MERKLE & PARTNER

Engineering Office for Structural Analysis
FEM, CFD
Mechanical Design

Presentation at the 4th International FEMFAT User Meeting
May 08, 2003

“ Evaluation of static and dynamic safety at different examples”

Aim of Presentation

Short overview of Merkle & Partner

Advantages for Merkle & Partner from the application of FEMFAT

Content

- Overview Merkle & Partner
- Basics study
- Project examples
- Discussion

Presentation of Company

Company

Foundation:	**beginning of 1989**
Head office:	**D-89518 Heidenheim / Brenz**
Manager / Owner	**Dipl.- Ing. Stefan Merkle**
Team:	**20 employees**

Areas of business

- Computational services
  - Structural analysis
  - Fluid mechanics
- Design services
- Training in computational analysis

Applied Software

Structural mechanics: ANSYS
PRO/MECHANICA
I-DEAS
SYSTUS+
(NASTRAN)
FEMFAT

Fluid mechanics: ICEM-CFD
STAR-CD

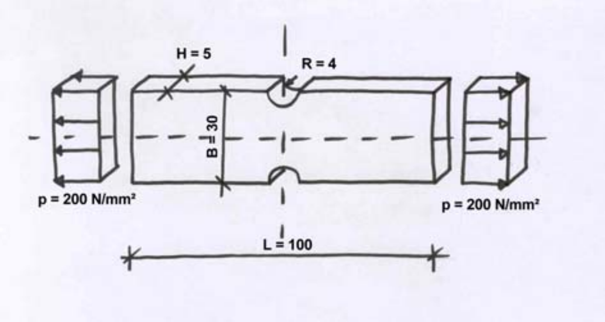
Design: PRO/E
I-DEAS
(CATIA V4)

Special Skills

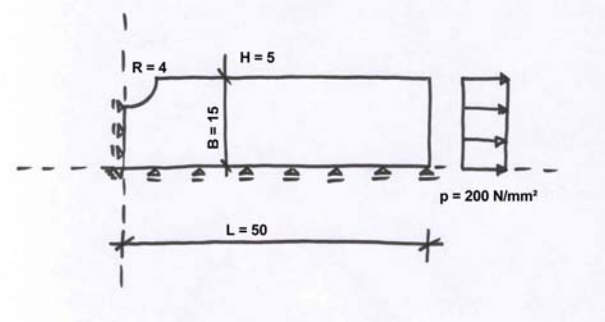
- Long-standing experience
- Intersectoral experience (more than 250 customer)
- Independent of software

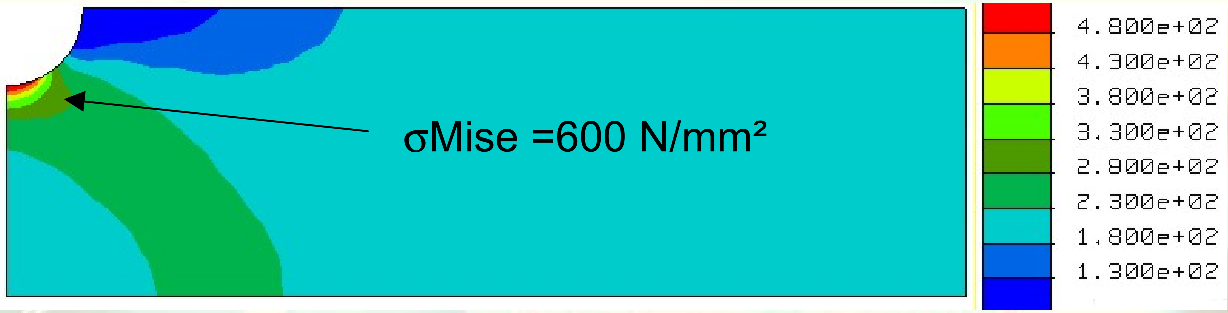
Basics Study

Tensile Test



pulsating load >10^6
Material: St-37
Rp0,2 =220 N/mm²
Rm =370 N/mm²
σS,ZD =220 N/mm²





Safety against abuse?

Proof of long fatigue strength possible?

How many percent of the force can be borne?

Analytical Approach:

Statical proof of strength:

$s_F = R_{p0,2} / \sigma_{Mises}$ = 220/273 = 0,81 (concept of nominal stress)

$s_F = R_m / \sigma_{Mises}$ = 370/600 = 0,62 (only reasonable for local notch stress !)

Dynamic:

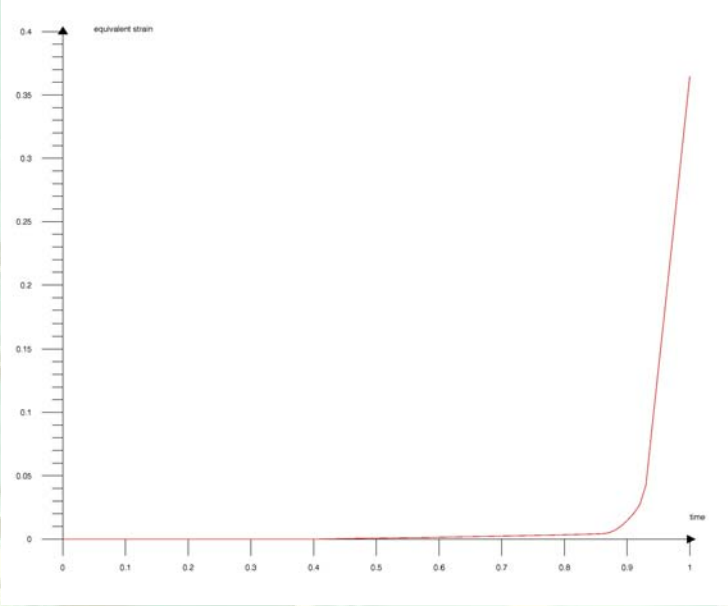
$\sigma_{S,ZD}$ = 220 N/mm² (pulsating endurance strength St-37)

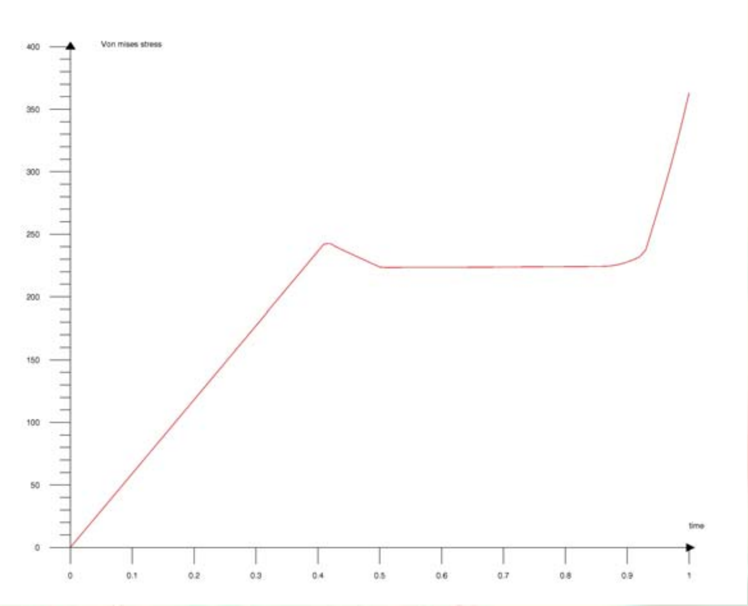
$s_F = \sigma_{S,ZD} / \sigma_{Mises}$ = 220/600 = 0,37

Material strength cannot be proven.

Recommendation: plastic analysis

Nonlinear Plastic Analysis



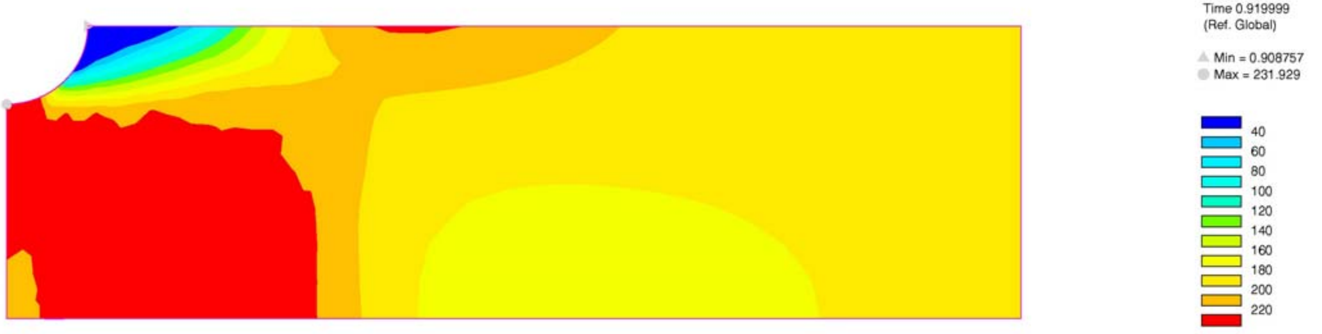


static ultimate load (at 5 % strain)
= 92% of the total load

safety against abuse load 0,92

ideal-plastic material behavior,
$R_{p0,2}$=220 N/mm²

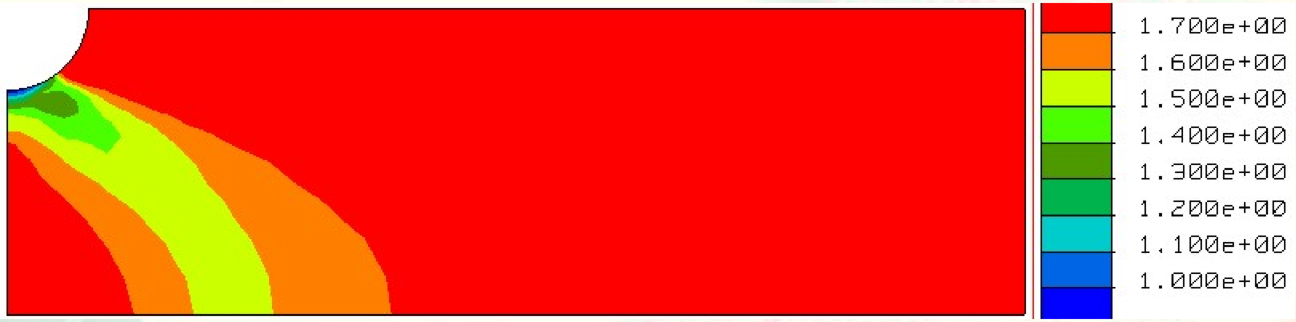
comparing stress von Mises (92% load)



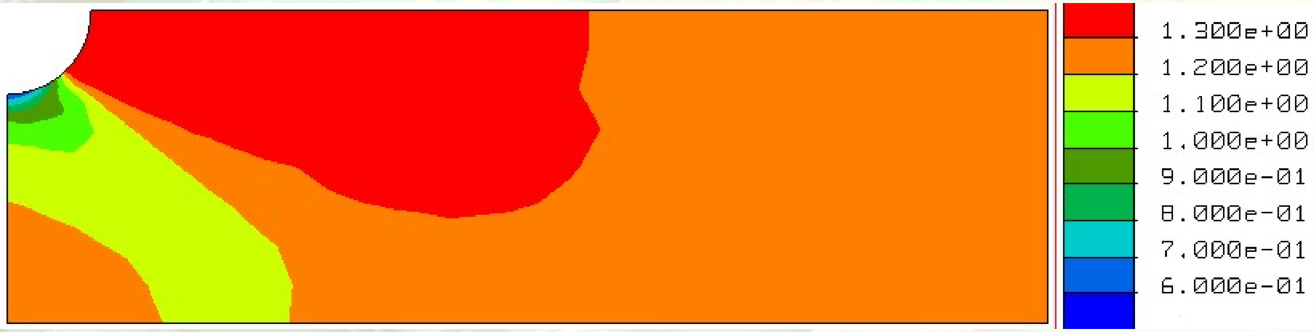
plastic strain (92% load)

Analysis with FEMFAT

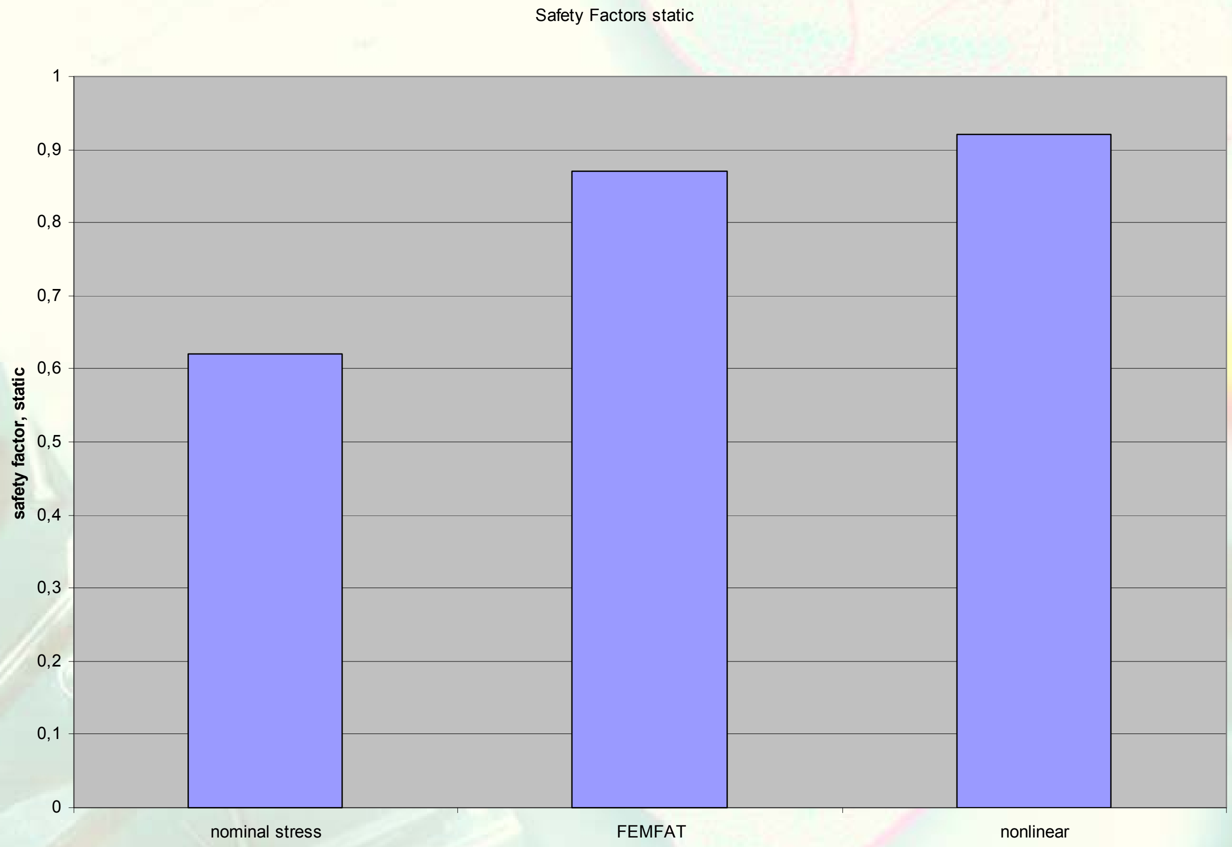
Safety against abuse load: 0,87



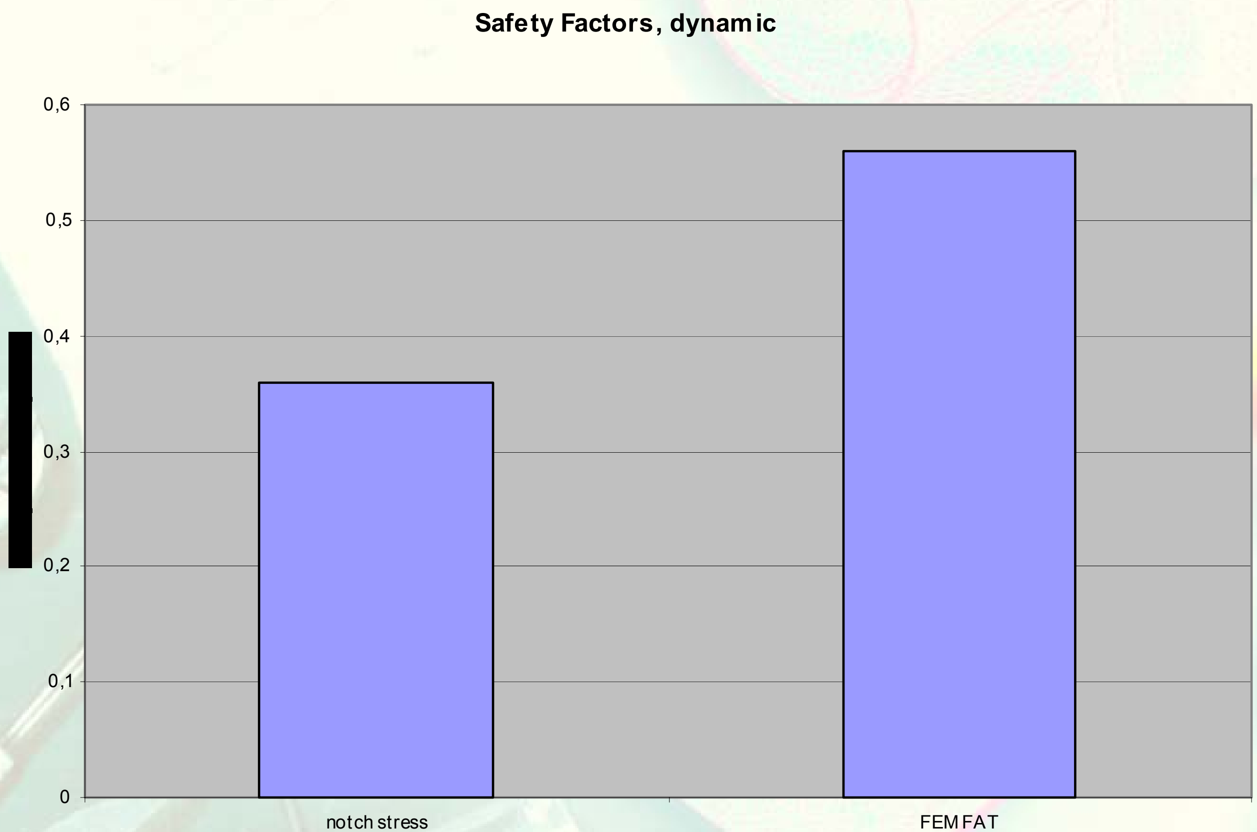
Safety against endurance load: 0,56



Comparison of the Results, static



Comparison of the Results, dynamic

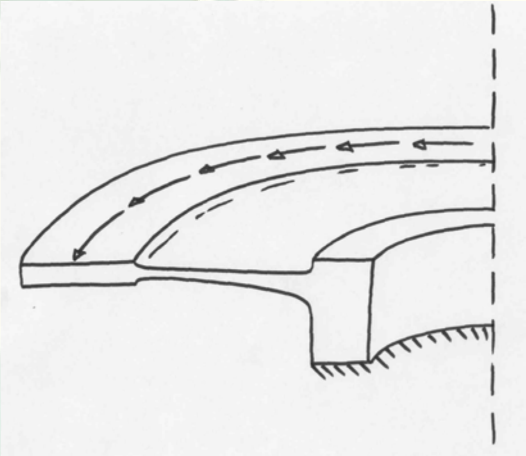


Result:

- Statements without precise consideration are very conservative in this case
- Results with FEMFAT are conservative compared to plastic material behavior, however acceptable
- Analysis with FEMFAT is suitable for reducing extensive plastic analysis of breaking strength

Clutch Membrane

Renk AG in Rheine



Load: Torsion

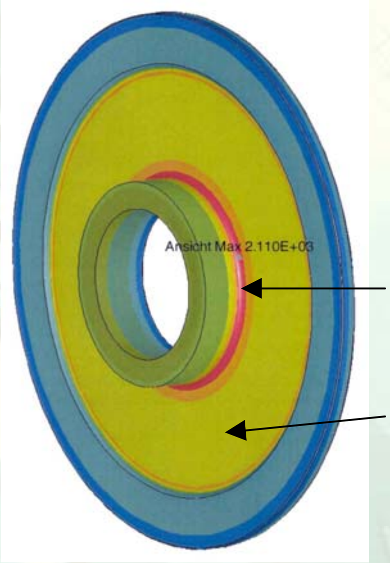
Rm: 1250 N/mm²

Rp0,2: 1050 N/mm²

Question:

Which maximum load can be borne statically?

How does the rupture proceed?

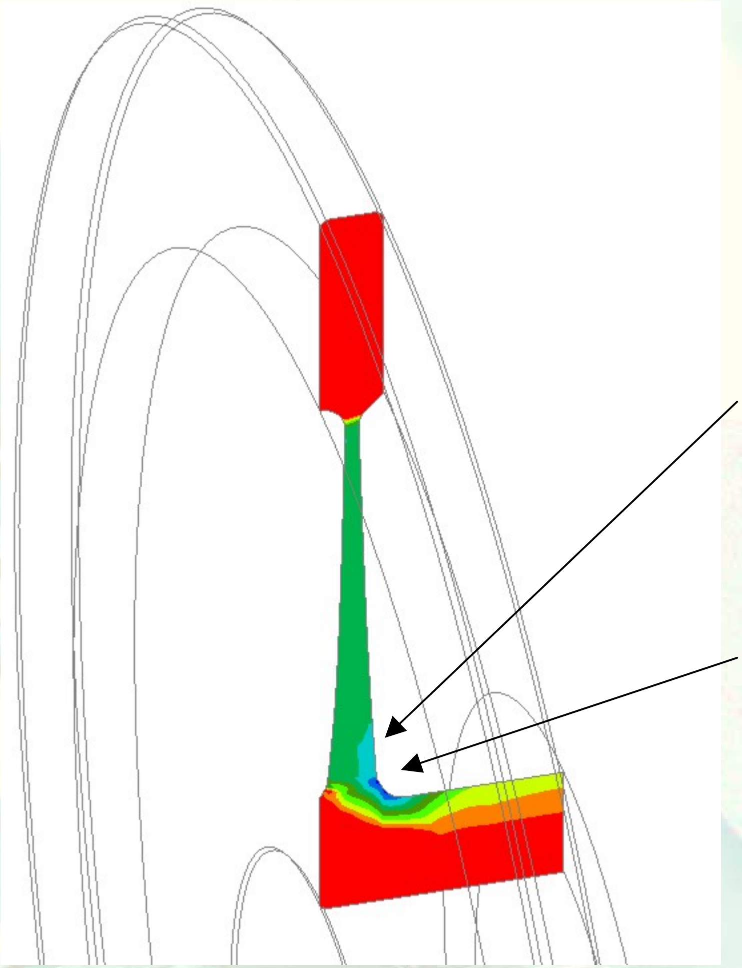


static linear analysis:

σMise, notch = 2110 N/mm²

σMise, membrane = 1400 N/mm²

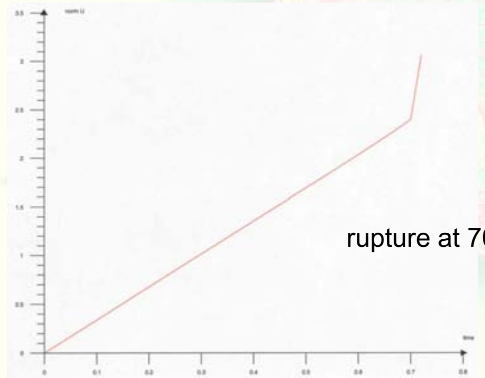
Analysis with FEMFAT



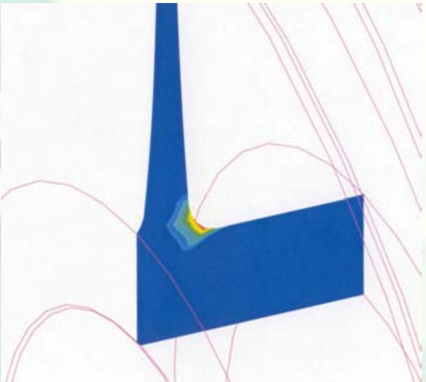
safety against abuse load: 0,82

safety against abuse load : 0,60

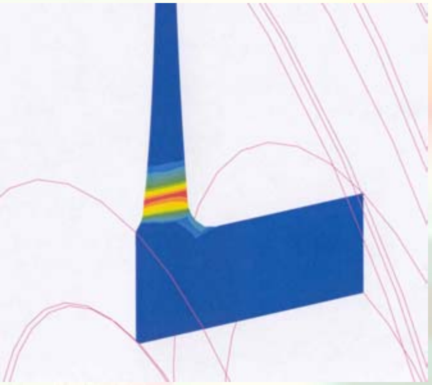
Nonlinear, Ideal-Plastic Analysis



rupture at 70 % of load



plastic strains



immediately before the break

during rupture !

Supporting-effect no longer present !

Result:

- **Cause of damage due to analysis with FEMFAT:**
  notch stress at 58% of load
  membrane stress at 82 % of load

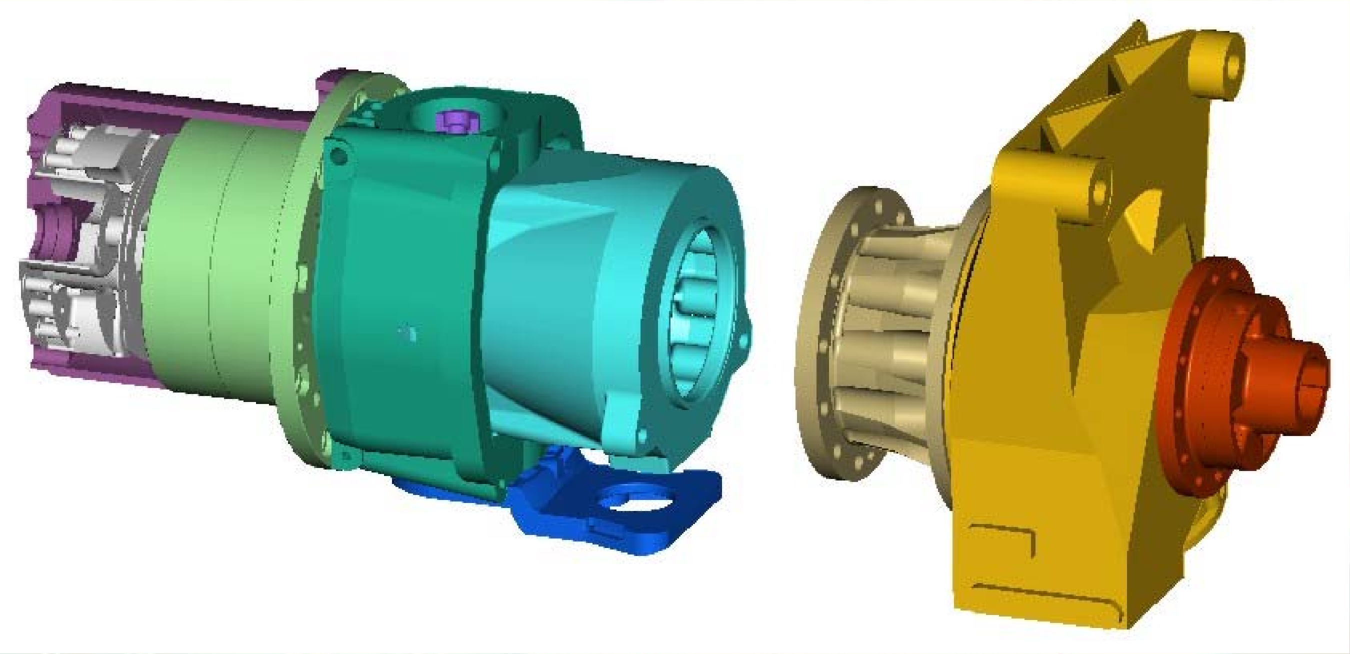
- **Cause of damage due to ideal-plastic approach:**
  membrane stress reaches yield strength (at 70 % of load)
  no conclusion possible about bearable load in notch

- **Cause of damage during experiment:**
  rupture pattern corresponds to plastic analysis
  rupture does not start in notch !

Steering knuckle

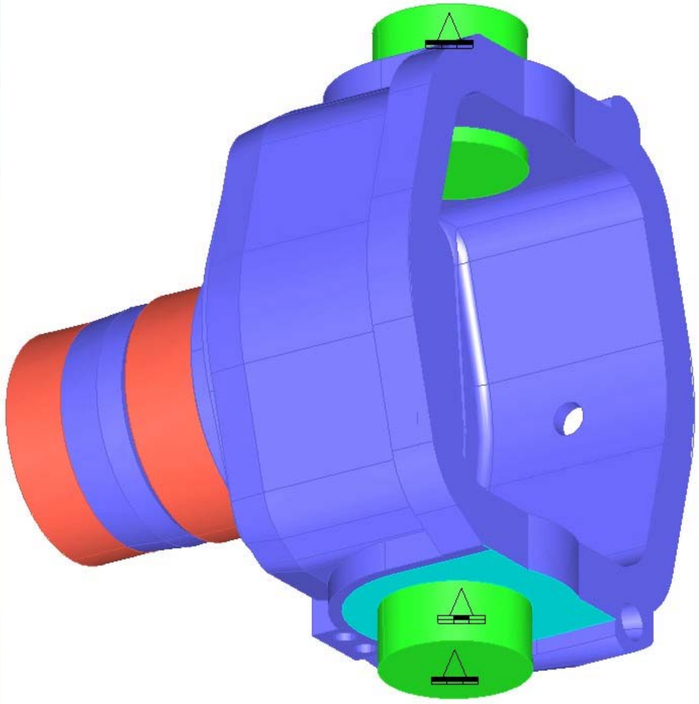
(Achsschenkel)

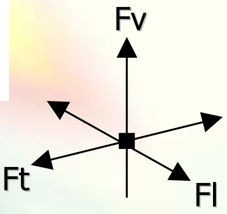
Röchling-Getriebe KG in Meppen



Safety against Abuse Loads ?

Safety against Endurance Load ?



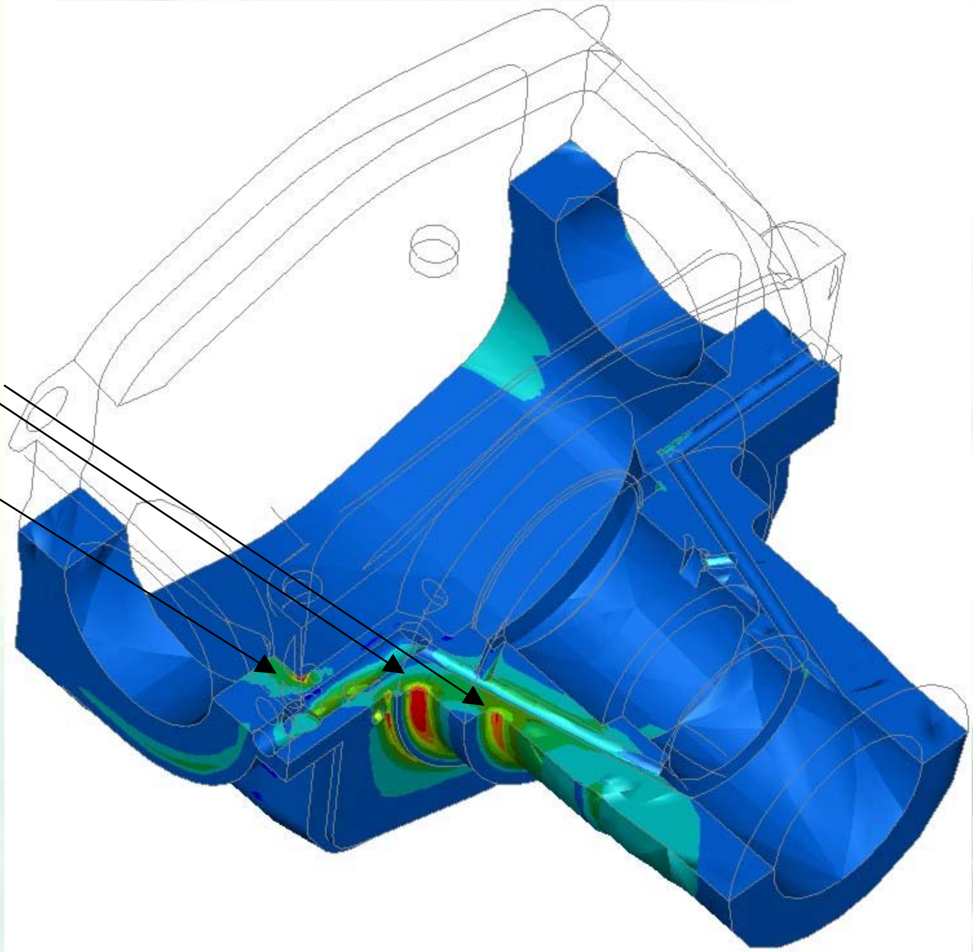


Load **C**ase **C**ombination

Load case	**LCC1**	**LCC2**	**LCC3**	**LCC4**	**LCC5**	**LCC6**	**LCC7**	**LCC8**
Vertical (Fv)	100	100	100	100	50	50	50	50
Transversal (Ft)	10	10	-10	-10	10	10	-10	-10
Longitudinal (Fl)	30	-30	30	-30	30	-30	30	-30
Bearing pre-stress const.				120				

static analysis of 4 load cases

critical notches
load case combination 4

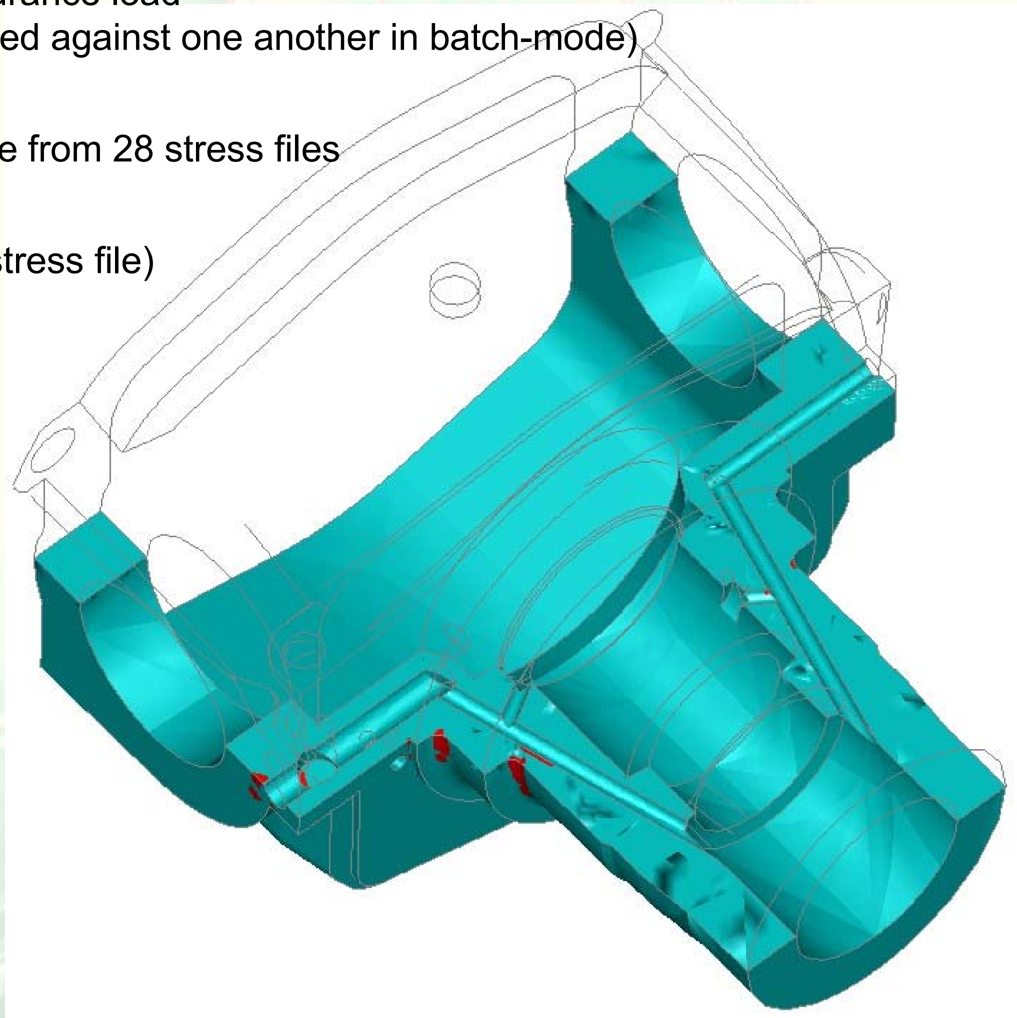


Preparation of 8 stress files (load case combinations) from 4 load cases

28 FEMFAT-Analysis against endurance load
(8 load case combinations compared against one another in batch-mode)

Fortran-program:
smallest safety factor at each node from 28 stress files
→ written to 29th stress file

Evaluation of safety factors (29th stress file)



Safety against Endurance Load:

	LCC1	LCC2	LCC3	LCC4	LCC5	LCC6	LCC7	LCC8
LCC1								
LCC2	2,40							
LCC3	>5	1,92						
LCC4	2,18	>5	2,33					
LCC5	>5	2,62	2,70	1,85				
LCC6	1,94	>5	**1,61**	2,64	2,48			
LCC7	>5	2,31	>5	2,52	>5	1,98		
LCC8	2,34	>5	1,89	>5	2,14	>5	2,41	

Result:

- Optimization of the initial variant with FEMFAT
- Sufficient accuracy, as there are no damage cases in the experiment
- Analogous procedure for further spindle parts: fork carriage, axle bearing bolt, planet carrier, wheel flange, break carrier flange, break disk flange, intermediate flange, and bevel gear casing
- Time advantage, since a plastic analysis can be omitted
- Time advantage, since the static load cases are created in FEMFAT and compared against each other → only the smallest safety factor for each node is evaluated graphically

Discussion ?