Gearbox lubrication studies with meshless CFD methods
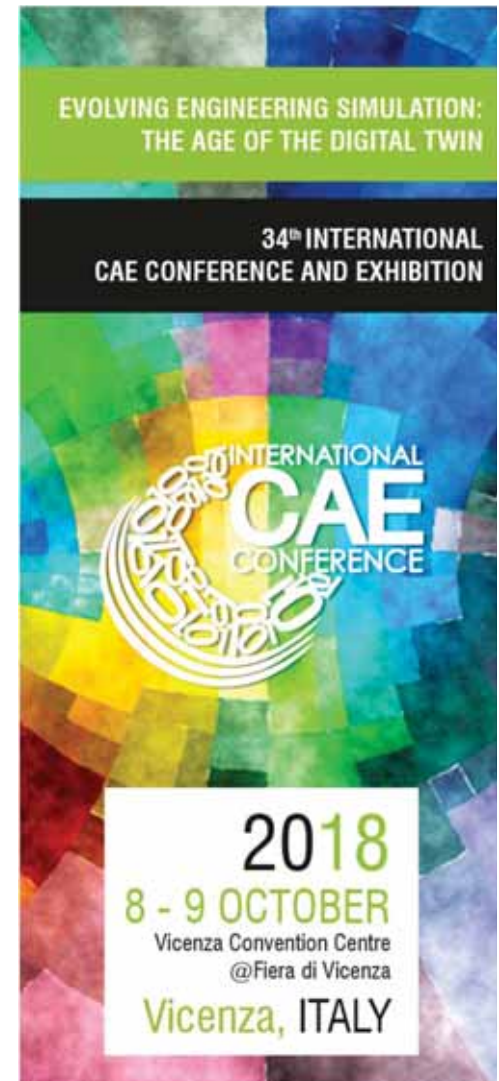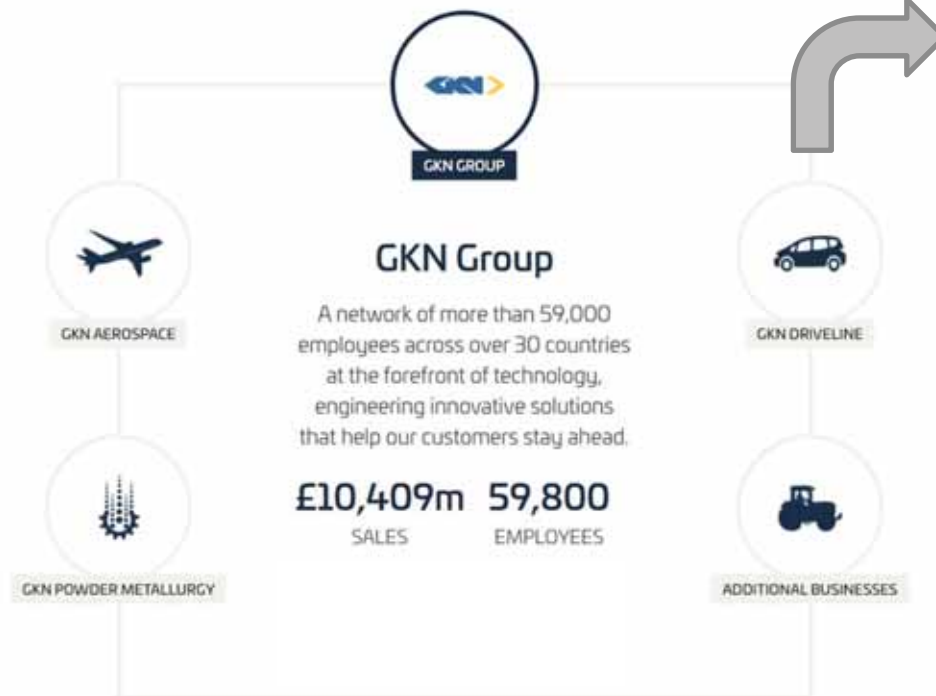
Henning Dombrowski

GKN Driveline

Introduction

GKN at a glance

GKN Group

A network of more than 59,000 employees across over 30 countries at the forefront of technology, engineering innovative solutions that help our customers stay ahead.

£10,409m — SALES
59,800 — EMPLOYEES

GKN AEROSPACE

GKN POWDER METALLURGY

GKN DRIVELINE

ADDITIONAL BUSINESSES

GKN Driveline

The leading tier one supplier of automotive driveline systems and solutions to the world's leading vehicle manufacturers.

£5,308m — SALES
31,700 — EMPLOYEES

Constant velocity jointed systems including CV joints and sideshafts.

All-wheel drive (AWD) systems including propshafts, couplings, power transfer units, rear drive modules and a range of differentials and torque management technologies.

eDrive systems including electric axles, transmissions and motors.

GKN Driveline Locations

⭐ We are here today

⭐ GKN Driveline Technology Centre Lohmar
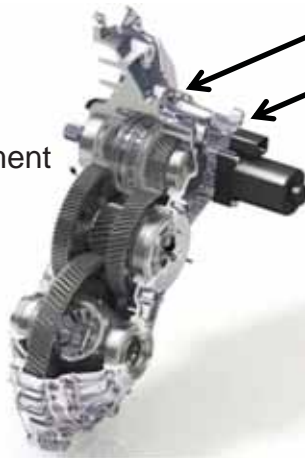
GKN Driveline Locations

Overview (1/3)

Product Development @ GKN Driveline

For example:
EV Step-down gearbox development

Oil flow required for lubrication of bearings, seals and for cooling

Efficiency improvement through churning loss reduction (targeted)

Yesterday	**Today**	**Tomorrow**
Several Lubrication Tests with transparent gear box housing and/or dyed oil	Several Lubrication Tests with transparent gear box housing and/or dyed oil	Only One Lubrication Test
CFD Analysis (Classic approach) through external CAE support	Particle CFD Approach @ GKN Driveline CAE Team	…thanks to extensive CFD analysis in concept design stage
👎 Costs	👍 Costs	
👎 Response time	👍/👎 Response Time	
👎 Know-How Build-Up	👍 Know-How Build-Up	

Overview (2/3)

Particle CFD @ GKN Driveline

ASCII Text

| Previous Preprocessing Tools | Previous Particle CFD Tool | Open source Tool & Excel |

Advantage: Common floating license pool, common preproc. tools

STEP
CATIA
creo

CAD clean up
Boolean operations
Simplifications

| Preparation of CFD model | Computation on GPU Server | Postprocessing of Particle CFD Results |

or CPU Server
or Local CPU or Local GPU

Particleworks®
Particle-based simulation software for CAE
& Excel

Overview (3/3)

Particle CFD @ GKN Driveline

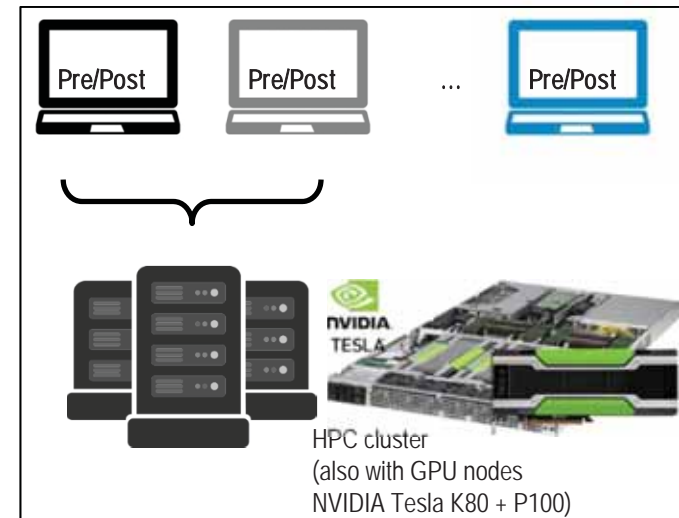**GKN Driveline CAE Environment**

- Response time
  - Really good for lower rpm (up to 500 rpm) with normal particle size
  - Acceptable for higher rpm levels
- Result quality
  - Due to very complex physics sometimes difficult to judge, ongoing validation
  - In general very realistic, also the visualization options with post processing
- Growing field
  - Multiple requests from projects at the same time
  - Will influence also the way we are testing at GKN

- Previous CFD limitations
  - Multi phase (air effects on oil flow)
    - Suction effects (pressure delta)
    - Foaming prediction
  - Complicated Pre- and Postprocessing
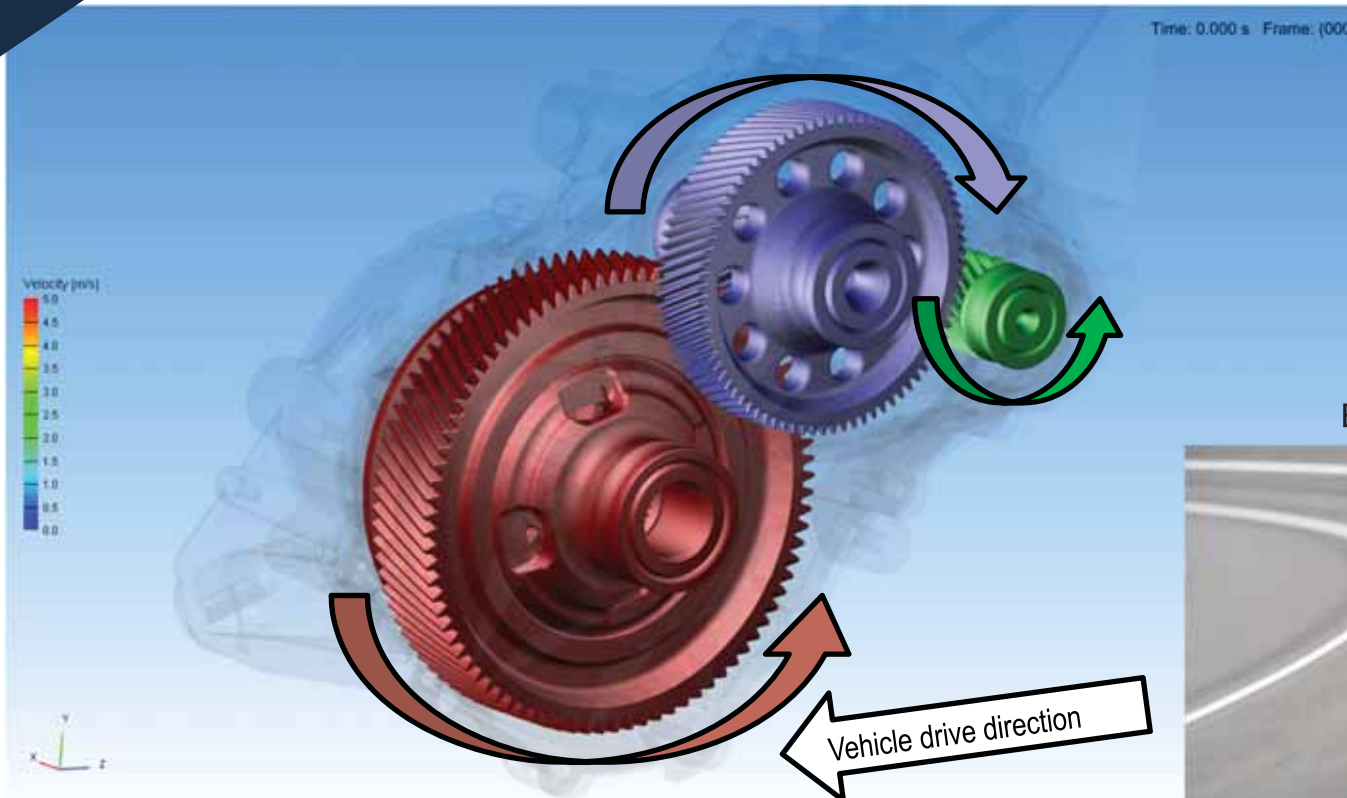 - Resolution to capture small features accurately ↔ Computation performance

Motivation for

Particleworks®
Particle-based simulation software for CAE

Test

HPC cluster
(also with GPU nodes
NVIDIA Tesla K80 + P100)

- Potential future applications
  @ GKN Driveline
  - CV joint boot grease simulation
    (from semi-solid to very liquid)
  - Clutch oil flow simulation
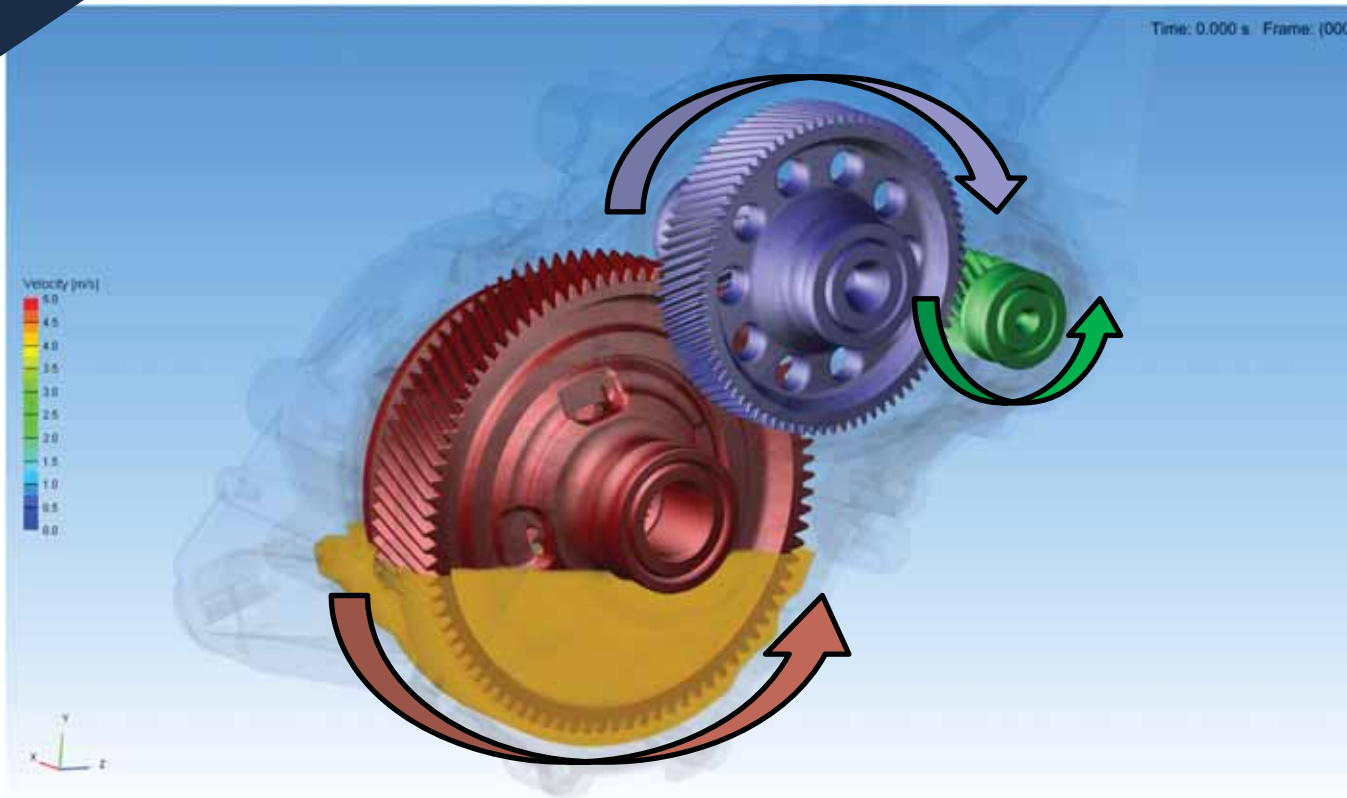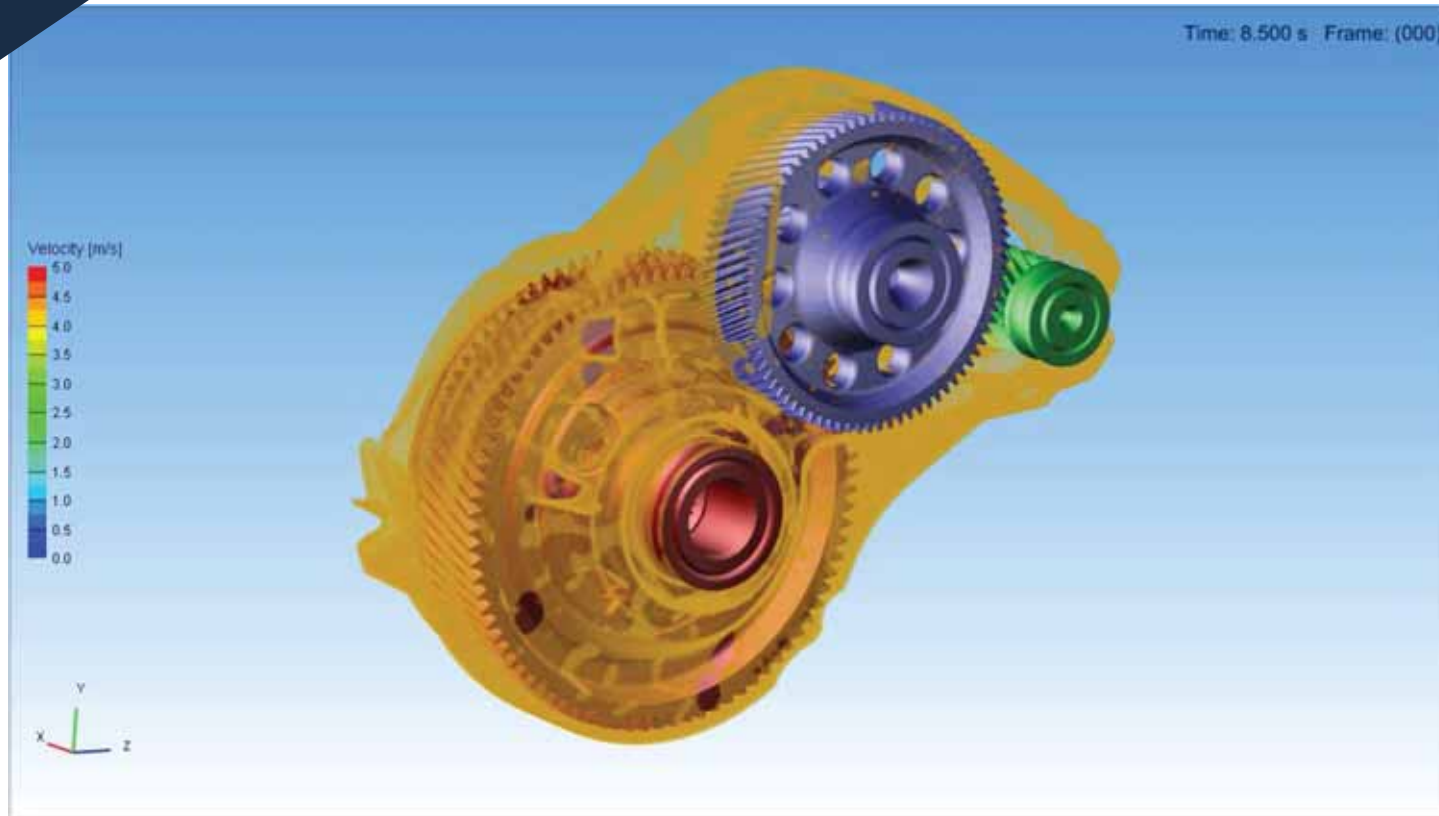   (very small gaps)

Gearbox example (1/8)

Time: 0.000 s   Frame: (000)

Velocity [m/s]
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

BMW 2 Series Active Tourer 225xe

Vehicle drive direction

Gearbox example (2/8)

Static oil fill level

Gearbox example (3/8)

Time: 8.500 s   Frame: (000)

Velocity [m/s]
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0

Dynamic oil distribution
Vehicle speed ≈ 25 kph
Straightline

Gearbox example (4/8)

Time: 9.000 s   Frame: (050)
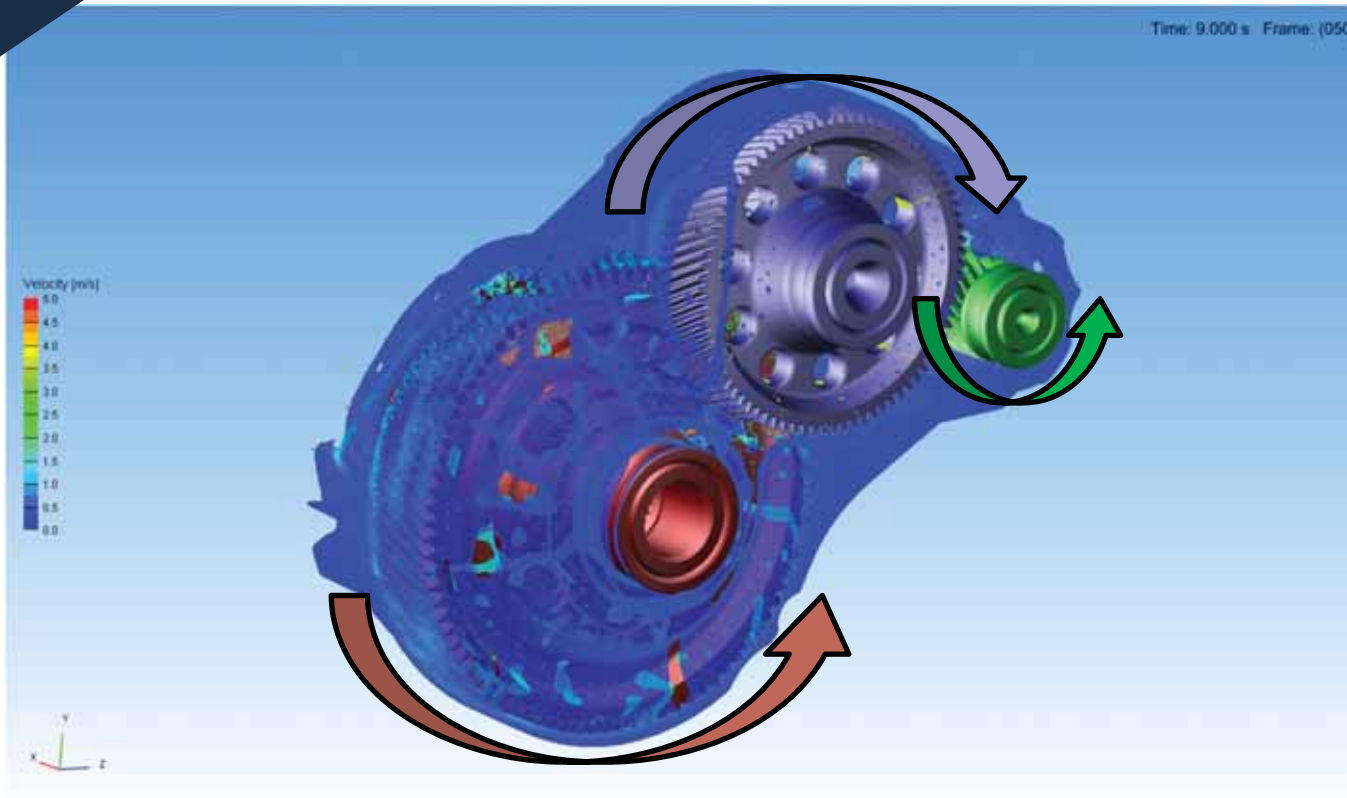
Velocity [m/s]

Dynamic oil distribution
plus mapped
Velocity Magnitude (m/s)

Gearbox example (5/8)

Time: 8.500 s   Frame: (000)

Velocity [m/s]
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
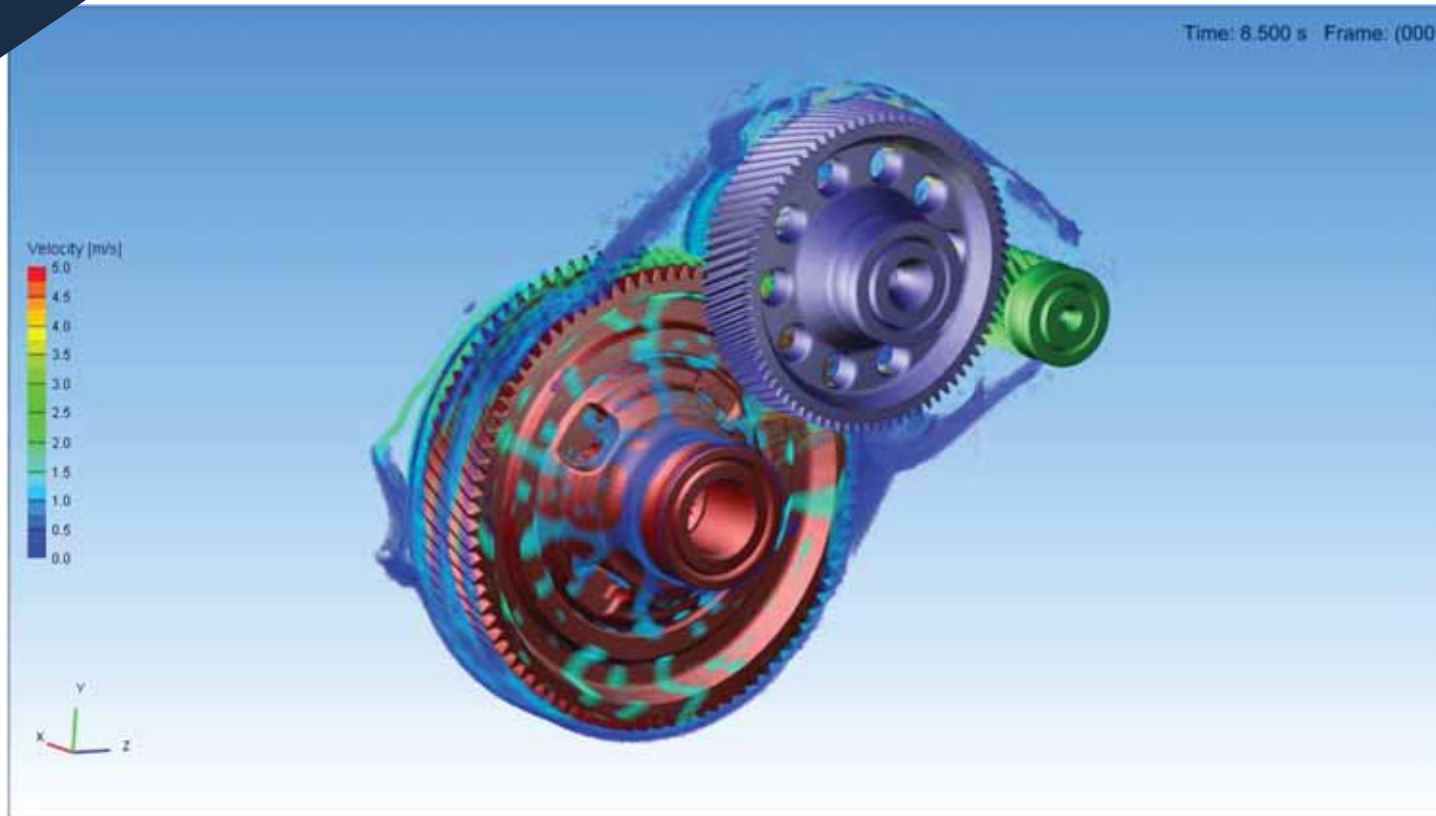
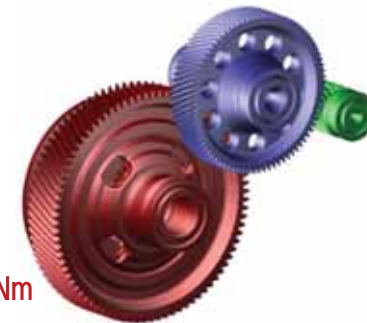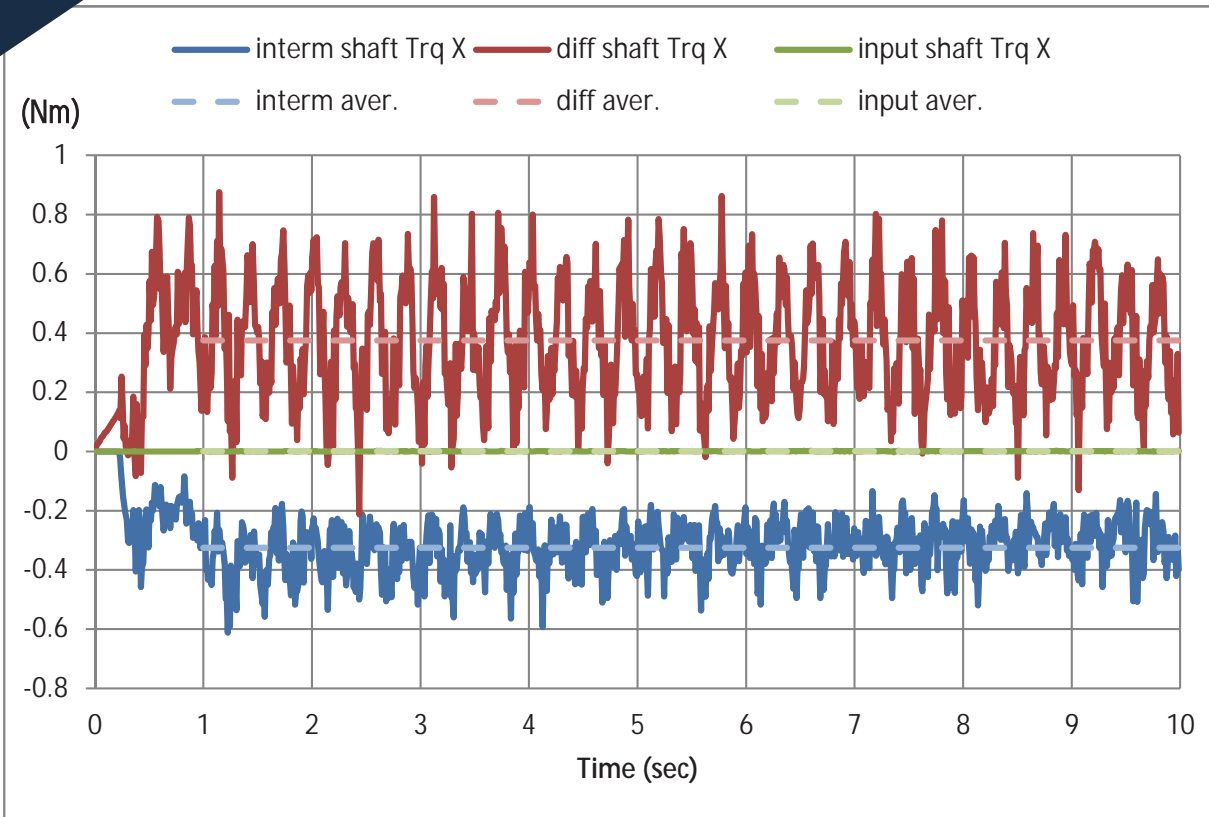**Dynamic oil distribution**
plus mapped
Velocity Magnitude (m/s)
with low speed oil particles
(<0.1 m/s) clipped
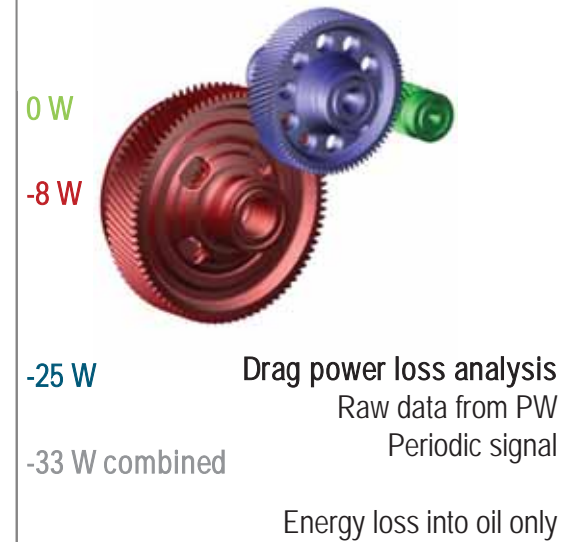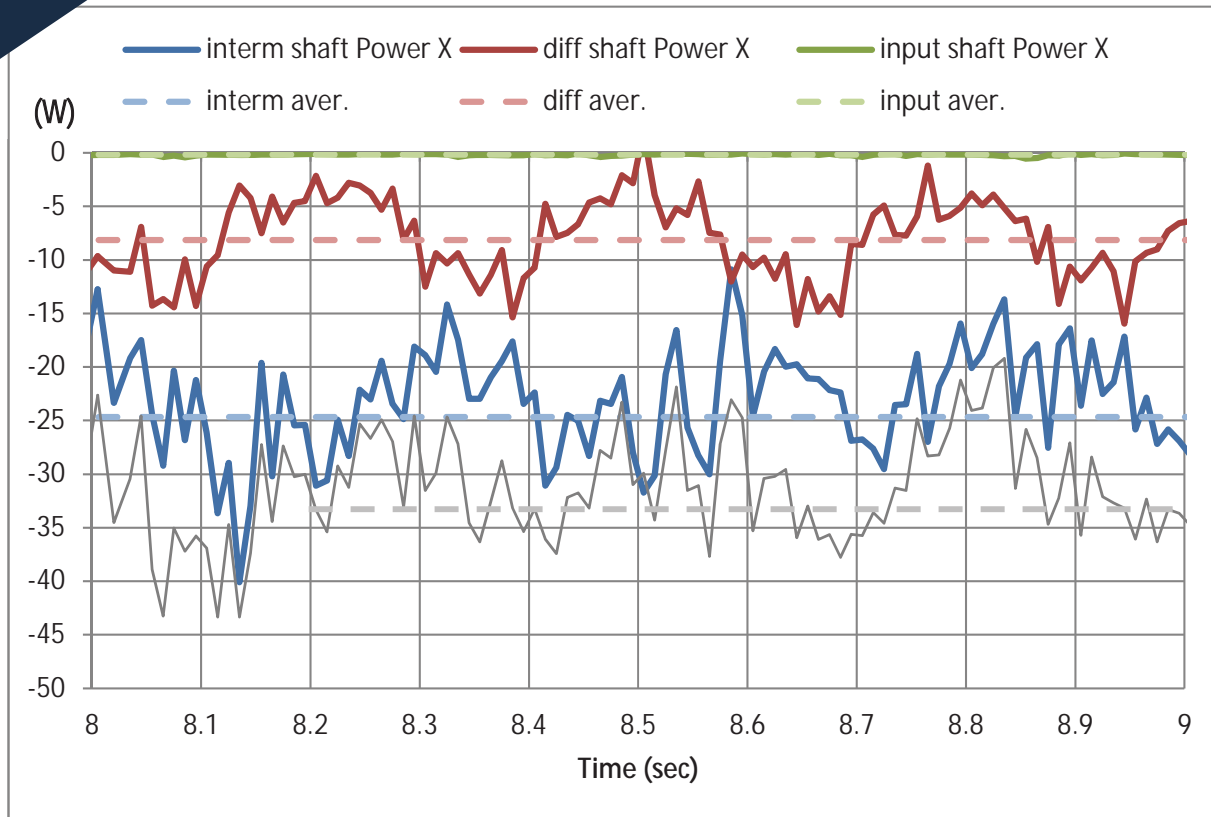
Gearbox example (6/8)

Drag torque analysis
Raw data from PW
Periodic signal

Averaged values
used for drag loss

Gearbox example (7/8)
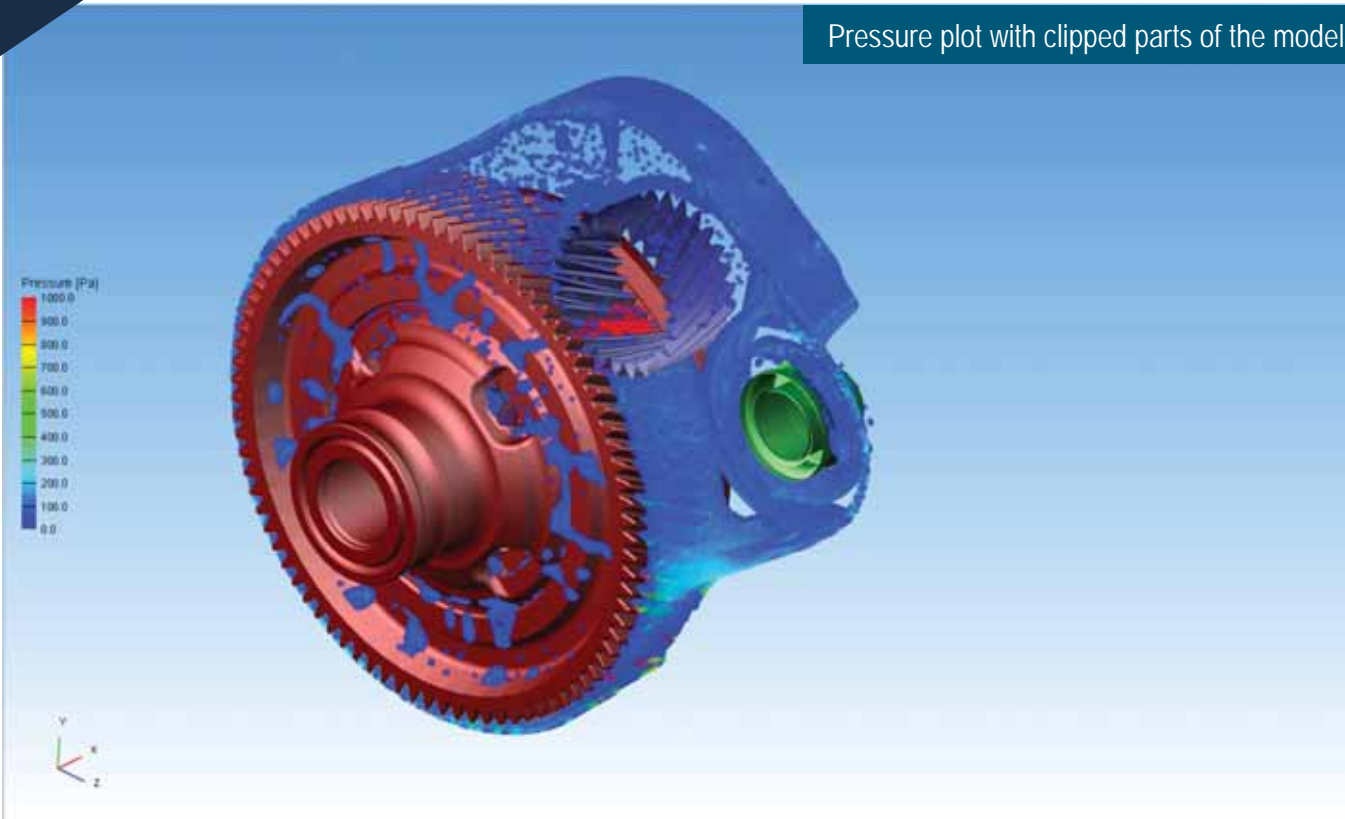

Legend:
- interm shaft Power X
- diff shaft Power X
- input shaft Power X
- interm aver.
- diff aver.
- input aver.

0 W

-8 W

-25 W

-33 W combined

Drag power loss analysis
Raw data from PW
Periodic signal

Energy loss into oil only

Gearbox example (8/8)

Pressure plot with clipped parts of the model

Pressure [Pa]
1000.0
900.0
800.0
700.0
600.0
500.0
400.0
300.0
200.0
100.0
0.0

Drag torque analysis
Raw data from PW
Periodic signal

Effects from pressure gradient,
viscosity and surface tension
split up

Summary

Specific gearbox challenges
- Complex, moving geometries inside gearbox housing
- Development of passive lubrication systems with reduced churning losses
- Tight customer timings and increasing customer requirements demand tools to predict the oil flow and distribution at wide range of operating conditions already at initial development stages

Meshless CFD methods (SPH … MPS)
- Allow GKN Driveline to perform rapid concept development
- Provide additional understanding of the oil flow, also in combination with experimental data

Remaining challenges
- Complex validation
- Speed of sound (numerical) settings have large effect on oil behaviour in gear mesh region

A theory is something nobody believes, except the person who made it. An experiment is something everybody believes, except the person who made it.

Albert Einstein (1879-1955)