National Renewable Energy Laboratory
Innovation for Our Energy Future

NREL Gearbox Reliability Collaborative

Presenter
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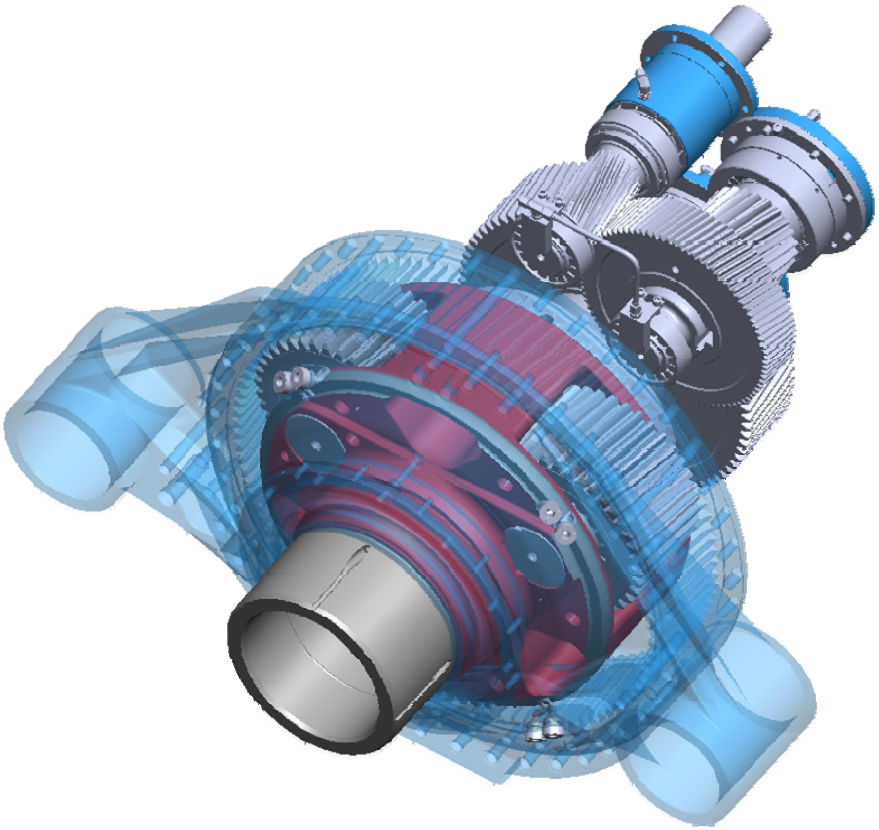
NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC

Gearbox Reliability Collaborative

Overview

- GRC Overview
- Instrumentation
- GRC Gearbox Redesign
- Analysis Description
- Analysis Overview
- Progressive Parameter Comparison
- Tooth Stress Results
- Current and Future Work



NREL Gearbox Reliability Collaborative Overview

GRC Goals

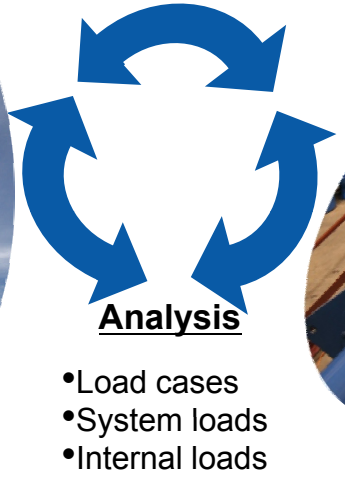
- Facilitate dialog among the parties involved in the gearbox reliability
  - Designers and consultants
  - Suppliers and rebuilders
  - Operations and maintenance organizations
- Understand physics of premature failure of wind turbine gearboxes
- Explore gaps in design process
  - Field-test
  - Dynamometer testing
  - Analysis
- Understand gearbox response to specific loading
  - Pure torque, bending, thrust (dynamometer)
  - Turbulence (field)
- Evaluate viability of dynamometer testing
- Suggest improvements in design practices and analytical tools

Field Test

- Test plan
- Test turbine
- Test setup & execution
- Data analysis

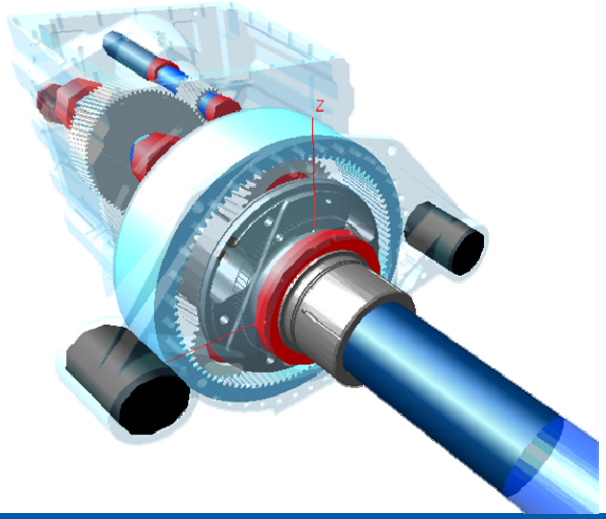
Dynamometer Test

- Test plan
- Test article
- Test setup & execution
- Data analysis

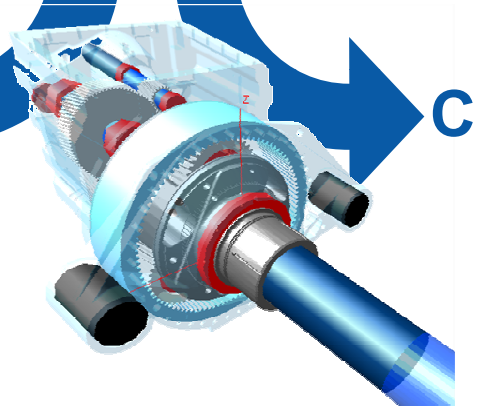


Analysis

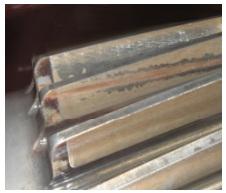
- Load cases
- System loads
- Internal loads

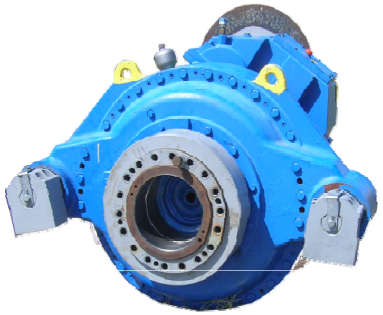


NREL Gearbox Reliability Collaborative Overview



Failure Database

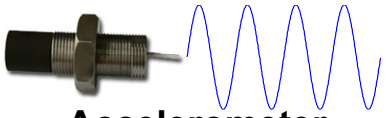




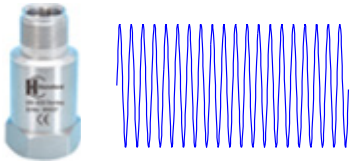
Condition Monitoring

Frequency range
to above 20 kHz

Proximity probe



Accelerometer



Acoustic emission sensor

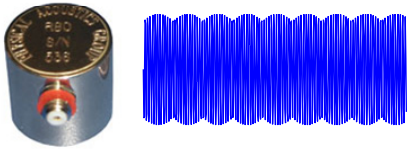
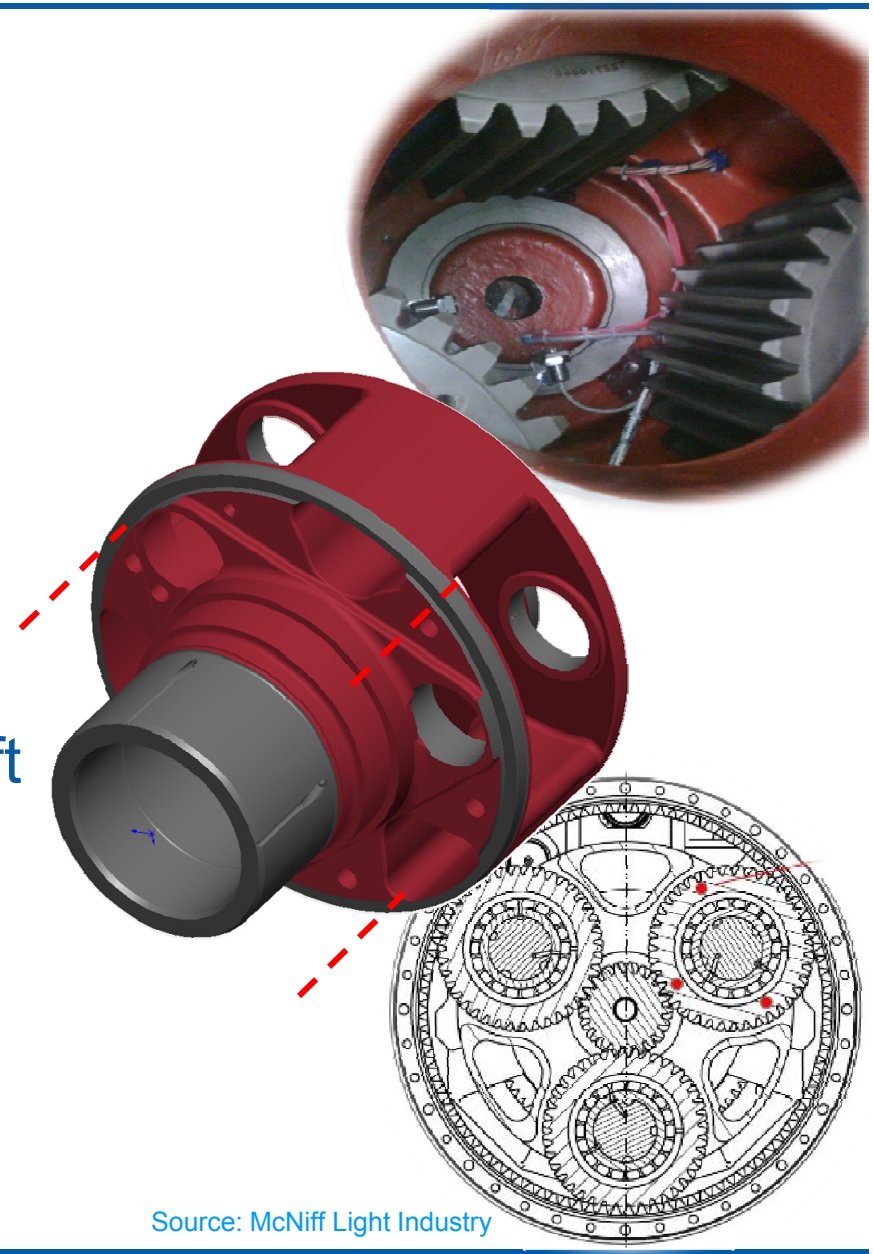


Photo Sources: ProvibTech, Machine Condition Monitoring Ltd, Physical Acoustics Corporation

Instrumentation

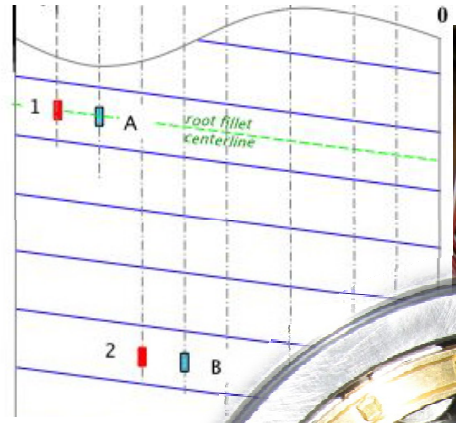
- Proximity sensors
  - Relative motion of planet carrier to the housing
  - Sun to the planet carrier
  - Planet to the planet carrier
  - Housing to the main frame
- Forces, moments, on main shaft
- Gearbox rigid body motion



Source: McNiff Light Industry

Instrumentation

- Tooth load sharing between planet gears
- Bearing roller load distribution
- Temperature gradients of bearings
- Planet bearing collective roller slip



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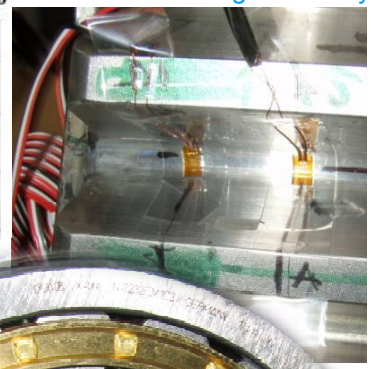
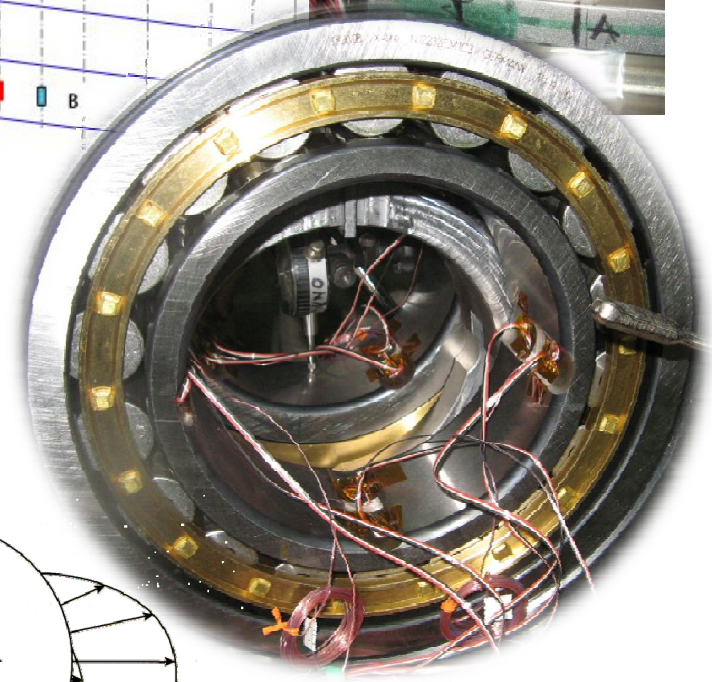
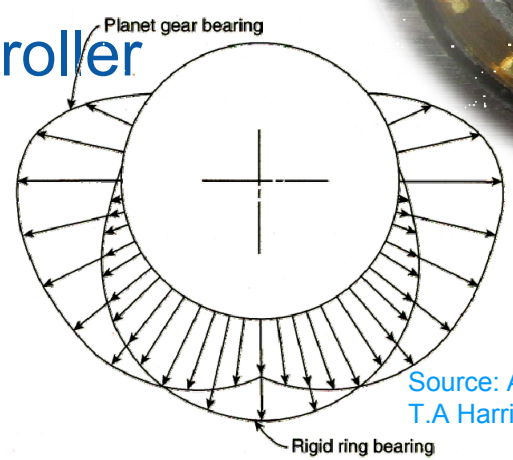




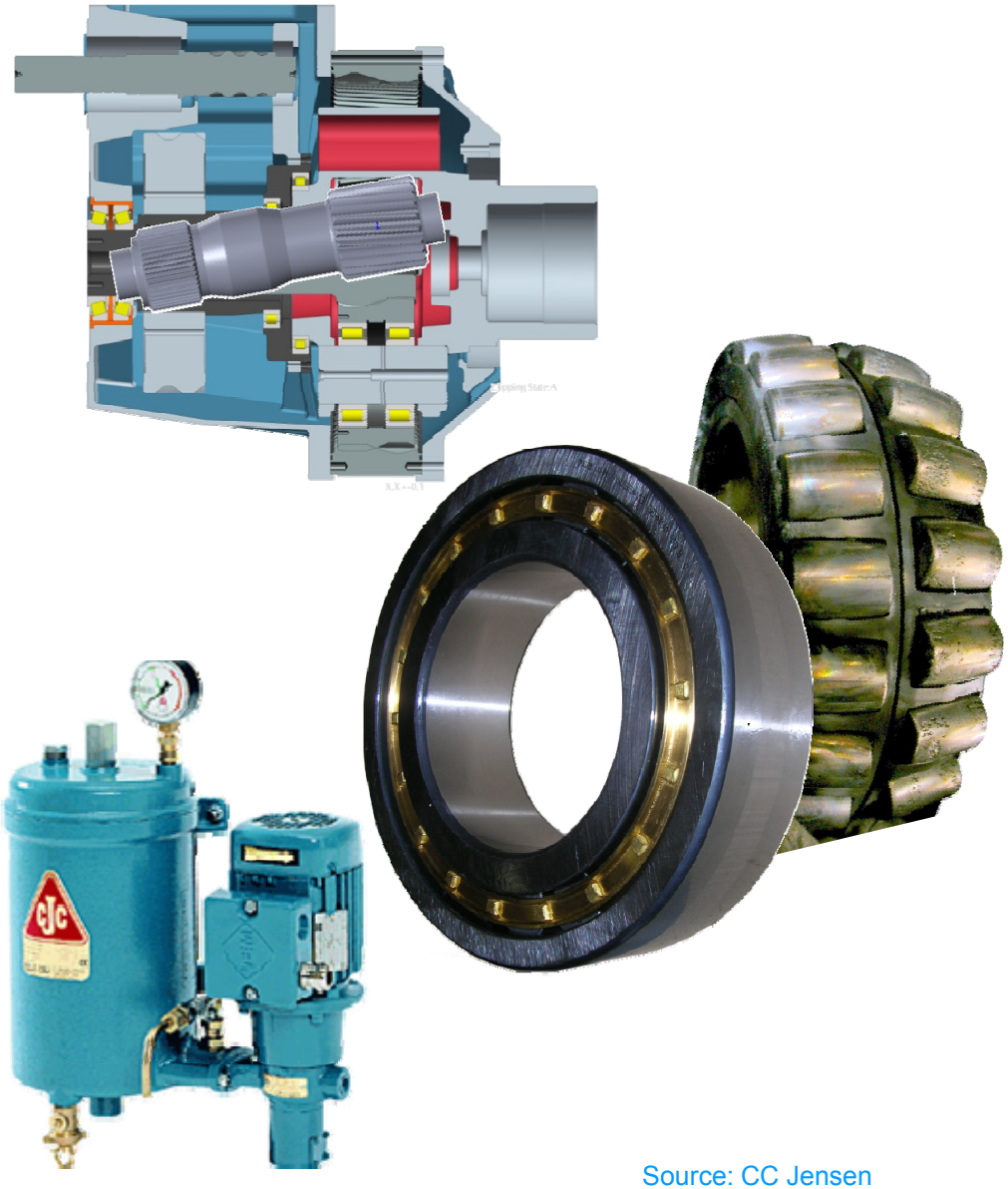


Source: Advanced Concepts of Bearing Technology
T.A Harris

The GRC Gearbox Redesign

Gearbox Redesign

- Floating sun
- Bearing arrangement
- Lubrication
- Filtration
- Gearing micro geometry



Source: CC Jensen

Analysis Description

The GRC gearbox

- Detailed technical specifications (confidential to GRC participants for a limited period)
- Drawings and solid models
- Material

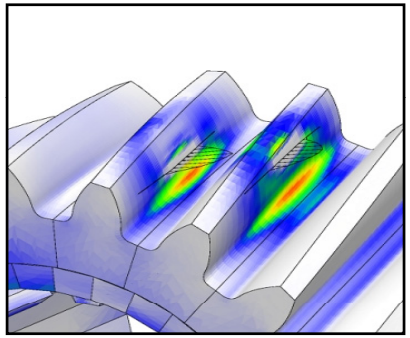
Analysis Round Robin

- Many standard analytical approaches
- Results from many commercial and in-house codes
- Provide calibration load cases
- Follow a progressive approach

Analysis Overview

Gearing Analysis

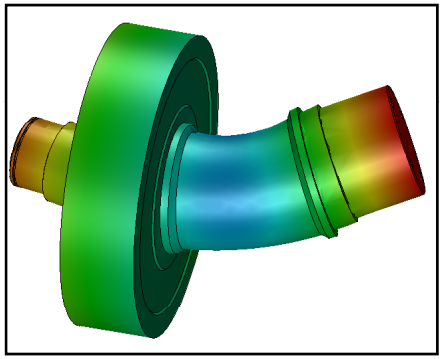
- Gear tooth loading
- Gear mesh stiffness
- Gear tooth contact stress



Source: Ansol (Calyx)

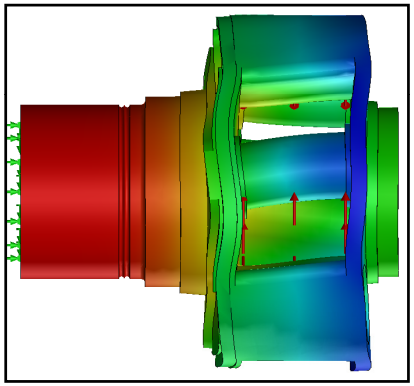
Shaft Analysis

- Torsional deflections
- Bending defection and misalignment



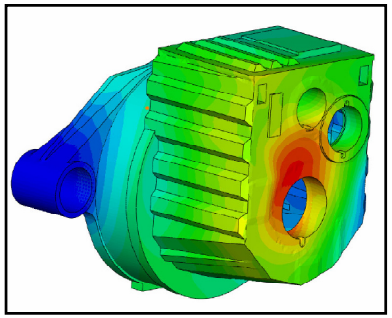
Planet Carrier Analysis

- Torsional deformation of the planet carrier
- Misalignment the planet pin
- Planet carrier and pin interaction



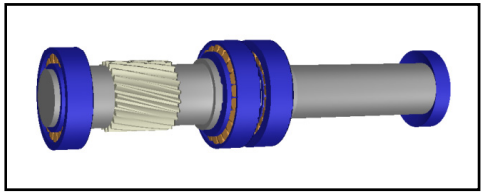
Housing Analysis

- Deflections
- Misalignment
- Tolerance stack up
- Virtual modal testing



Bearing Analysis

- Bearing stiffness
- Roller contact stress
- Roller load distribution
- Bearing life



Progressive Parameter Comparison

Parameter Guidelines

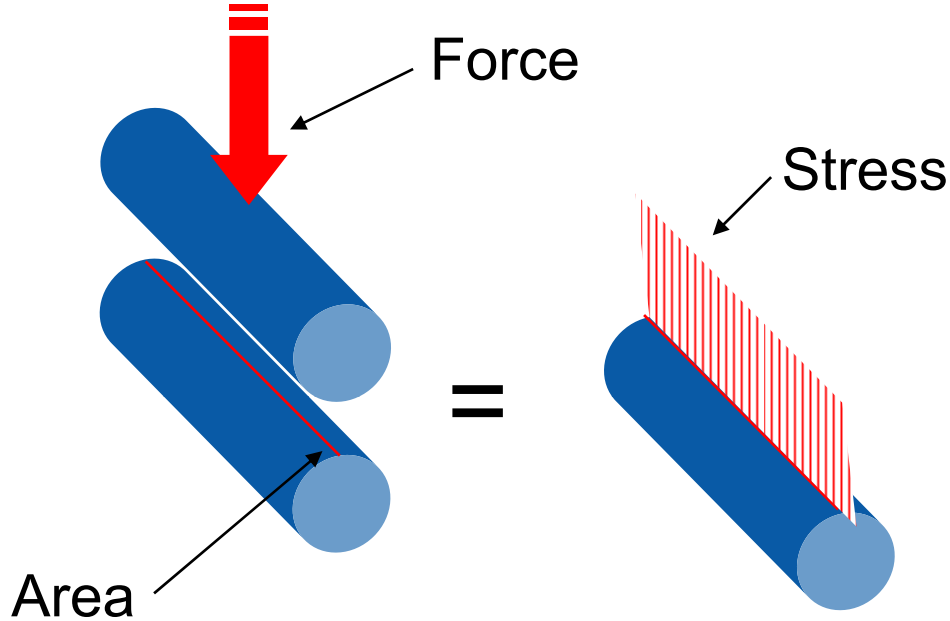
- Simple loading conditions
- Simple parameters
- Low dependence parameters
- Common assumptions and constraints

Tooth Stress Distribution

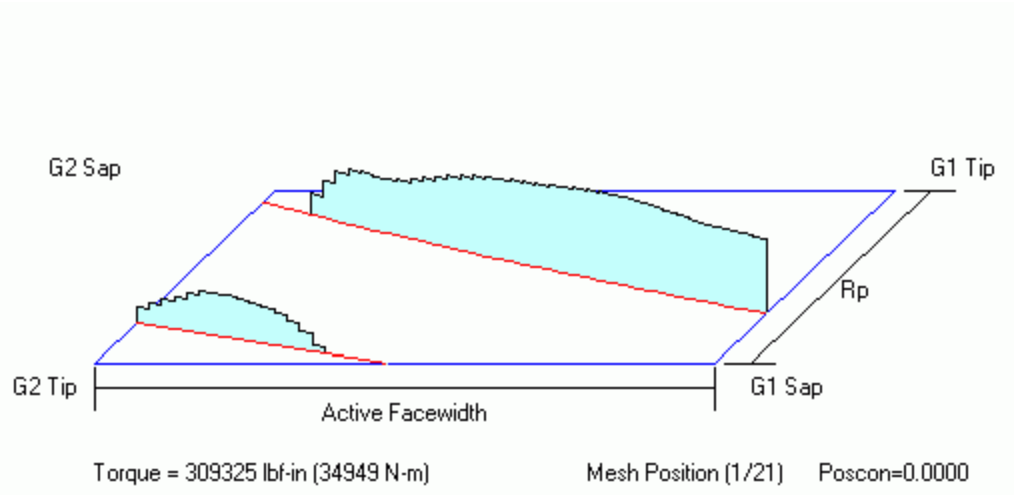
Gear Tooth Contact Stress

Spur gear contact

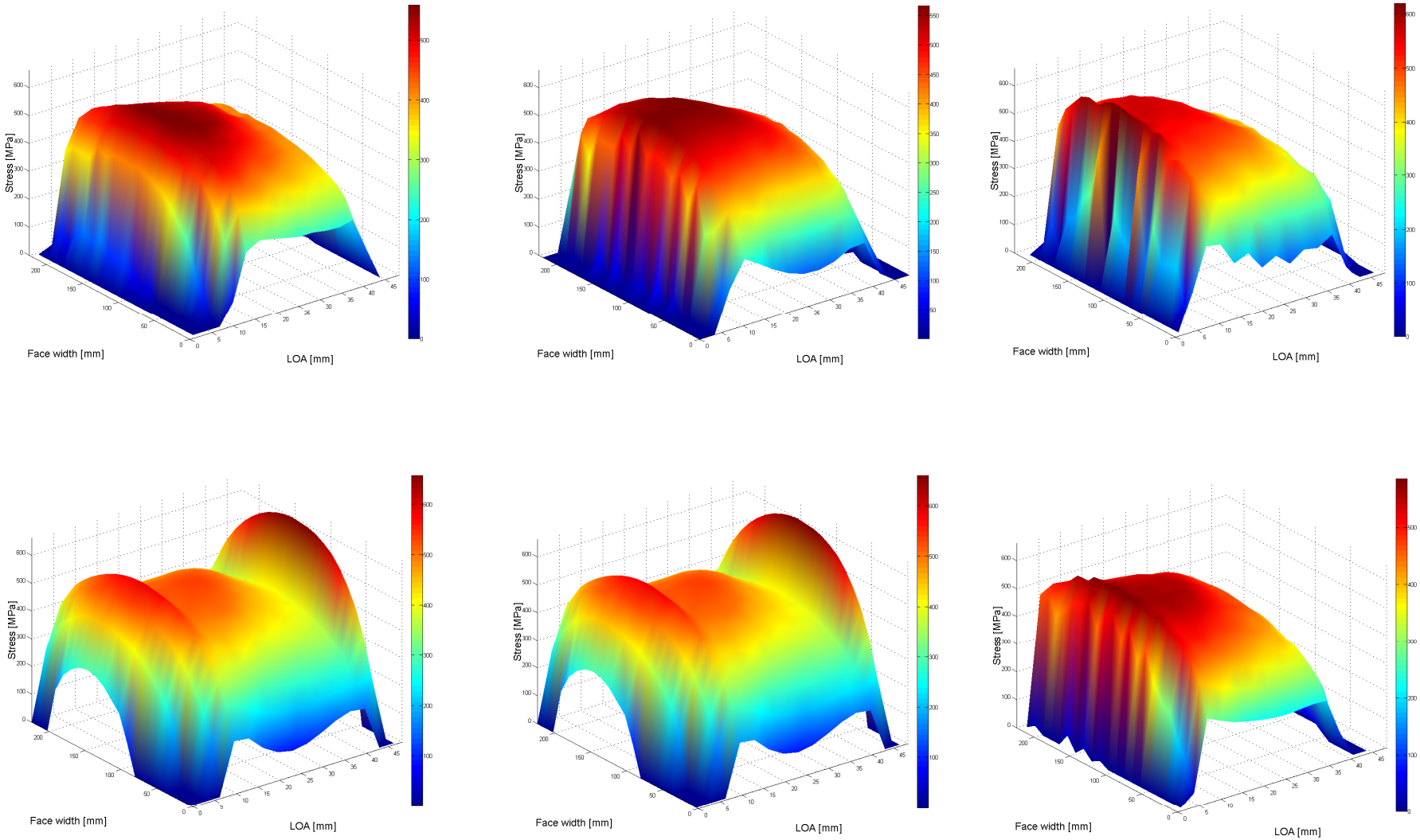
$$\sigma = \frac{F}{A}$$



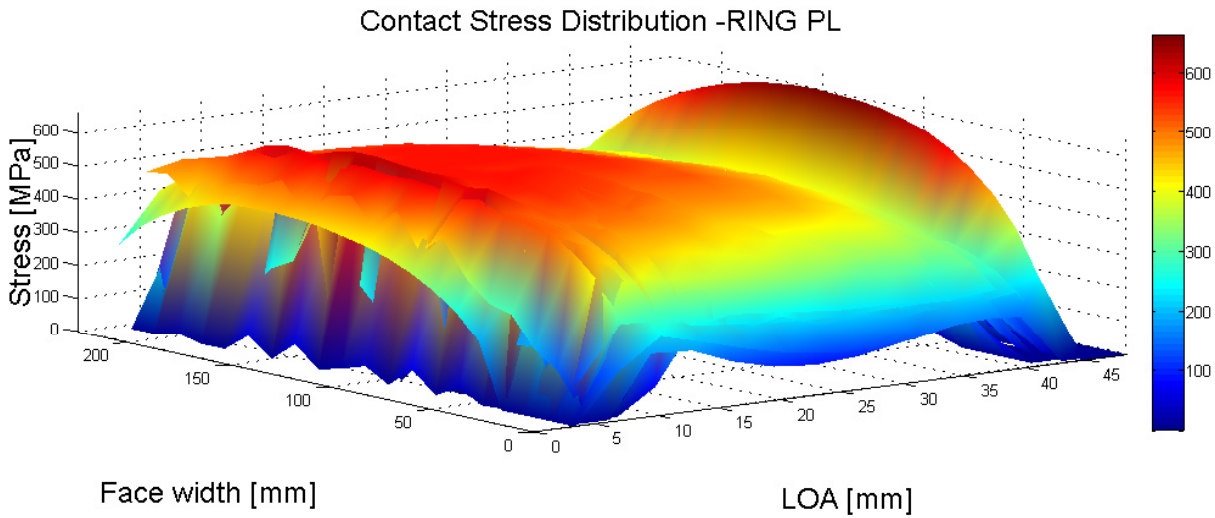
Helical contact

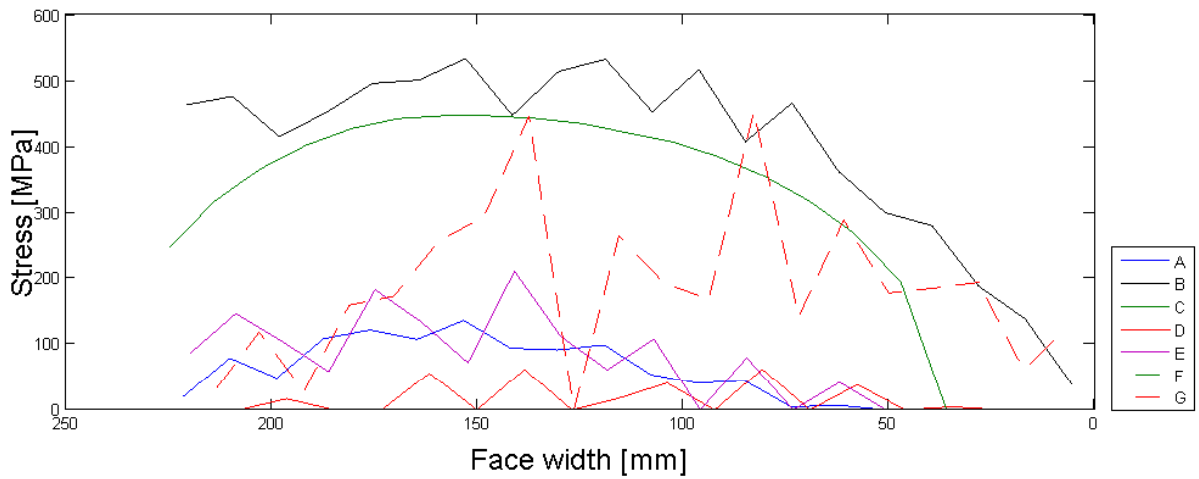


RING_PL Contact Stress Distribution

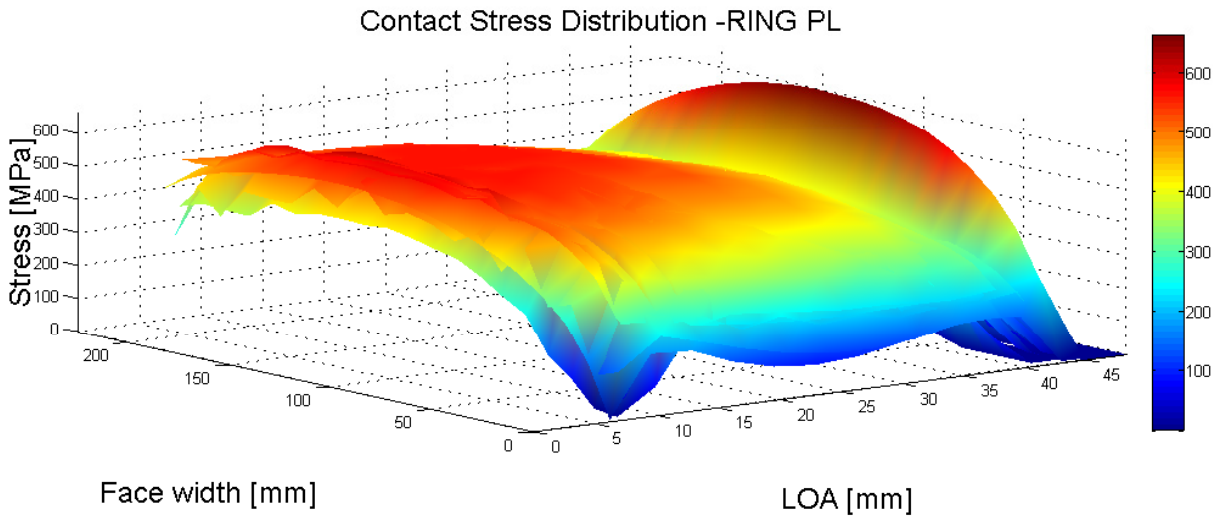


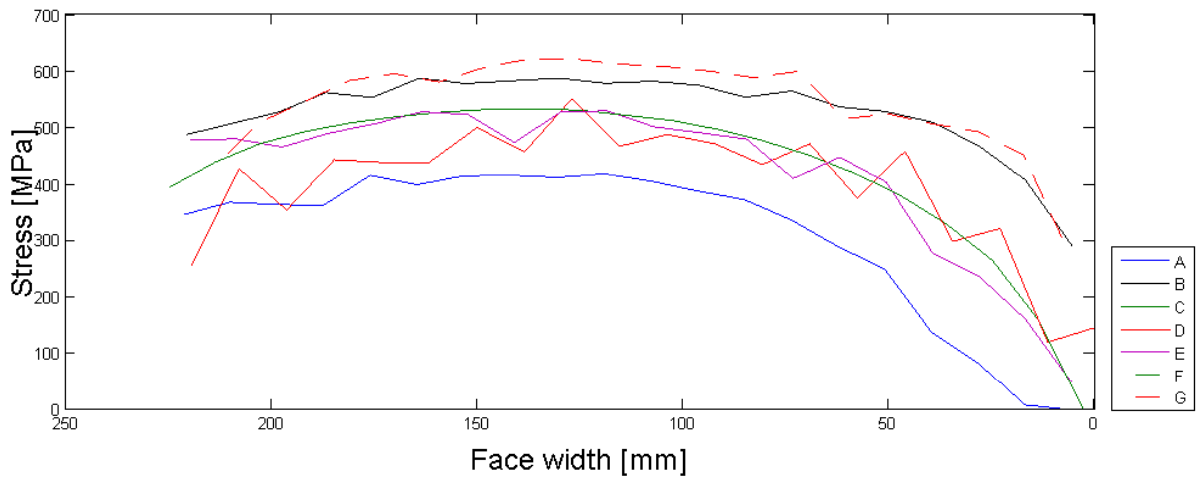
Contact Stress Distribution Comparison (1)



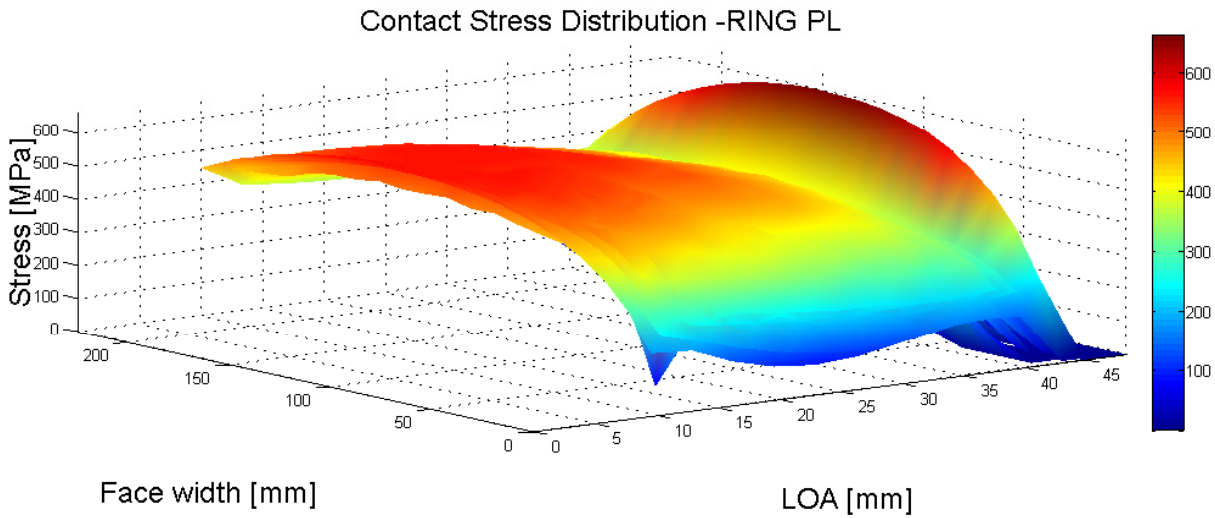


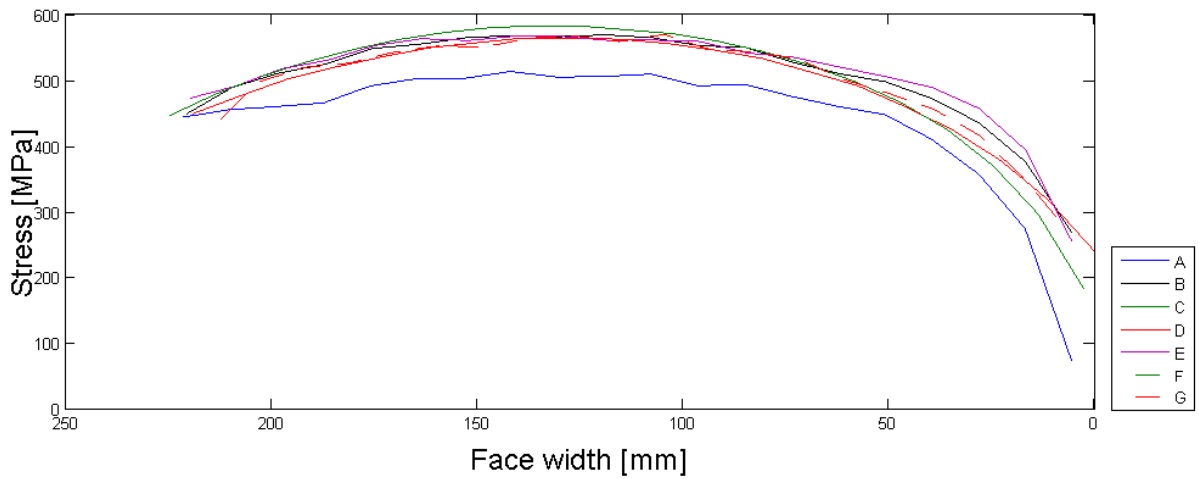
Contact Stress Distribution Comparison (2)



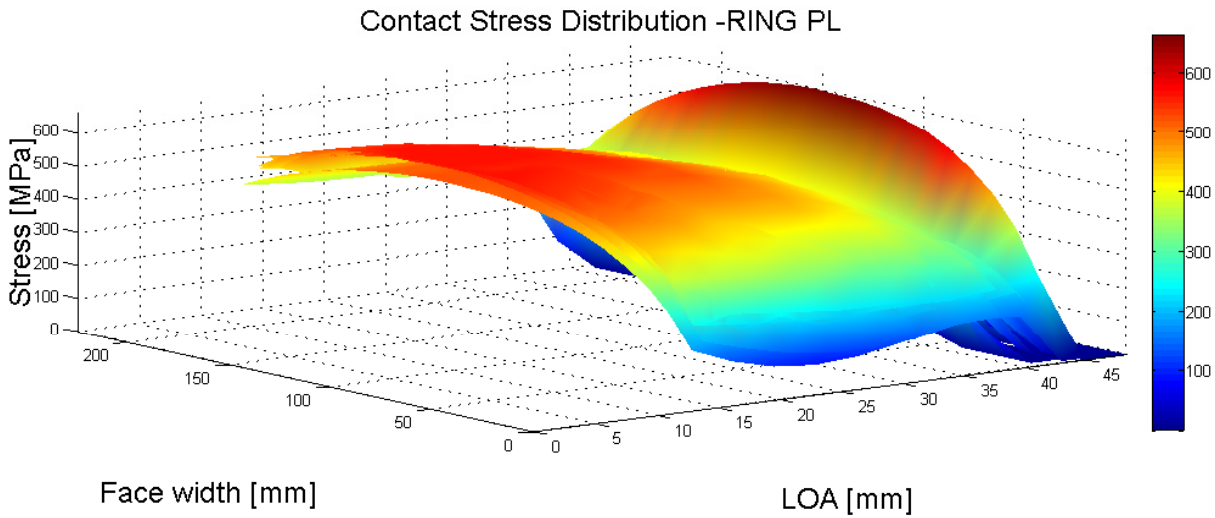


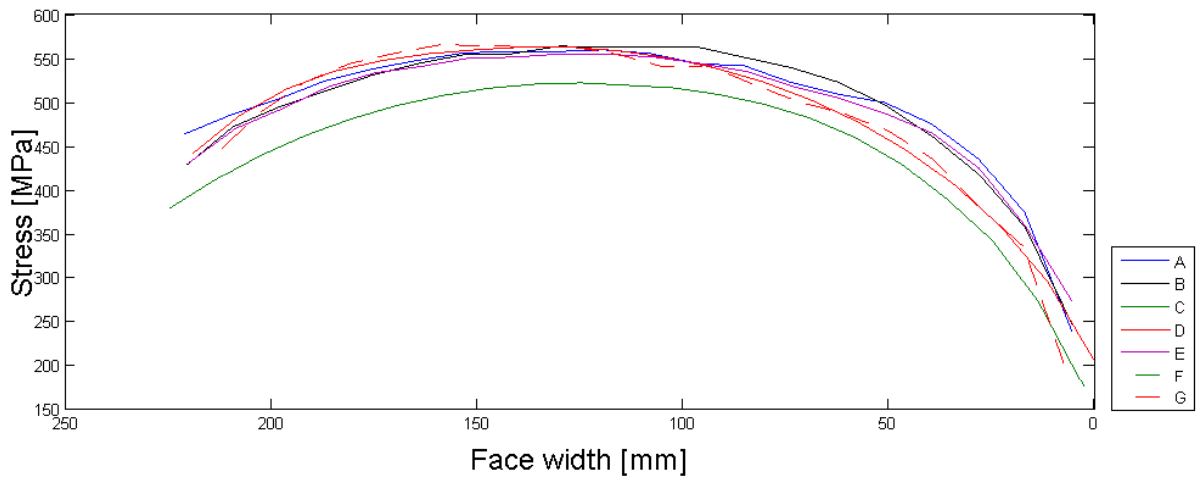
Contact Stress Distribution Comparison (3)



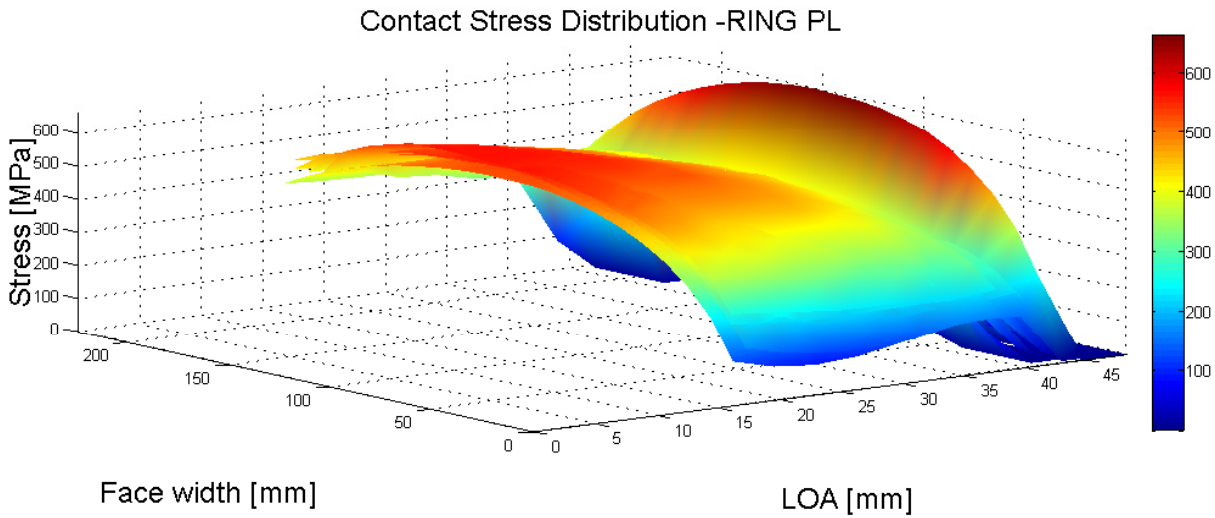


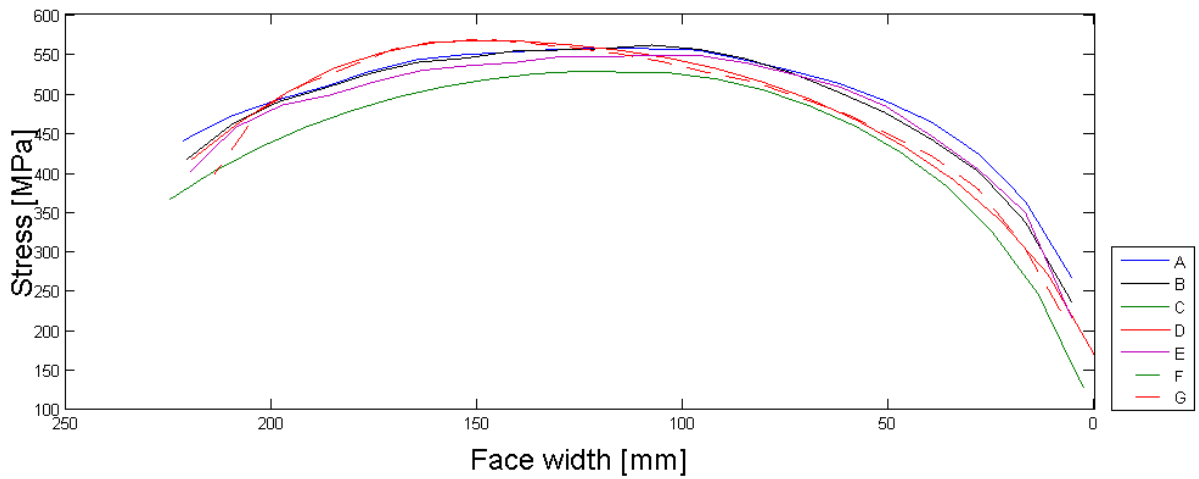
Contact Stress Distribution Comparison (4)



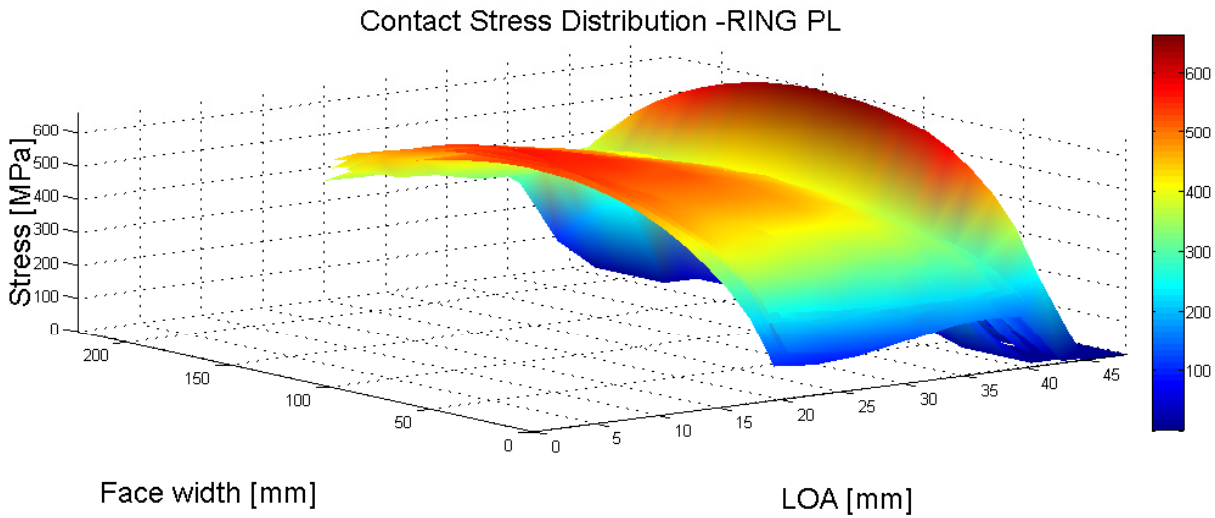


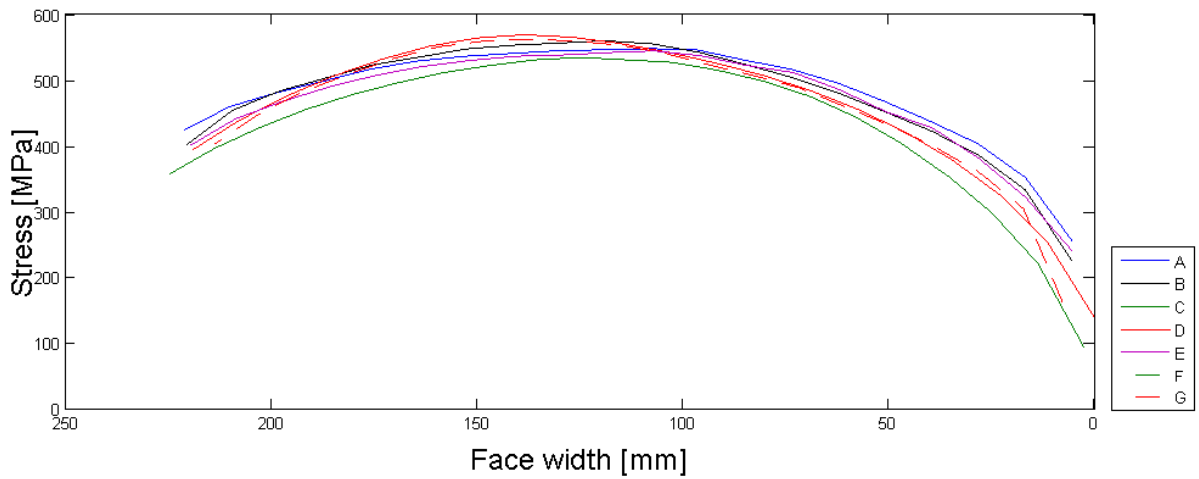
Contact Stress Distribution Comparison (5)



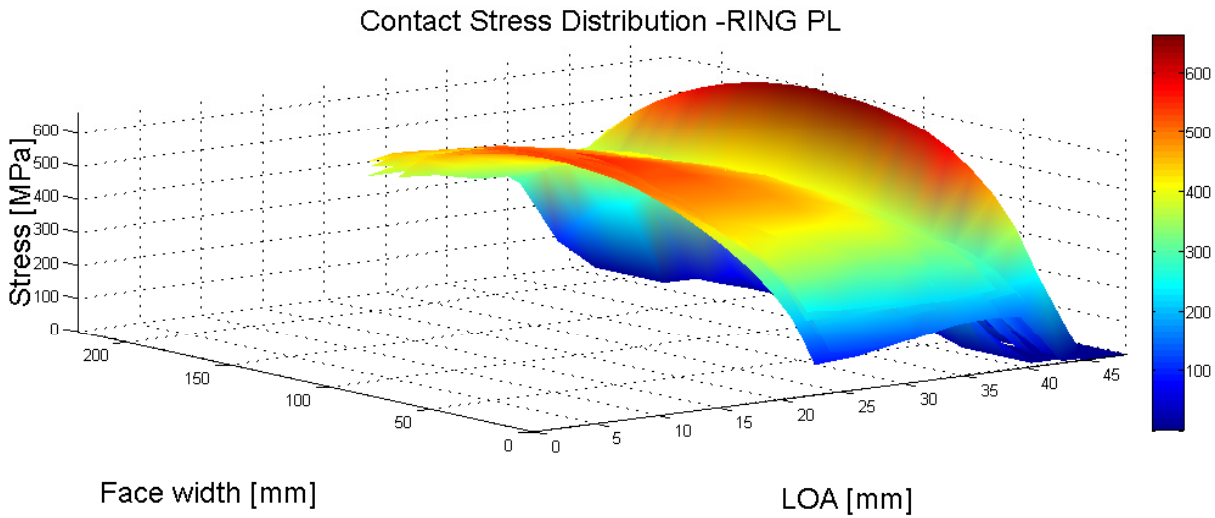


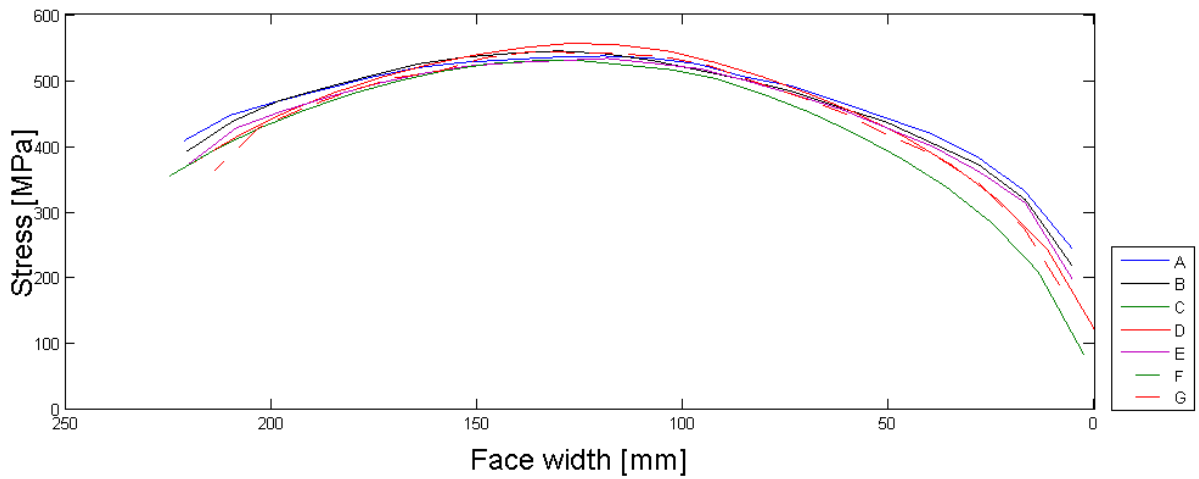
Contact Stress Distribution Comparison (6)



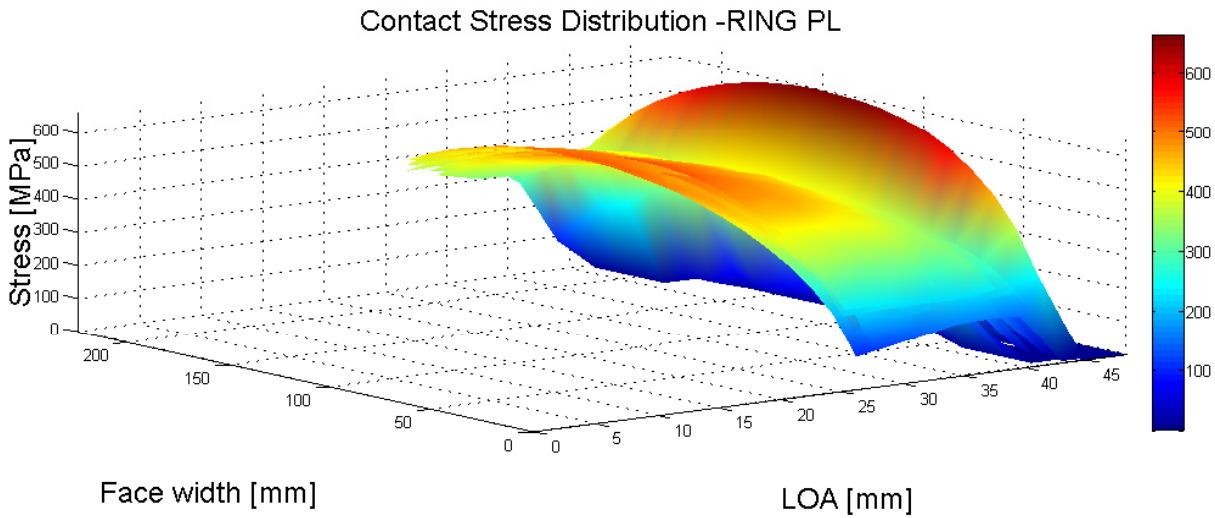


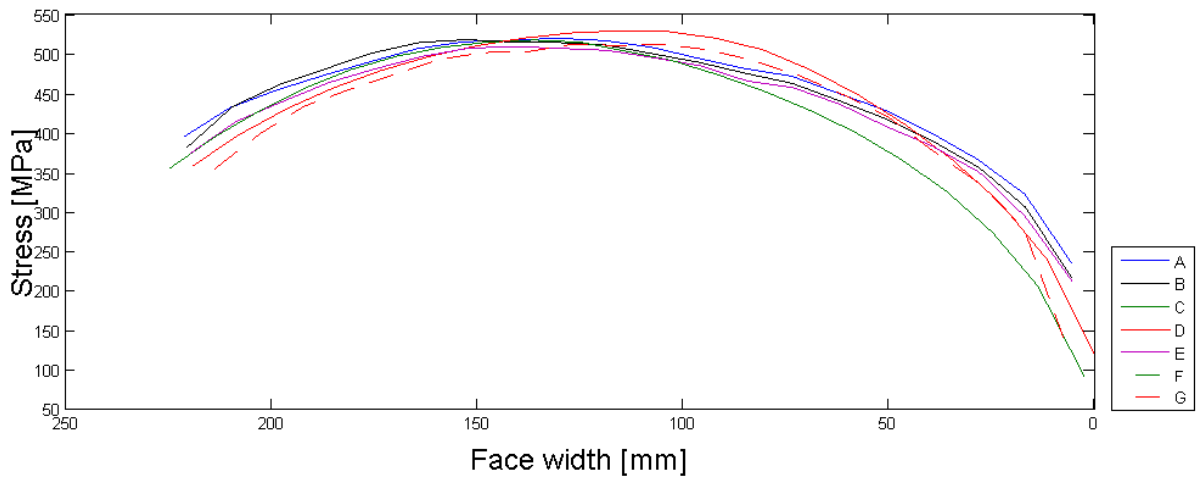
Contact Stress Distribution Comparison (7)



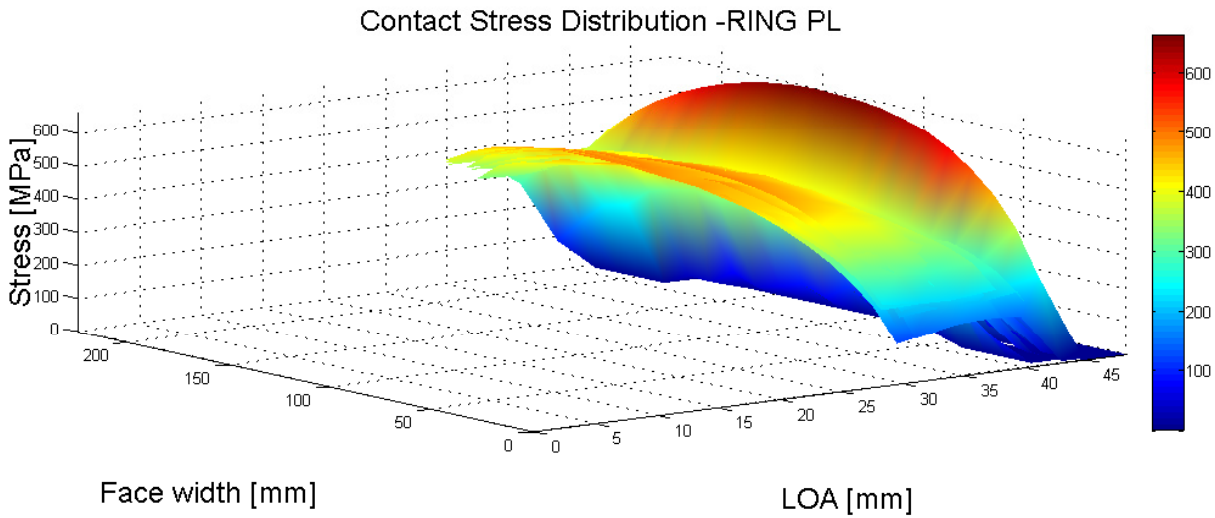


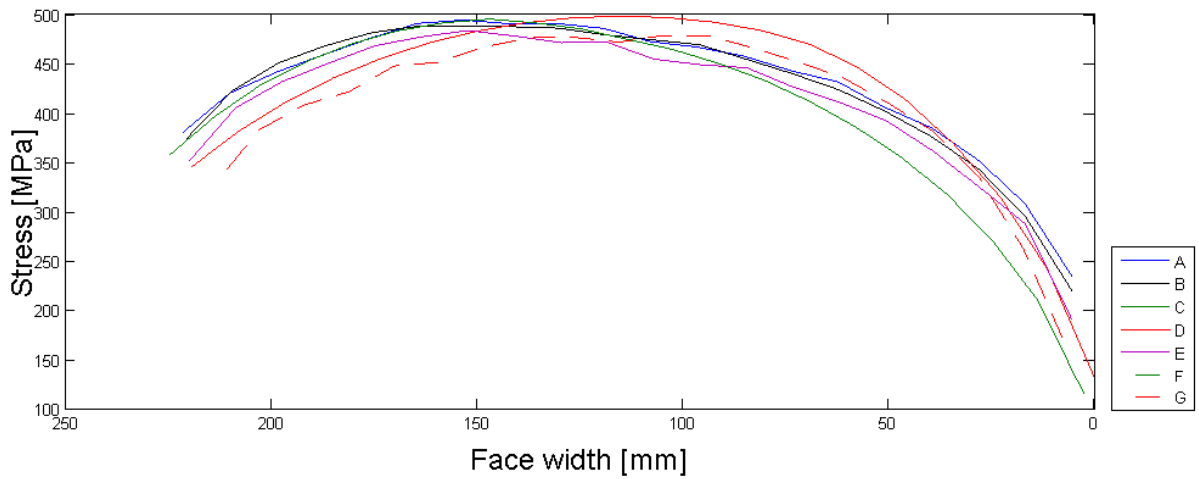
Contact Stress Distribution Comparison (8)



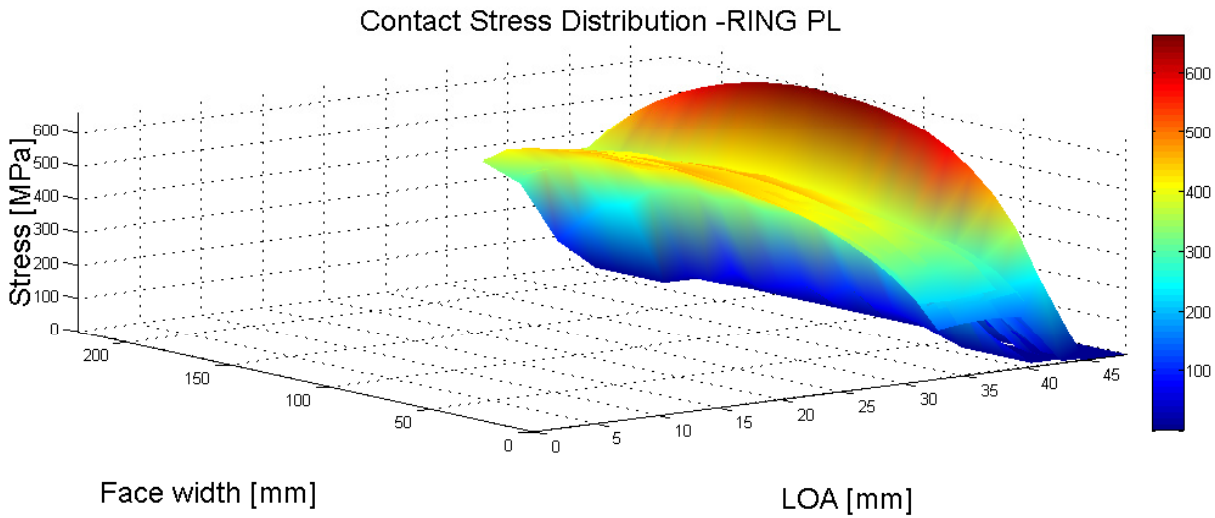


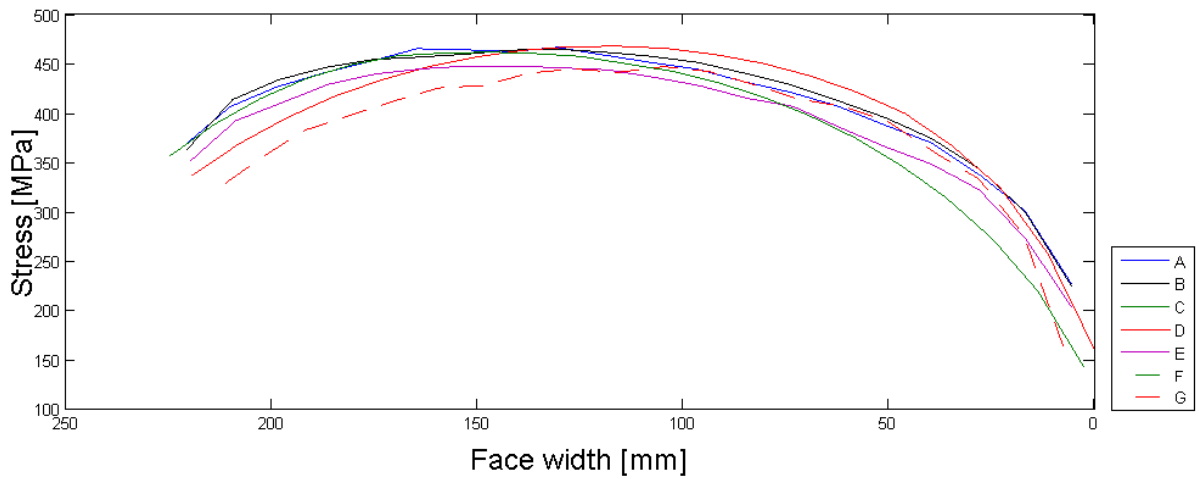
Contact Stress Distribution Comparison (9)



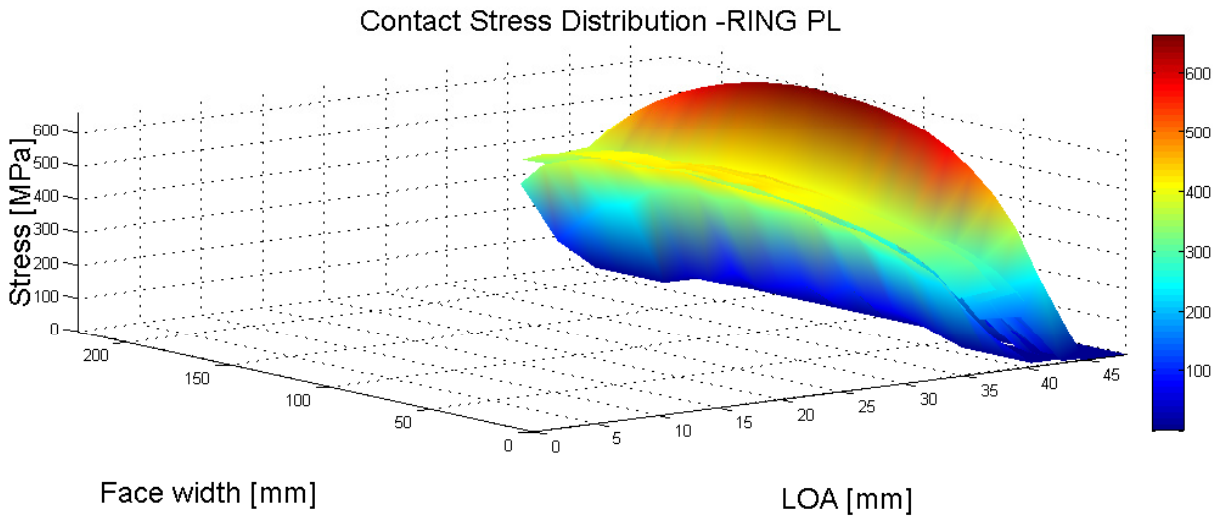


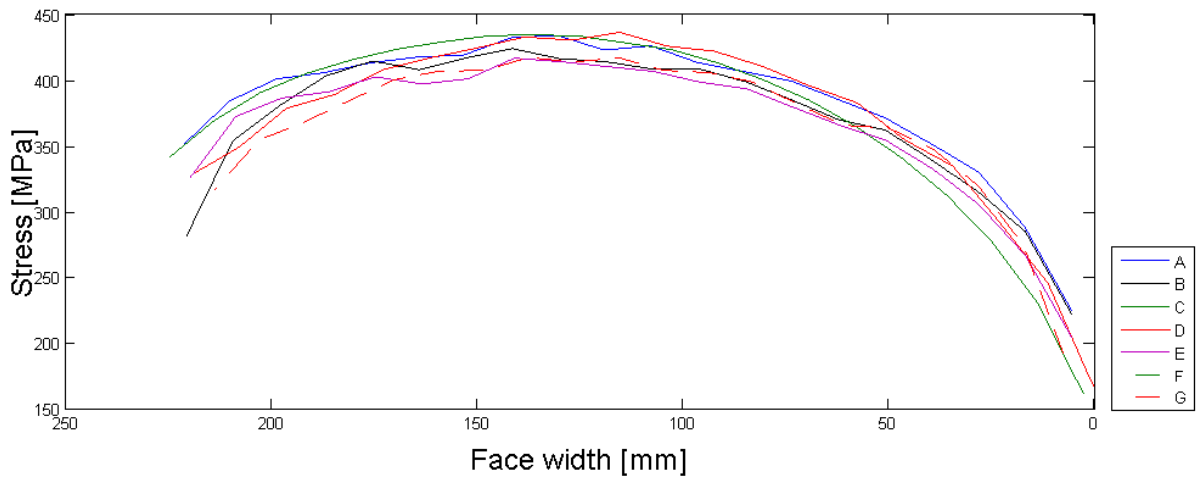
Contact Stress Distribution Comparison (10)



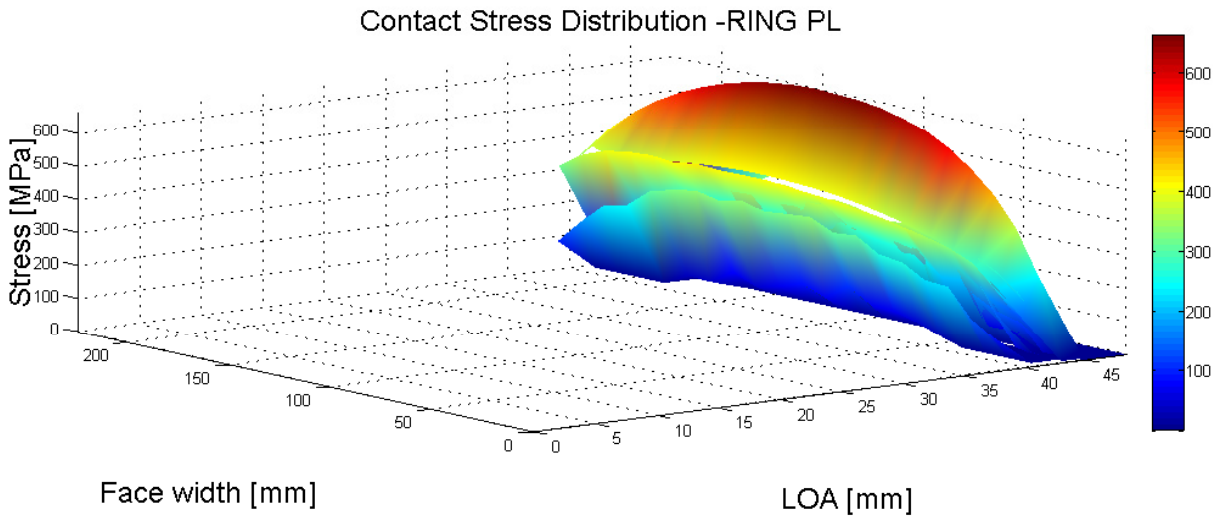


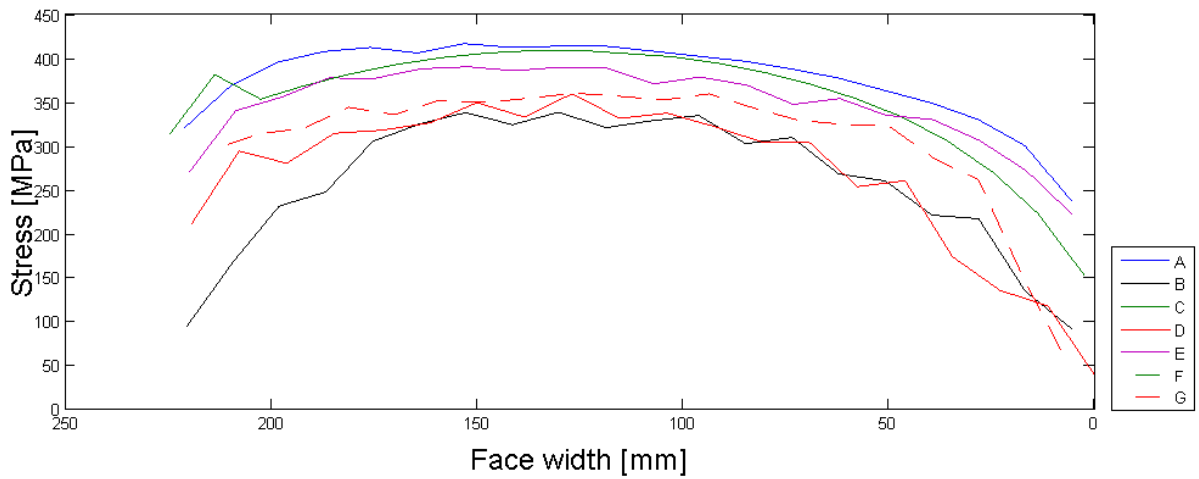
Contact Stress Distribution Comparison (11)



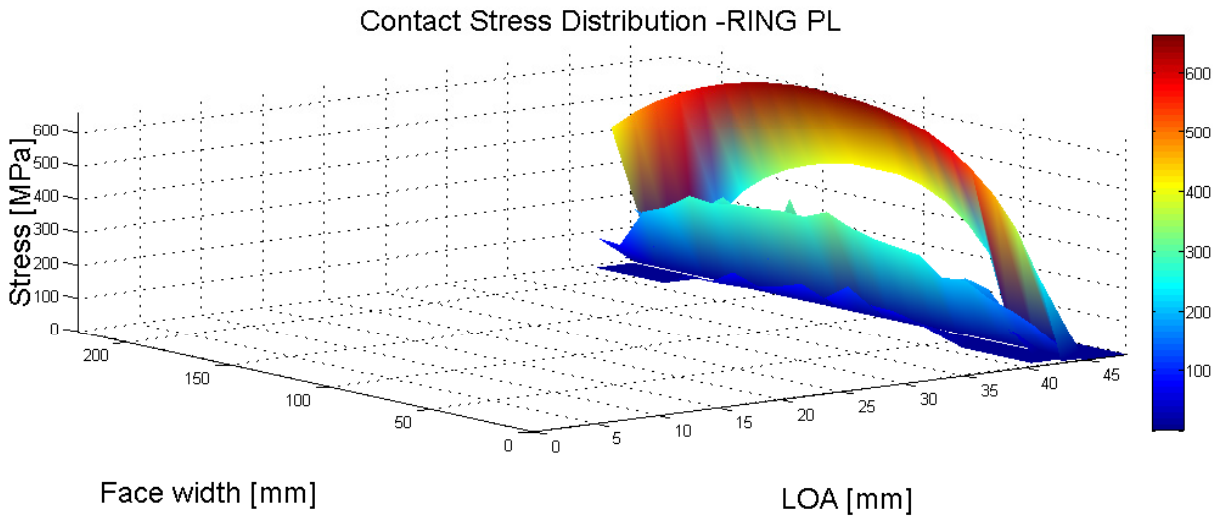


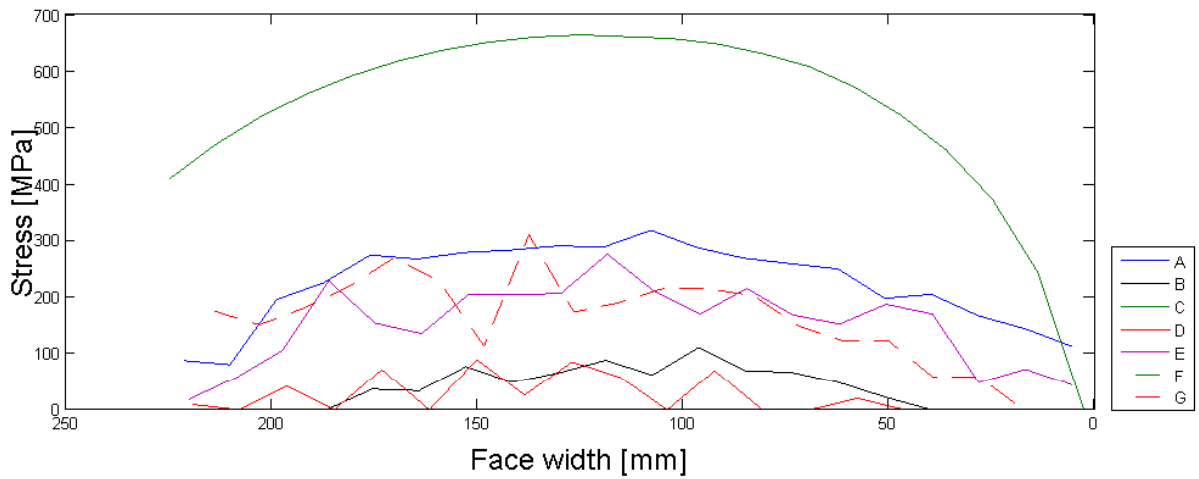
Contact Stress Distribution Comparison (12)





Contact Stress Distribution Comparison (13)





Current and Future Work

- Finish initial parameter comparison
- Revaluate highly dependent parameters
- Compare and validate dynamometer and field-test data
- Evaluate assumptions
- Add components to encompass the entire drivetrain
- Long term:
  - Produce multiple topical reports
  - Provide reference data set for future testing of analytical tools and analysis approaches
  - Provide support for standards updates