An Introduction to ANSI/AGMA/AWEA 6006-A03

AGMA 6006 TECHNICAL REQUIRMENTS

GEARBOX ARCHITECTURES

GEAR TOOTH LOAD DISTRIBUTION

GEARBOX VALIDATION

Ed Hahlbeck P.E. CMfgE

Powertrain Engineers

AGMA 6006 TECHNICAL REQUIRMENTS

Gearbox Architectures

- **OPERATION**
  - Upwind - Downwind
  - Stall - Pitch Controlled
  - Speed Fixed – Speed Variable
- **No of BLADES**
  - 2 Blade – Teetered 3 Blade
- **GENERATOR**
  - Induction – Synchronous
  - Direct Drive – Speed Increased
- **CONTRUCTION**
  - Modular - Integrated

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Gearbox Architectures

DESIGNS DRIVEN BY:

- Cost Of Energy
- Market Acceptance

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Gearbox Architectures

ARCHITECTURE INFLUENCE ON GEARBOX:

- Torque Spectrum
- Rotor Loads
- Control Strategy

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Gearbox Architectures - Influences

TORQUE SPECTRUM

- Stall vs. Pitch regulated, torque excursions
- Controlled torque, related to speed range
- Extreme events
  - Brake loads
  - Generator shorts
  - Inverter events

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Gearbox Architectures - Influences

ROTOR LOADS

- Fatigue structural path to tower
- Torque through bolted joints
- Extreme hub loads
- Reverse rotation

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Gearbox Architectures - Influences

CONTROL STRAGITY

- Over-speed limits
- Brake and rotor-lock application
  - Grid loss
  - Un-commissioned machines
  - E-Stop sequence

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Gearbox Architectures - Influences

INTEGRATION

- Understand interfaces
  - Loads, including gravity and inertial
  - Air movement at seals
- Understand structural flexibility
  - Full structure FEA
  - Consider unintended external loads
- Serviceability of gearbox

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GEAR TOOTH LOAD DISTRIBUTION

Section 5.1.1.2

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Gear Tooth Load Distribution

DIRECT PROPORTIONAL INFLUENCE

- $K_{H\beta}$ Load distribution, pitting
- $K_{F\beta}$ Load distribution, root bending strength

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Gear Tooth Load Distribution

Per 5.1.1.3 ADVANCED ANALYSIS *SHALL* BE USED

- **Load distribution-profile and lead at same time, micro-geometry level**
- **Influence of adjacent meshes**
- **Influence of shaft and bearing deflection**
- **Influence of stiffness in extremities**
- **Influence of manufacturing tolerances**

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Gear Tooth Load Distribution

INPUTS TO ADVANCED CONTACT ANALYSIS

- Fixed portion of bearing clearance, translated to plane of action
- Known deflections such as carrier torsion
- Nominal micro-geometry
- Range of manufacturing tolerances, f_{ma}

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Gear Tooth Load Distribution

INPUTS TO ADVANCED CONTACT ANALYSIS

- **Range of manufacturing tolerances, f_{ma} typical worksheet**

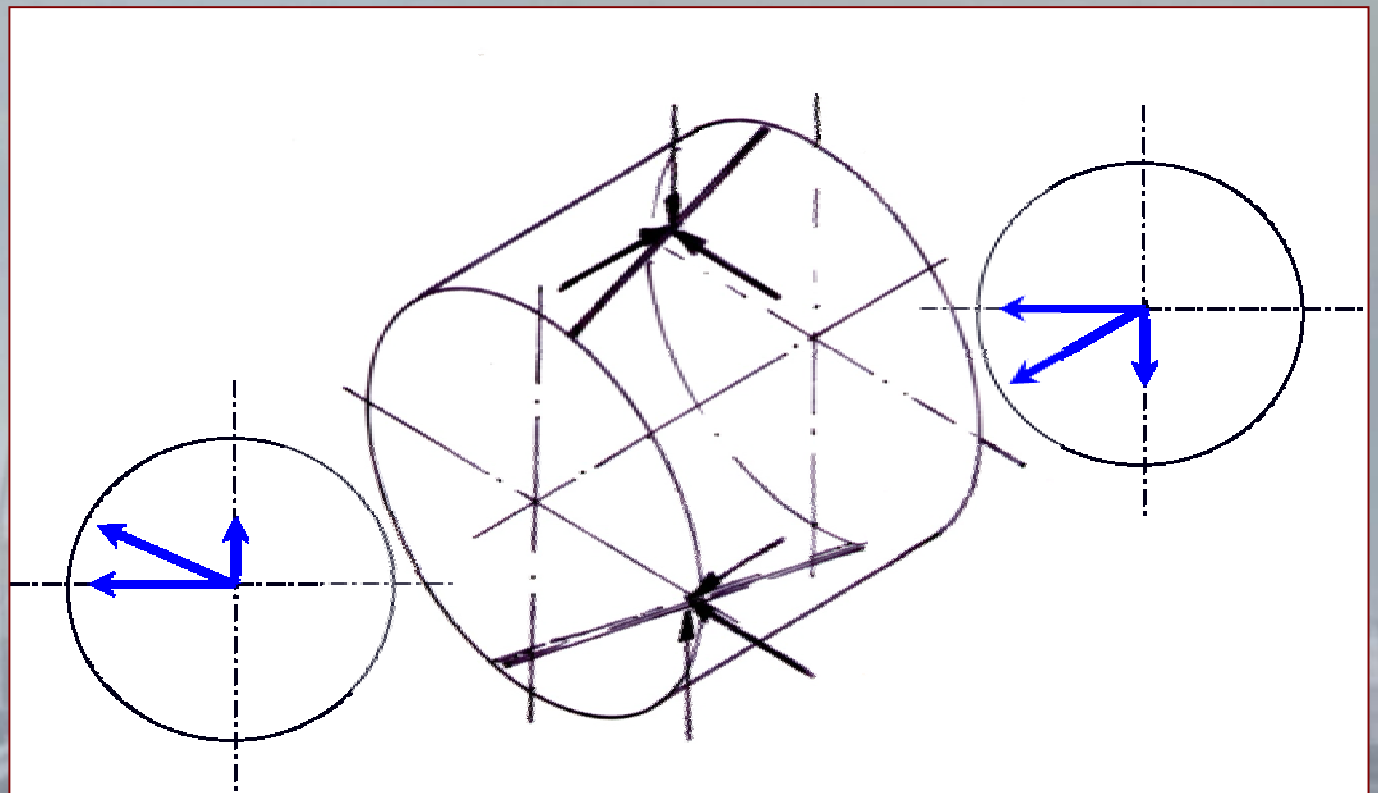
							Max deviation		Min deviation		
Ref	Item	Description of variable tolerances	Deviation, +	Deviation, -	Span	Face width	Deviation in tooth face width	Deviation in tooth facewidth^2	Deviation in tooth face width	Deviation in tooth facewidth^2	
Stage 1	1	Misalignment, mainshaft bores	0.0950	-0.0950	780.000	175	0.021	0.00045	-0.021	0.00045	Planetary stage
	2	Misalignment, pinion bores	0.0400	-0.0400	780.000	175	0.009	0.00008	-0.009	0.00008	
	3	uriation lrg dr, Bearing probable fit	0.0430	-0.0430	780.000	175	0.010	0.00009	-0.010	0.00009	
		Total offset	0.178	-0.178			0.040	0.00063		0.00063	
Bull gear	4	Bullgearhelix slope deviation	0.0070	-0.0070	780.000	175	0.0016	0.00000	0.0016	0.00000	
		Total offset	0.0070	-0.0070				0.00000		0.00000	
Stg 1 pinion	5	Stage 1 pinion helix slope deviatio	0.0070	-0.0070	780.000	175	0.0016	0.00000	0.0016	0.00000	
			0.0070	-0.0070				0.00000		0.00000	
							RMS value	0.02516		-0.02516	

AGMA 6006 TECHNICAL REQUIRMENTS

Gear Tooth Load Distribution

INPUTS TO ADVANCED CONTACT ANALYSIS

- **Offset due to bearing clearance**

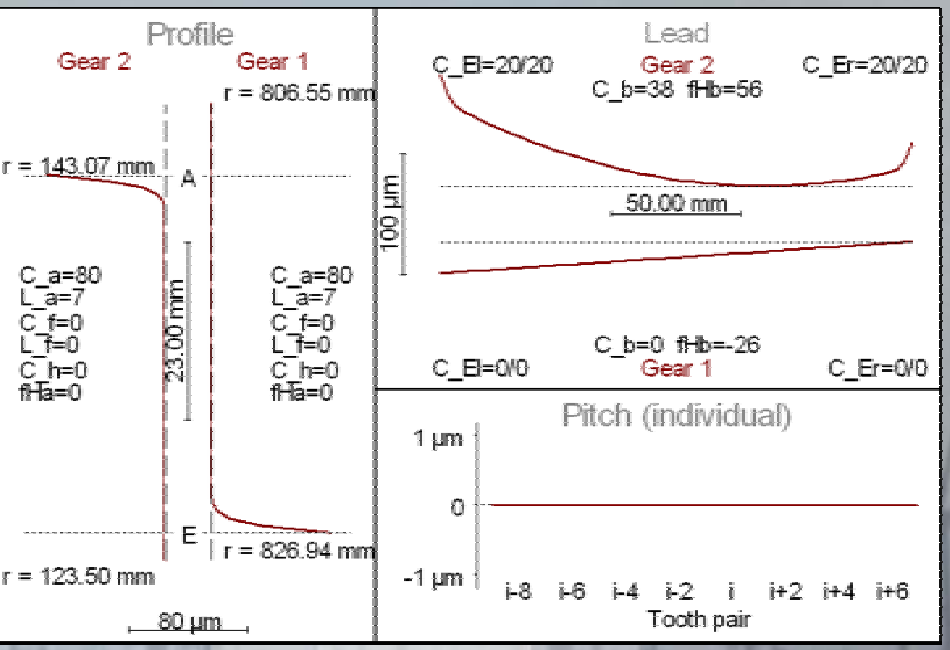


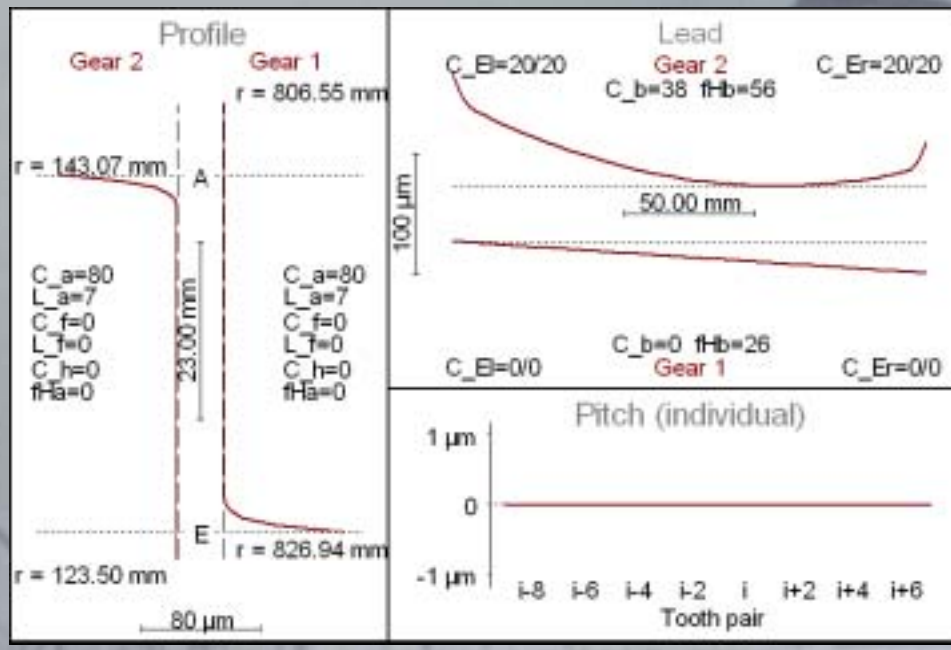
AGMA 6006 TECHNICAL REQUIRMENTS

Gear Tooth Load Distribution

INPUTS TO ADVANCED CONTACT ANALYSIS

- **Input of micro-geometry**



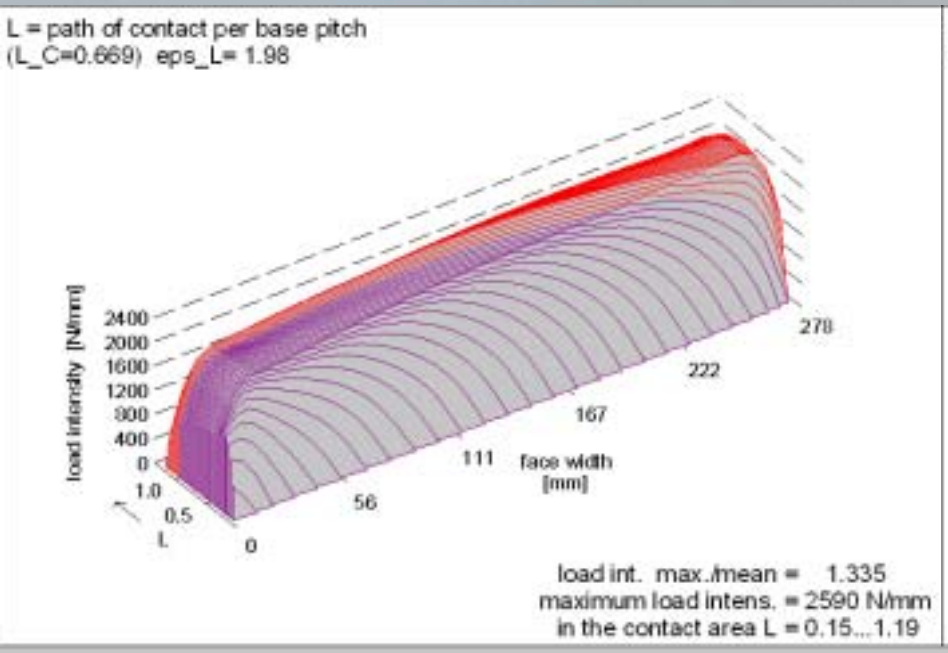


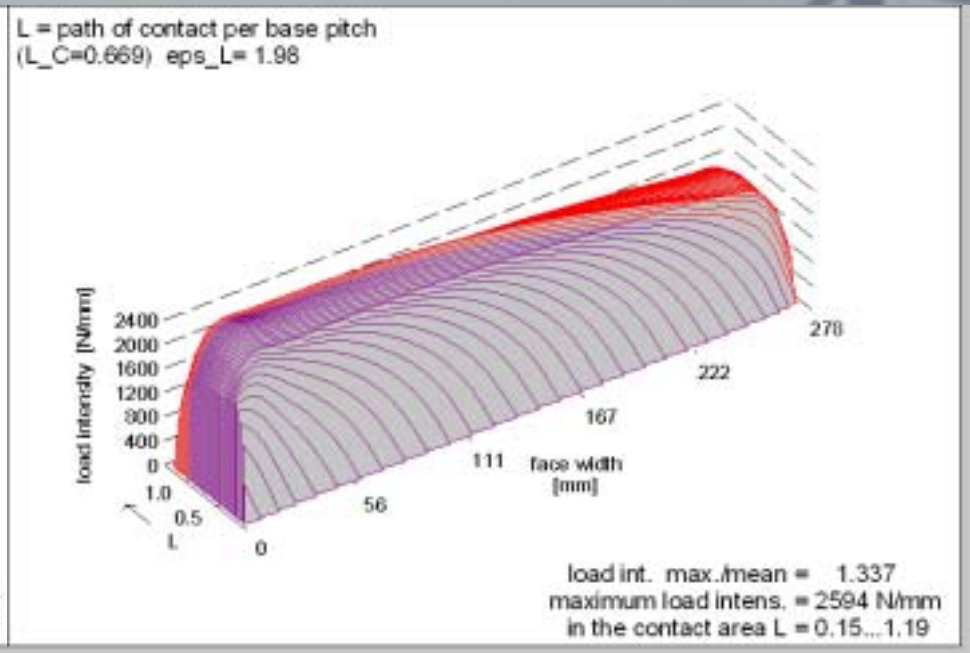
AGMA 6006 TECHNICAL REQUIRMENTS

Gear Tooth Load Distribution

RESULTS OF MESH ANALYSIS, $K_{H\beta}$

- **With influence of mfg tolerances**





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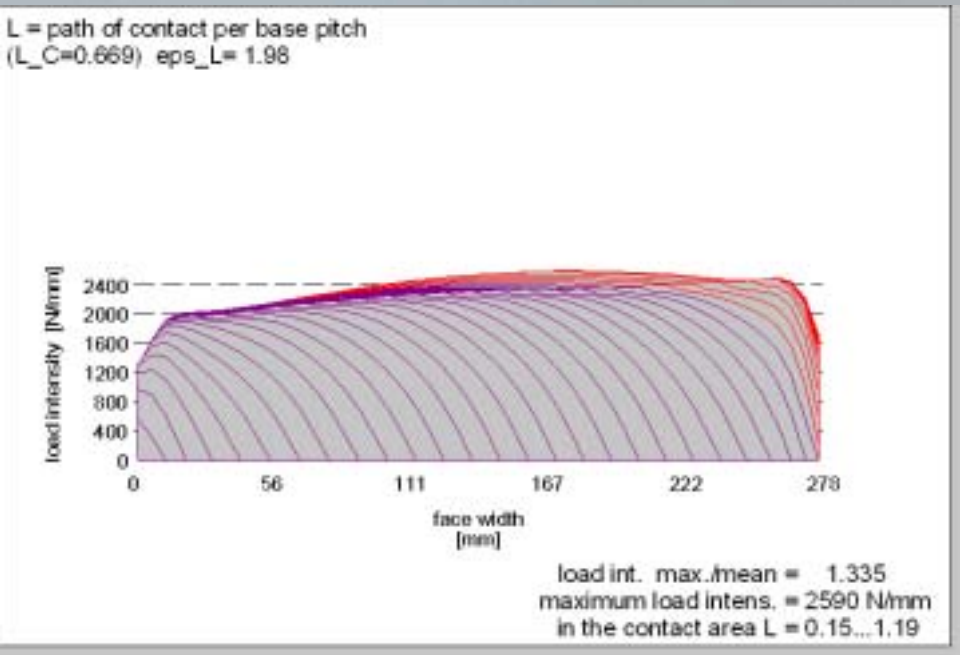

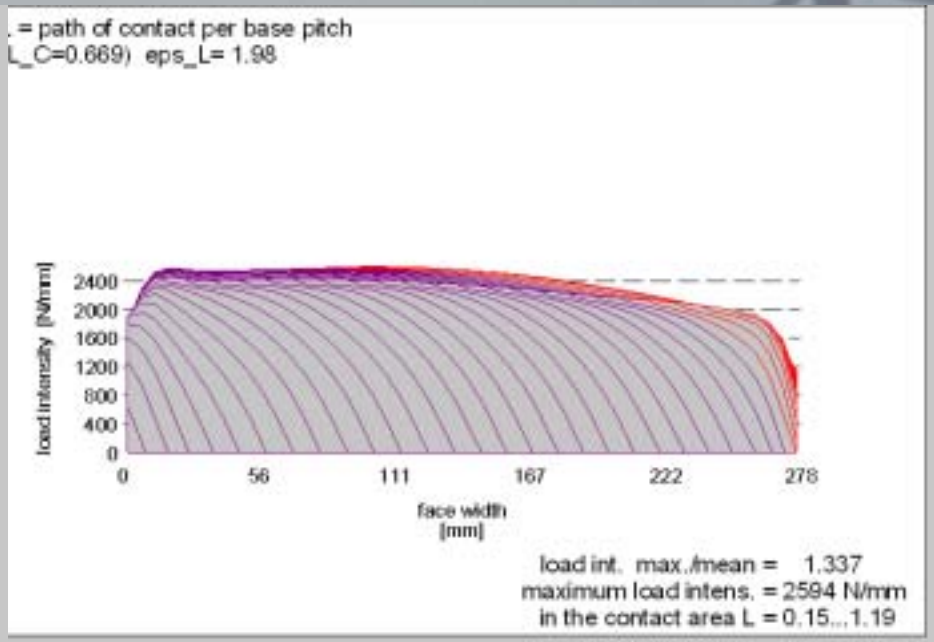

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Gear Tooth Load Distribution

RESULTS OF MESH ANALYSIS, $K_{F\beta}$

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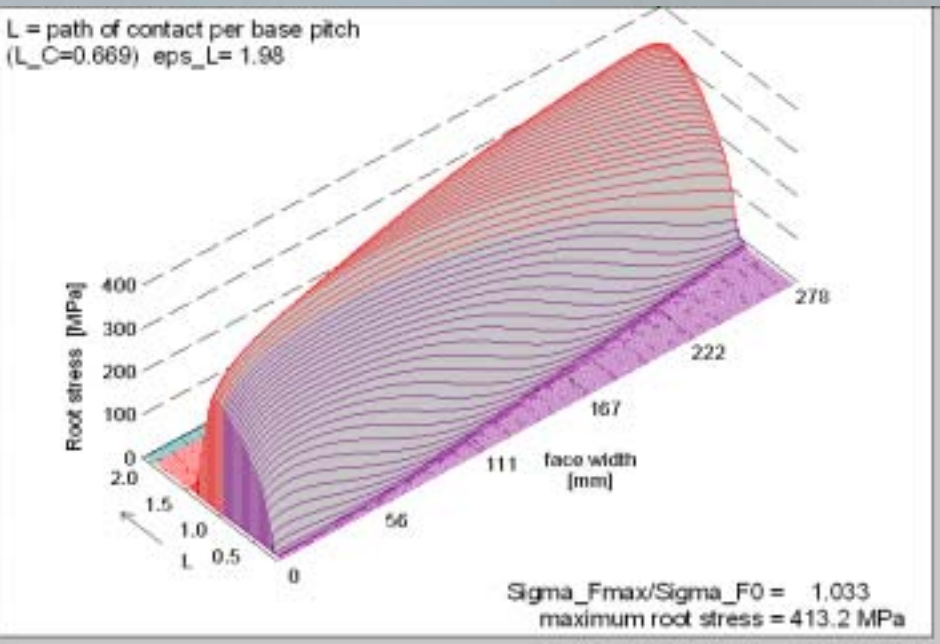

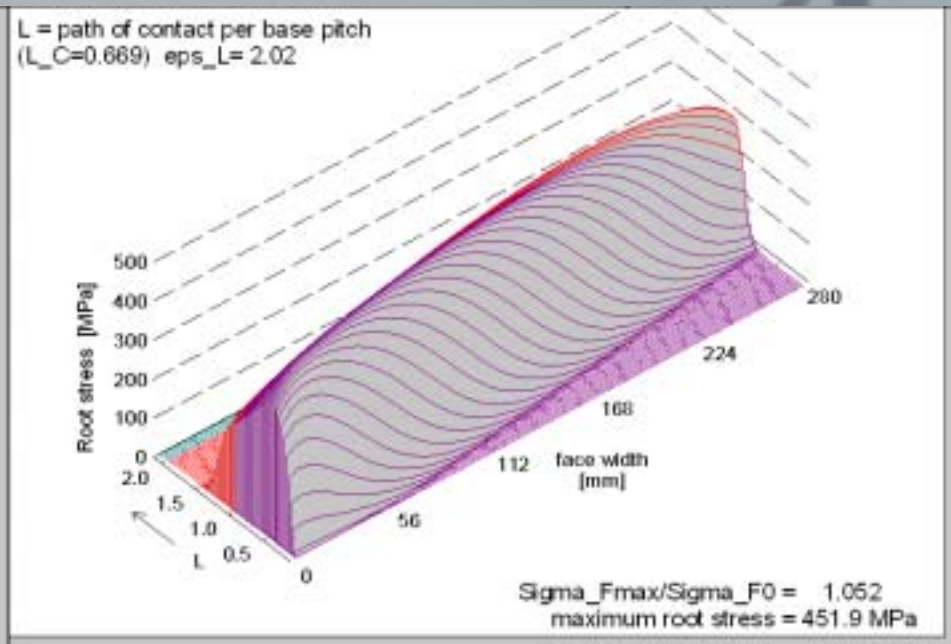

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Gear Tooth Load Distribution

RESULTS OF MESH ANALYSIS, Bearing loads

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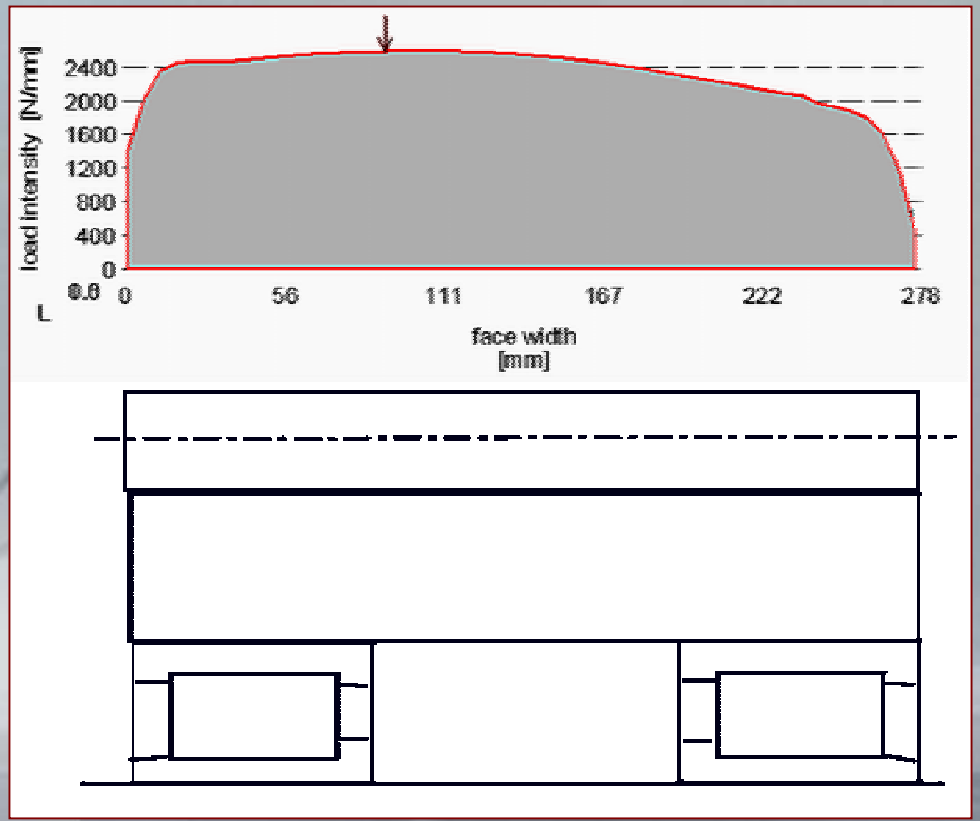


AGMA 6006 TECHNICAL REQUIRMENTS

Qualification testing (Gears)

Section 4.8.1

AGMA 6006 TECHNICAL REQUIRMENTS

Qualification Testing (Gears)

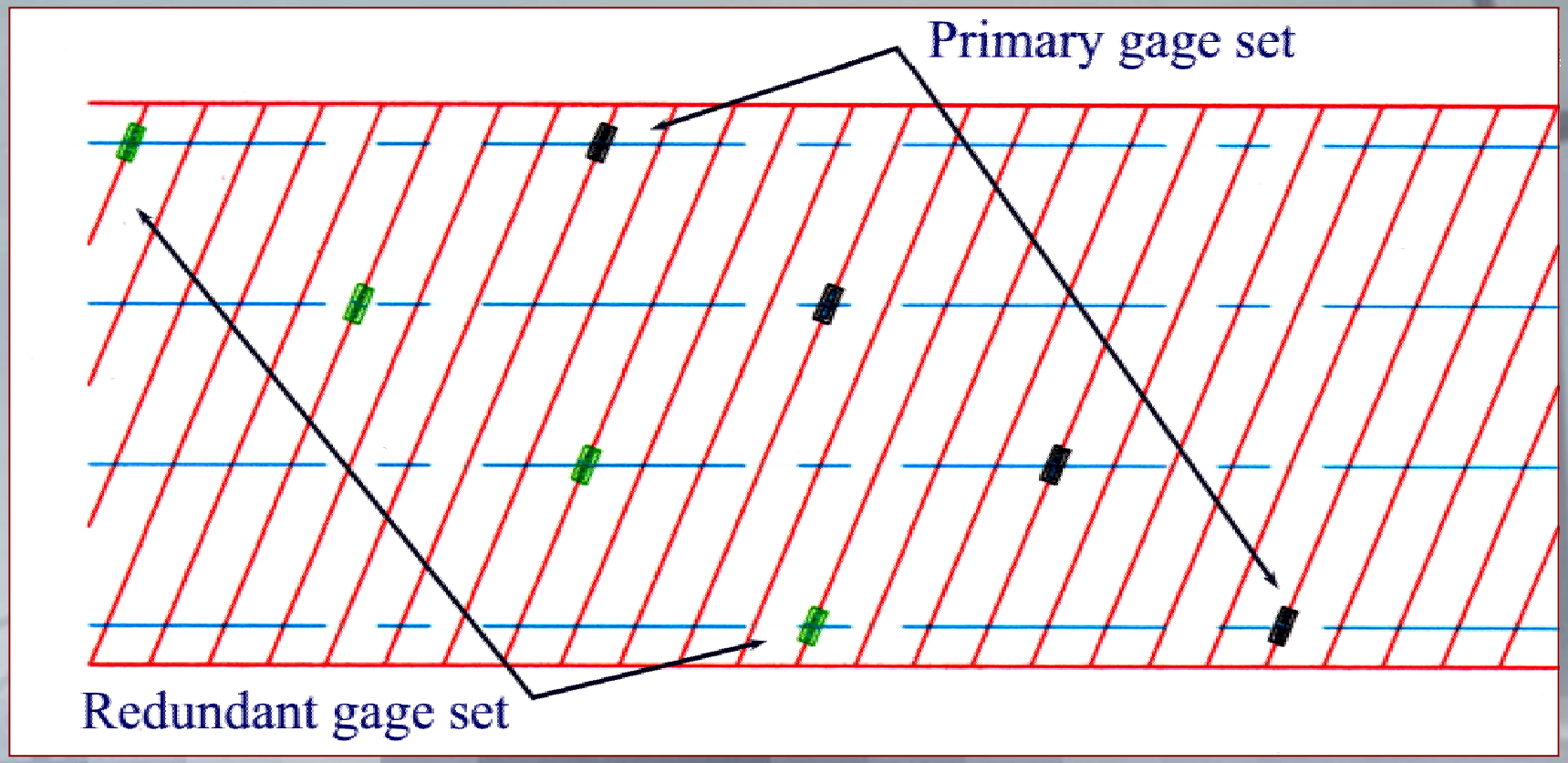
TESTING PROCESS

- Micro geometry via advanced mesh analysis
- Produce and measure prototype
- Measure root strain across the face width, at design load
- Tune mesh model to duplicate exact conditions and results
- Modify micro geometry and repeat process

AGMA 6006 TECHNICAL REQUIRMENTS

Qualification Testing (Gears)

TESTING PROCESS, MEASURING STRAIN



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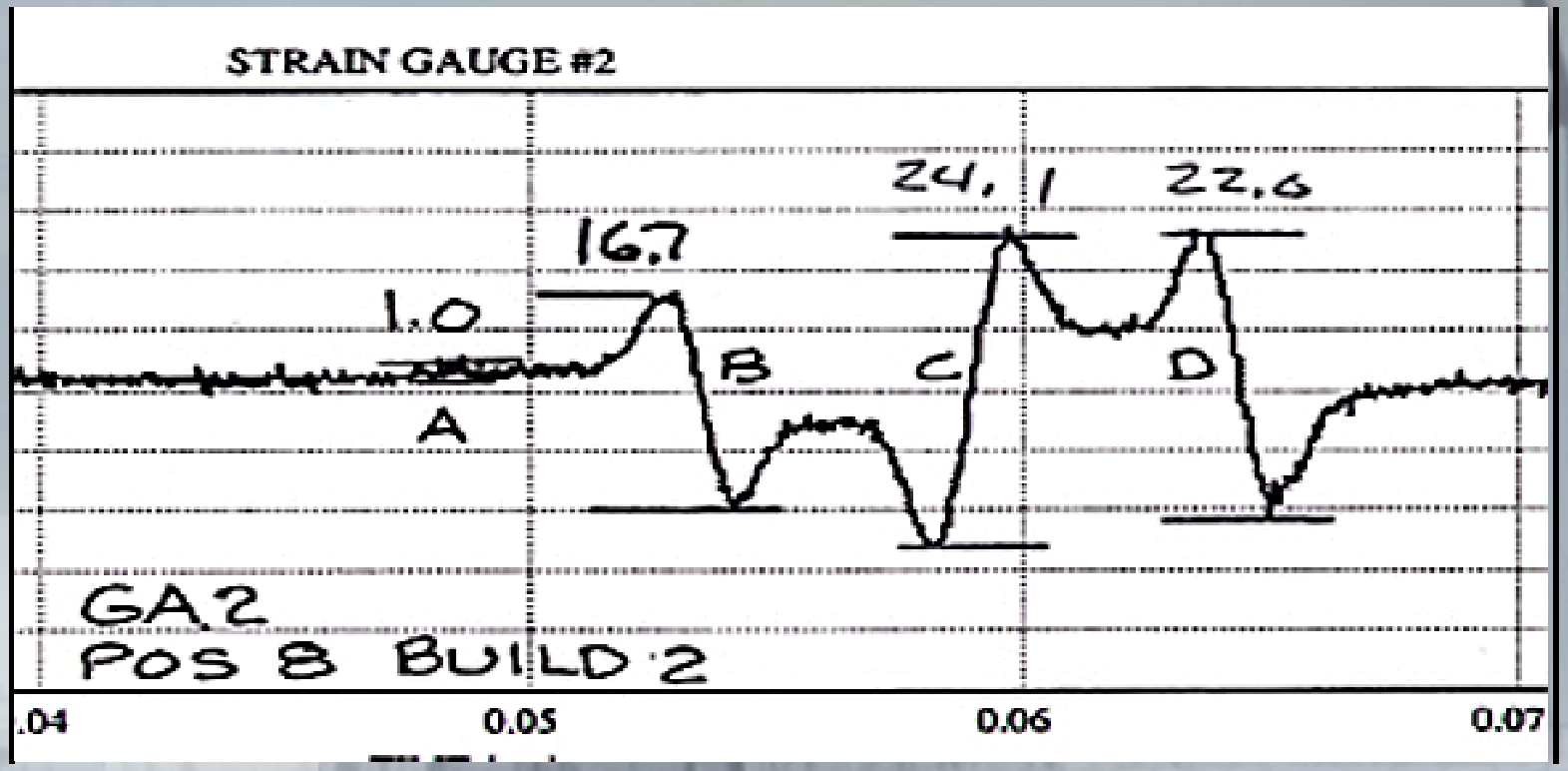
Qualification Testing (Gears)

TESTING PROCESS, RESULTING SIGNAL



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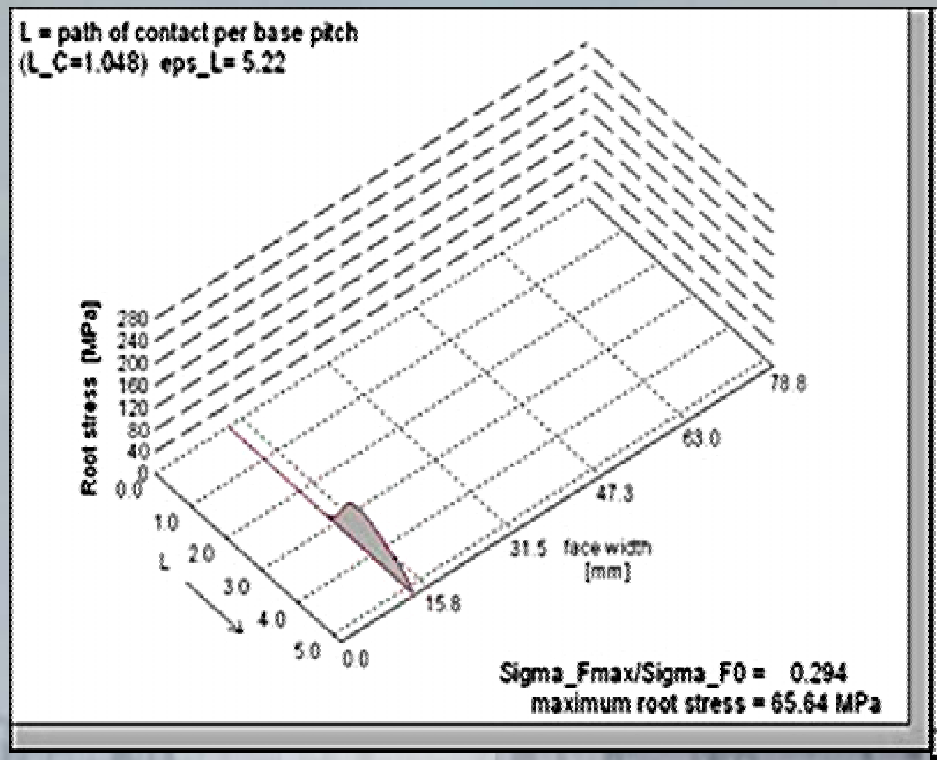
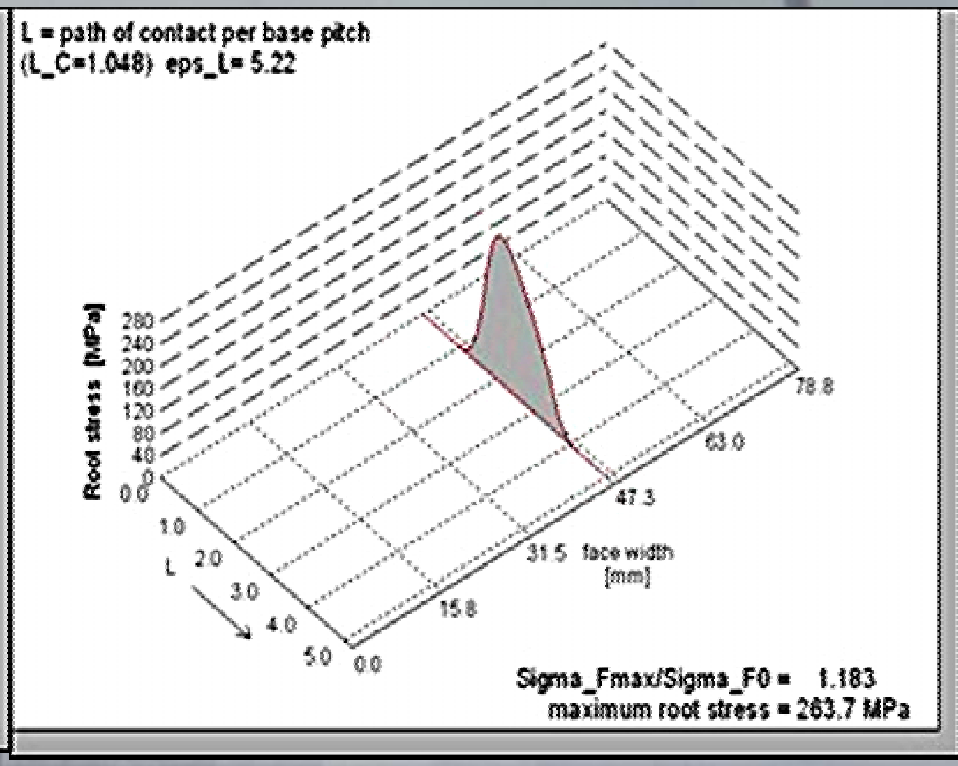
Qualification Testing (Gears)

TESTING PROCESS, OBTAIN THEORETICAL VALUES





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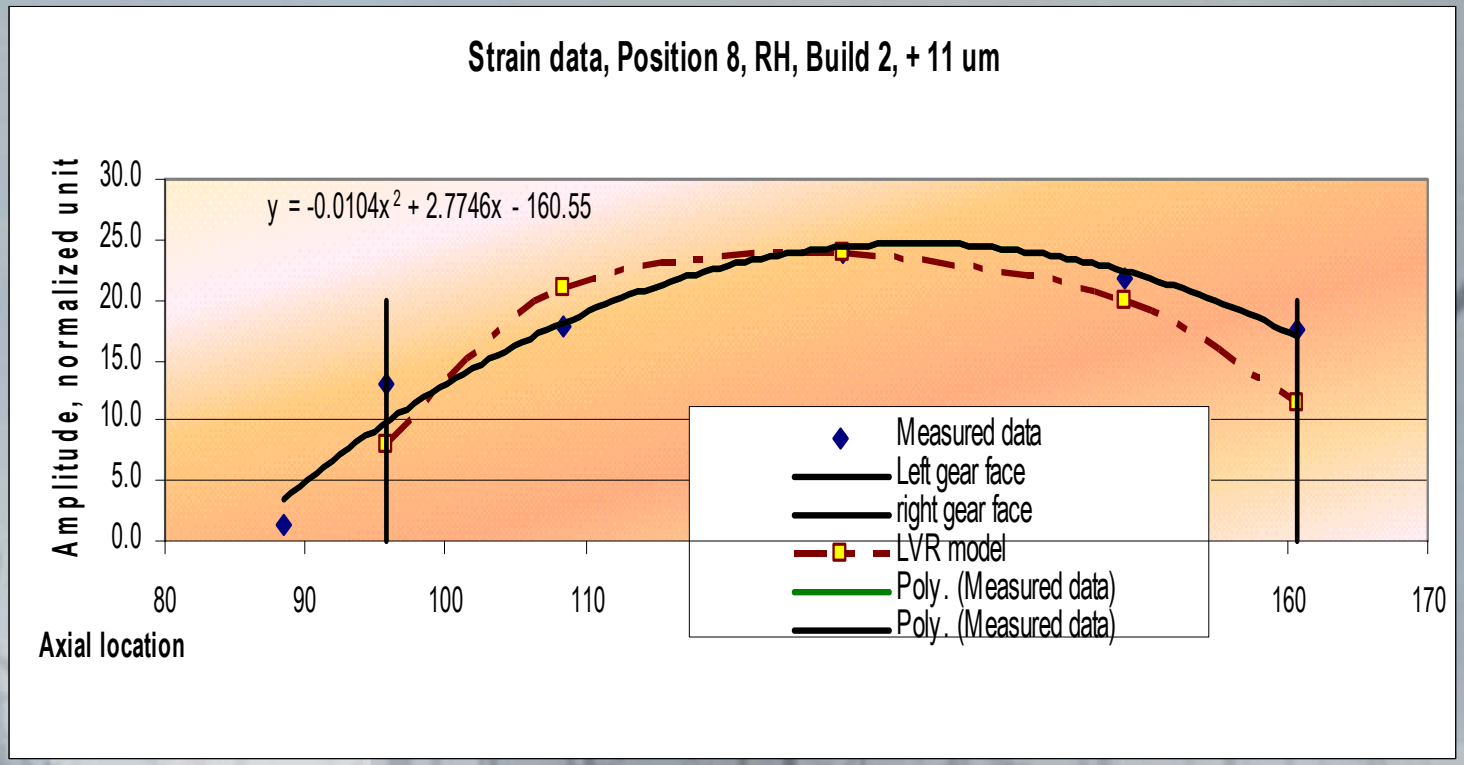
Qualification Testing (Gears)

TESTING PROCESS, COMPARE TO MODEL



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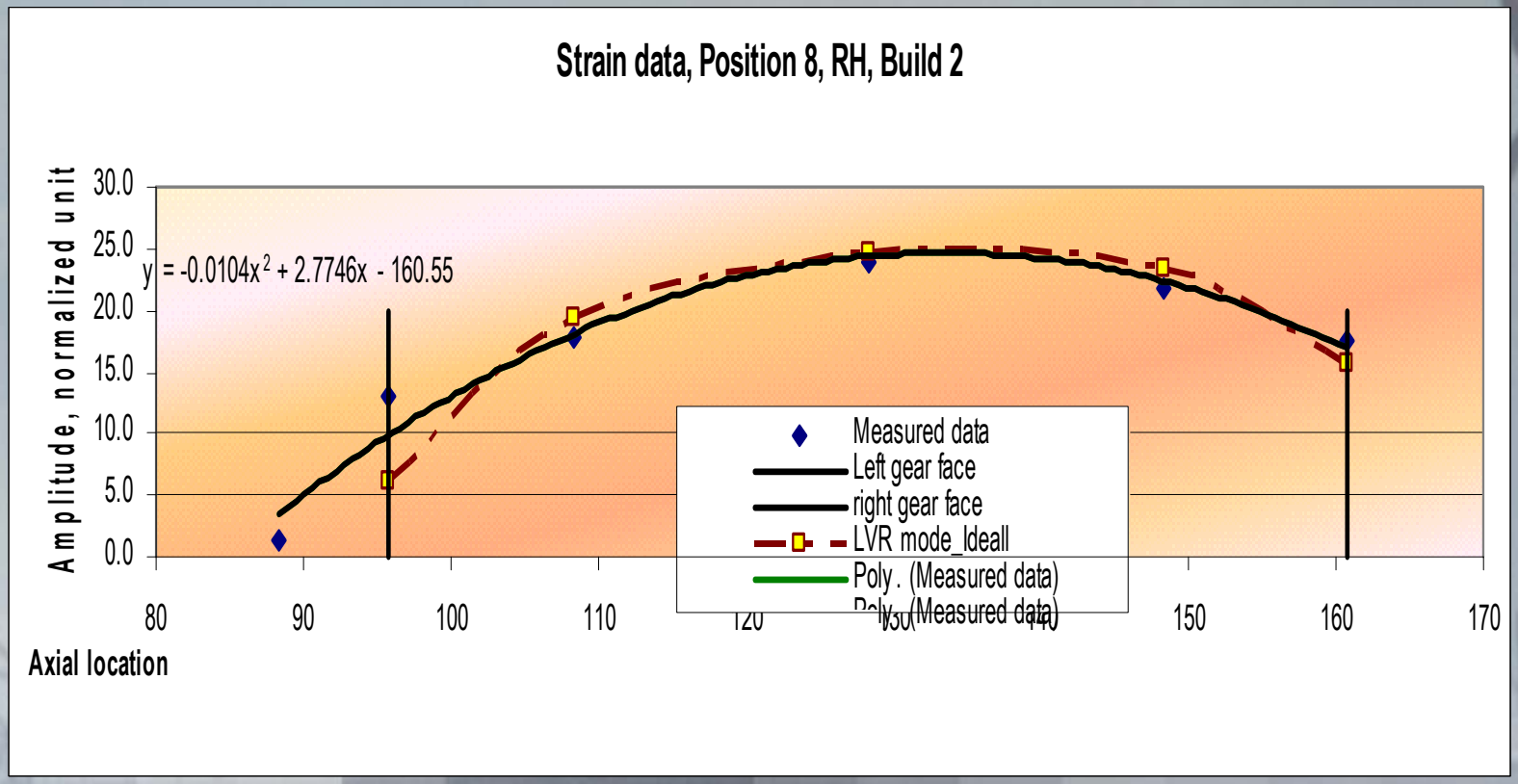
TESTING PROCESS, TUNE MODEL



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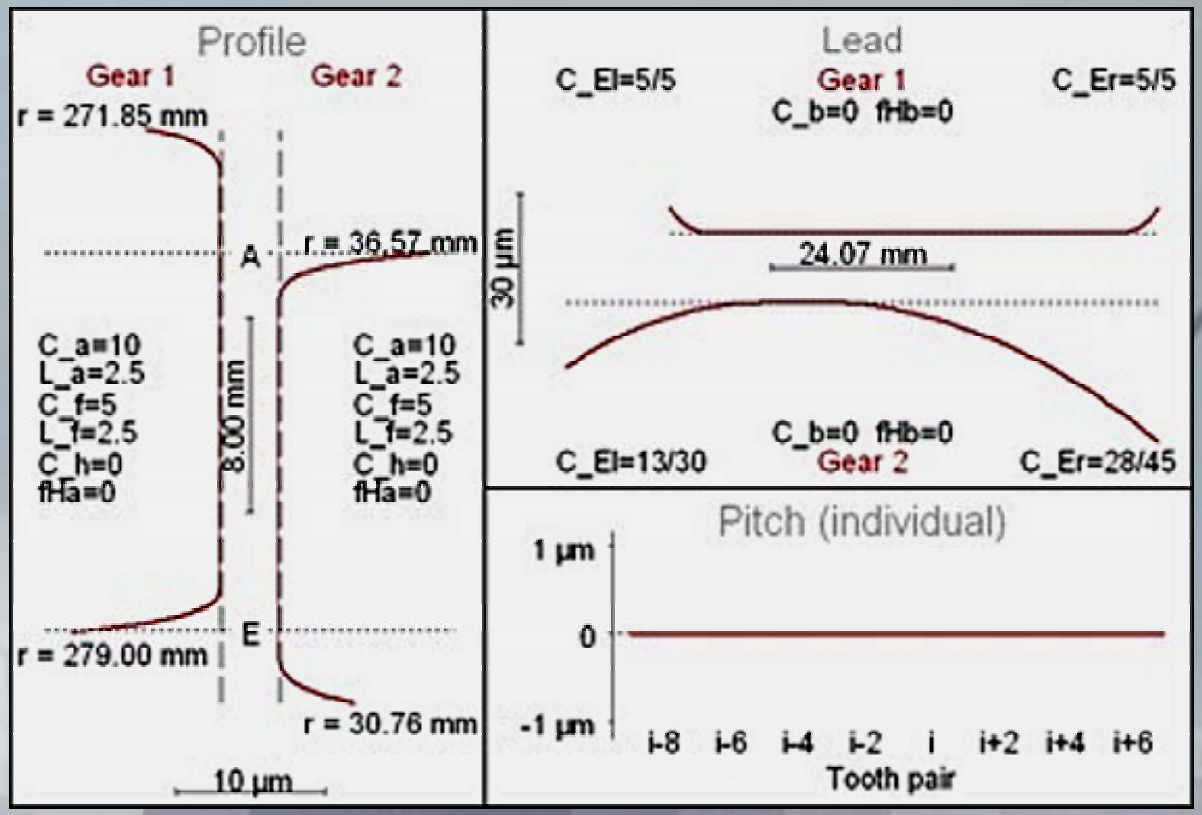
Qualification Testing (Gears)

TESTING PROCESS, MODIFY MICRO - GEOMETRY AND RE-TEST



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Gear Tooth Load Distribution

RESULTS OF MESH ANALYSIS, $K_{H\beta}$

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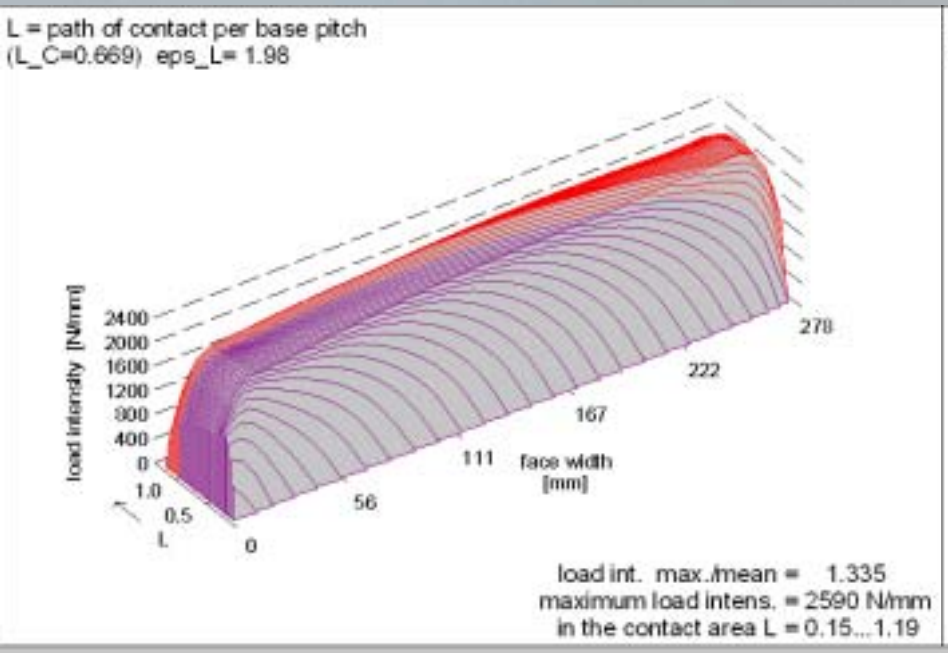

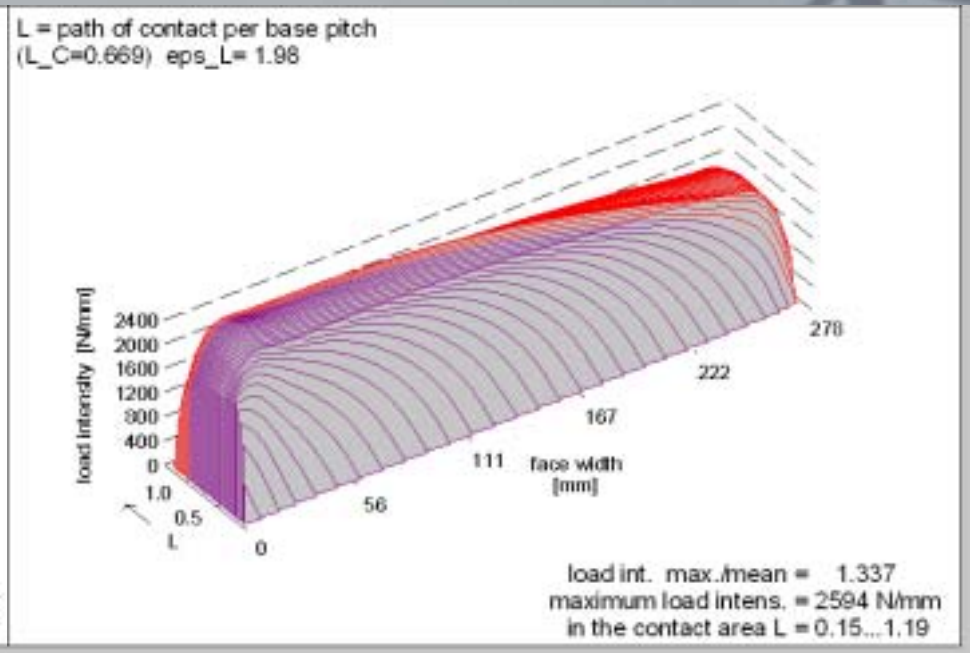

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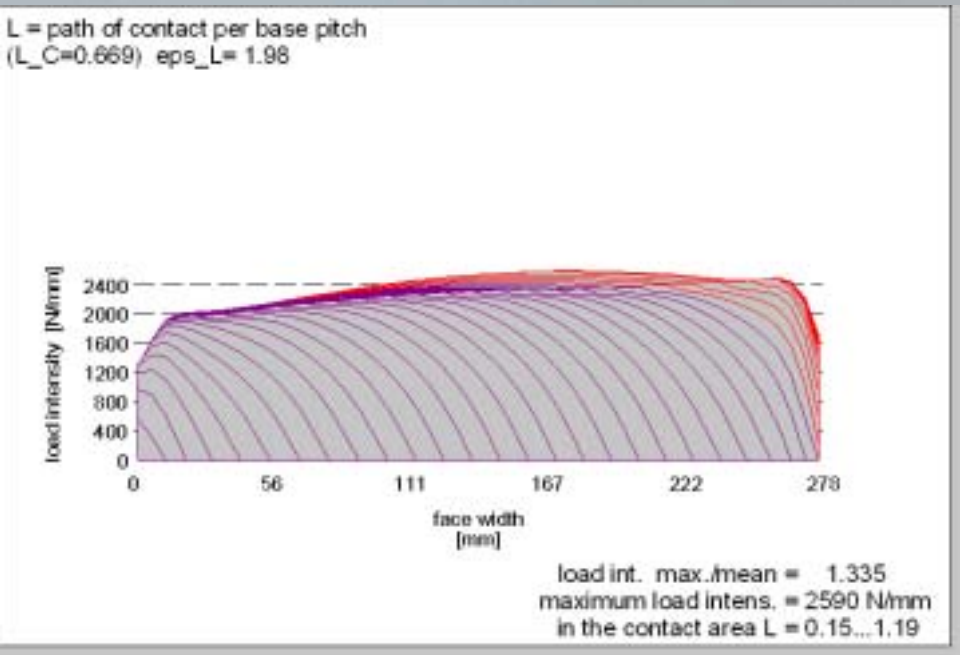

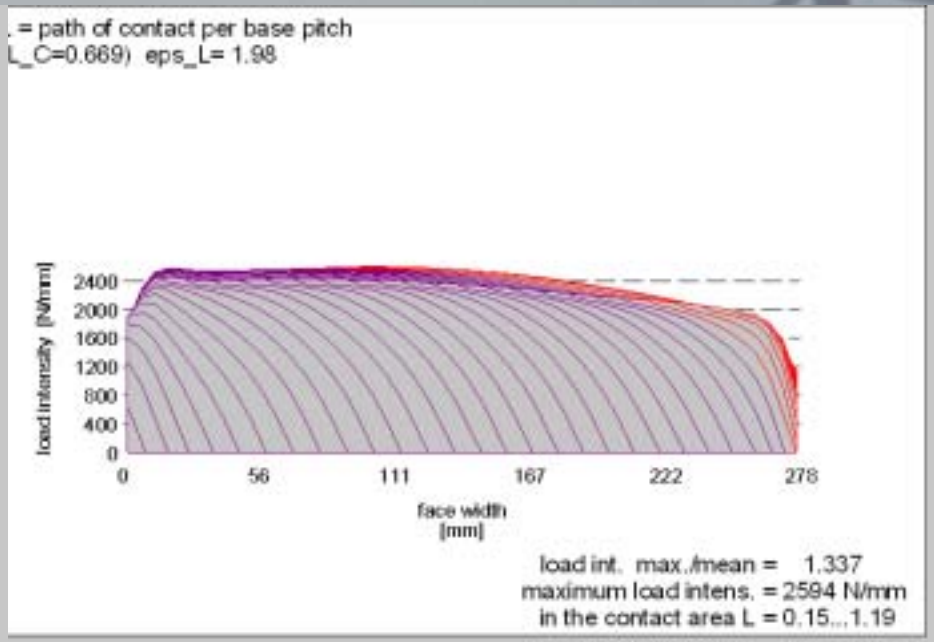

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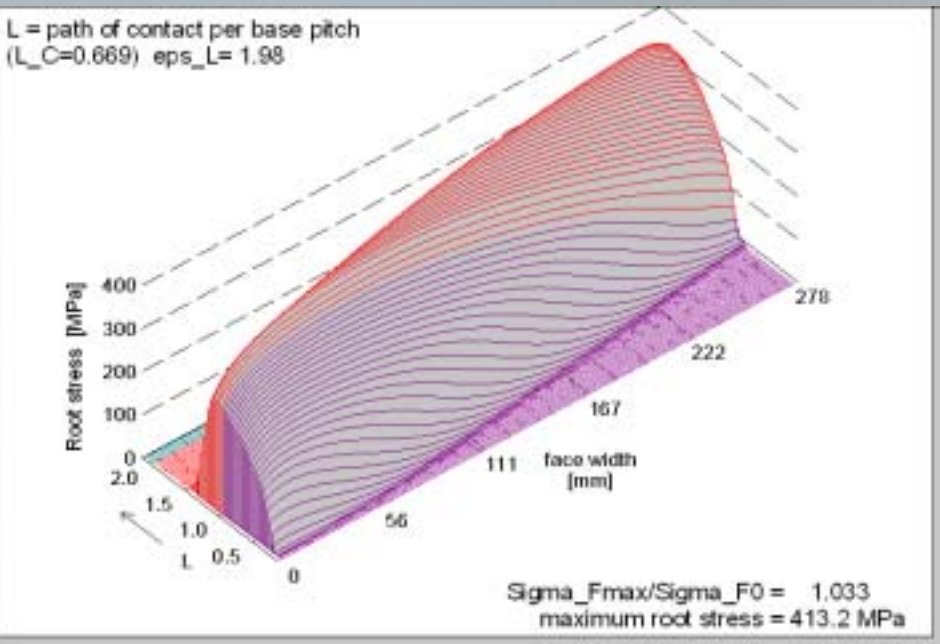

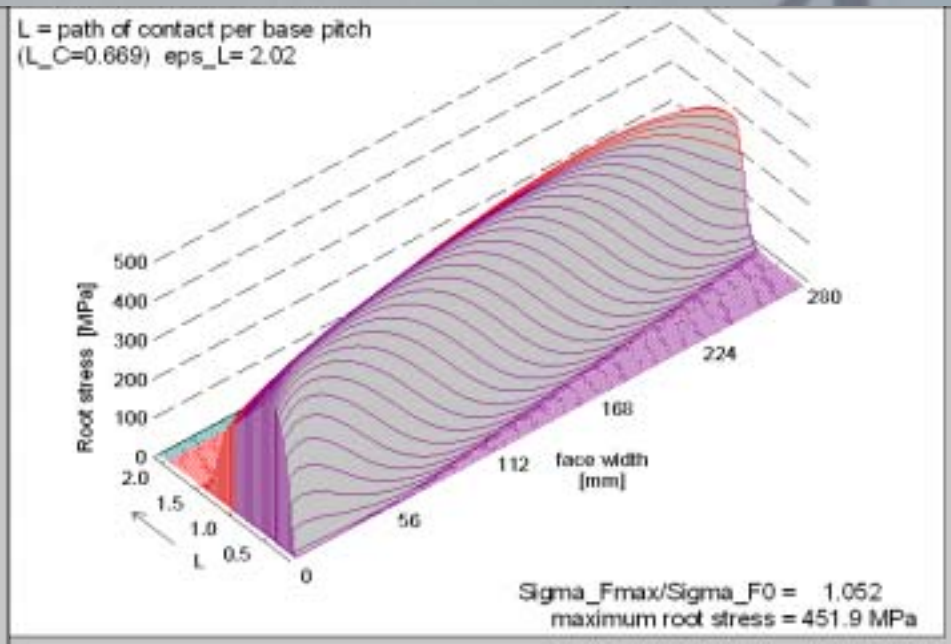

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Gear Tooth Load Distribution

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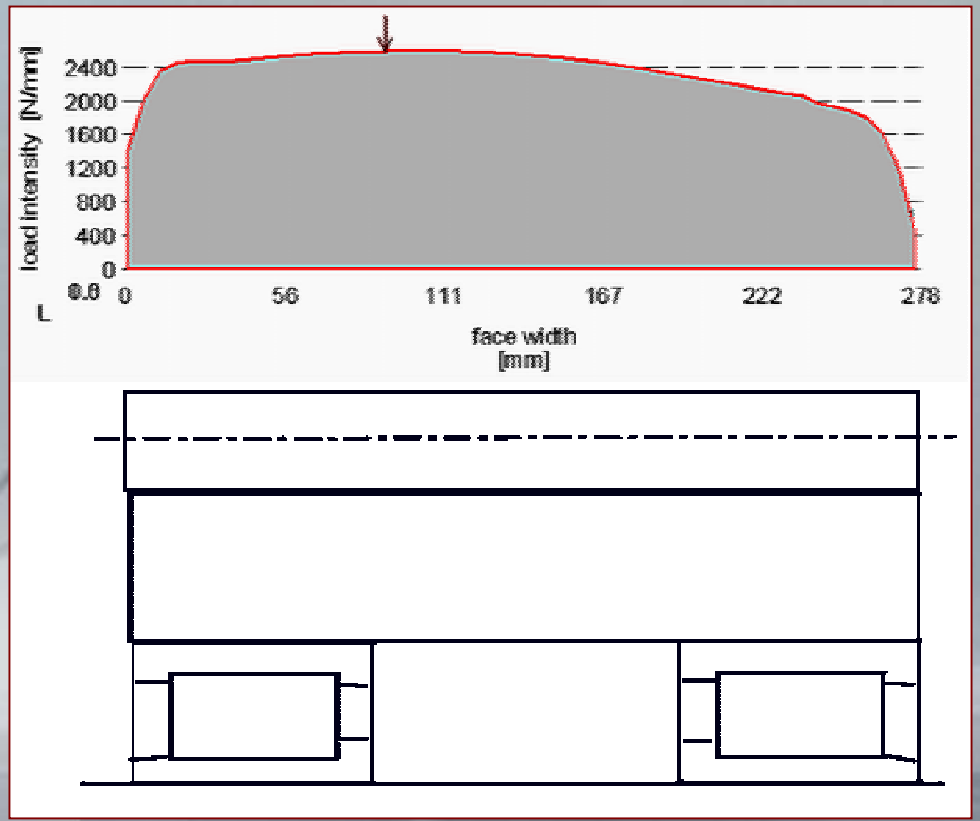

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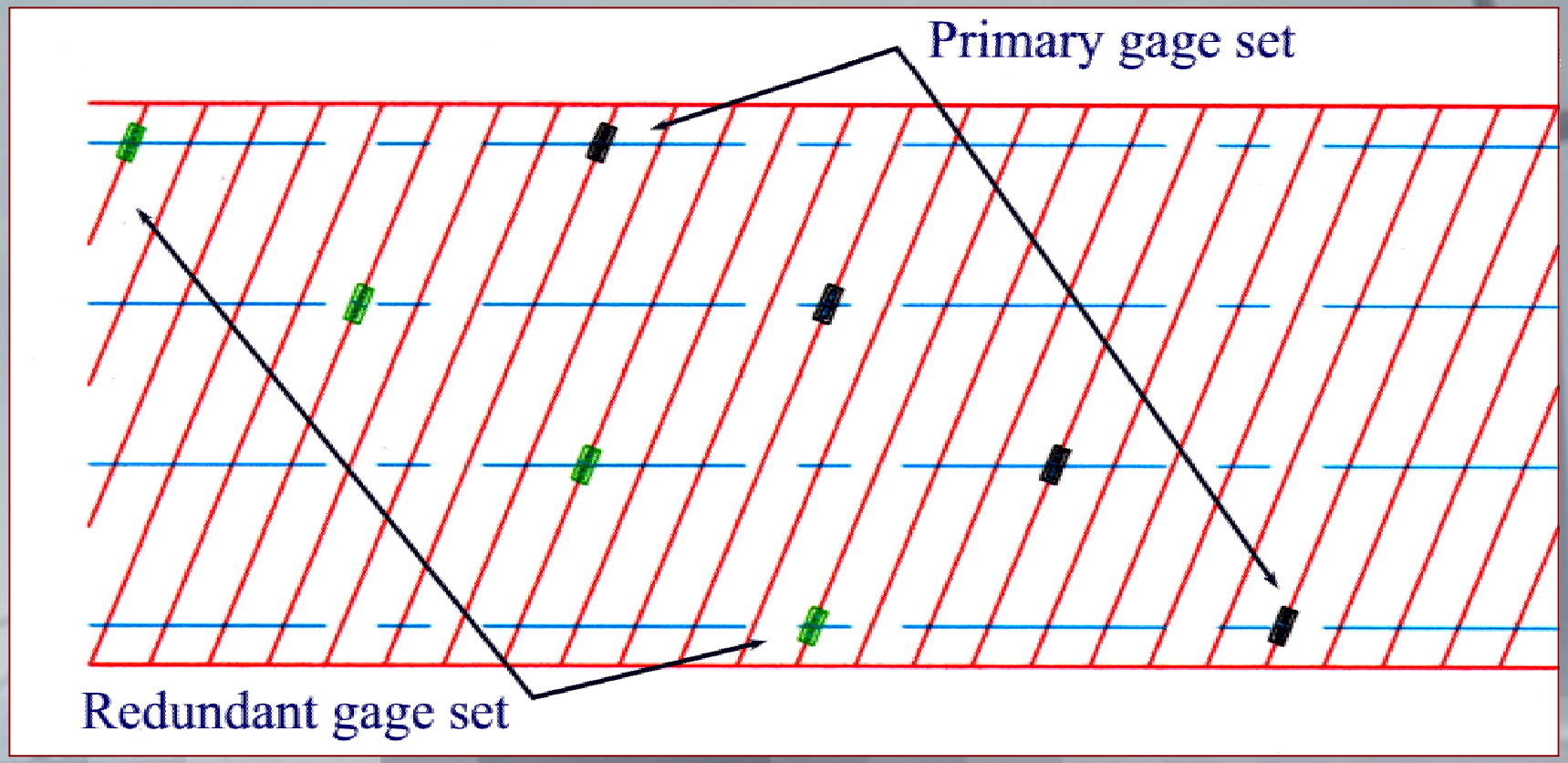

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Qualification Testing (Gears)

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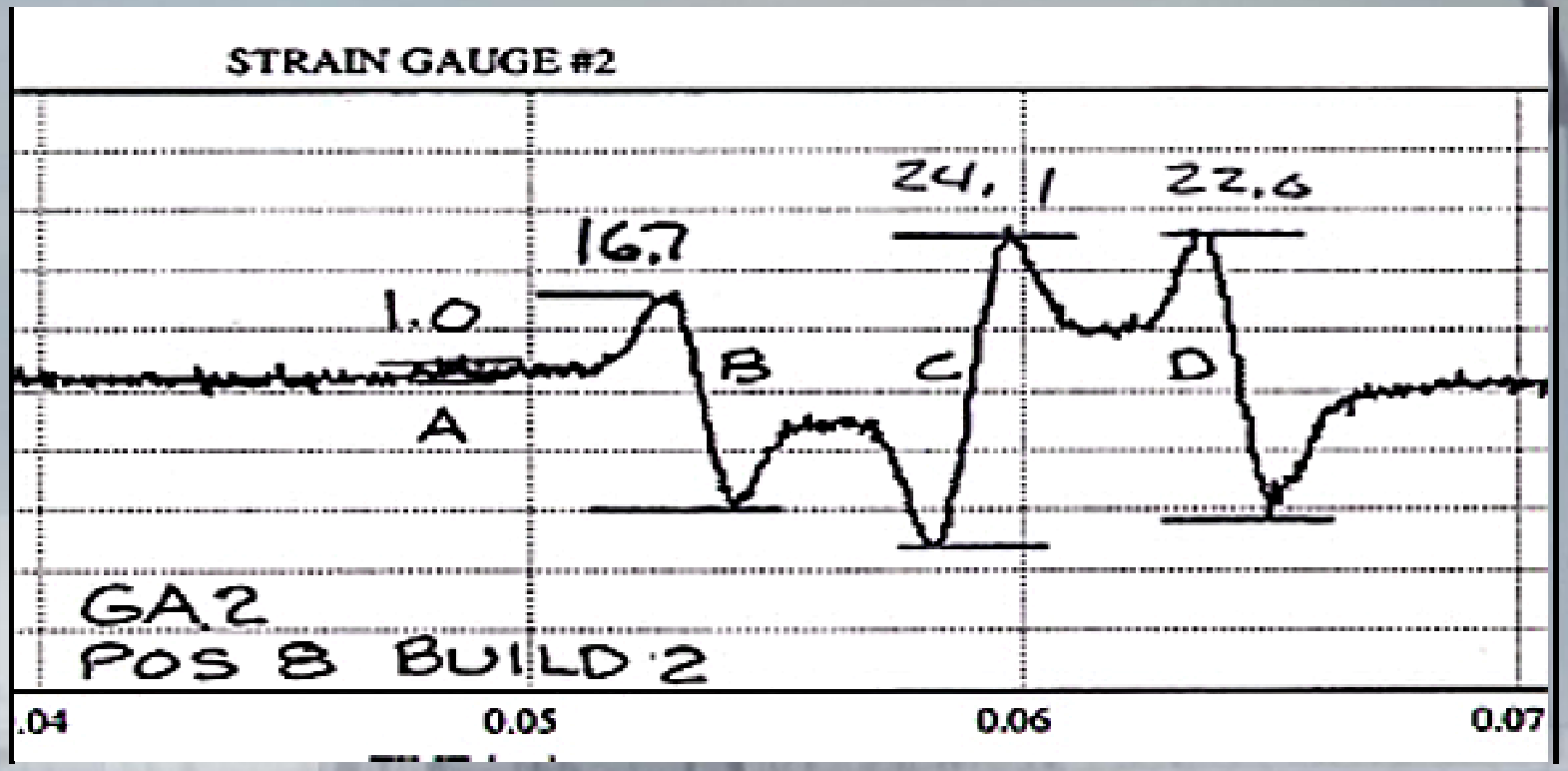

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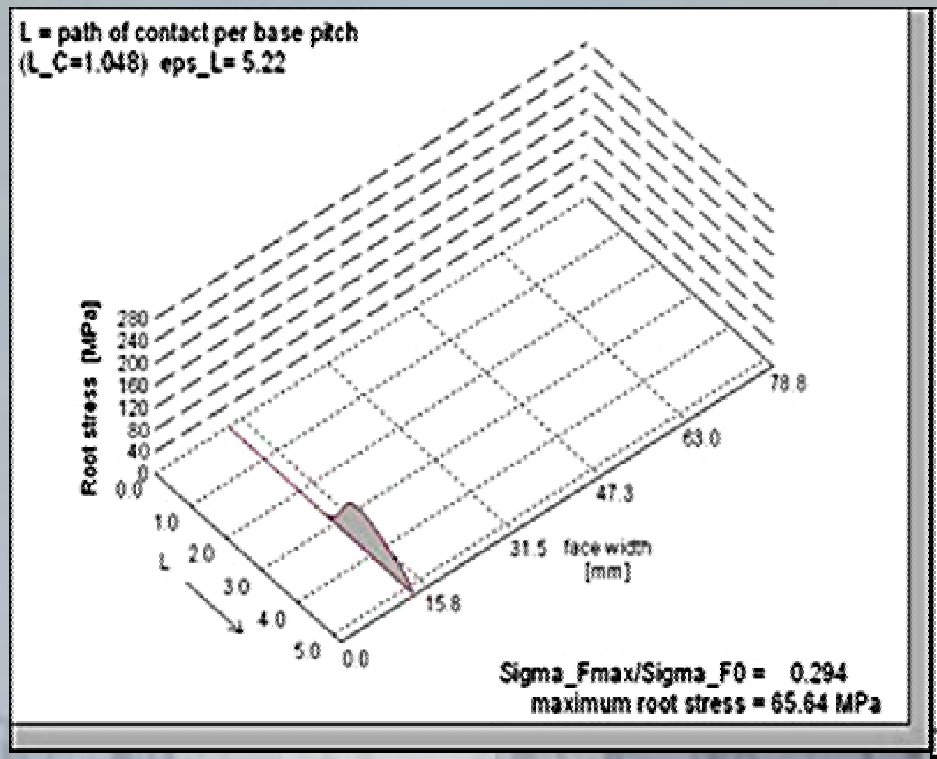

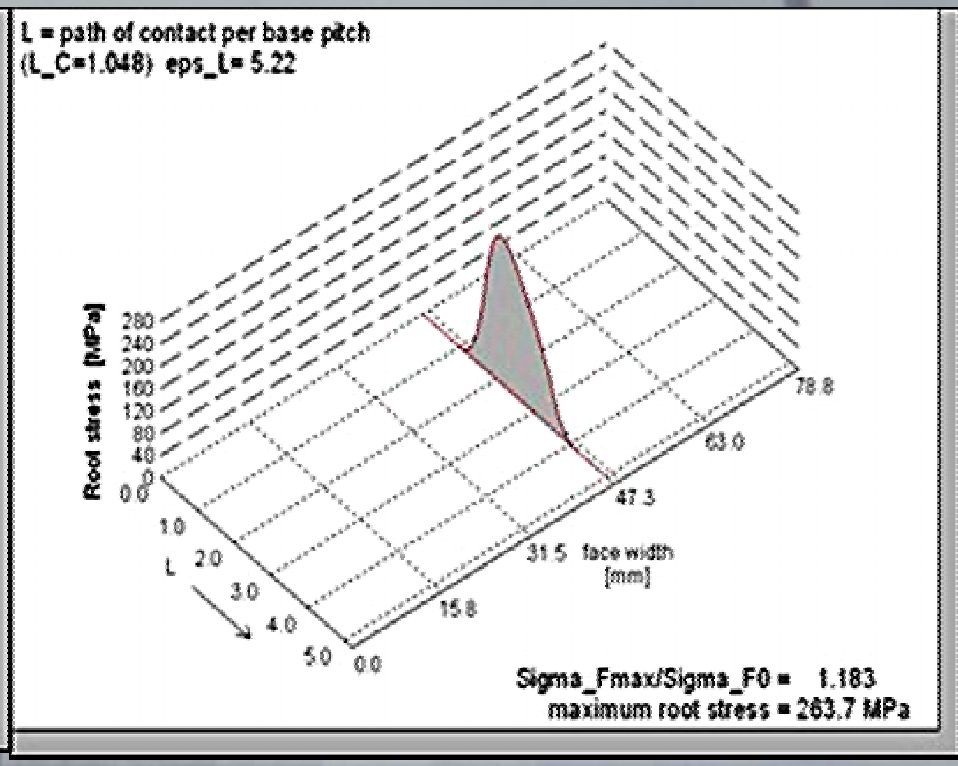

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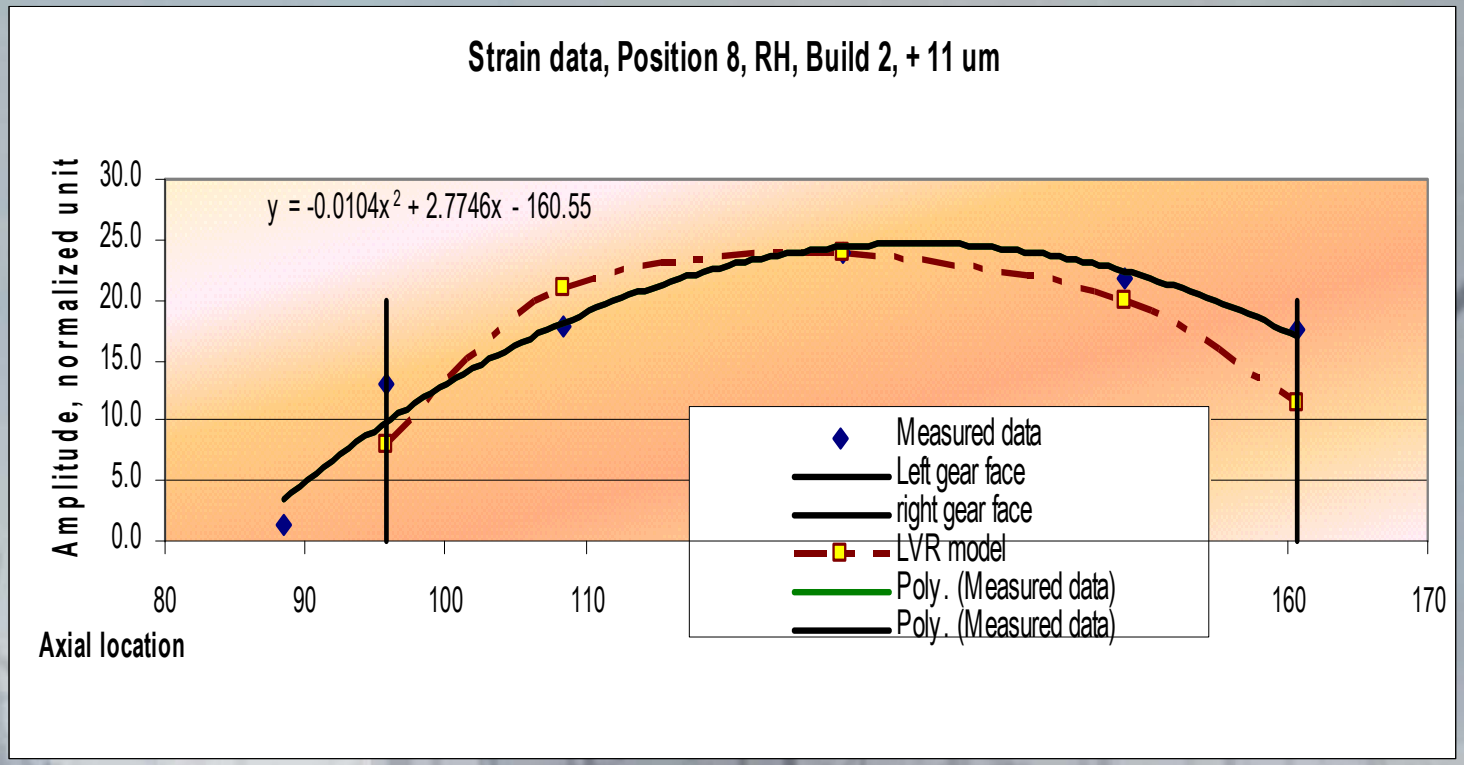

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Qualification Testing (Gears)

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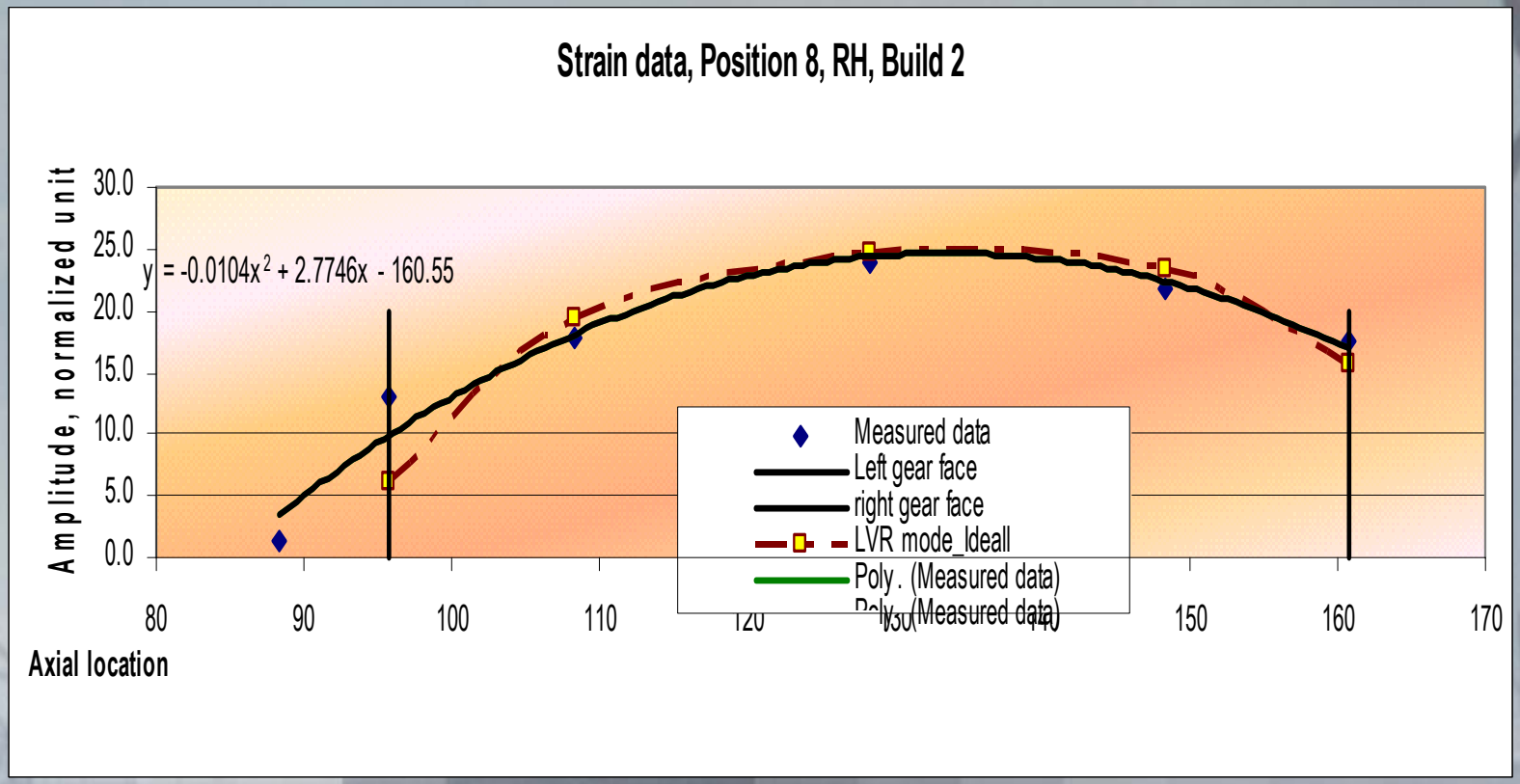

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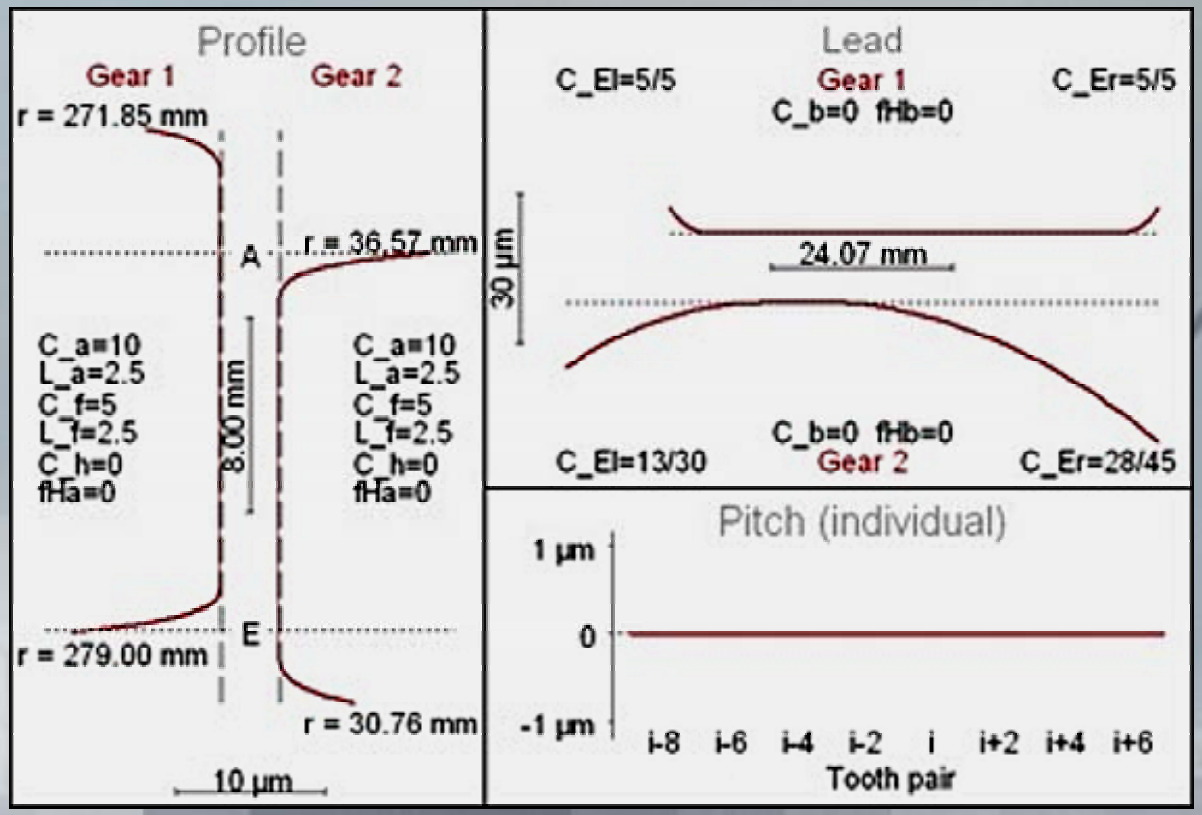
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