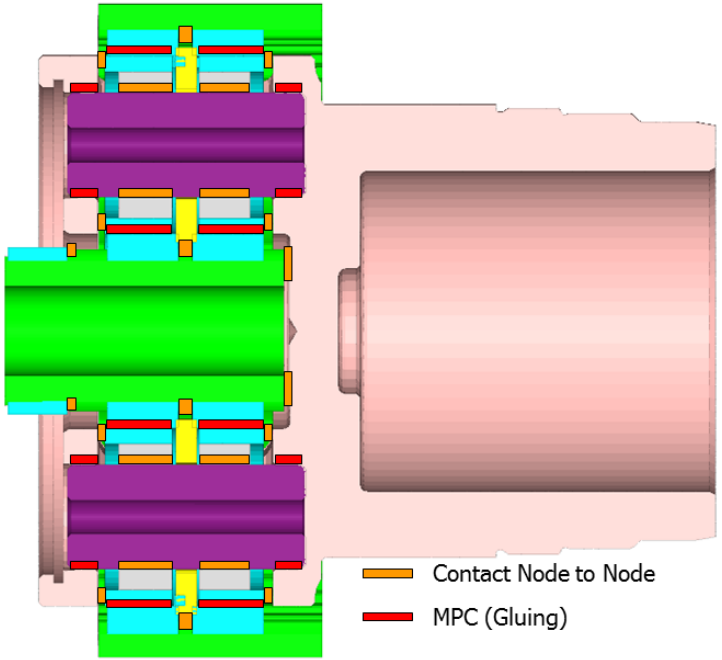
Model without modification for CAU



CA-DOFs: ~ 180 000

Reduction of Contact Surface to Node

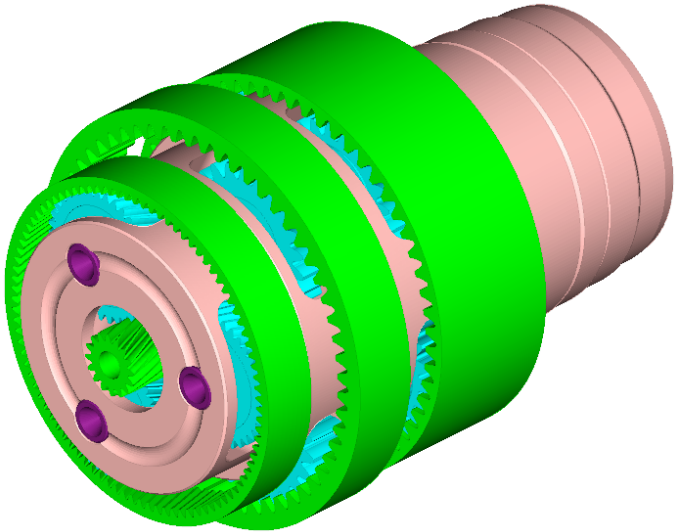
Model with modification for CAU



CA-DOFs: ~ 135 000

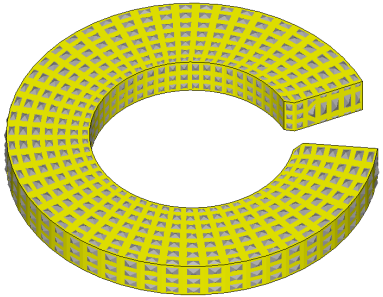
Contact Update Simulation
Customizing of Contacts for CAU

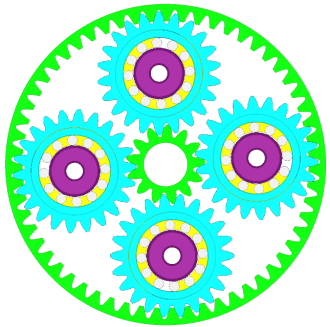
Planetary Gear Set



Reduction of Contact **Surface to Node**

Contact **Surface to Surface** on the Spring inside of the Split Gear and on the contact flanks of the teeth have to be **preserved**





Settings of CAU Simulation

- **UCI-file setting [3]**

  SET CAMAXGEOUP = –1

  - < 0 No CAU
  - = 0 CAU only once after each time step
  - > 0 Maximal updated steps for each time step given by user

  SET CATOLGEOUP = 0.01

- **CAMAXGEOUP**
  - Increasing the maximal value of updated steps to reach the status of **convergence** of CAU

- **NLLOAD table (simplified)**

LPAT/TIME	0.0	0.5	1.0
Contact	1.0	1.0	1.0
Pretension	0.0	1.0	1.0
Torque	0.0	0.0	1.0

- **CAMAXGEOUP + NLRESULTS**
  - DAT-file settings (example):
    - NLRESULTS STEPS = EQUI
      0.0 0.5 0.1
  - More time steps → **very long computation time**

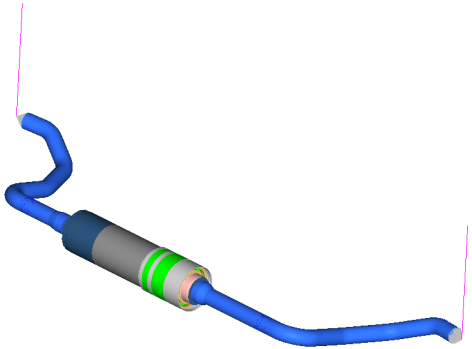
CAMAXGEOUP = 10 → All time steps **converged**

04

Summary and Discussion

Summary

	Model without CAU	Model with CAU
Number of Elements	~ 3.4 million	
Number of Nodes	~ 4.5 million	
CA-DOFs	~ 180 000	~ 135 000
CAMAXGEOUP	= –1	= 10
Computation Time	~ 2 hours	~ 8 hours



Thank you for your attention

References
[1] https://www.zf.com/corporate/en_de/homepage/homepage.html
[2] https://www.zf.com/corporate/en_de/products/product_range/cars/cars_erc_electromechanical_roll_control.shtml
[3] PERMAS User's Reference Manual, INTES Publication No. 450