ANSA Plugin of
Virtual Strain Gauge Utilities for FEMFAT

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ANSA Plugin of Virtual Strain Gauge Utilities for FEMFAT

- Overview of Multidisciplinary Fatigue Analysis by FEMFAT
- Development of the plugin - How it started?
- The functionalities of the plugin
- Use case
- Conclusions

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Multidisciplinary Fatigue Analysis FEMFAT

Comprehensive modules solve any tasks

FEMFAT (Finite Element Method FATigue)

Multidisciplinary Fatigue Analysis – comprehensive modules solve any tasks

Benefits

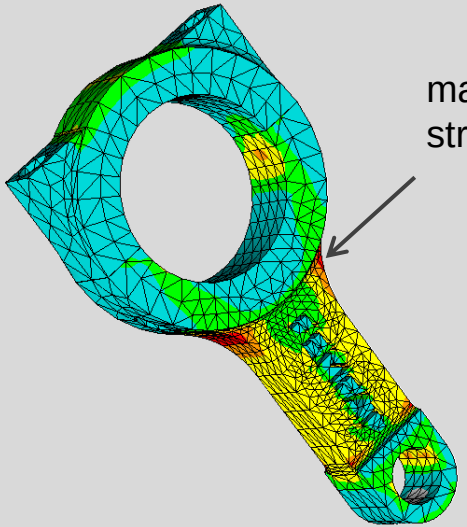
- Fatigue life, damage, and safety factors for all types of loading
- Compatible to all common FE-codes
- More than 500 material datasets and Material Generator
- Full choice of influence parameters on fatigue analysis
- Integration into automatic optimization workflows
- Combines engineering know how and standards
- Open SPOT and WELD database

Applications

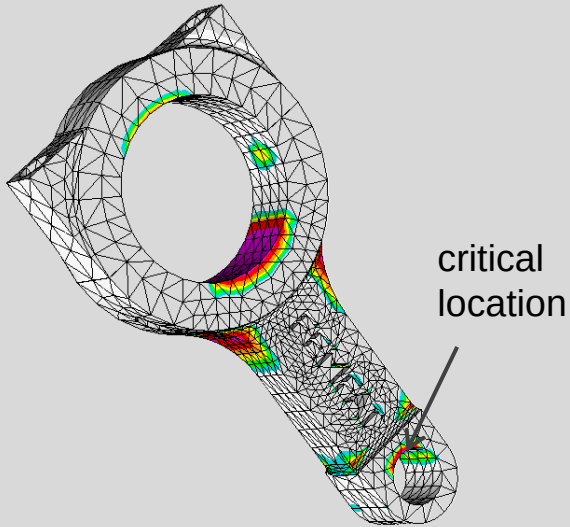
- Unique & patented multi-axial fatigue hypotheses
- Multi-axial fatigue analysis of stochastically excited systems in the frequency domain
- Analysis of metals, composites, rubber and fiber reinforced plastics
- Assessment of point connections (SPOT welds, rivets, FDS…) and line connections (seam welds, adhesive bonding)

The exclusive analysis of stress in a traditional way doesn‘t often reveal damage occurrence at the right point

Traditional view



Modern life-cycle stress analysis



Only modern fatigue analysis tools are capable of predicting critical crack locations and the number of load cycles until failure

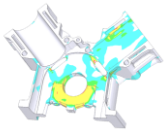
Depending on the stress state, joining technique or analysis target different FEMFAT modules are used for analysis

FEMFAT modules

FEMFAT basic

plast

break



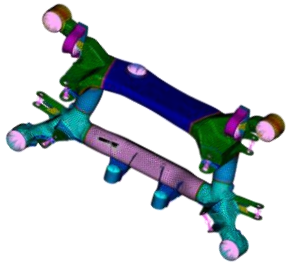
MEHD

FEDIS

MNOISE

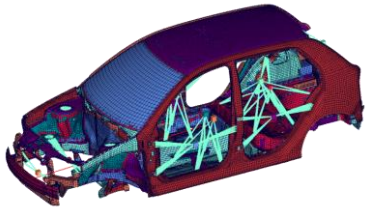
MAMBA

FEMFAT weld

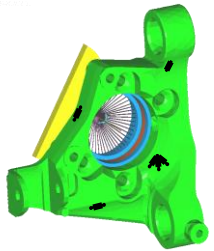


FEMFAT spot

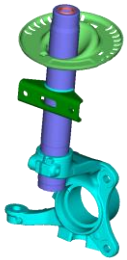
MAMBA



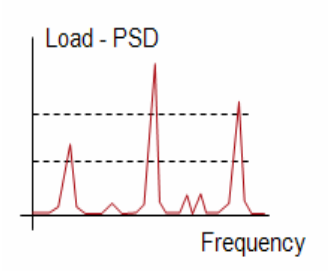
FEMFAT strain



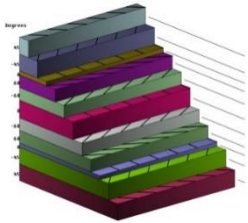
FEMFAT max



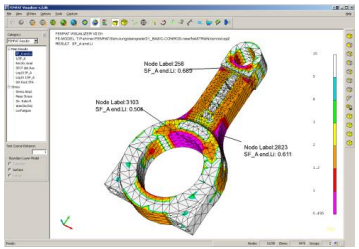
FEMFAT spectral



FEMFAT laminate parallel



FEMFAT visualizer

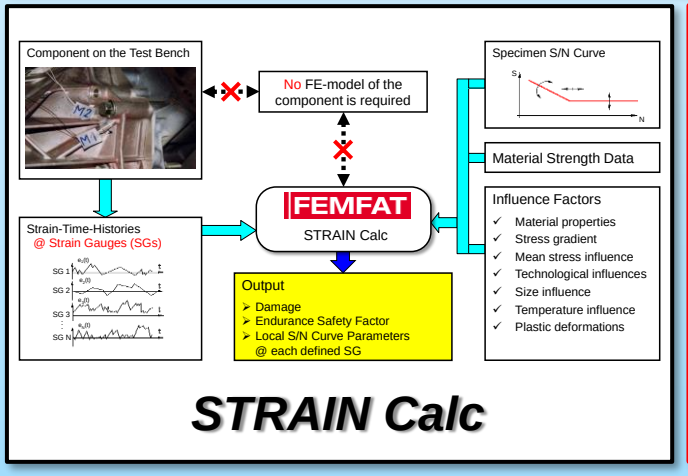


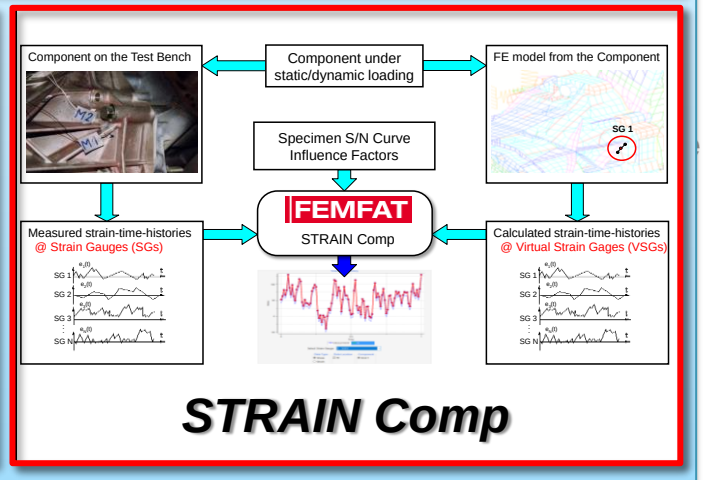
Depending on the stress state, joining technique or analysis target different FEMFAT modules are used for analysis

FEMFAT strain is an extension module for processing fatigue strength analysis using time history data from strain gages attached to components, and for checking the correlation between measured and calculated stress and strain.

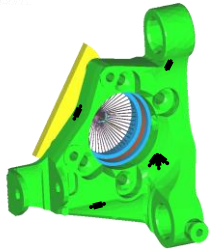
- **STRAIN Calc**:
  Processing measured strains directly without FE model for durability and strength analyses

- **STRAIN Comp**:
  Checking the correlation between measured and calculated stresses and strains using virtual strain gages at FE model

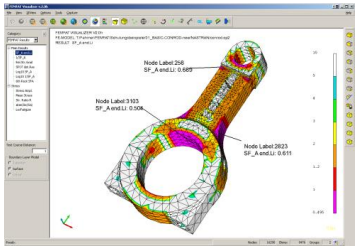




FEMFAT strain



FEMFAT visualizer

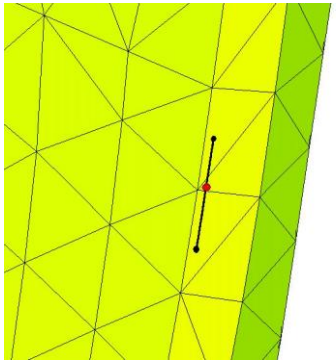


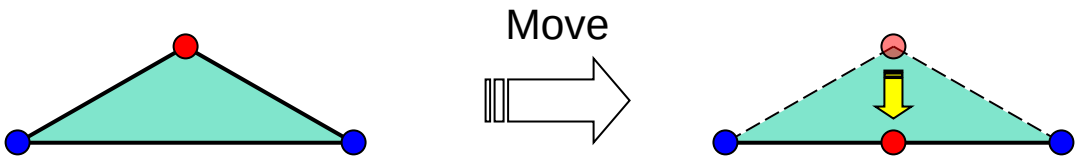
Virtual Strain Gauge model (1/2)

- Definition

Measurement Grid Node

Direction grid Node



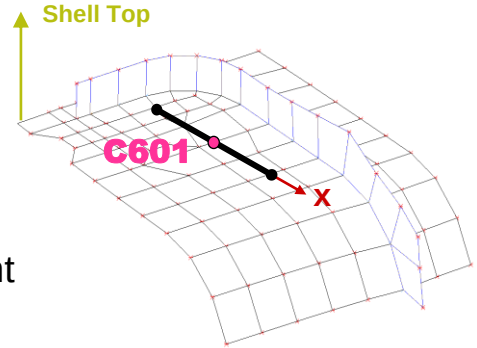


Three-node shell element

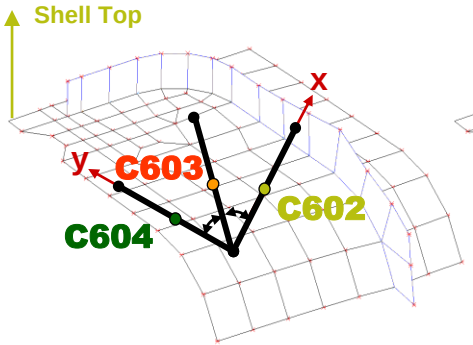
Virtual strain gauge model

Virtual Strain Gauge model (2/2)

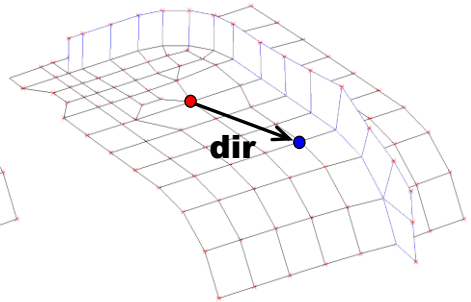
- Virtual Strain Gauge: Modeling guideline
  - Predefined triangular model
    - Using three-node linear shell element
    - Node color (CID) is defined according to gauge type
    - Material label (MAT ID) is defined for three-node shell element
  - Attribute-free triangular model
    - Using three-node linear shell element
    - Strain gauge is defined by GUI using EIDs
  - Node to Node
    - Two nodes of NID is defined by GUI



Linear strain gauge modeling



Rosette strain gauge modeling



“Node-to-node” modeling

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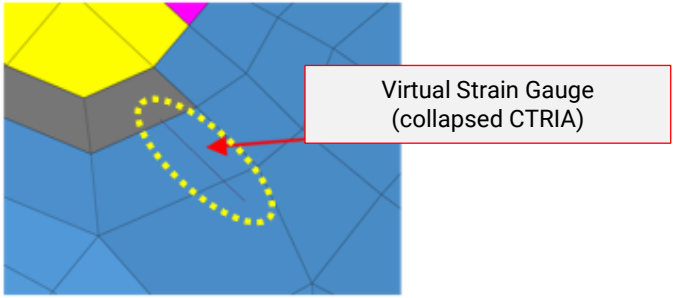
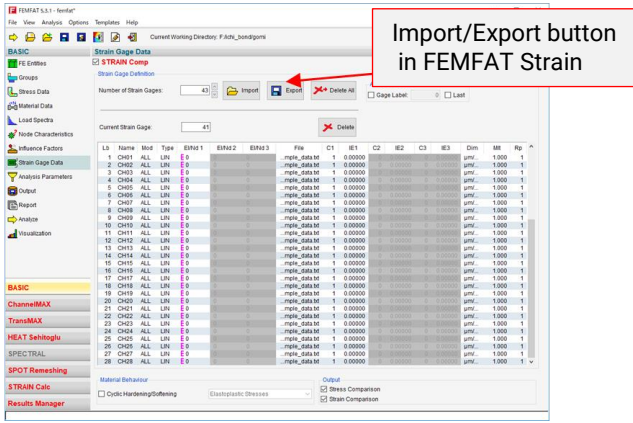
Development of the plugin - How it started?

＜Current issue raised by TOYOTA＞

- Creation/Handling of Virtual Strain Gauges for FEMFAT Strain is COMBERSOME!

  - Not easy to create/handle “collapsed CTRIA”…
  - Specific ID/Coord/Material settings…
  - Relevant inputs required after imported to FEMFAT Strain…





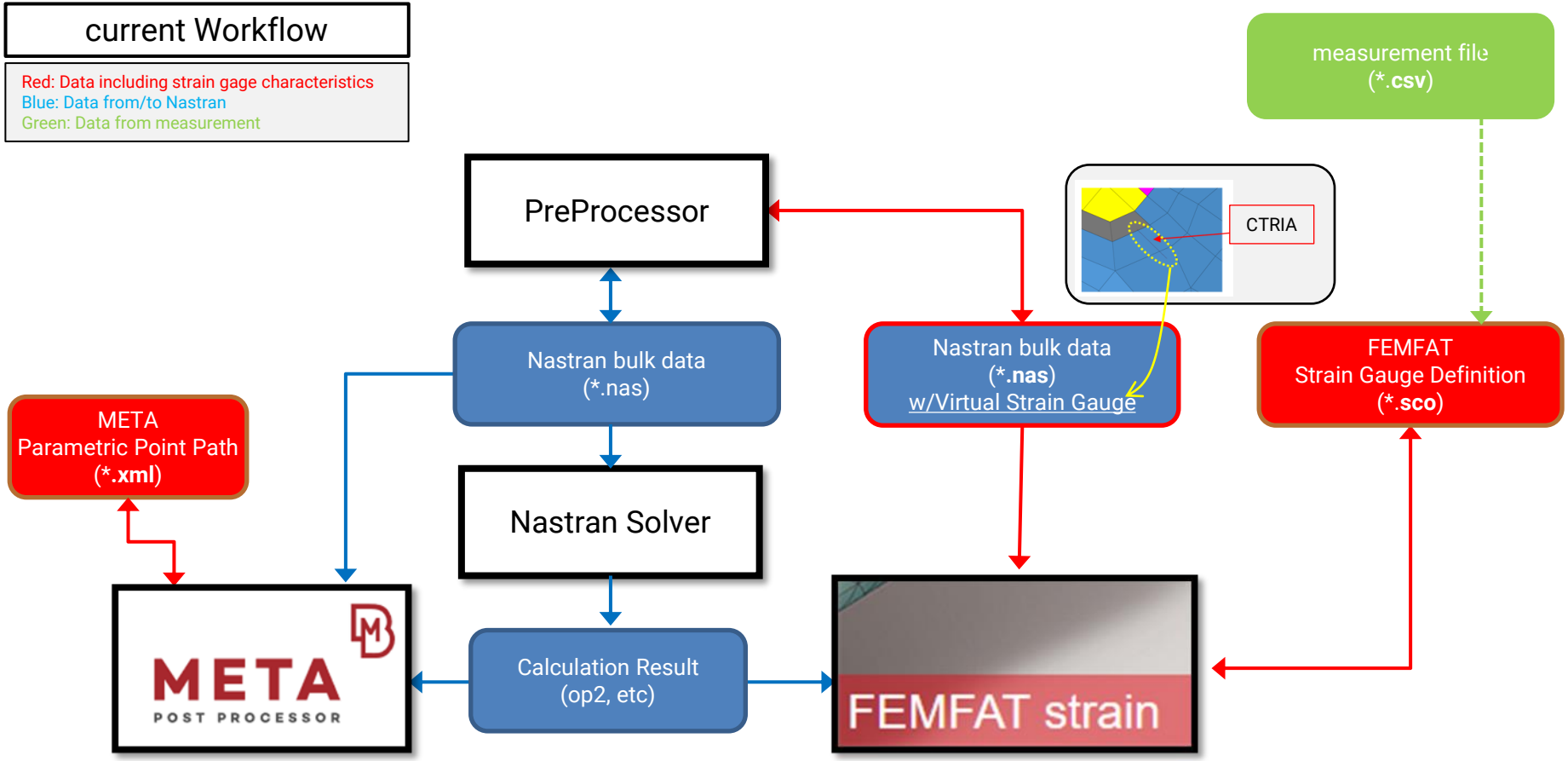
  - Gauge definition is NOT compatible with FEMFAT Strain…
  - It should be made in pre-processors…

＜What is expected＞

- **Enable ANSA to create/handle Virtual Strain Gauges, available for FEMFAT, also for META!**

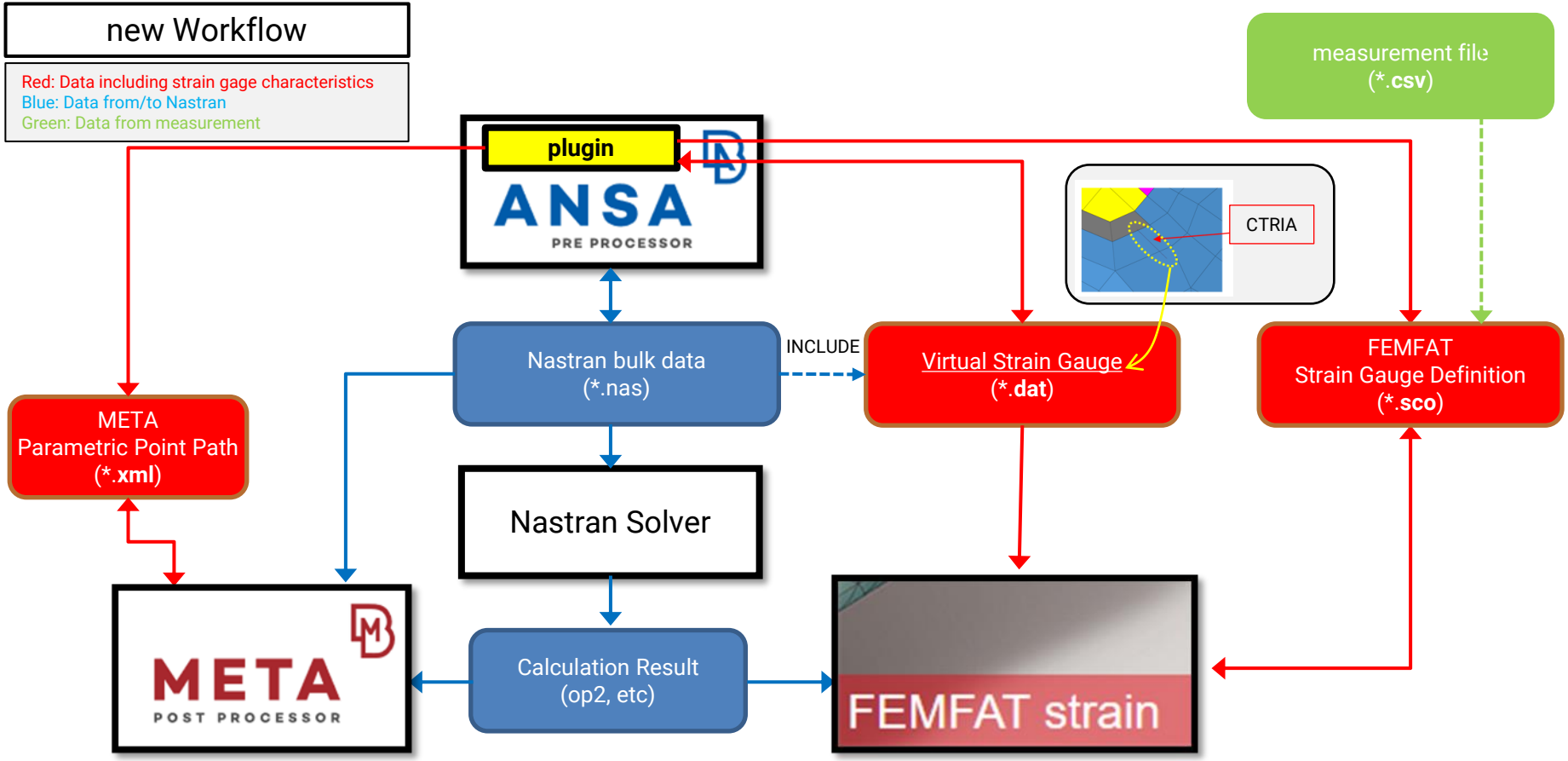
current Workflow

Red: Data including strain gage characteristics
Blue: Data from/to Nastran
Green: Data from measurement



new Workflow

Red: Data including strain gage characteristics
Blue: Data from/to Nastran
Green: Data from measurement



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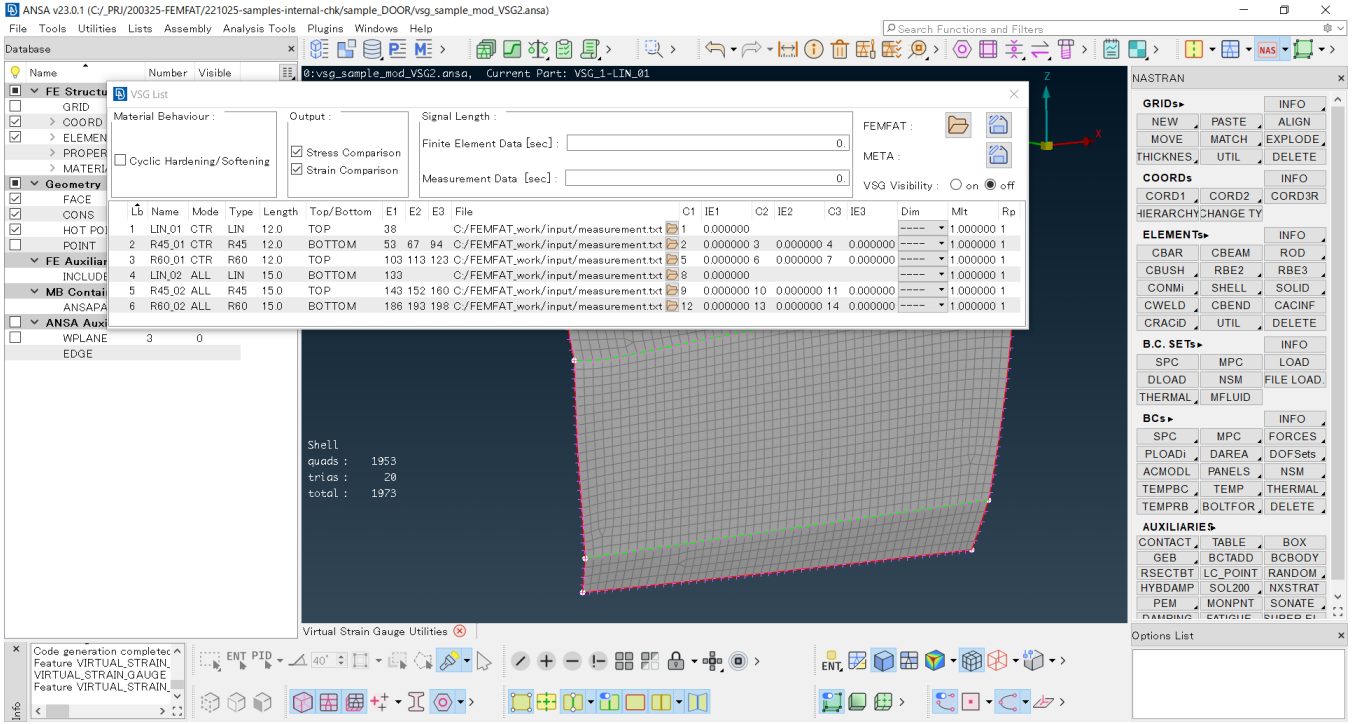
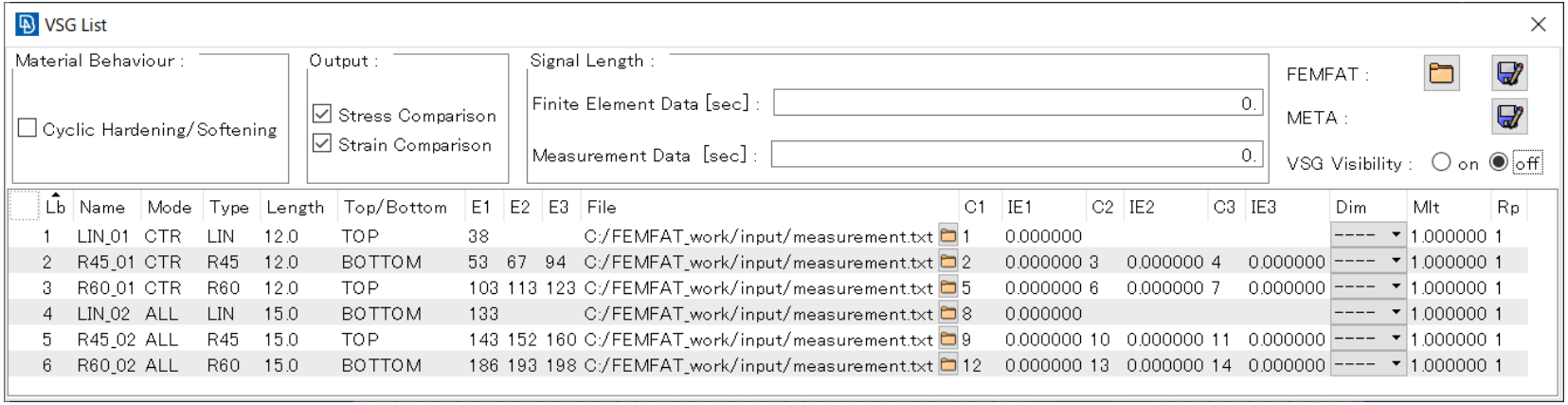
Launch the plugin



GUI of the plugin



Lb	Name	Mode	Type	Length	Top/Bottom	E1	E2	E3	File	C1	IE1	C2	IE2	C3	IE3	Dim	Mlt	Rp
1	LIN_01	CTR	LIN	12.0	TOP	38			C:/FEMFAT_work/input/measurement.txt	1	0.000000					----	1.000000	1
2	R45_01	CTR	R45	12.0	BOTTOM	53	67	94	C:/FEMFAT_work/input/measurement.txt	2	0.000000	3	0.000000	4	0.000000	----	1.000000	1
3	R60_01	CTR	R60	12.0	TOP	103	113	123	C:/FEMFAT_work/input/measurement.txt	5	0.000000	6	0.000000	7	0.000000	----	1.000000	1
4	LIN_02	ALL	LIN	15.0	BOTTOM	133			C:/FEMFAT_work/input/measurement.txt	8	0.000000					----	1.000000	1
5	R45_02	ALL	R45	15.0	TOP	143	152	160	C:/FEMFAT_work/input/measurement.txt	9	0.000000	10	0.000000	11	0.000000	----	1.000000	1
6	R60_02	ALL	R60	15.0	BOTTOM	186	193	198	C:/FEMFAT_work/input/measurement.txt	12	0.000000	13	0.000000	14	0.000000	----	1.000000	1

◇Common Settings
- Material Behaviour, Output, Signal Length

◇Strain Gauge List View
- Creation and list up of gauges
- edit settings (measurement file, etc)

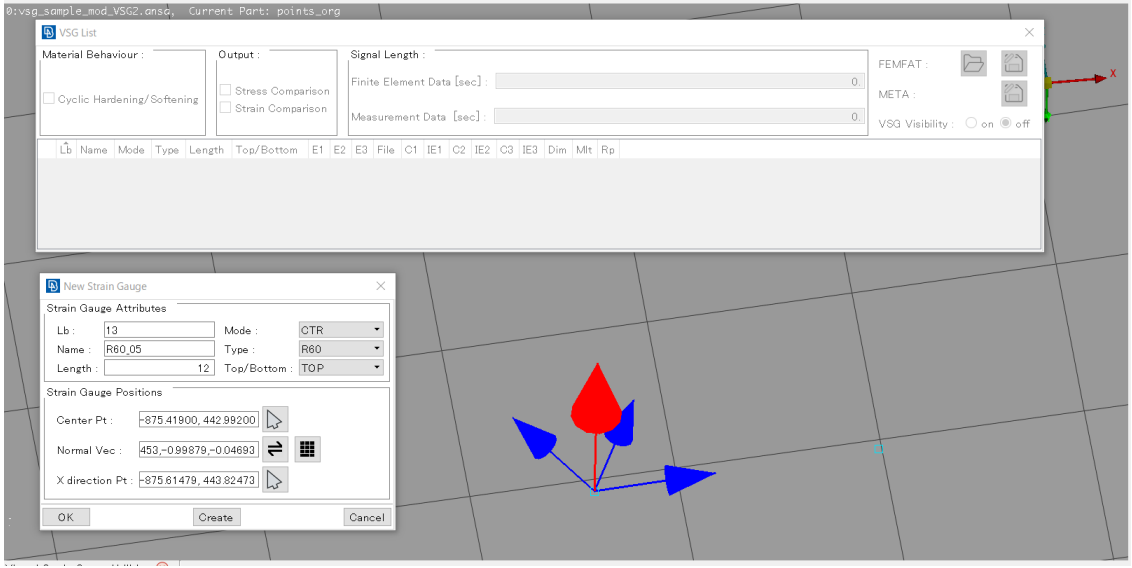
◇FEMFAT File Input/Output
- [Output] ・・・ VSG Model File (*.dat) , Definition File (*.sco)
- [Input] ・・・ VSG Model File (*.dat)

◇META File Output
- Parametric Point Path File (*.xml)

◇VSG Visibility
- visualize gauges defined on current model

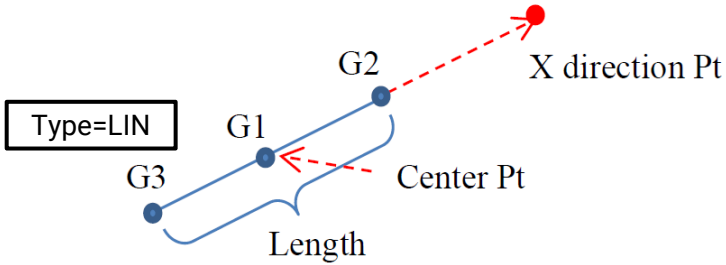
Creation of Virtual Strain Gauges

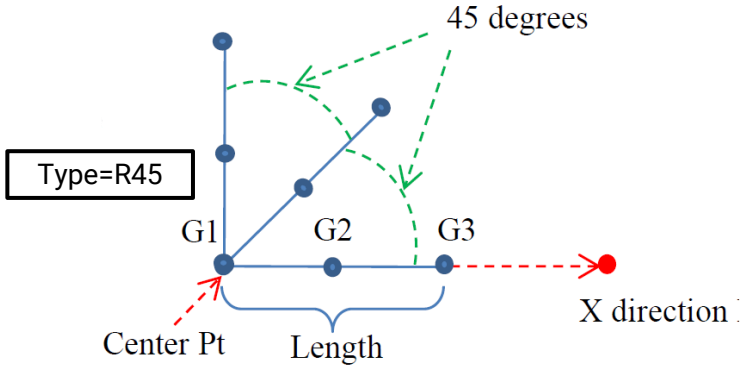
- RMB>Add Gauge on the list view
- Input/select each field (Lb, Name, Length, Mode, Type, Top/Bottom)
- specify Center Pt on the model
- confirm Normal Vec. preview (invert/arbitrary direction is also available)
- specify X direction Pt
- confirm Virtual Strain Gauge preview
- press Create/OK button



Definition of Virtual Strain Gauge

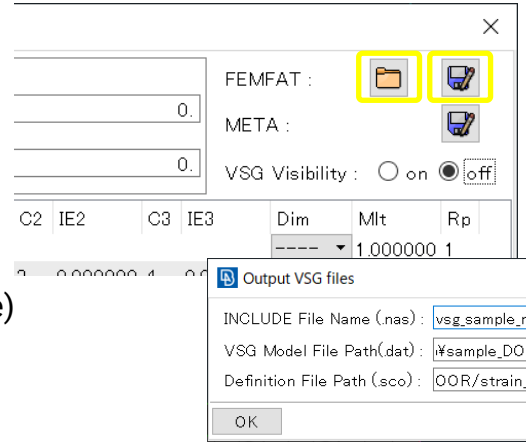
- Nastran CTRIA is created according to the input.
- In case of Type=R45/R60, 3 CTRIAs are aligned to counter-clockwise around Normal Vec.
- CD is set for the node lying at the middle of each CTRIA.





Type	GRID	TOP/BOTTOM	CORD_R ID
LIN	G1	TOP	601
	G1	BOTTOM	701
R45, R60	G2	TOP	602, 603, 604
	G2	BOTTOM	702, 703, 704

Interface with FEMFAT Strain



"FEMFAT File Ouput" exports 2 following files :

◇VSG Model File (*.dat)

- NASTRAN CTRIAs and relevant cards
- INCLUDE statement (specifies solver input file name)

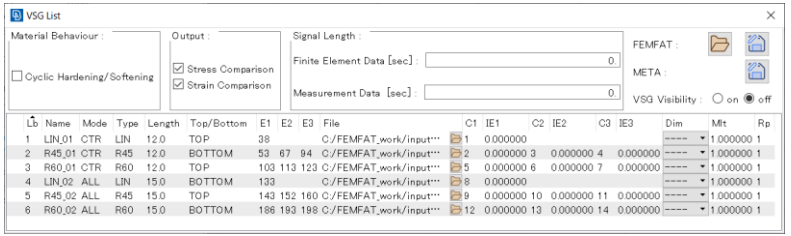
◇Definition File (*.sco)

- compliant to original *.sco (meas. file, etc)

Evaluation of fatigue in FEMFAT Strain is possible by reading solver input/result(*.nas/*.op2) and 2 files mentioned above(*.dat、*sco)

"FEMFAT File Input" imports the following file :

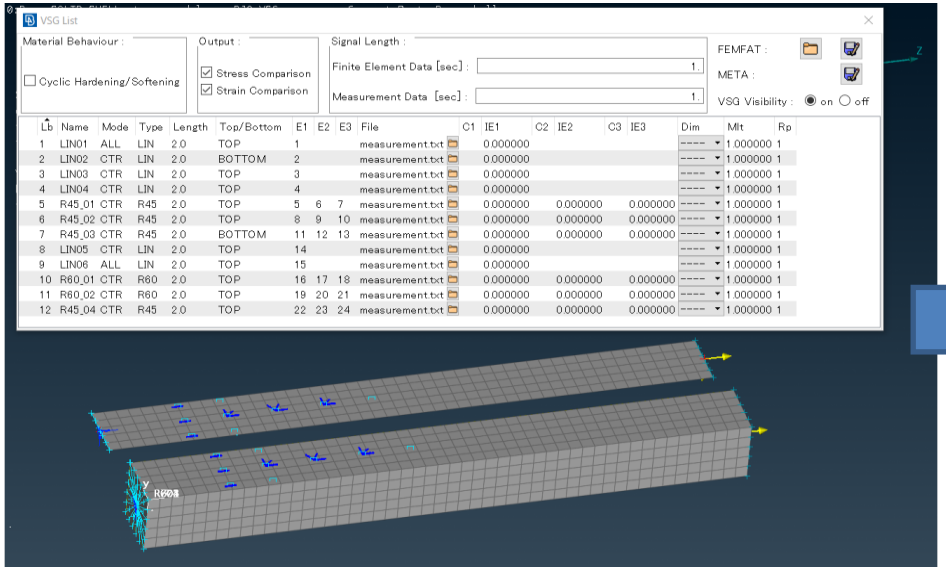
◇VSG Model File (*.dat)



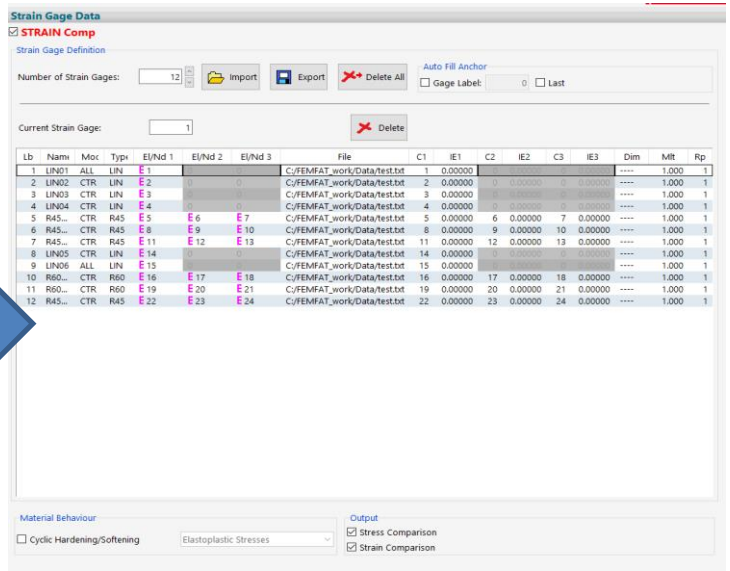
Strain Gauges can be imported and applied to another model through VSG Model File (*.dat)

Interface with FEMFAT Strain

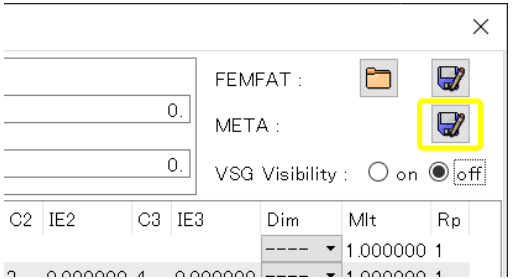
Virtual Strain Gauges defined in ANSA plugin



Fatigue calculation in FEMFAT Strain

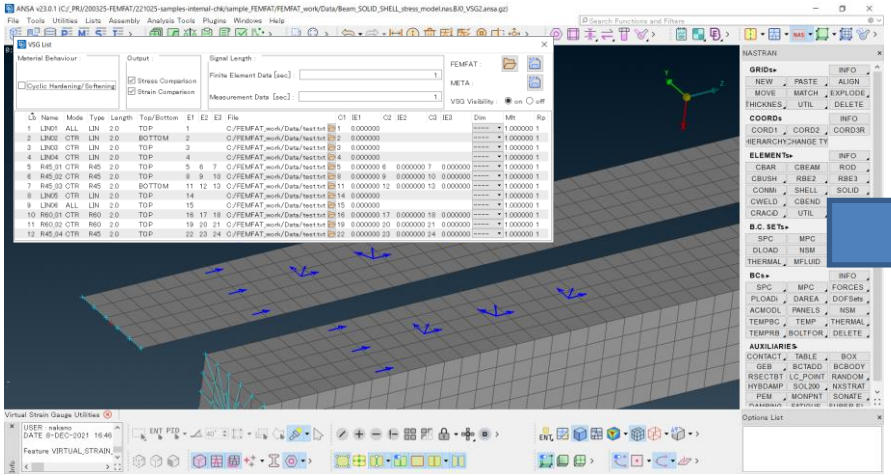


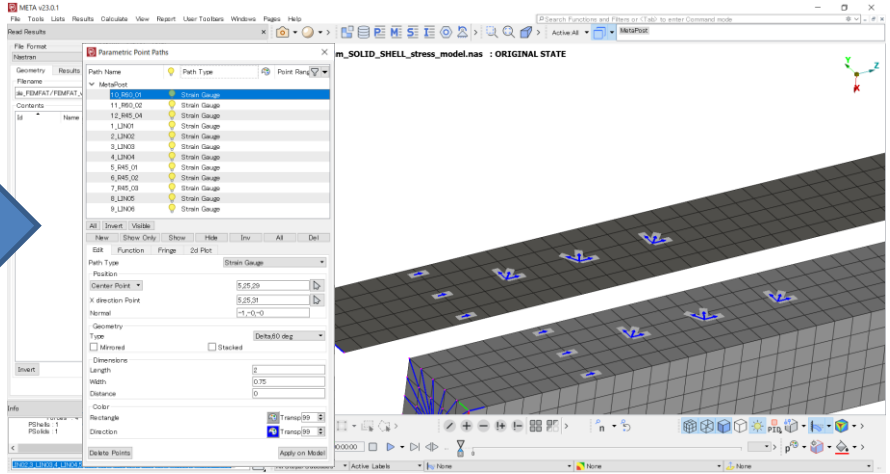
Interface with META



- “META File Output” exports the following file:
  - ◇Parametric Point Path File (*.xml)
    - compatible with Strain Gauge of META

Strain Gauges defined by the plugin are available also in META





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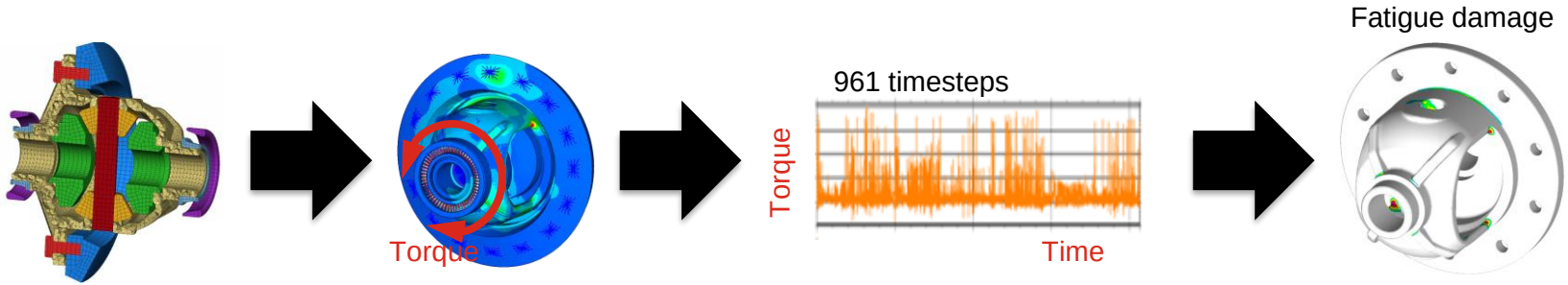
Problem definition

Fatigue analysis of differential cage with variable loads

Strain gauge measurement

Challenges

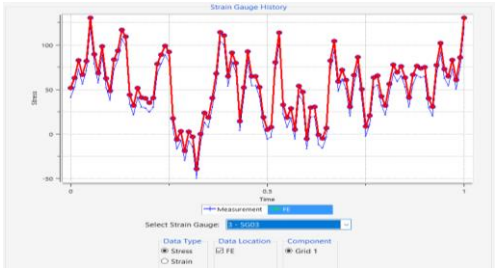
1. How to perform fatigue analysis for the differential cage with variable loads?
   - ➢ Want to perform fatigue simulation with real vehicle condition.
     → There are 961 timesteps (7.96sec.) of load condition.



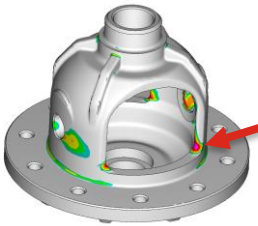
2. How big is the orientation sensitivity of strain gauge measurement?
   - ➢ Want to compare the correlation between testing and simulation.
     → What is the deviation coming from measurement?

Motivation

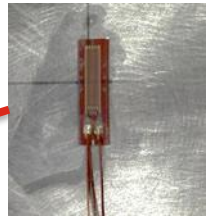
1. It is possible to detect following info from FEMFAT
   - Strain Gauge Position = “**Most critical damaged node**”
   - Strain Gauge Direction = “**Critical Cutting Plane Vector**”



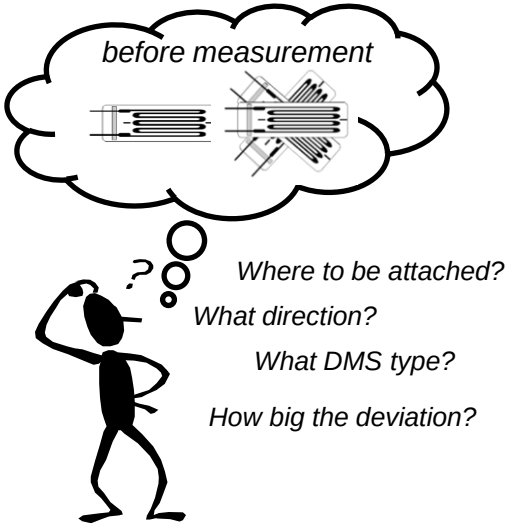
Check correlation test and simulation by FEMFAT strain



Fatigue analysis Damage distribution



Strain Gauge attachment



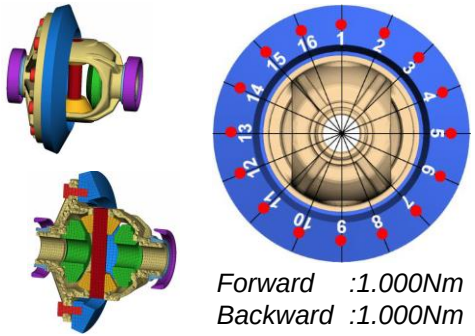
2. In general, the sensitivity of Strain Gauge orientation is very high!!
   - ➔ It is essential to find the appropriate position to be attached the Strain Gauge.
   - ➔ Measured position should be less sensitivity to the orientation.
   - ➔ Meaningful measurement to compare with FE simulation.

Fatigue simulation procedure

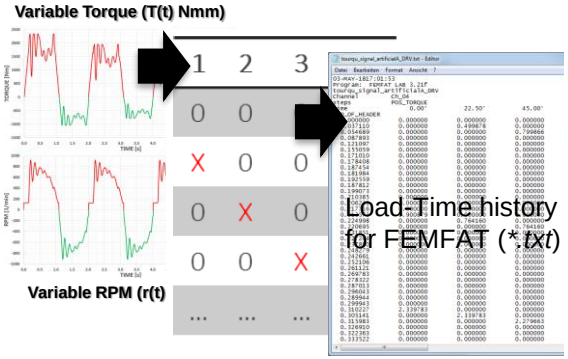
From FE modeling till Fatigue evaluation

Fatigue analysis procedure

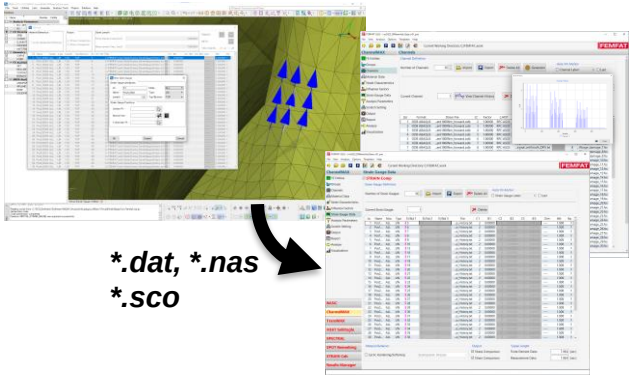
FE model setup by ANSA
FE analysis with unit load



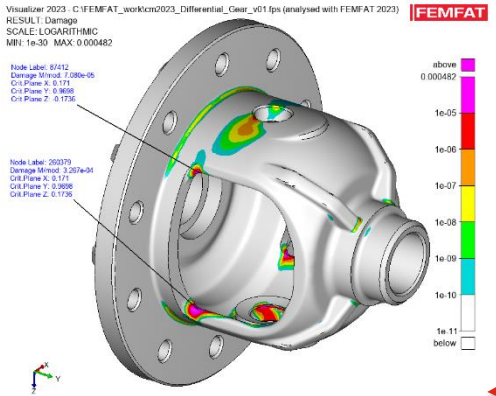
Load-Time history conversion by FEMFAT LAB



Strain Gauge Definition by ANSA
Fatigue analysis by FEMFAT

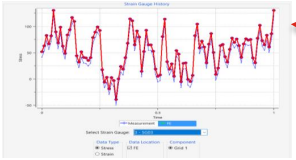


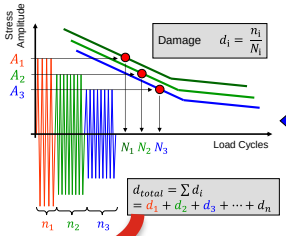
Damage distribution

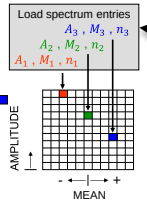


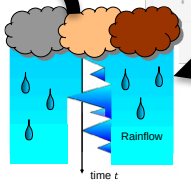
Strain Gauge Comparison

***.sts, *.sps**

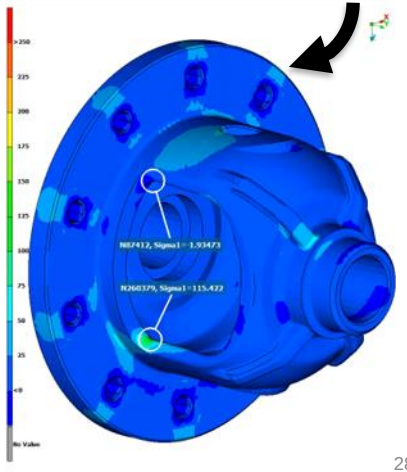








@ each nodes



Fatigue simulation results

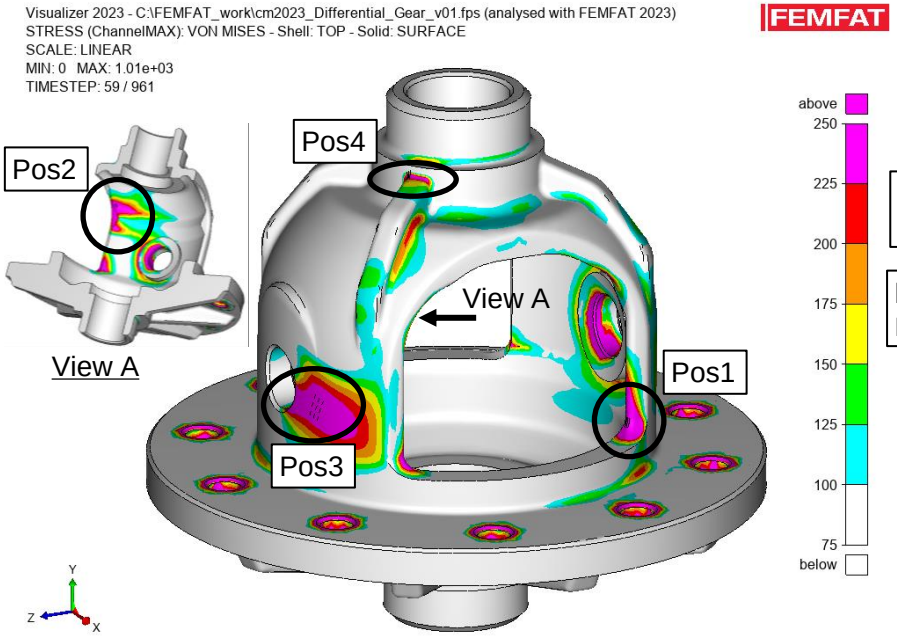
Detect strain gauge orientation ➔ 4 positions

Check sensitivity of strain gauge orientation

Detect evaluation positions

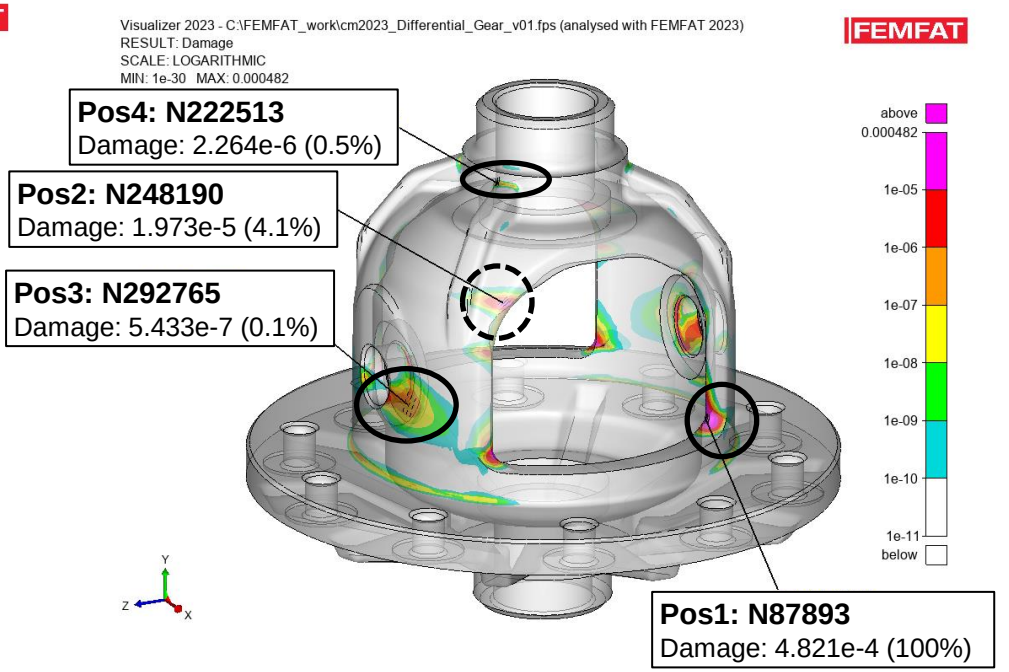
One of the max. stress at time point

Stress distribution at time point 59



Detect strain gauge measurement position

Four positions from damage distribution



➔ Four positions were extracted from stress and damage distribution.

Pos1: 100% of most critical damage at N87893

Upper Stress: 656MPa (100%)

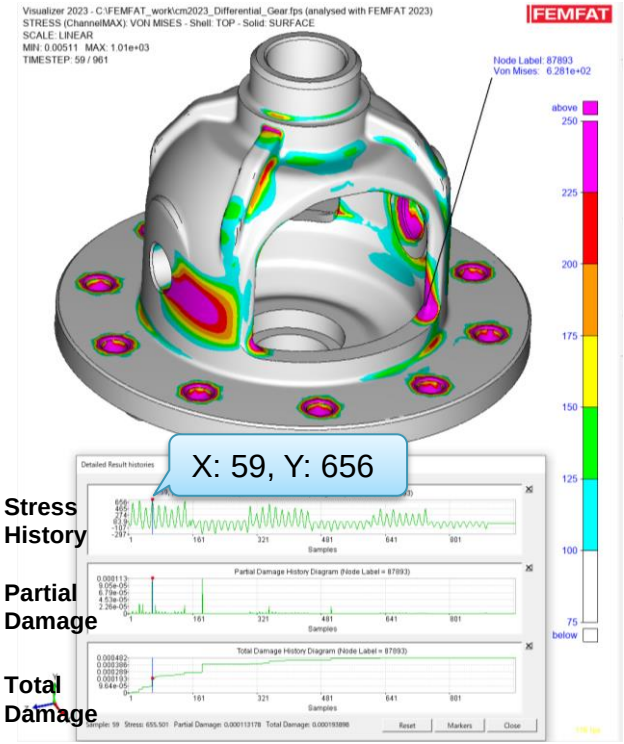
Equiv. stress @Time point = 59

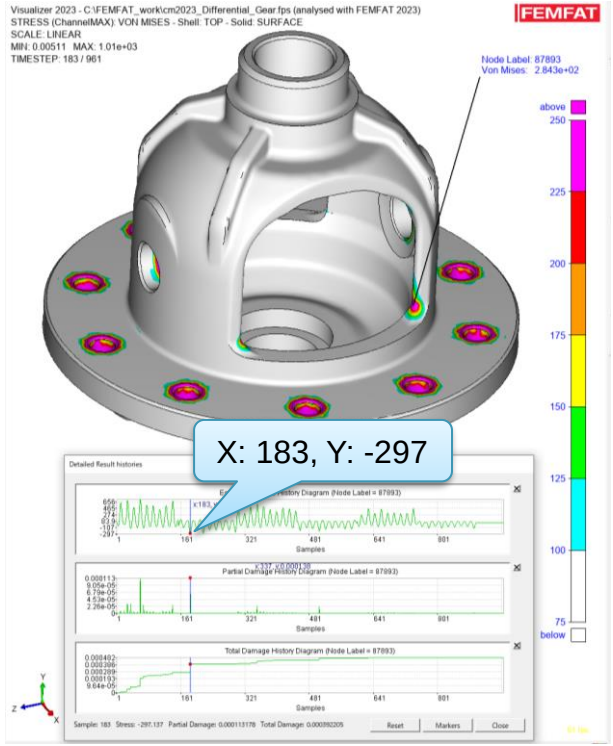
Lower Stress: -297MPa (100%)

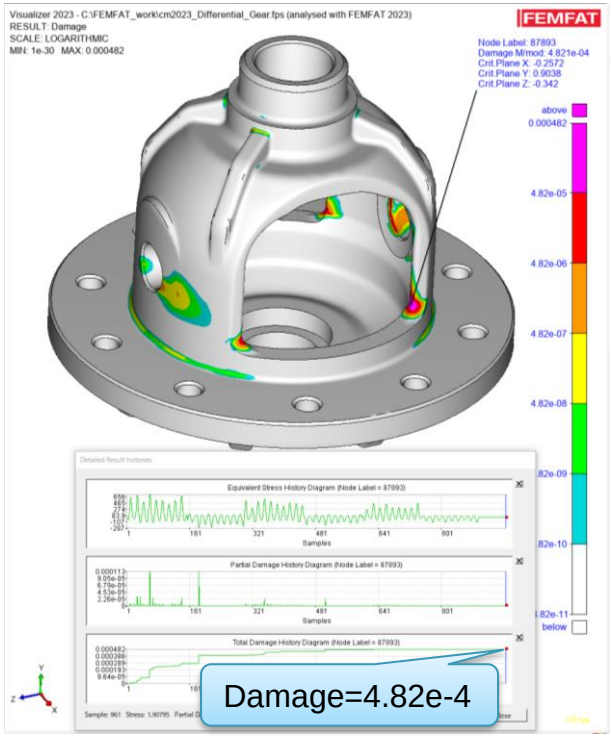
Equiv. stress @Time point = 183

FEMFAT: 4.281e-04 (100%)

Damage & Critical Cutting Plane Vector

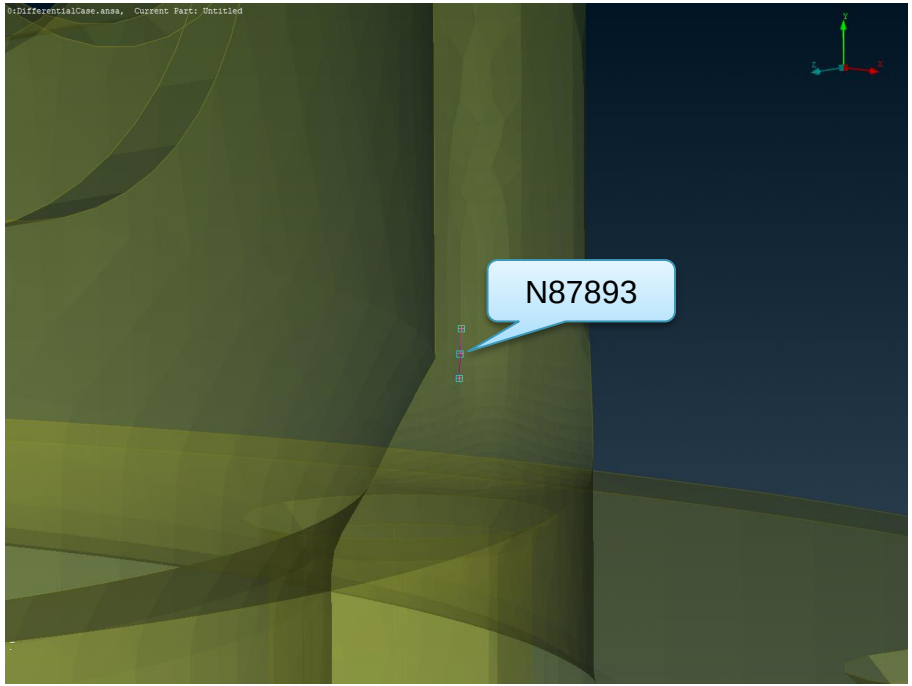


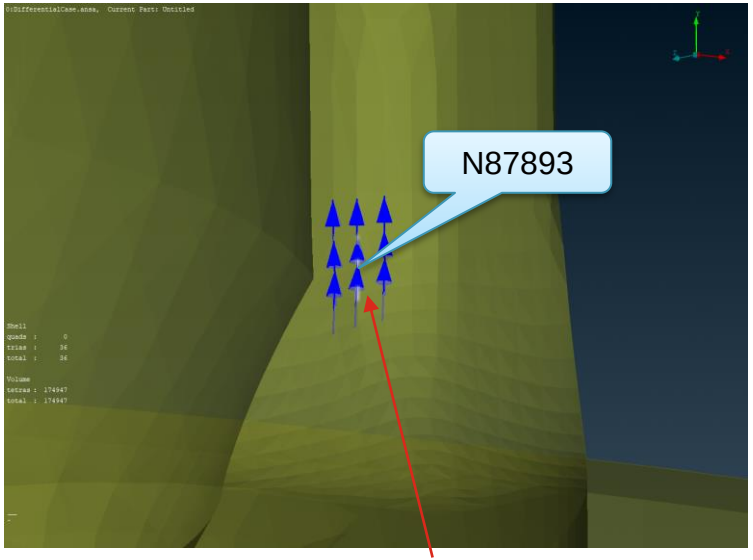




Pos1: Suggested strain gauge orientation by FEMFAT

- N87893 position and Critical Cutting Plane Vector & 9-gauge positions

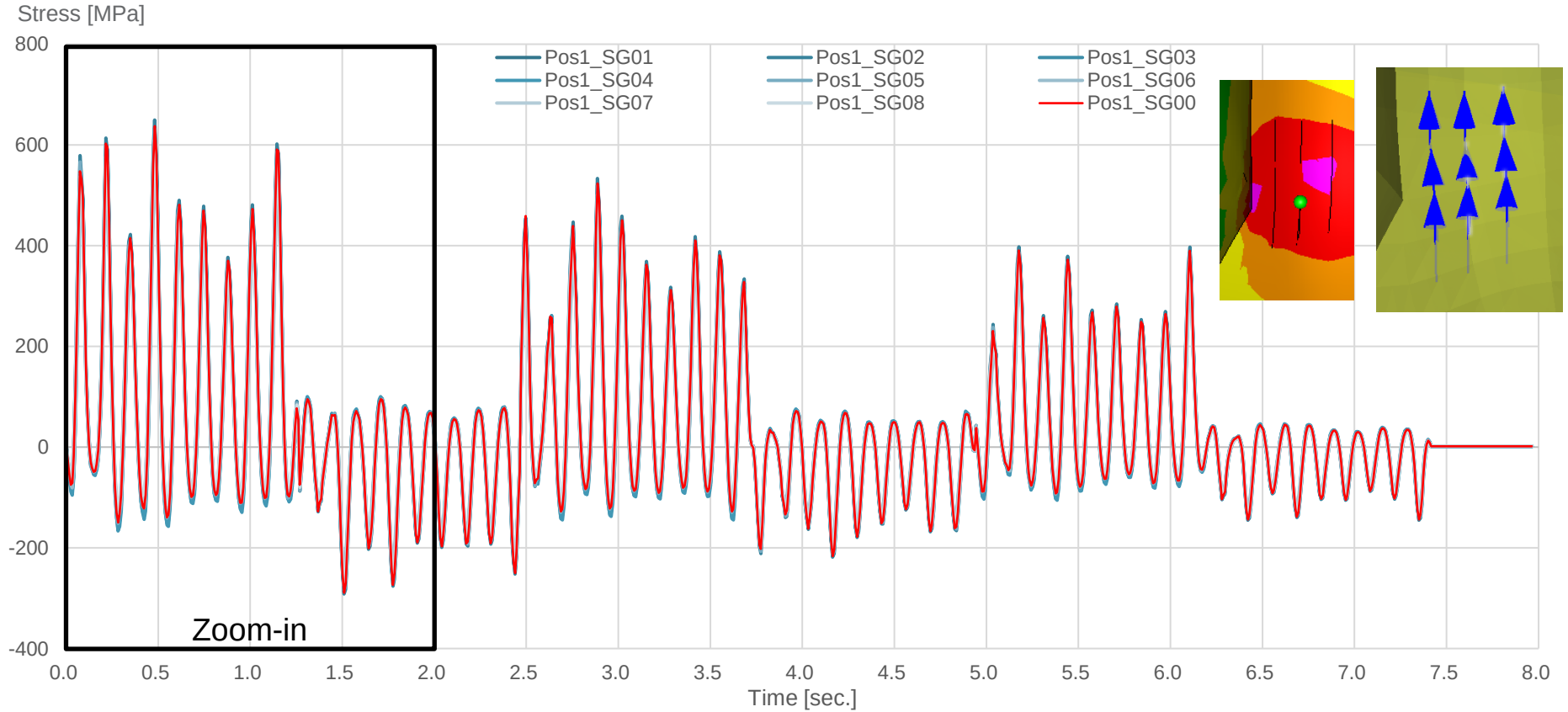




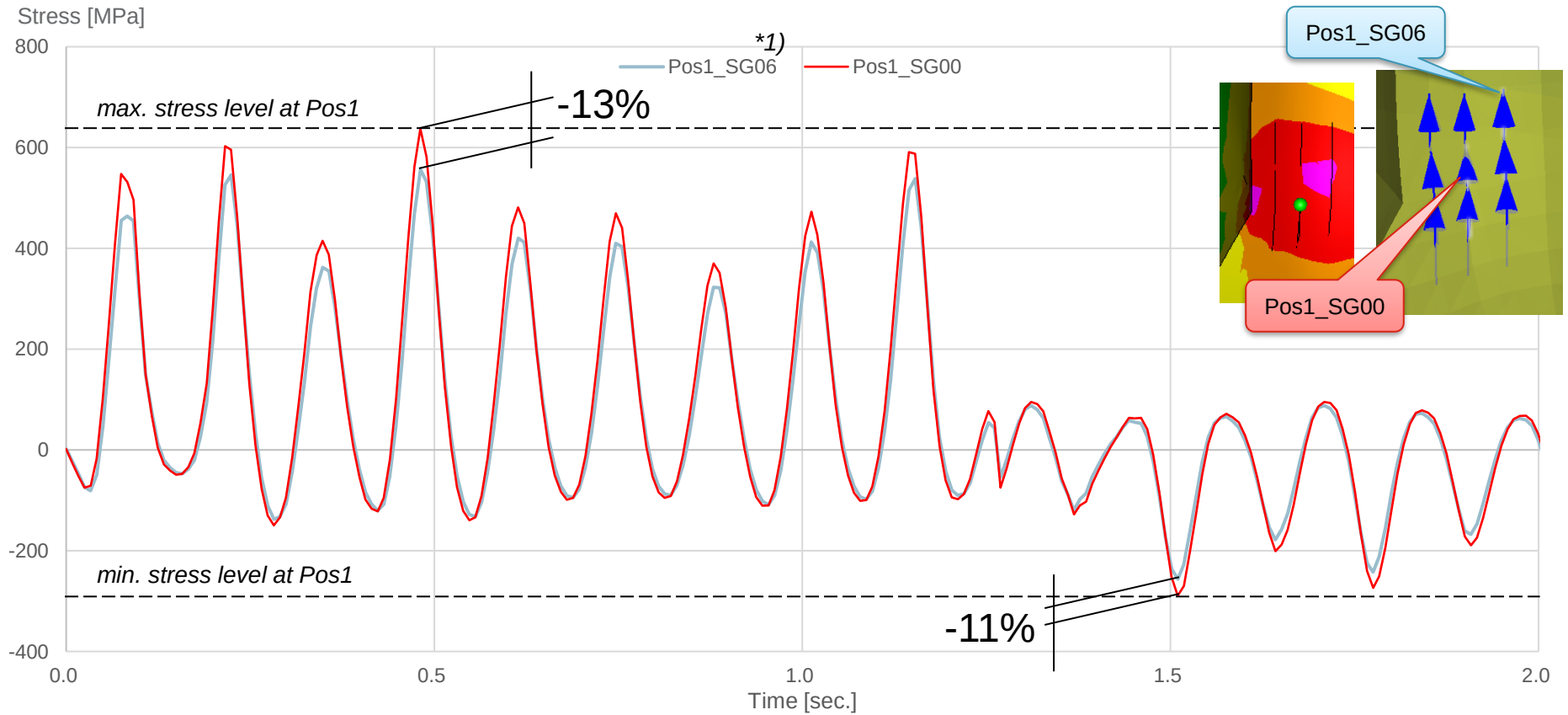
Linear Strain Gage, Length=1.52mm

Center arrow = Target position (white highlight)
Surround eight arrows = Check sensitivity
Gauge tolerance = +/-0.6mm

Pos1: Sensitivity of strain gauge position / overall



Pos1: Sensitivity of strain gauge position / zoom-in



*1) It was compared the negative deviation of strain gauge position from Pos1_SG00.

Pos2: 4.1% of most critical damage at N248190

Upper Stress: 432MPa (65.9%)

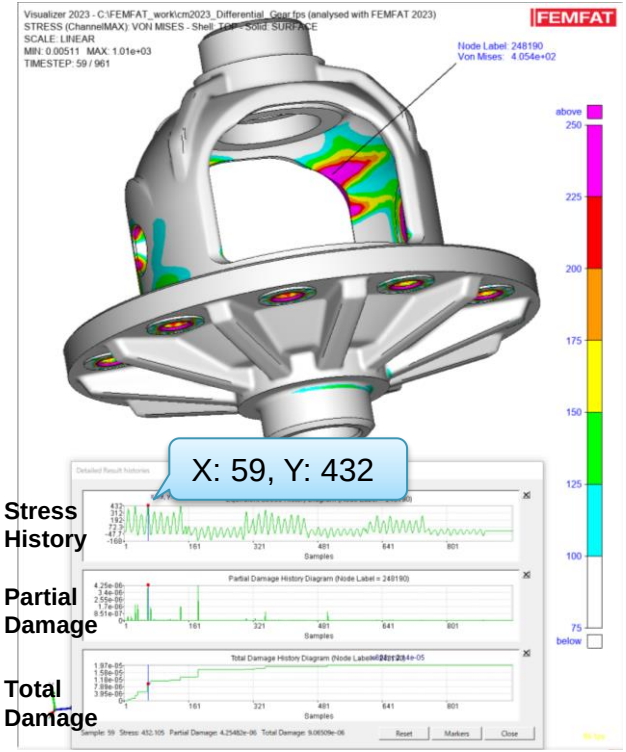
Equiv. stress @Time point = 59

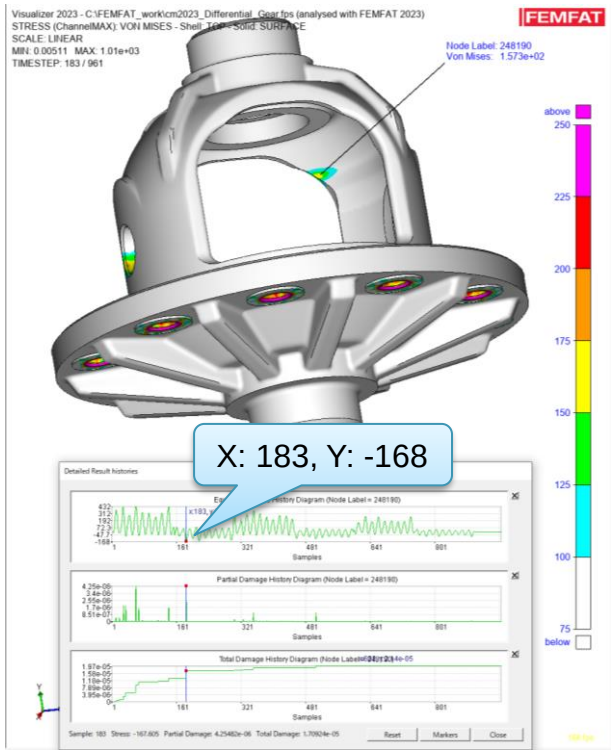
Lower Stress: -168MPa (56.6%)

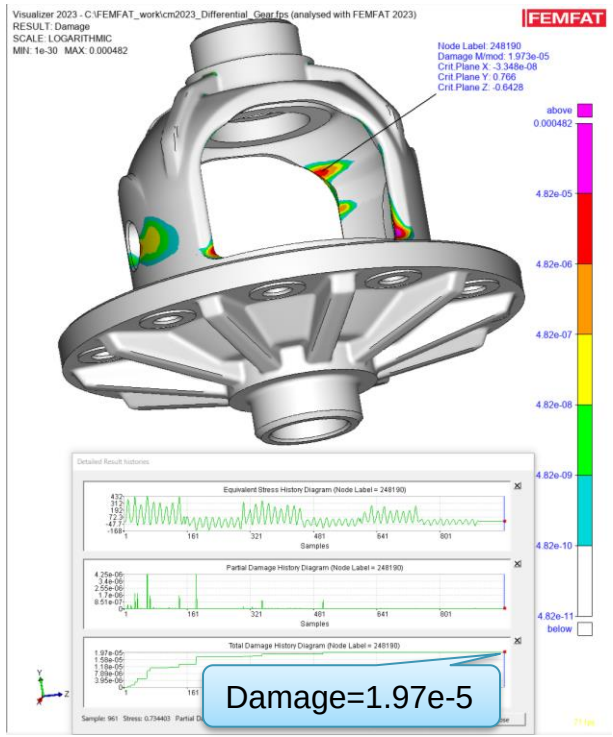
Equiv. stress @Time point = 183

FEMFAT: 1.973e-05 (4.1%)

Damage & Critical Cutting Plane Vector

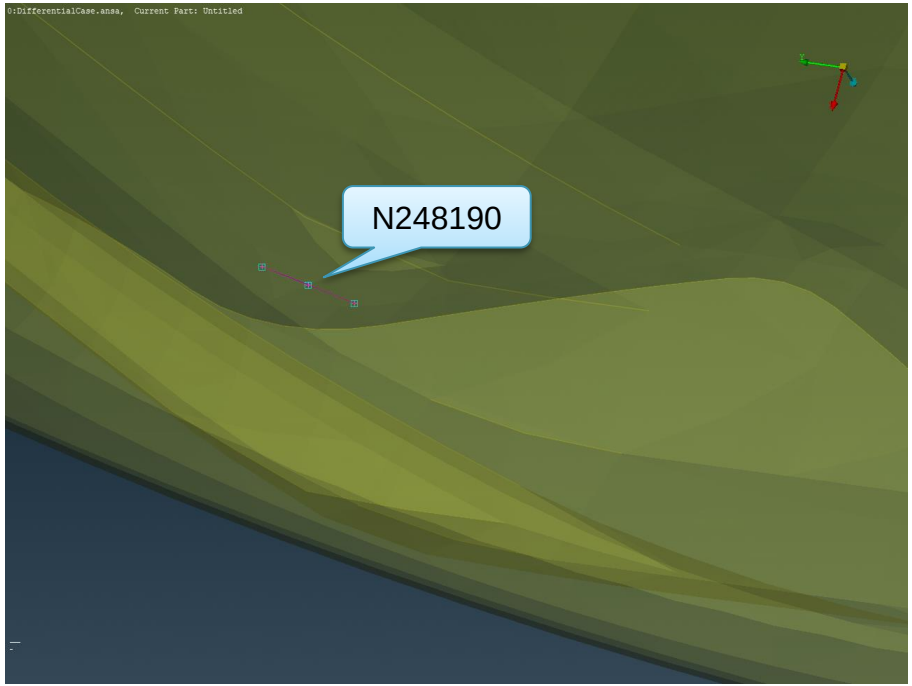


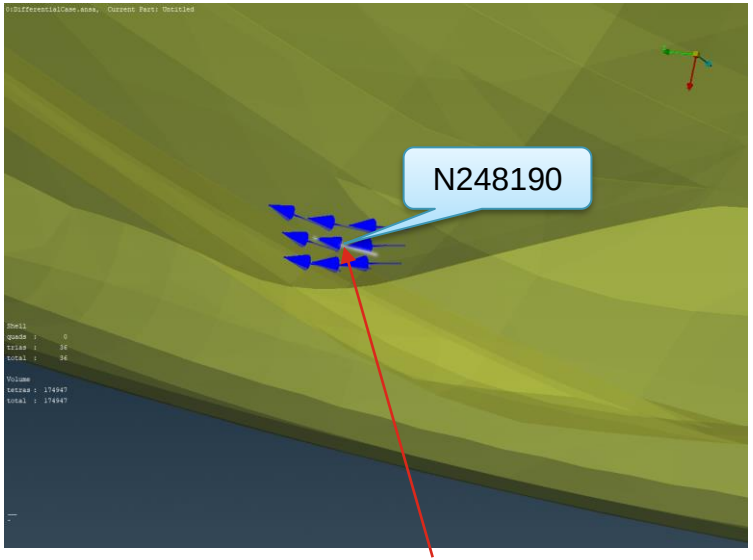




Pos2: Suggested strain gauge orientation by FEMFAT

- N248190 position and Critical Cutting Plane Vector & 9-gauge positions

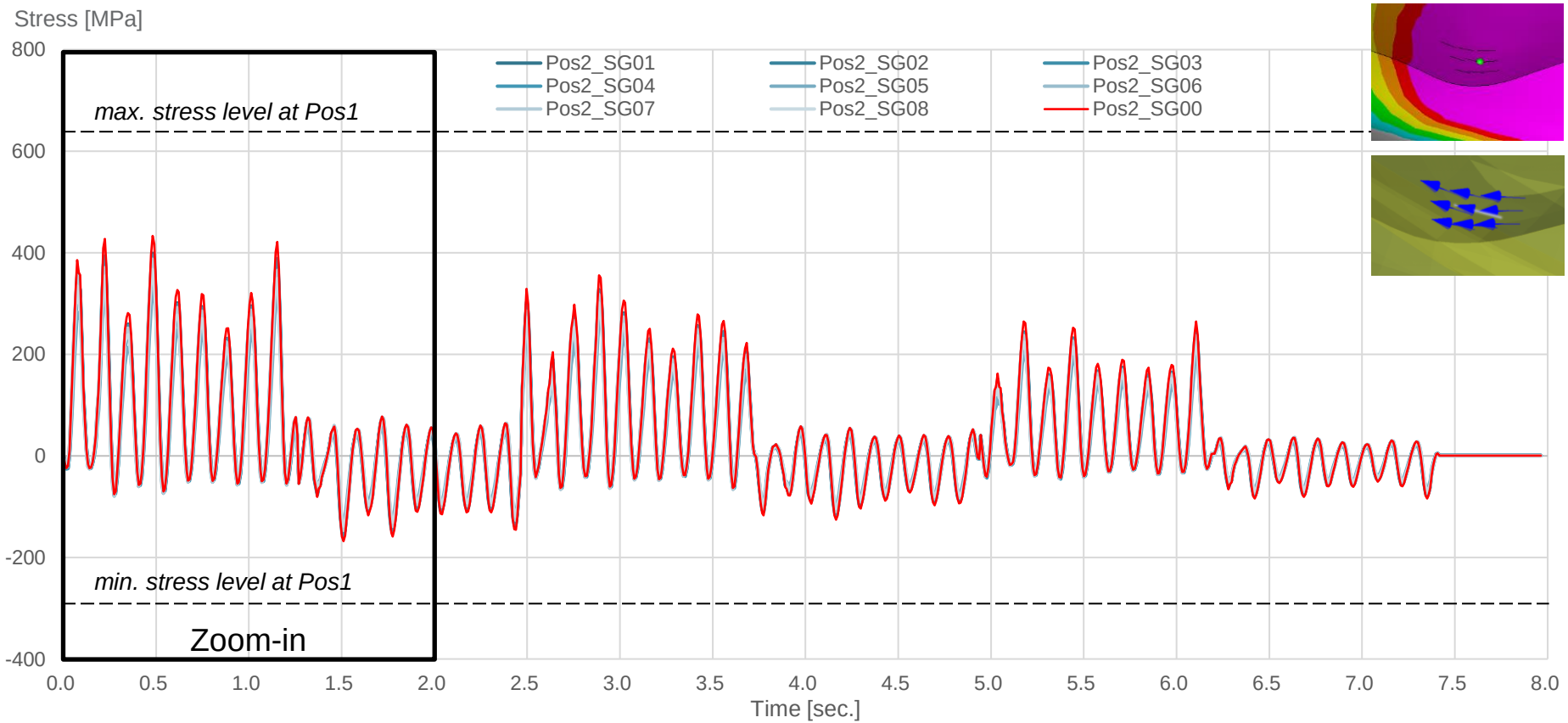




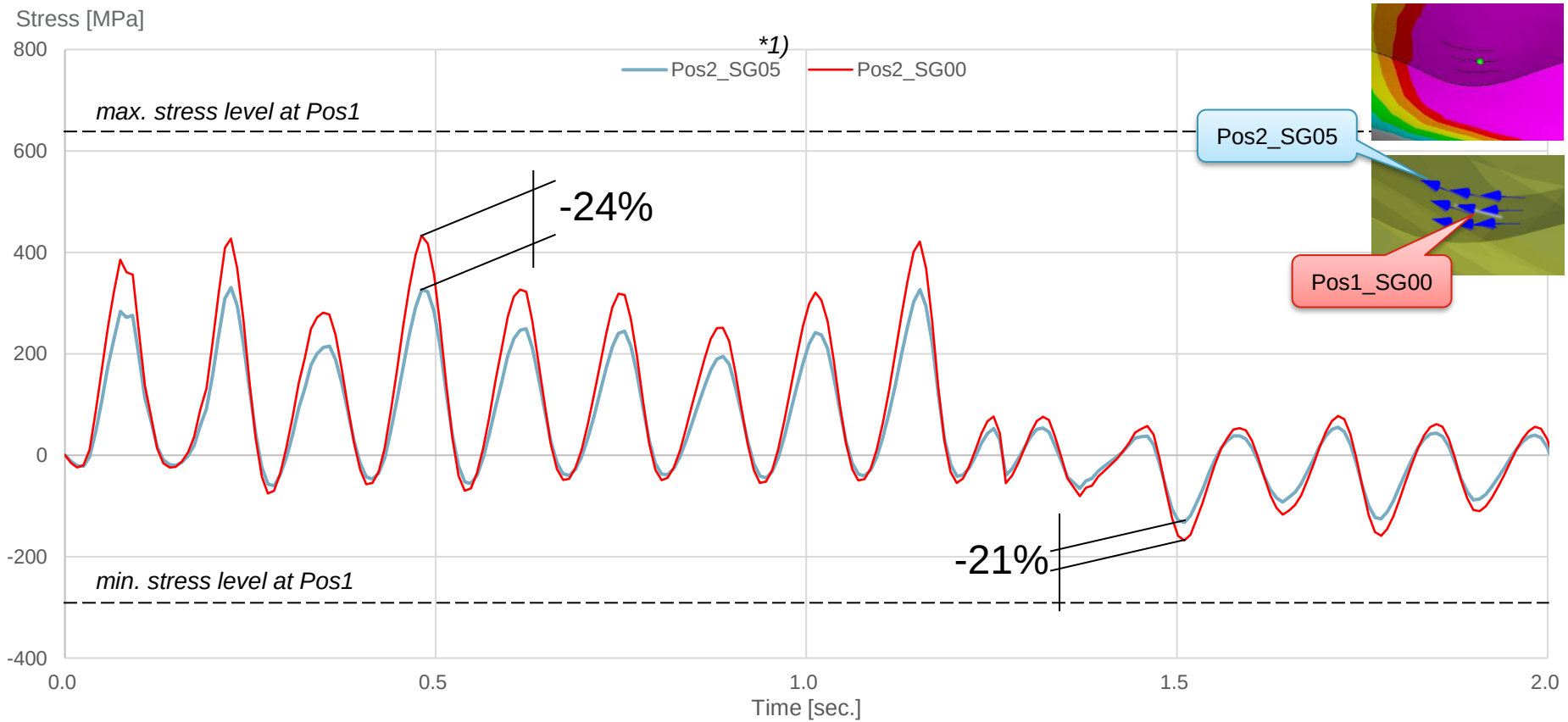
Linear Strain Gage, Length=1.52mm

Center arrow = Target position (white highlight)
Surround eight arrows = Check sensitivity
Gauge tolerance = +/-0.8mm

Pos2: Sensitivity of strain gauge position / overall



Pos2: Sensitivity of strain gauge position / zoom-in

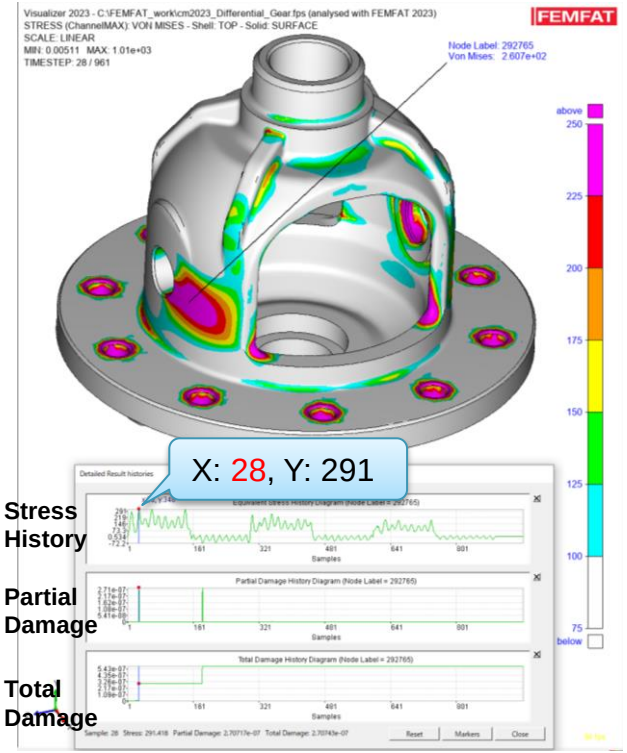


*1) It was compared the negative deviation of strain gauge position from Pos2_SG00.

Pos3: 0.1% of most critical damage at N292765

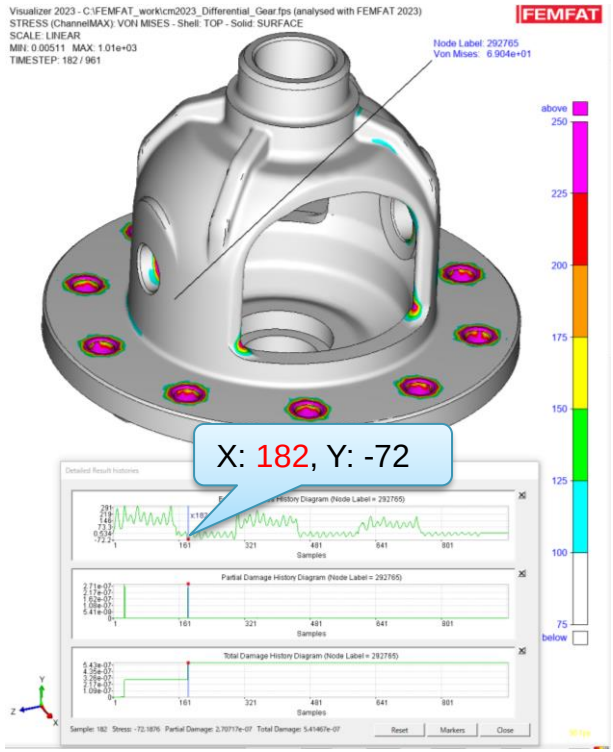
Upper Stress: 291MPa (44.3%)

Max. VM stress @Time point = 28



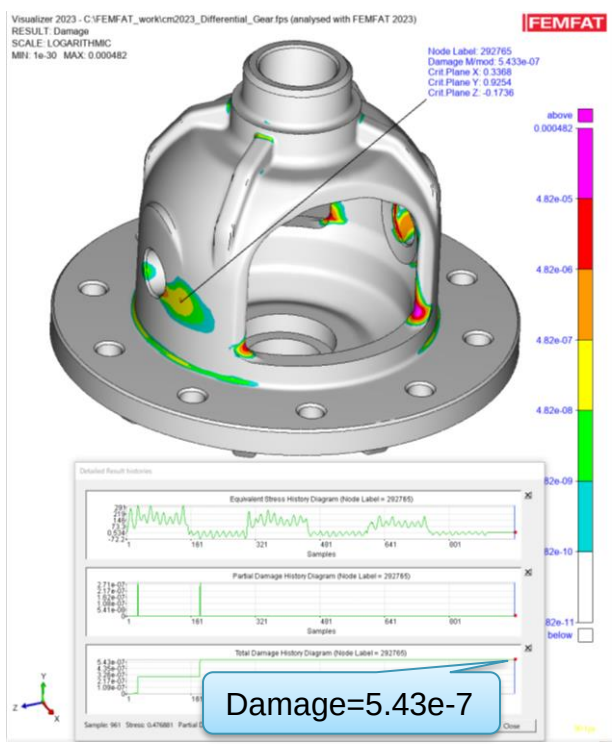
Lower Stress: -72MPa (24.2%)

Min. VM stress @Time point = 182



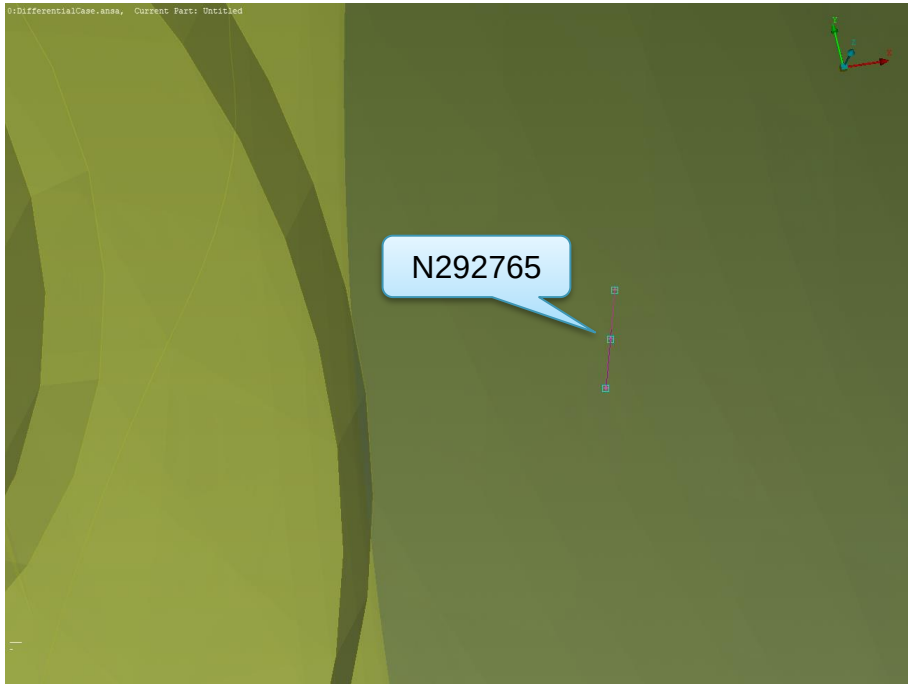
FEMFAT: 5.433e-07 (0.1%)

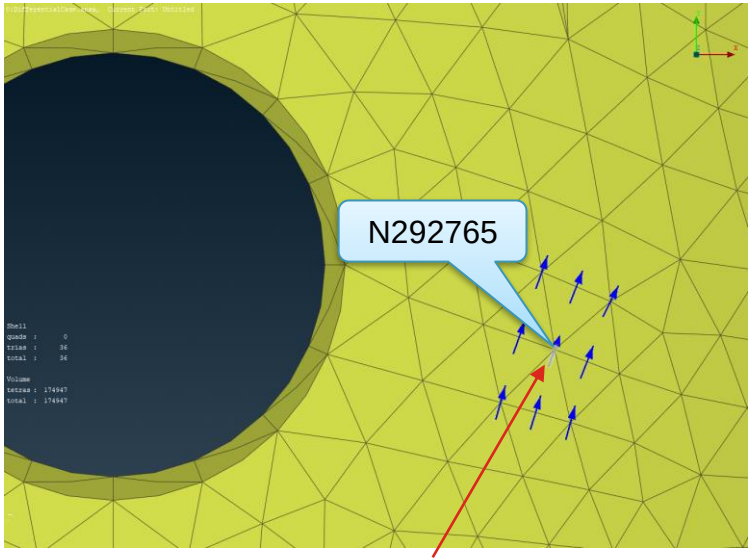
Damage & Critical Cutting Plane Vector



Pos3: Suggested strain gauge orientation by FEMFAT

- N292765 position and Critical Cutting Plane Vector & 9-gauge positions

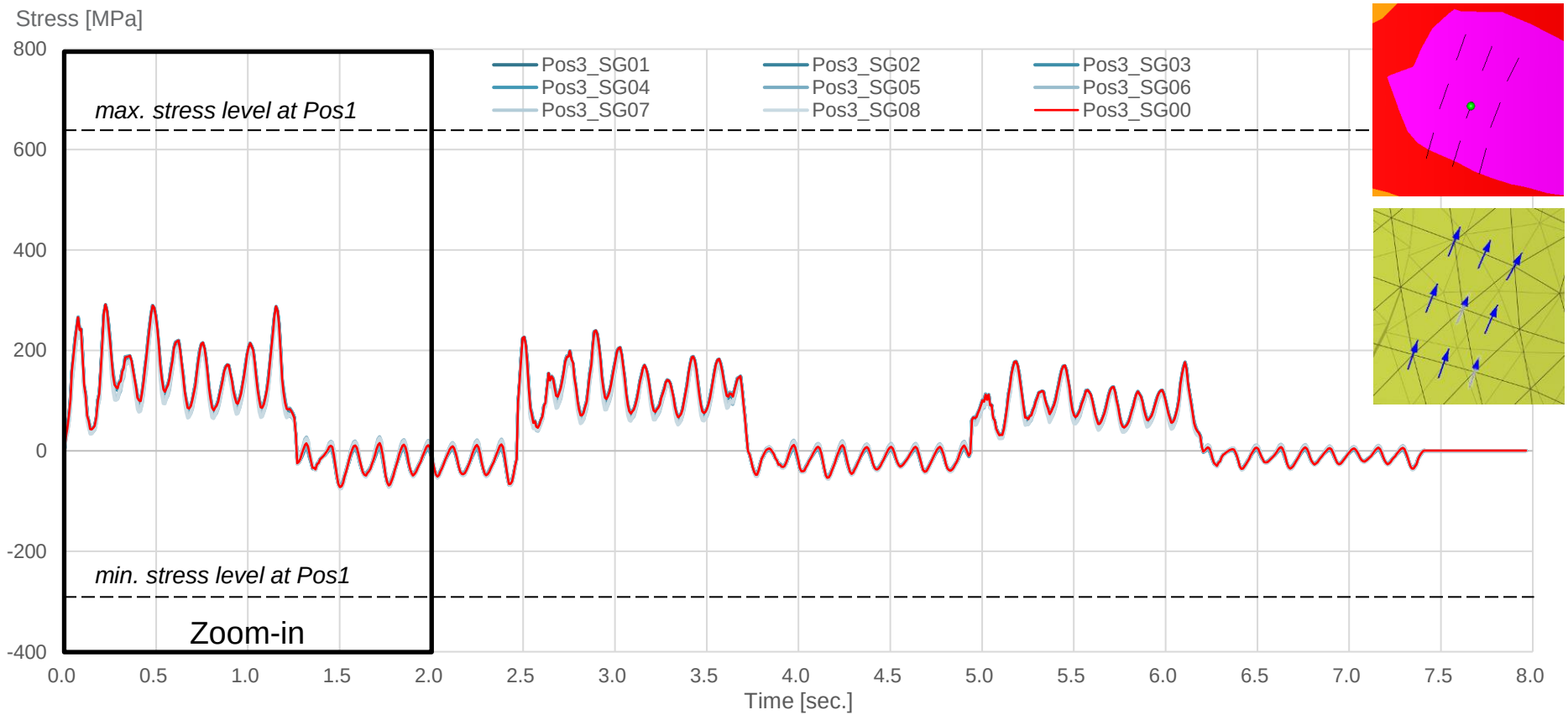




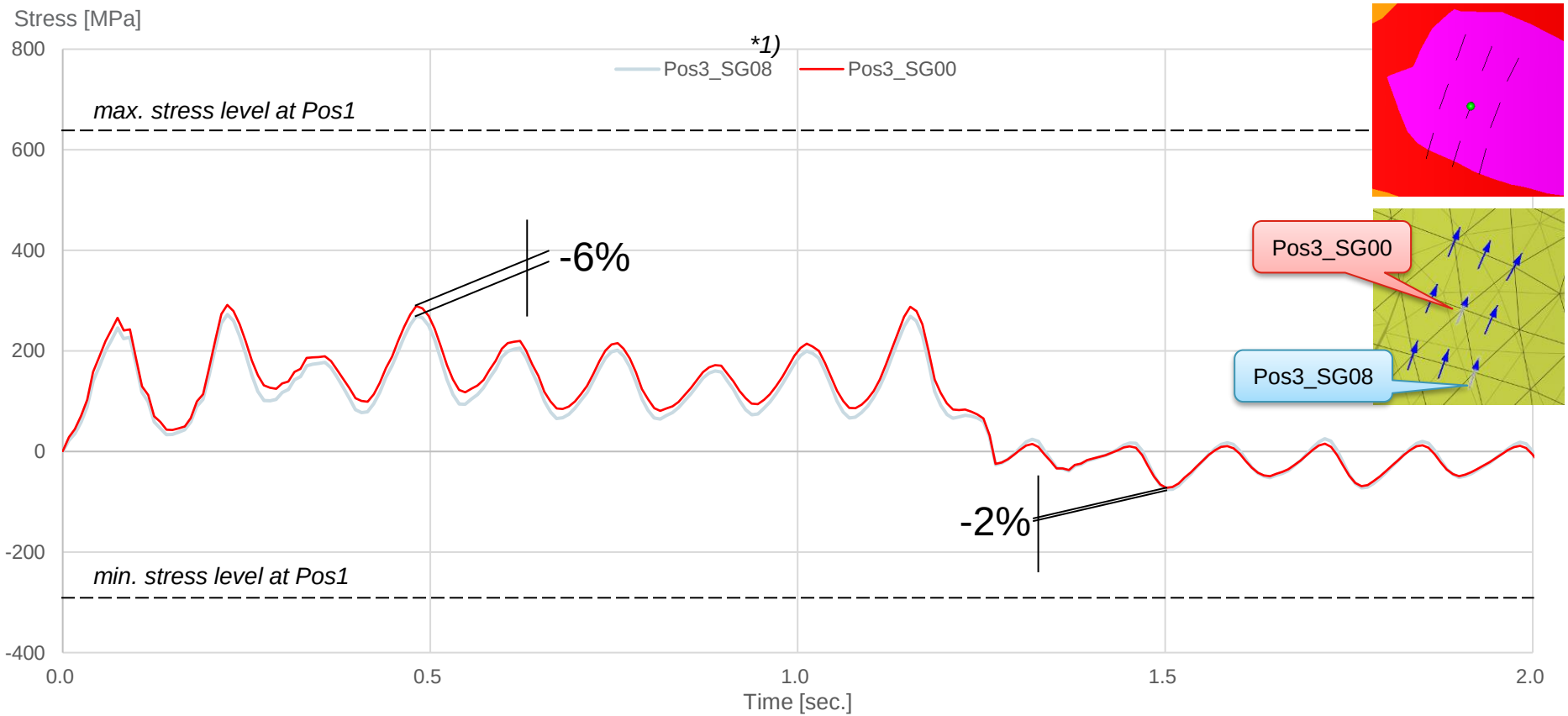
Linear Strain Gage, Length=1.52mm

Center arrow = Target position (white highlight)
Surround eight arrows = Check sensitivity
Gauge tolerance = +/-3.0mm

Pos3: Sensitivity of strain gauge position / overall



Pos3: Sensitivity of strain gauge position / zoom-in

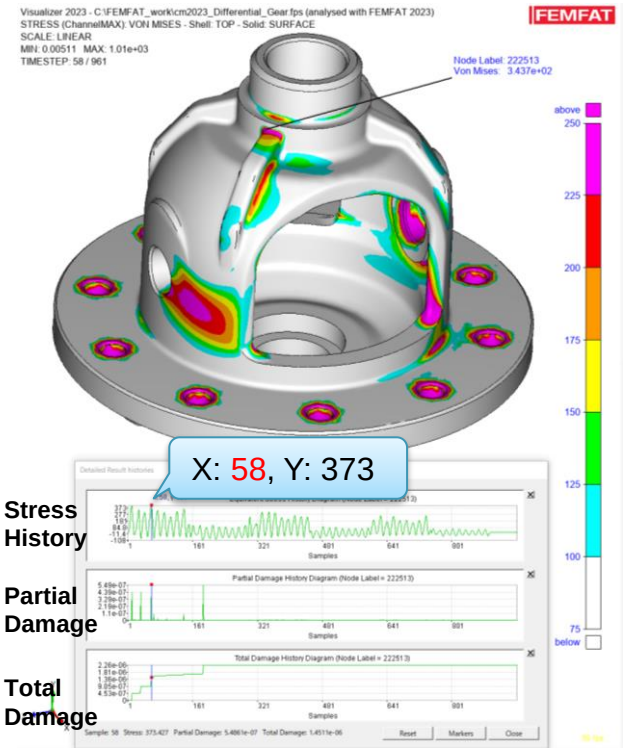


*1) It was compared the negative deviation of strain gauge position from Pos3_SG00.

Pos4: 0.5% of most critical damage at N222513

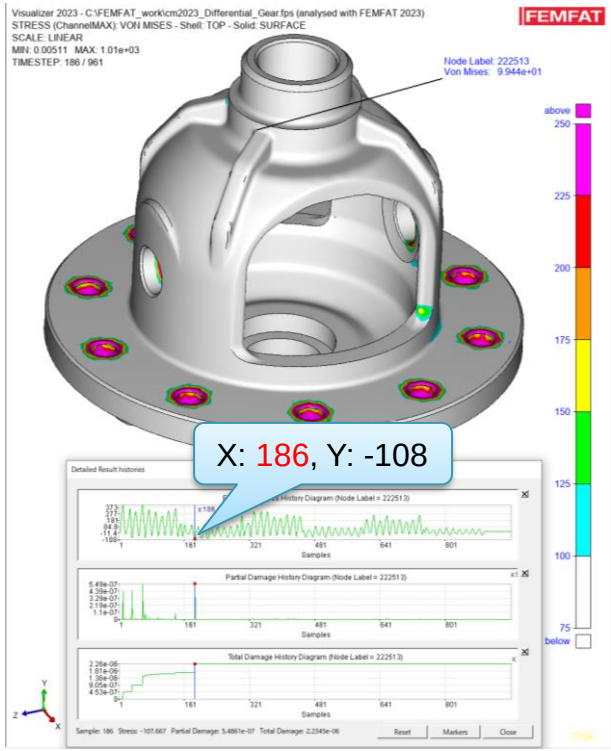
Upper Stress: 373MPa (56.9%)

Max. VM stress @Time point = 58



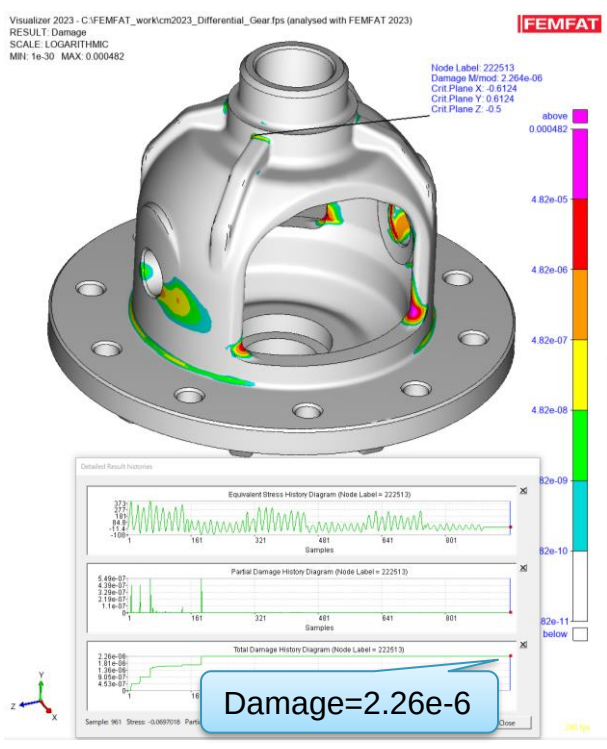
Lower Stress: -108MPa (36.4%)

Min. VM stress @Time point = 186



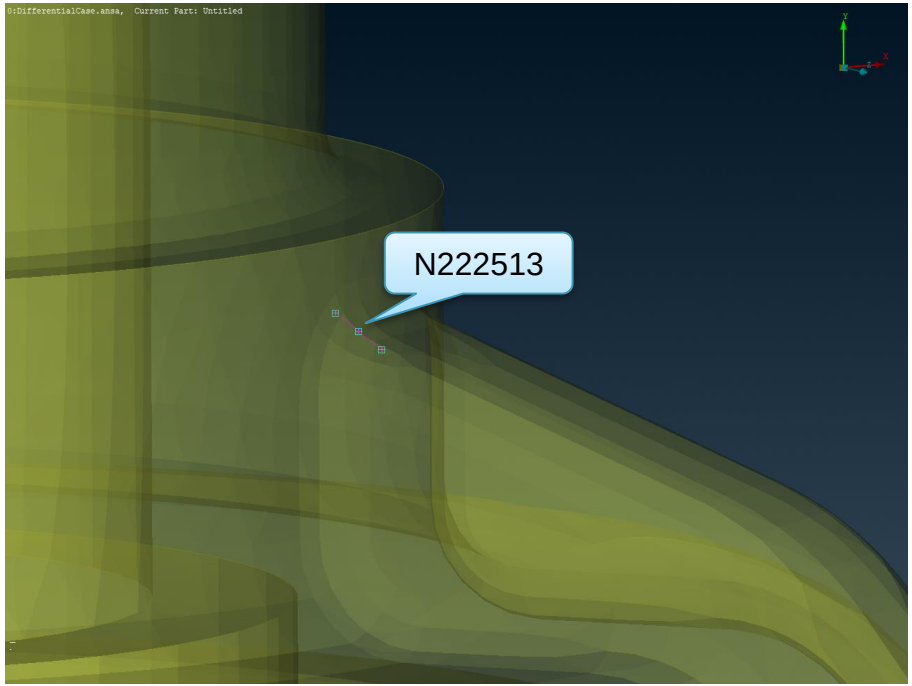
FEMFAT: 2.264e-06 (0.5%)

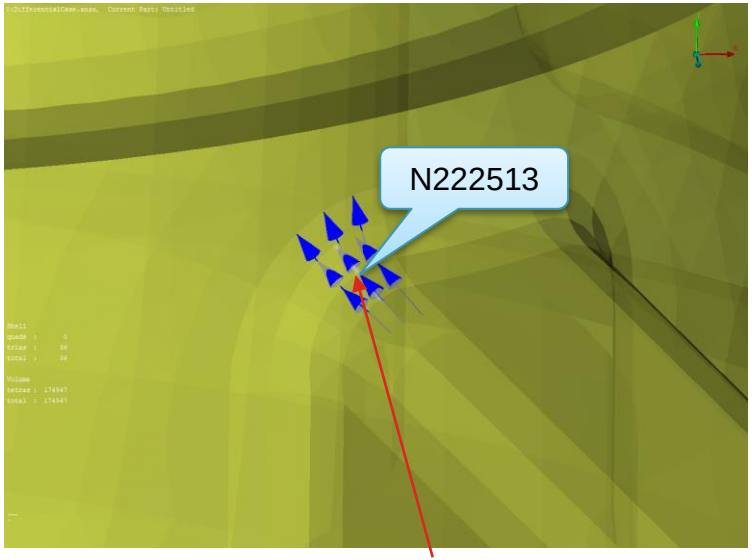
Damage & Critical Cutting Plane Vector



Pos4: Suggested strain gauge orientation by FEMFAT

- N22513 position and Critical Cutting Plane Vector & 9-gauge positions

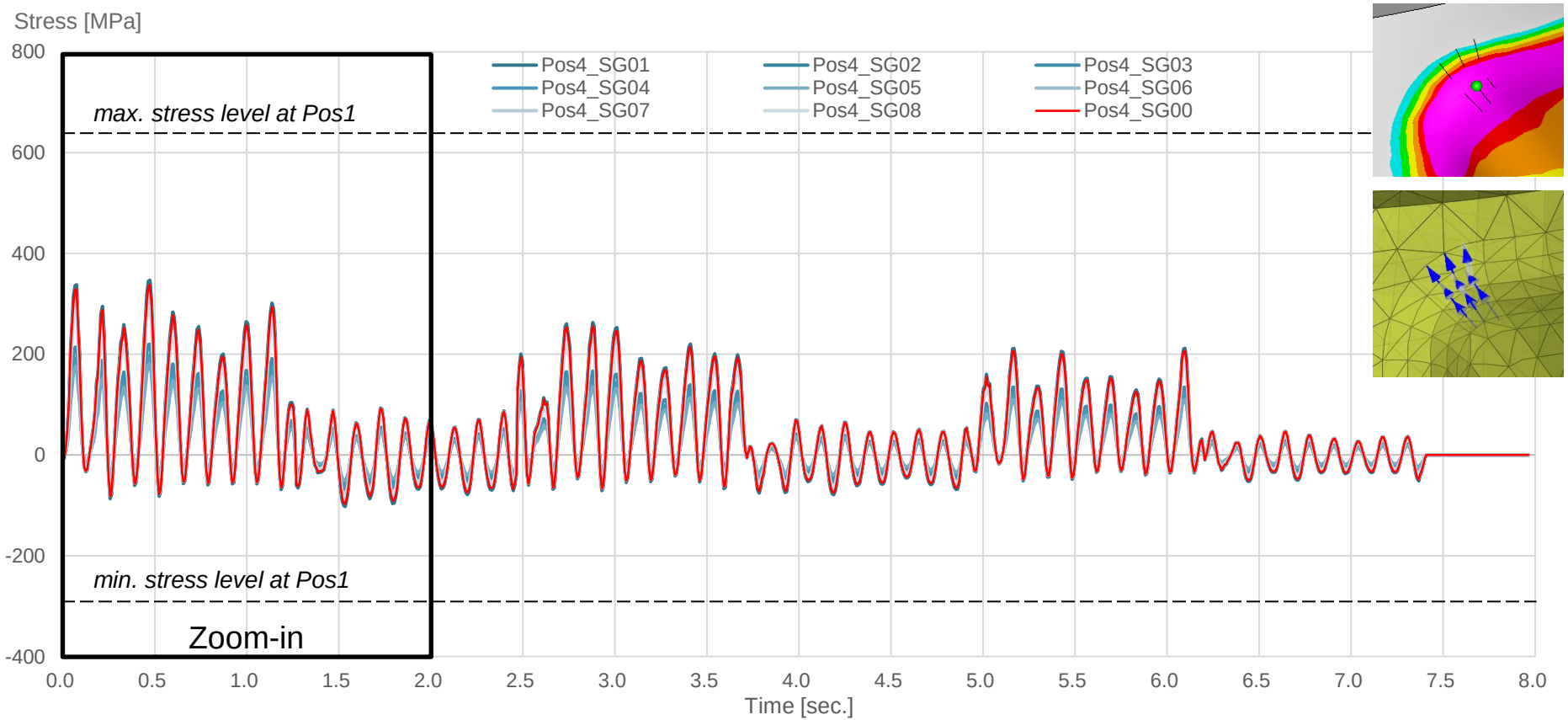




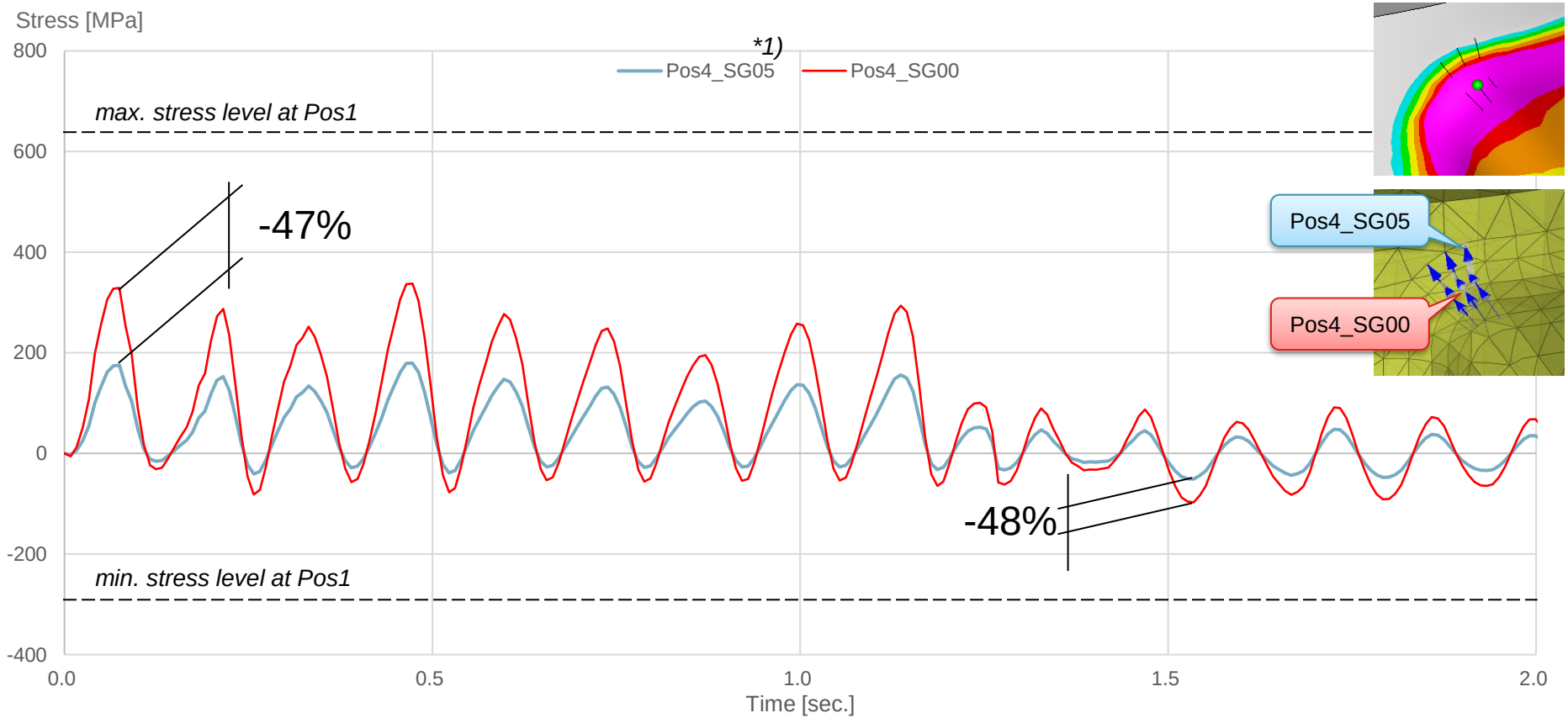
Linear Strain Gage, Length=1.52mm

Center arrow = Target position (white highlight)
Surround eight arrows = Check sensitivity
Gauge tolerance = +/-0.5mm

Pos4: Sensitivity of strain gauge position / overall



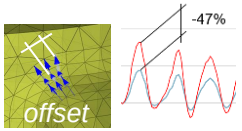
Pos4: Sensitivity of strain gauge position / zoom-in

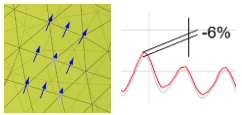


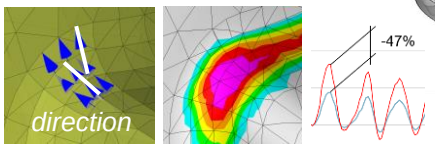
*1) It was compared the negative deviation of strain gauge position from Pos4_SG00.

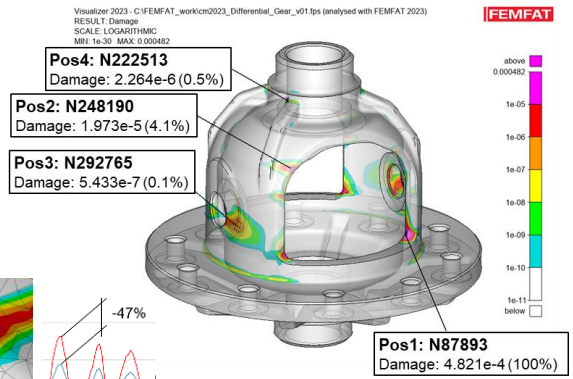
Summary

- When it is small radii with stress concentration area, the measured stress deviation can be high. (Pos4, ~50%)
- When it is flat area with homogeneous stress distribution, the measured stress deviation can be low. (Pos3, ~5%)
- It is not only the offset of the position (~0.5mm), but also the orientation of the direction, it is possible to have massive deviation in the stress history. (Pos4)









Position	Damage	Measured Stress (Target position)	Deviation (tolerance)	Remark
Pos1	4.821e-4 (100%)	637 / -289 MPa	-13% / -11% (+/-0.6mm)	Convex shape with small radii Equivalent fillet R ≅ 5.1
Pos2	1.973e-5 (4.1%)	433 / -168 MPa	-24% / -21% (+/-0.8mm)	Concave shape with small radii Equivalent fillet R ≅ 5.2
Pos3	5.433e-7 (0.1%)	292 / -72 MPa	-6% / -2% (+/-3.0mm)	Flatter shape with large radii Equivalent fillet R ≅ 15.0
Pos4	2.264e-6 (0.5%)	338 / -97 MPa	-47% / -48% (+/-0.5mm)	Concave shape with small radii Equivalent fillet R ≅ 3.0

ANSA Plugin of Virtual Strain Gauge Utilities for FEMFAT

- Overview of Multidisciplinary Fatigue Analysis by FEMFAT
- Development of the plugin - How it started?
- Overview of the functionalities of the plugin
- Use case
- Conclusions

Conclusions

・ANSA-plugin and FEMFAT strain are possible to examine where is the best position (less sensitivity, meaningful position) to be attached the strain gauge before physical tests.

・It is easy to locate virtual strain gauge by ANSA, and it is easy to prepare the necessary input data for FEMFAT strain.

・The definition of virtual strain gauge is possible to be used for META, too.

NOTICE: This plugin requires a license feature, different from ANSA/META(pre-post package).
Please contact us for details via:
- Our web site : https://beta-cae.jp/index.html
- Technical support : support@beta-cae.jp