ce masters

a pezy group company

Title:	**Advanced Simulations with Creo Simulate 2.0**
Author:	Theo Wijers
Date:	November 2012

mechanical product development and consultancy

ce masters
a pezy group company

Agenda:

- Introduction
- Why Simulations?
- Theory of Non-Linearity:
  - Geometric: Large Displacements
  - Constraints: Contact
  - Material: Elastoplastic, Hyperelastic
- Combining Non-Linearities with Creo Simulate 2.0
- Examples of combined Non-Linear Analyses
- Examples of Advanced Dynamic Analyses
- Discussion

Introduction

Office of CE Masters in Houten, NL

Contact information:

Sleepboot 11 | 3991 CN Houten | The Netherlands
T +31 (0)30 635 48 50 | F +31 (0)30 635 48 51
www.cemasters.nl

Introduction

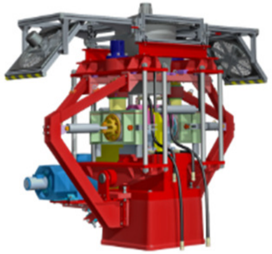
Our Customers

Heineken | Unilever | IHC Merwede | bugaboo | RHEINMETALL | THALES | SKF



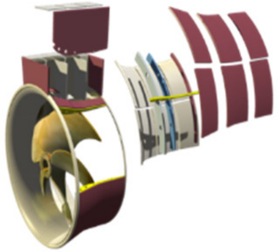











PHILIPS | ETNA VENDING TECHNOLOGIES | curver | ERICSSON TAKING YOU FORWARD | VDL BUS & COACH | Van Voorden | kraker

ce masters
a pezy group company

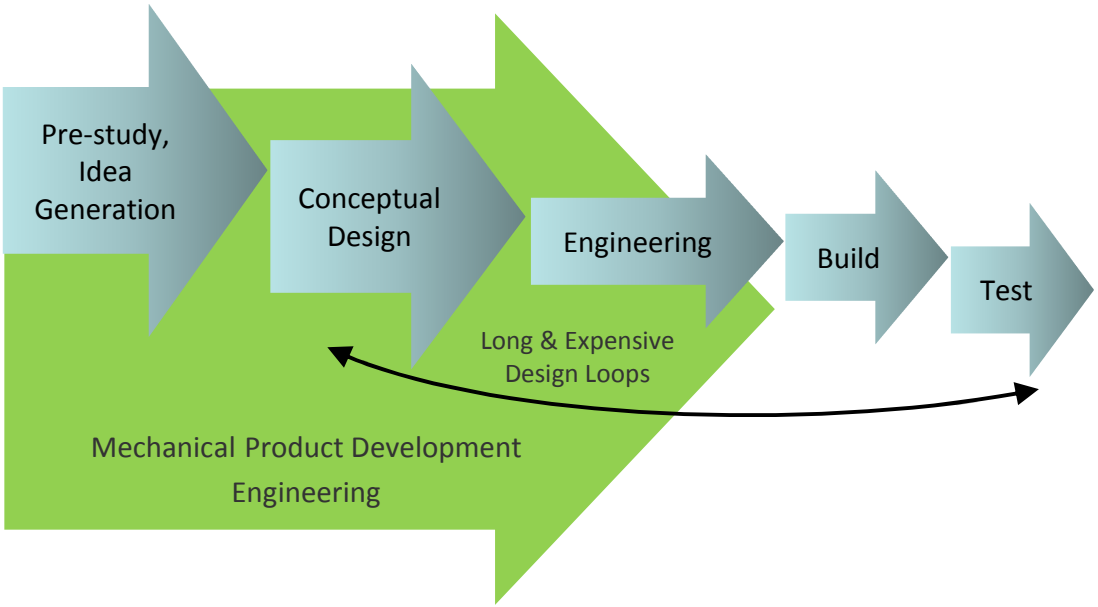
Why Simulations?

CE Masters distinguishes 3 Levels of Engineering:

1. Engineering without Simulation
2. Engineering with Simulation
3. Integrated Engineering & simulation

ce masters
a pezy group company

Engineering without Simulation



"Physical Testing"

Characteristics:

- Insufficient insight in product behavior
- Unable to compare design alternatives
- Long and expensive design loops
- Expensive physical prototypes
- Not first time right
- End result is compromise of design issues

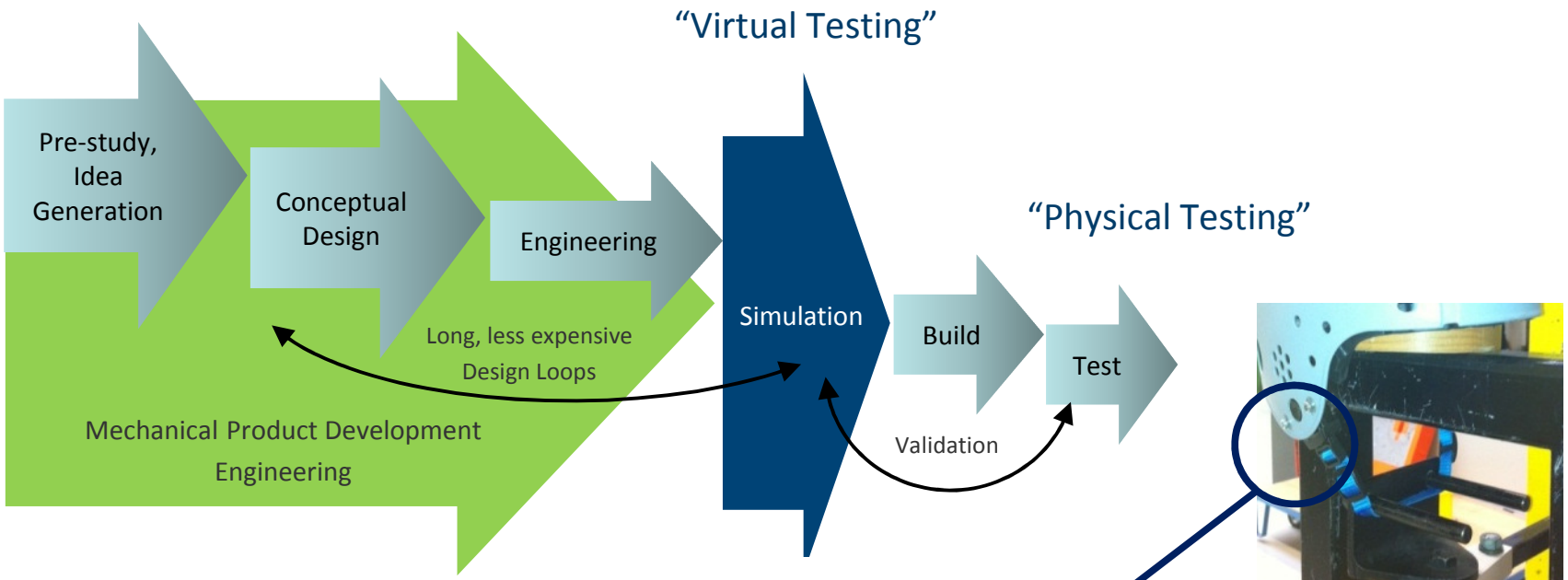
Long Time to Market

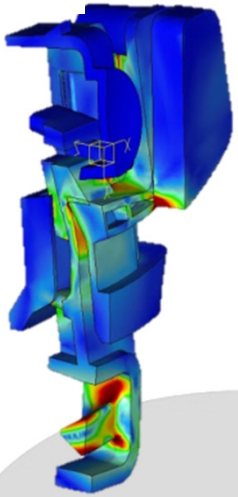
Low Quality

High Costs

ce masters
a pezy group company

Engineering with Simulation



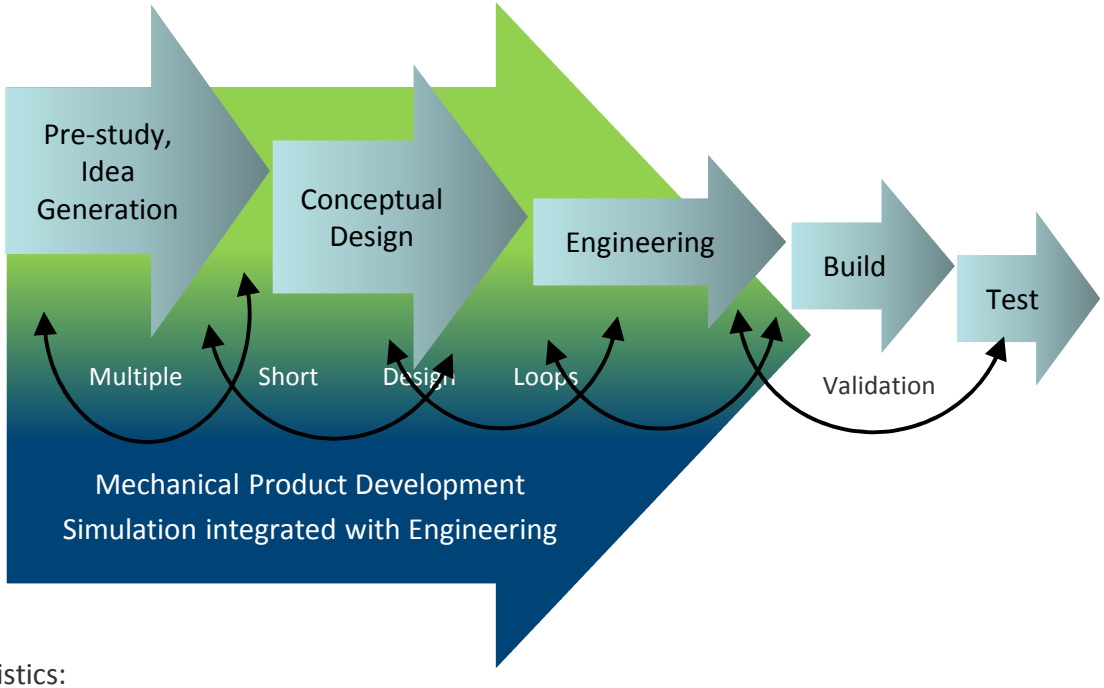


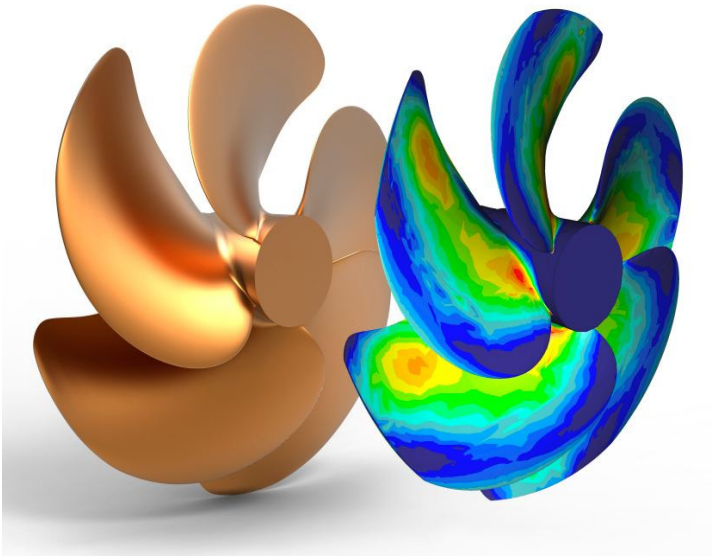
Characteristics:

- Simulation used as design check
- Simulation not integrated in development process
- Limited use of gained insight with Simulation
- No investigation of design alternatives
- Not first time right
- End result is still compromise of design issues

ce masters
a pezy group company

Integrated Engineering & Simulation





Characteristics:

- Early insight in product behavior
- Ability to compare many design alternatives
- Short and low cost design loops
- Less physical prototypes
- First Time Right approach
- Concept optimized and based on insight

Short Time to Market

High Quality

Low Costs

"Insight driven Engineering"

ce masters
a pezy group company

Simulation Characteristics

Principle Calculations and Analyses

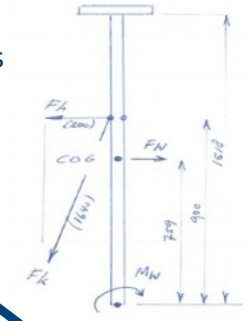
Analyses and Comparison of Design Alternatives

Design Optimization

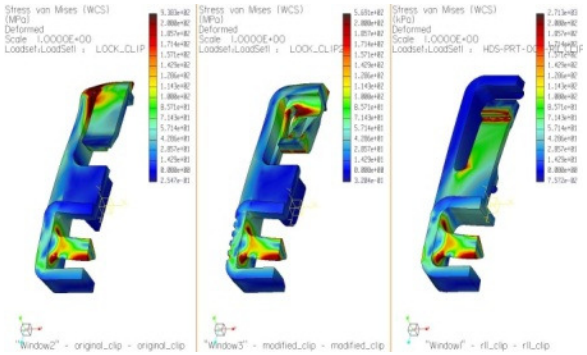
Verification

Problem Solving

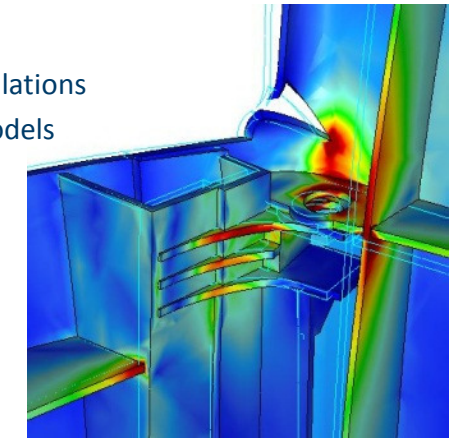
Simple Calculations
Small Models



Comparison Calculations
Conceptual Models



Complex Calculations
Detailed Models



Pre-study, Idea Generation

Conceptual Design

Engineering

Build

Test

Multiple Short Design Loops

Validation

Mechanical Product Development
Simulation integrated with Engineering

"Insight driven Engineering"

Theory of Non-Linearity

Comparison of Linear Analysis with:

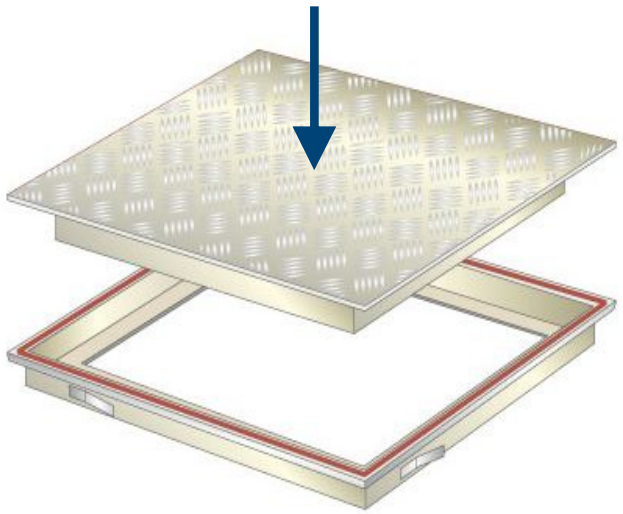
- ❑ Geometric Non-Linearity: Large Displacements
- ❑ Material Non-Linearity: Elastoplastic Material Property
- ❑ Constraint Non-Linearity: Contact Analyses

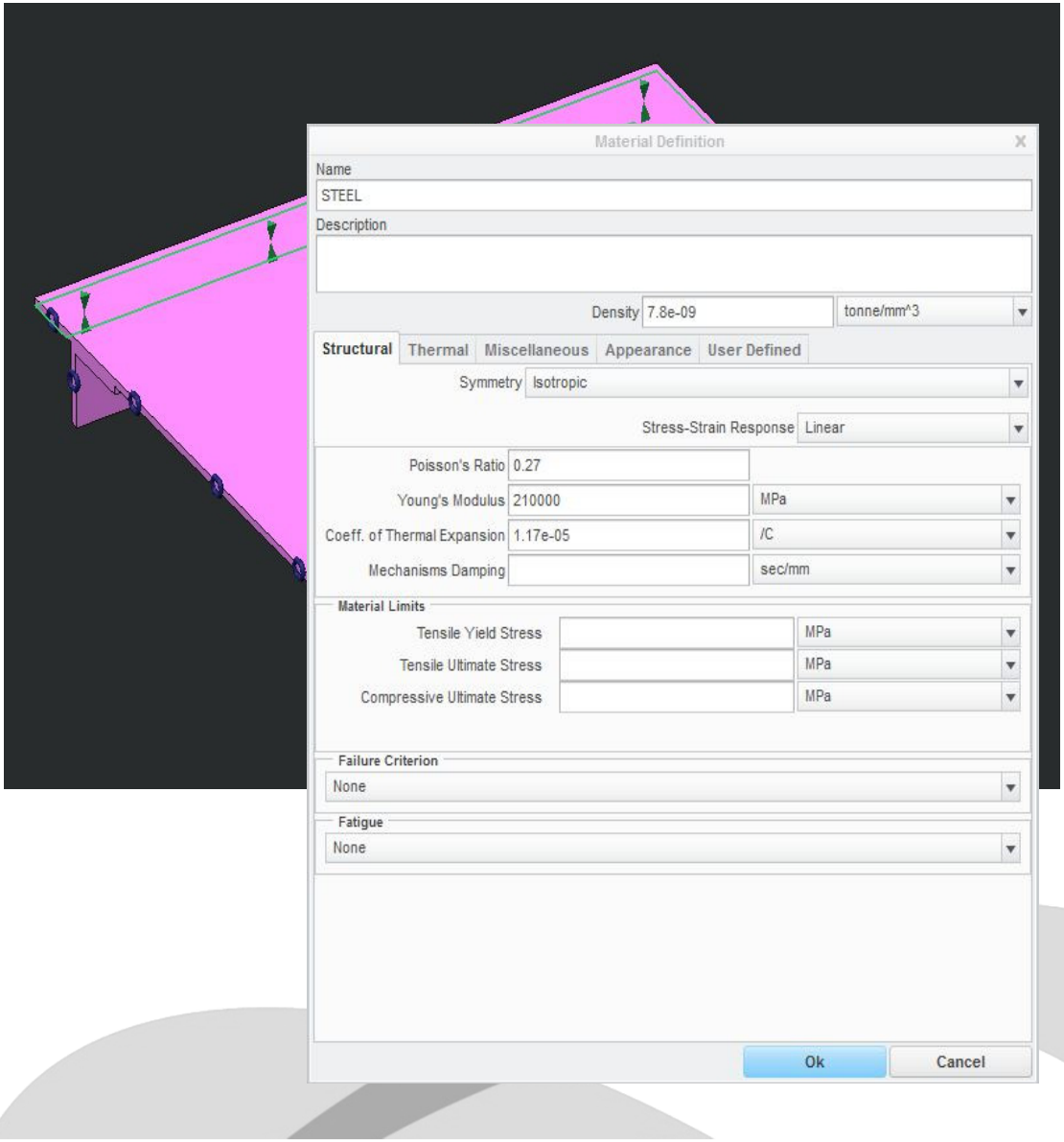
Theory of Non-Linearity

Example: Manhole Cover

Linear Analyses:

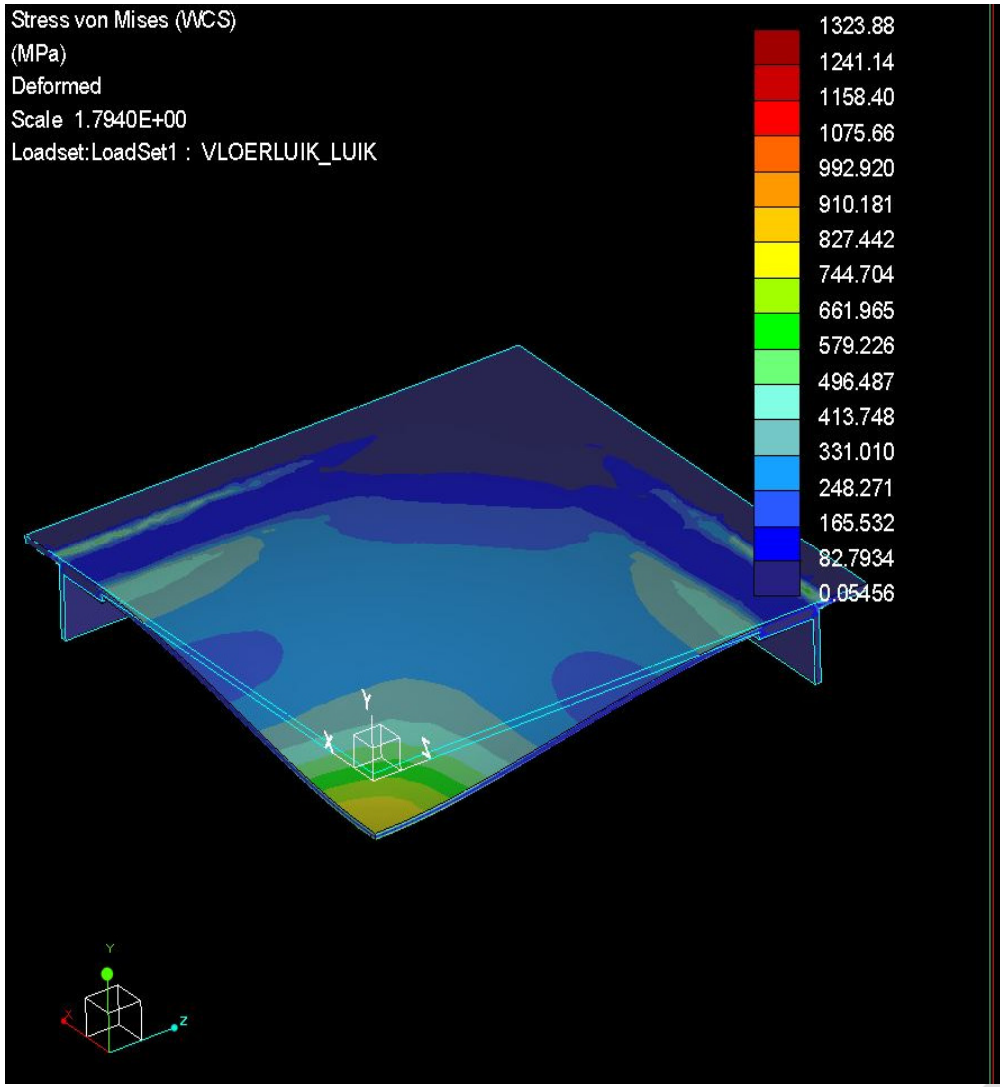
- ¼ of model due to symmetry
- Material Steel (linear): Emod = 210.000 MPa
- Constraint vertically at contact surface with base
- ¼ of total load: F = ¼ * 15 = 3,75 kN



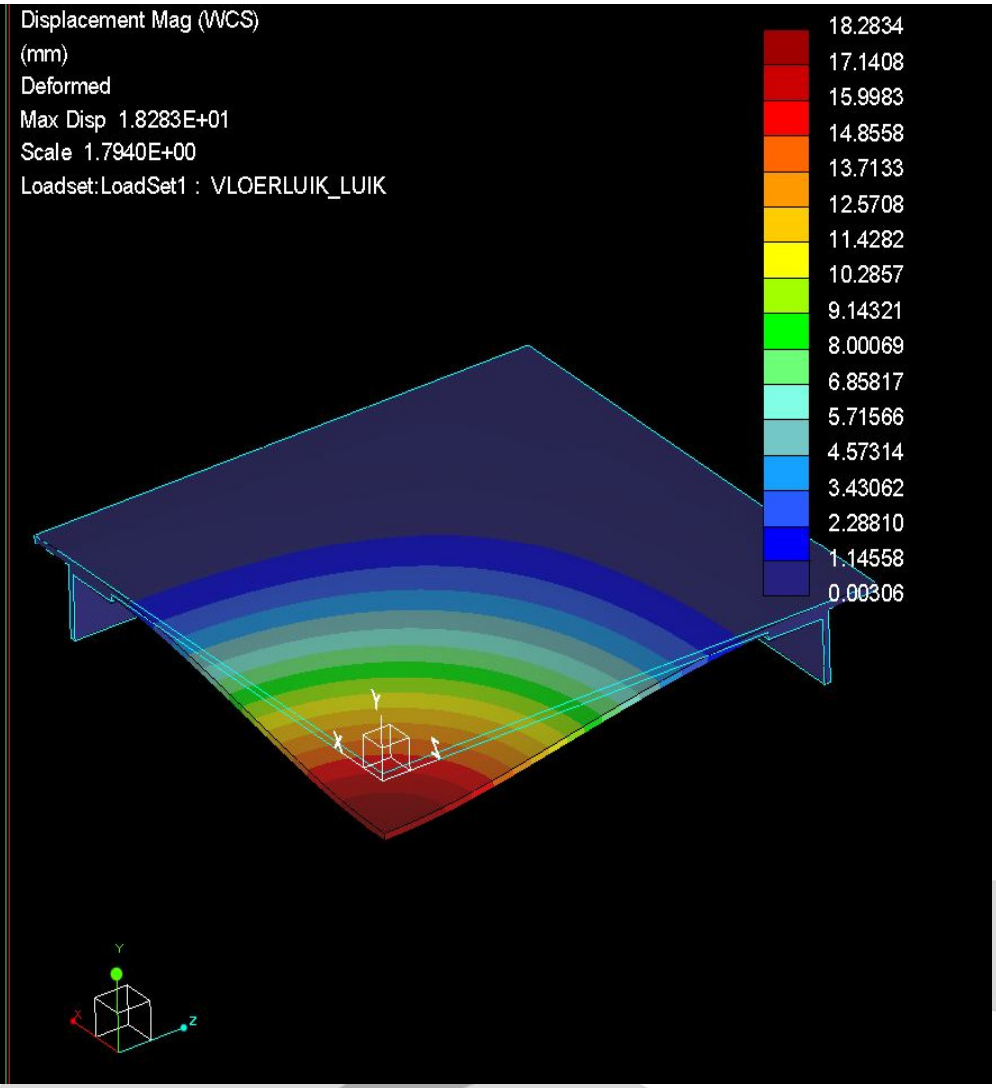


Results Linear Analysis

Max. VM stress = 1324 MPa



Max. Displacement = 18,3 mm



Theory of Non-Linearity

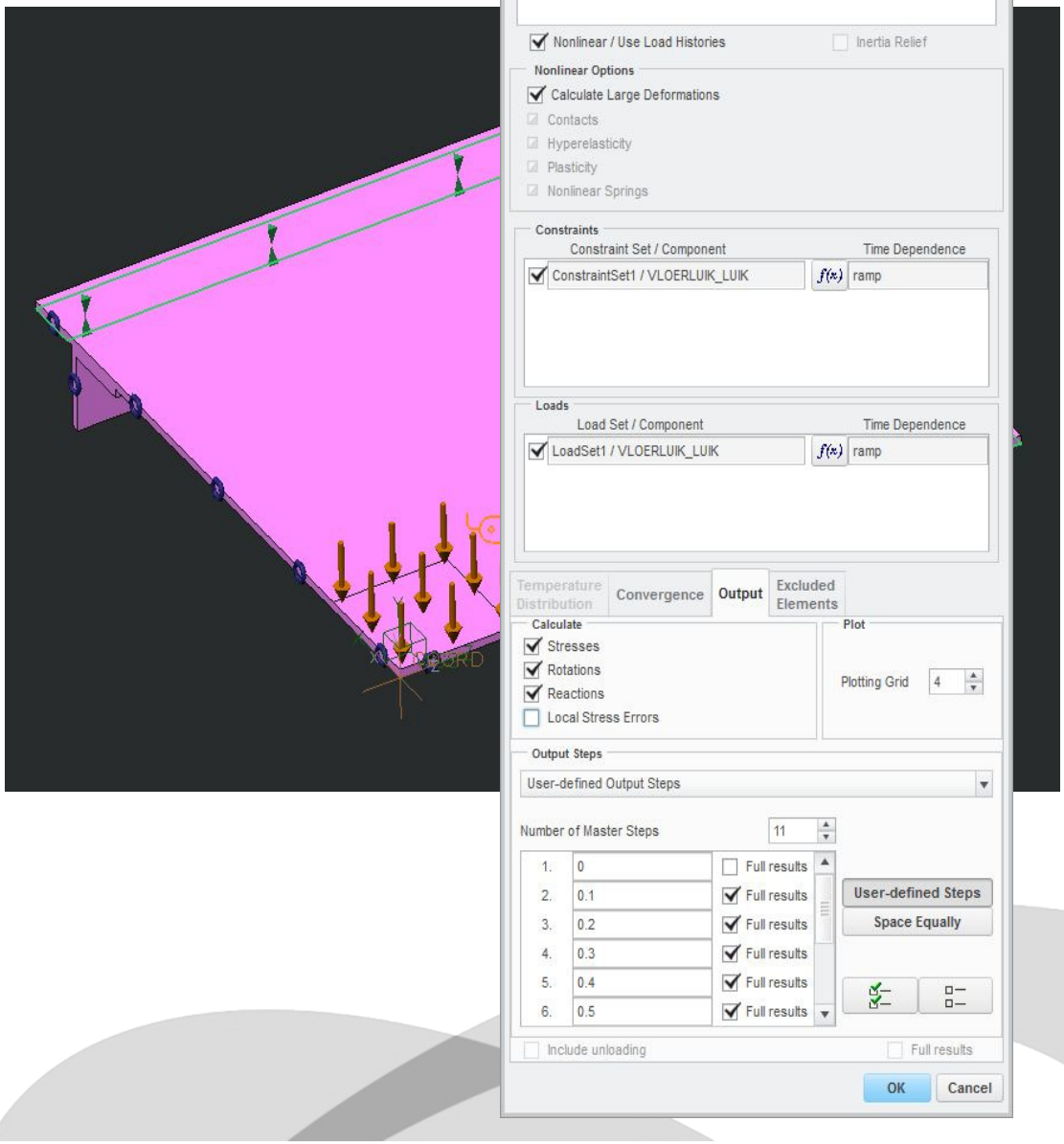
Geometric Non-Linearity: Large Displacements

Characteristics:

- The stiffness under loading is Non-Linear (i.e. the stiffness changes due to changed shape)
- The analyses is executed with load steps
- At each load step the stiffness matrix will be recomputed
- (reaction)Load direction can change

When to use Large Displacements (rules-of-thumb):

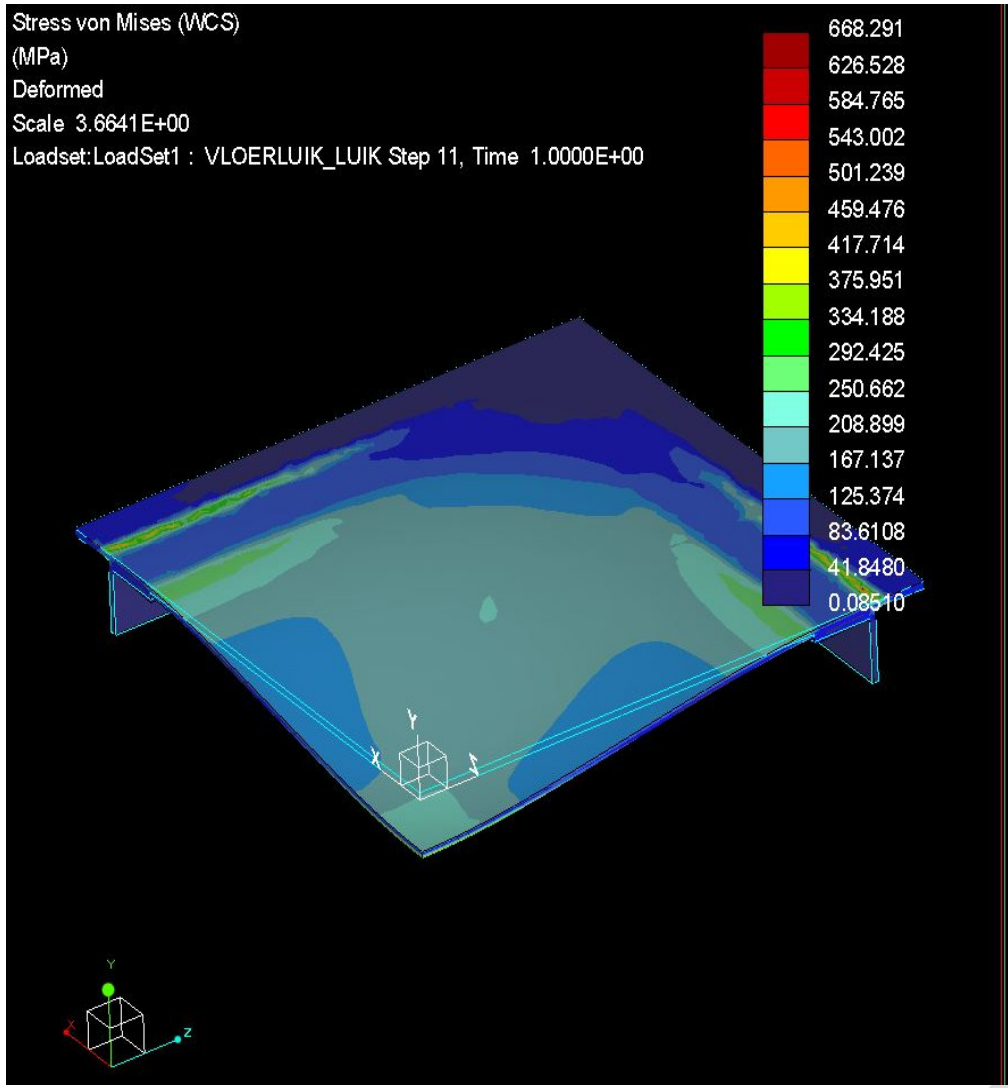
- Deformation larger than the (shell)thickness
- Deformation visible to the naked eye
- Deformation larger than 1/20th of part's largest dimension



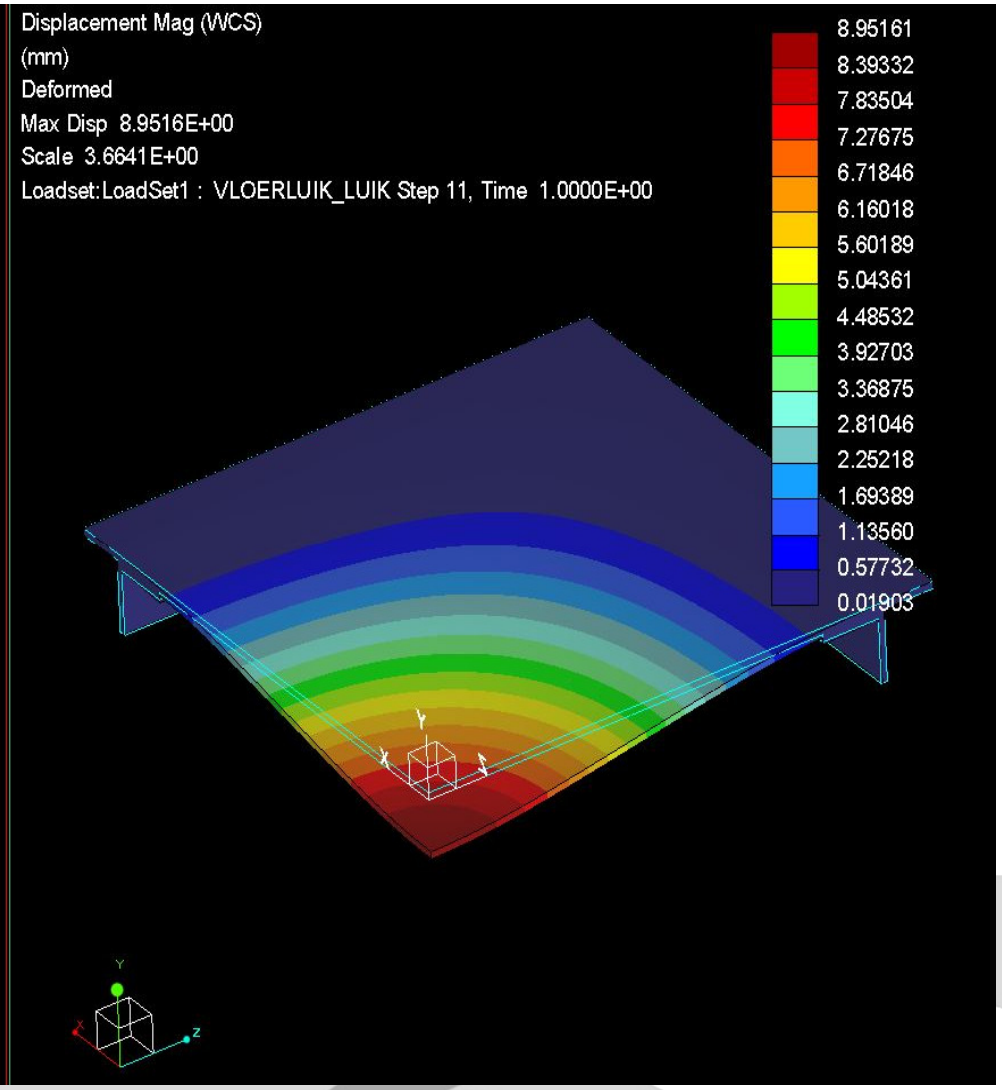
ce masters
a pezy group company

Results Non-Linear Large Displacement Analysis

Max. VM stress = 668 MPa



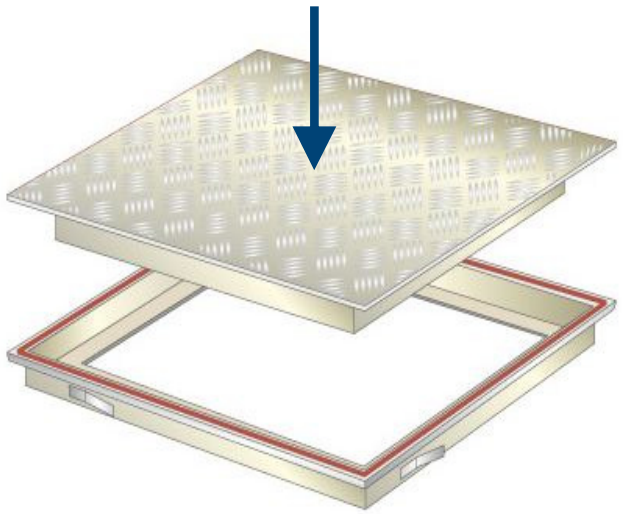
Max. Displacement = 8,95 mm

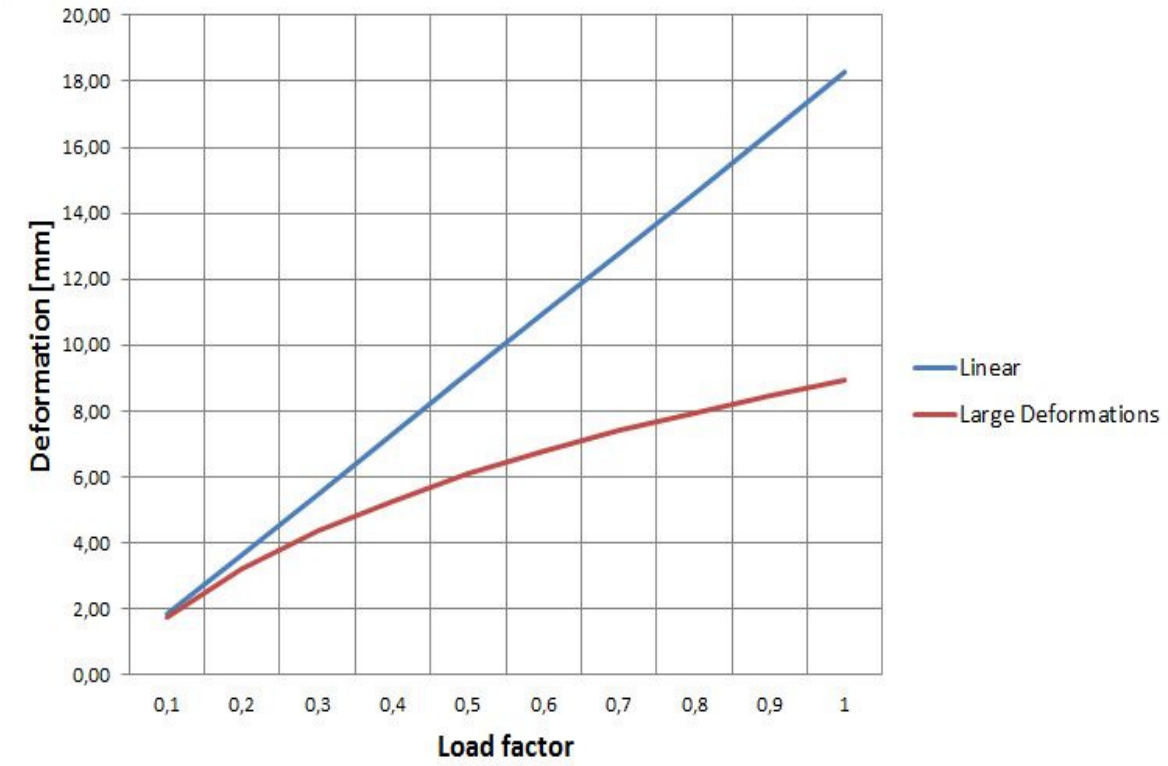


Theory of Non-Linearity

Example: Manhole Cover

Comparison Linear Analysis with Large Deformation analyses





ce masters
a pezy group company

Theory of Non-Linearity

Material Non-Linearity:

Elastoplastic Material

Characteristics:

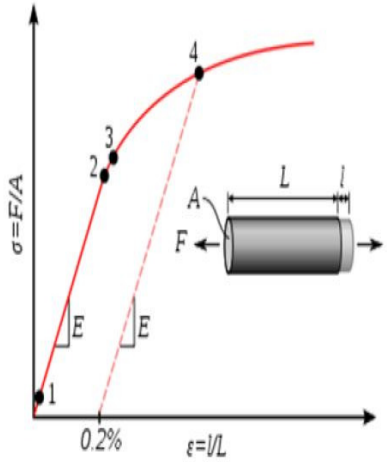
- Until the Yield point the material acts linear
- Above the Yield point the stress-strain curve changes
- Different material laws available

When to use Elastoplastic material:

- To calculate realistic deformation (elastic and/or plastic) when the Yield stress is exceeded

The elasto-plastic stress-strain curve

- True elastic limit (1):
  - The lowest stress at which dislocations move
  - Has no practical importance
- Proportionality limit (2):
  - Limit until which the stress-strain curve is a straight line characterized by Young's modulus, E
- Elastic limit, yield strength or yield point (3):
  - Is the stress at which a material begins to deform plastically, means non-reversible (this is the lowest stress at which permanent deformation can be measured)
  - Before the yield point, the material deforms only elastically and will return to its original shape
- Offset yield point or proof stress (4):
  - Since the true yield strength often cannot be measured easily, the offset yield point is arbitrarily defined by using the stress value at which we have 0.1 or 0.2 % remaining strain. It is therefore described with an index, e.g. $R_{p0.2}$ for 0.2 % remaining strain like shown in the image



A typical stress-strain curve for non-ferrous alloys [1]

Theory of Non-Linearity

Material Non-Linearity:

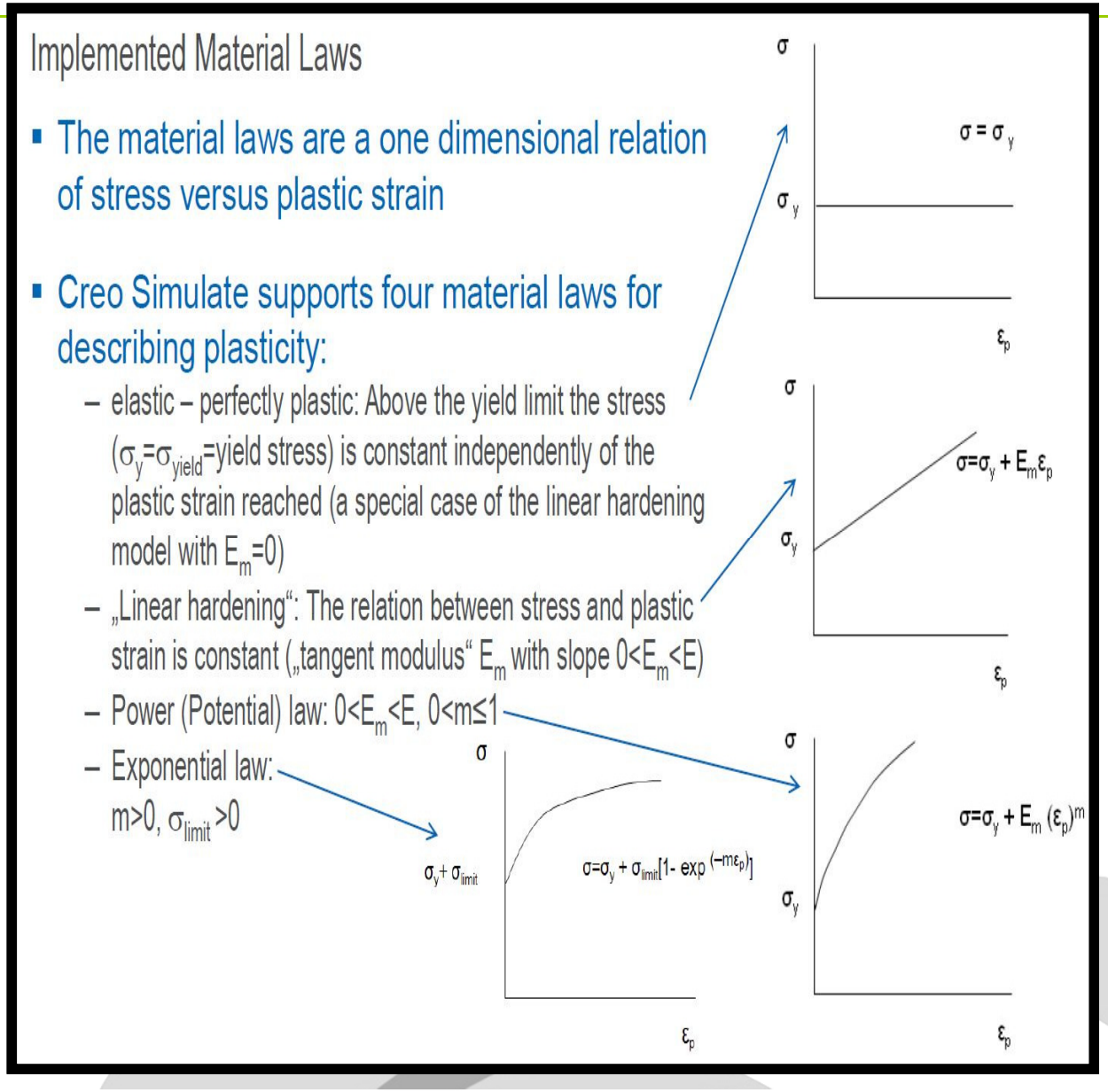
Elastoplastic Material

Characteristics:

- Until the Yield point the material acts linear
- Above the Yield point the stress-strain curve changes
- Different material laws available

When to use Elastoplastic material:

- To calculate realistic deformation (elastic and/or plastic) when the Yield stress is exceeded



Theory of Non-Linearity

Material Non-Linearity:

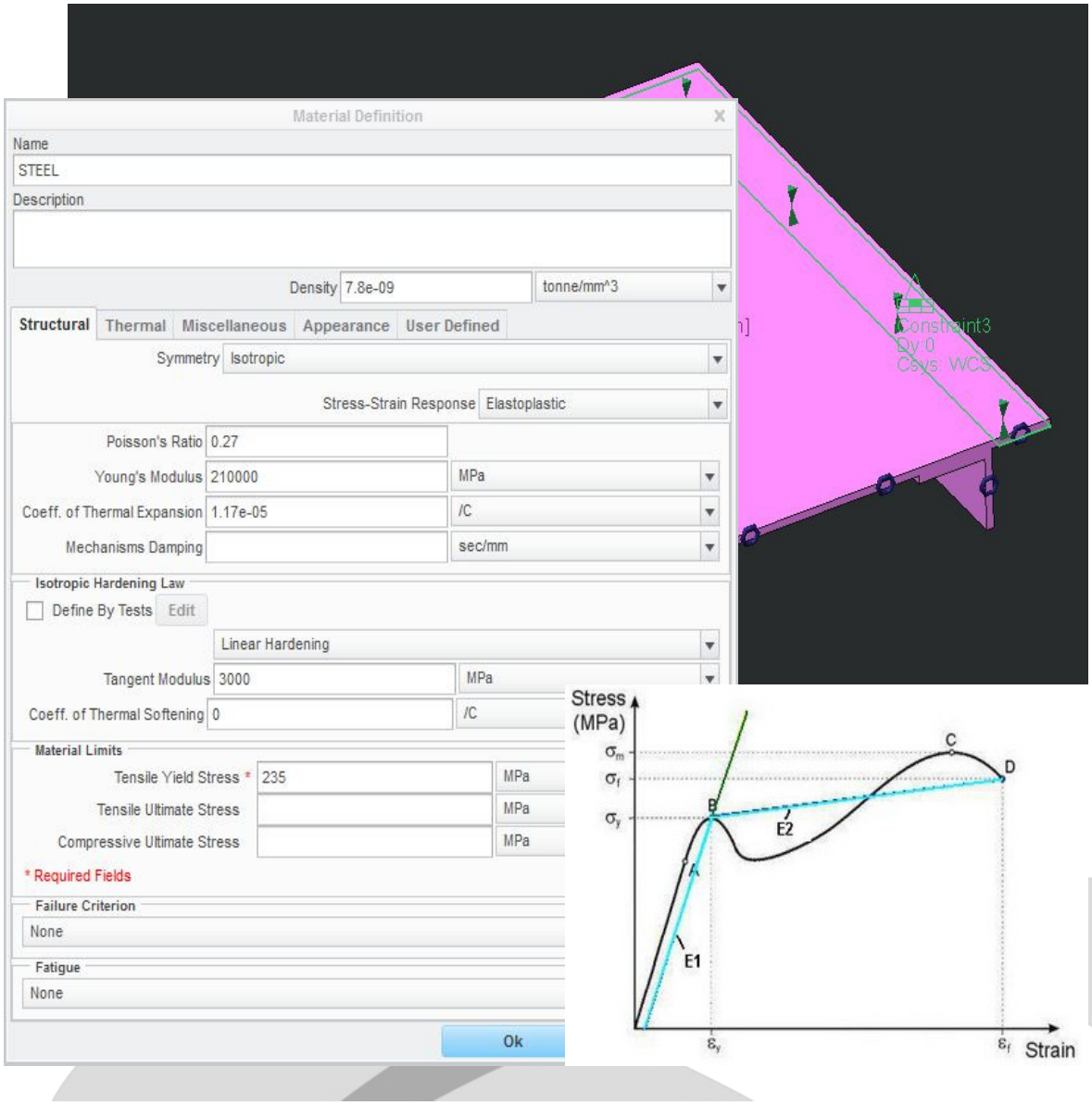
Elastoplastic Material

Characteristics:

- Until the Yield point the material acts linear
- Above the Yield point the stress-strain curve changes
- Different material laws available

When to use Elastoplastic material:

- To calculate realistic deformation (elastic and/or plastic) when the Yield stress is exceeded



ce masters
a pezy group company

Theory of Non-Linearity

Material Non-Linearity:

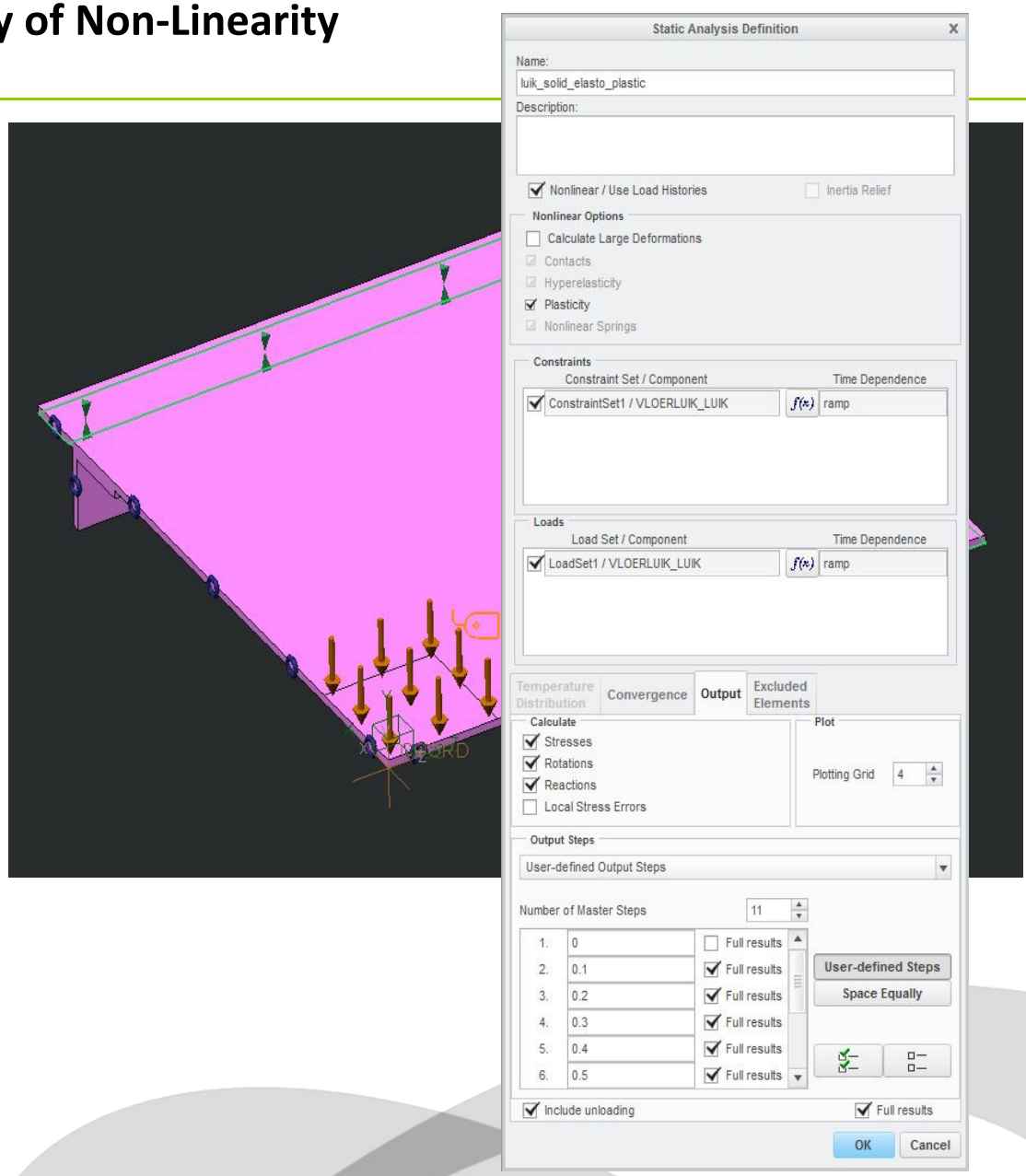
Elastoplastic Material

Characteristics:

- Until the Yield point the material acts linear
- Above the Yield point the stress-strain curve changes
- Different material laws available

When to use Elastoplastic material:

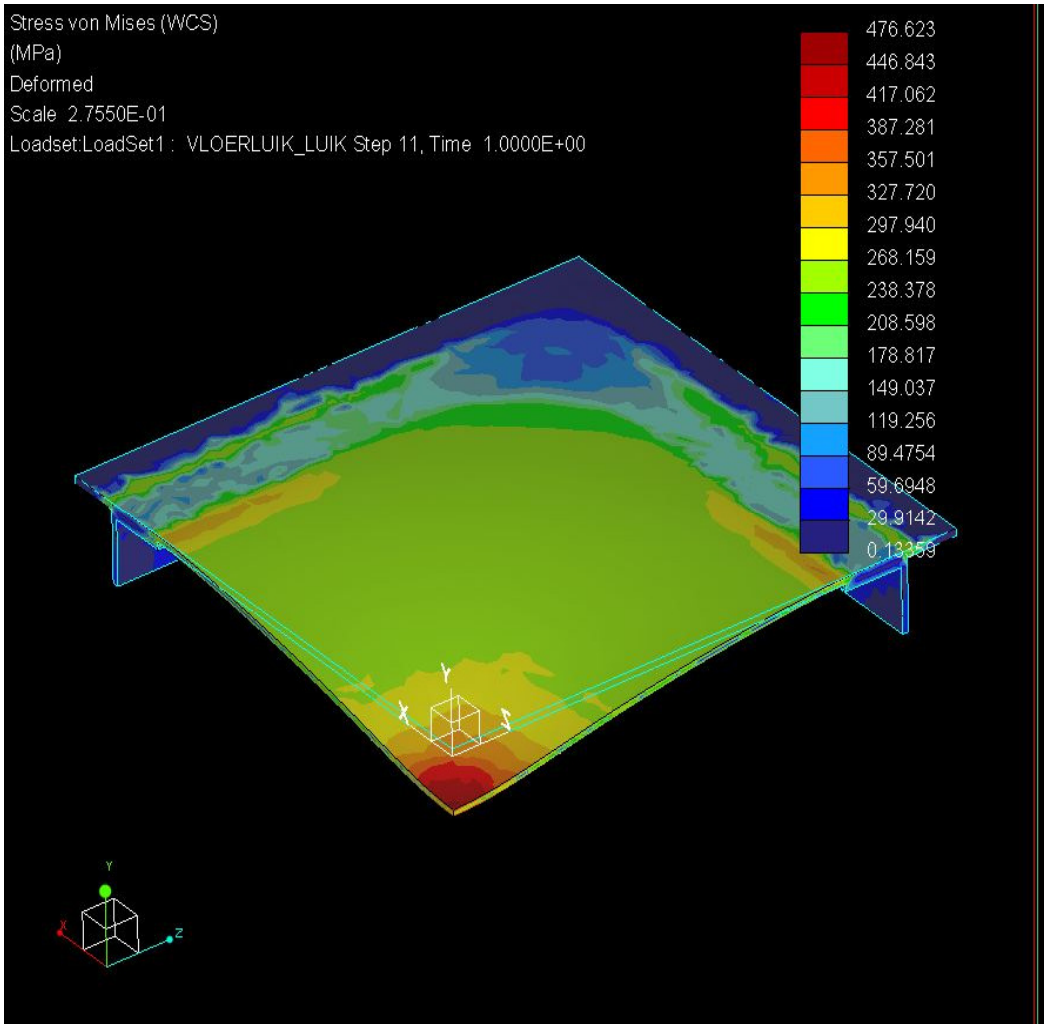
- To calculate realistic deformation (elastic and/or plastic) when the Yield stress is exceeded



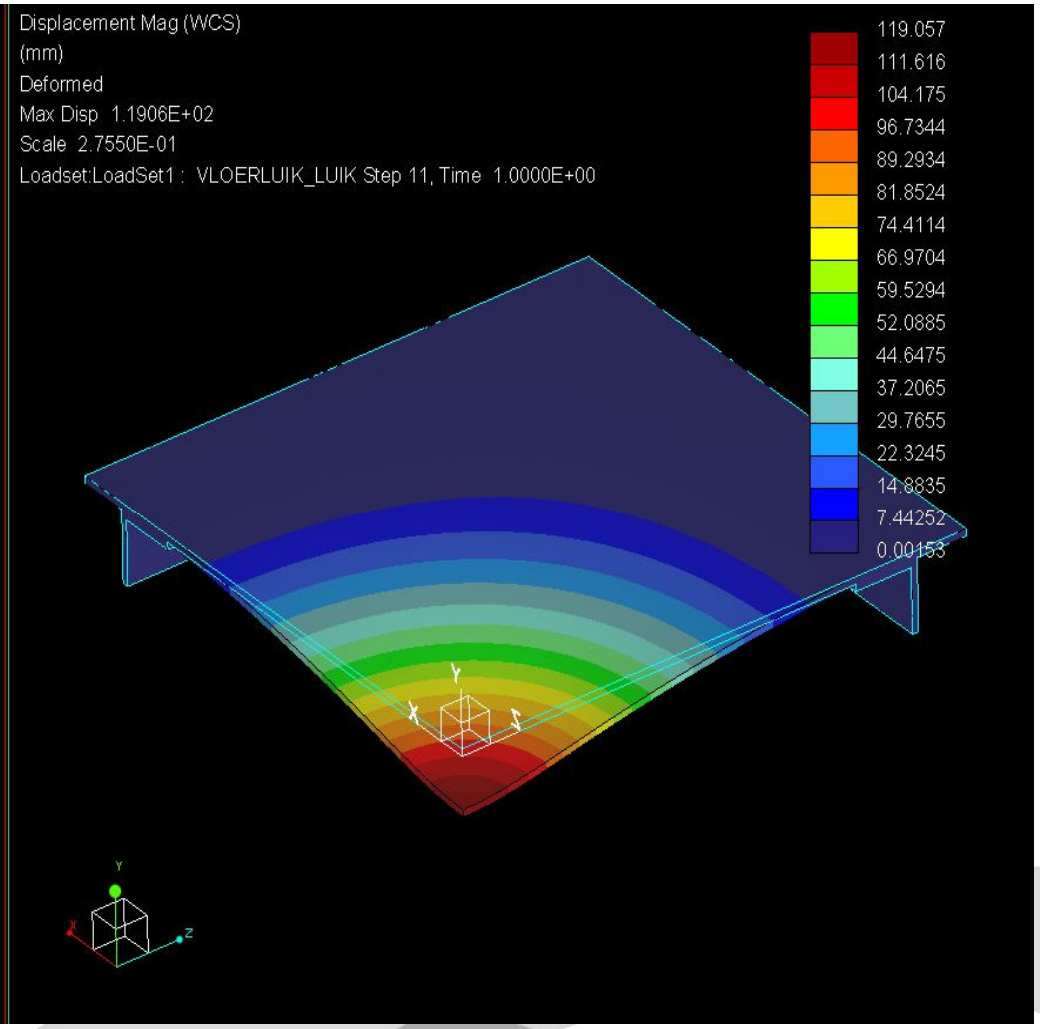
ce masters
a pezy group company

Results Non-Linear Elastoplastic Analysis

Max. VM stress = 477 MPa



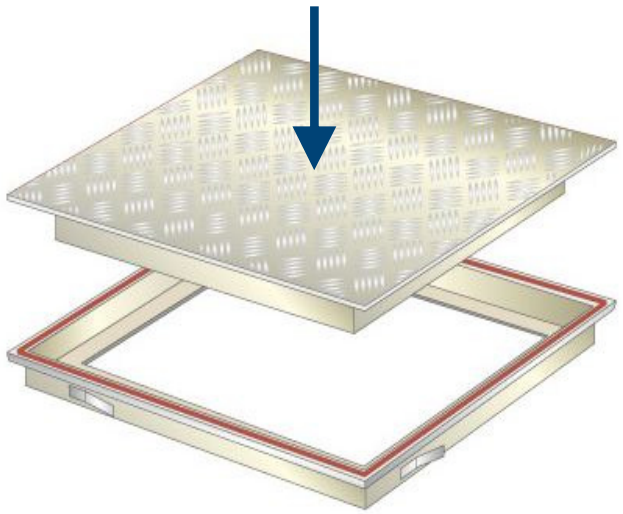
Max. Displacement = 119 mm

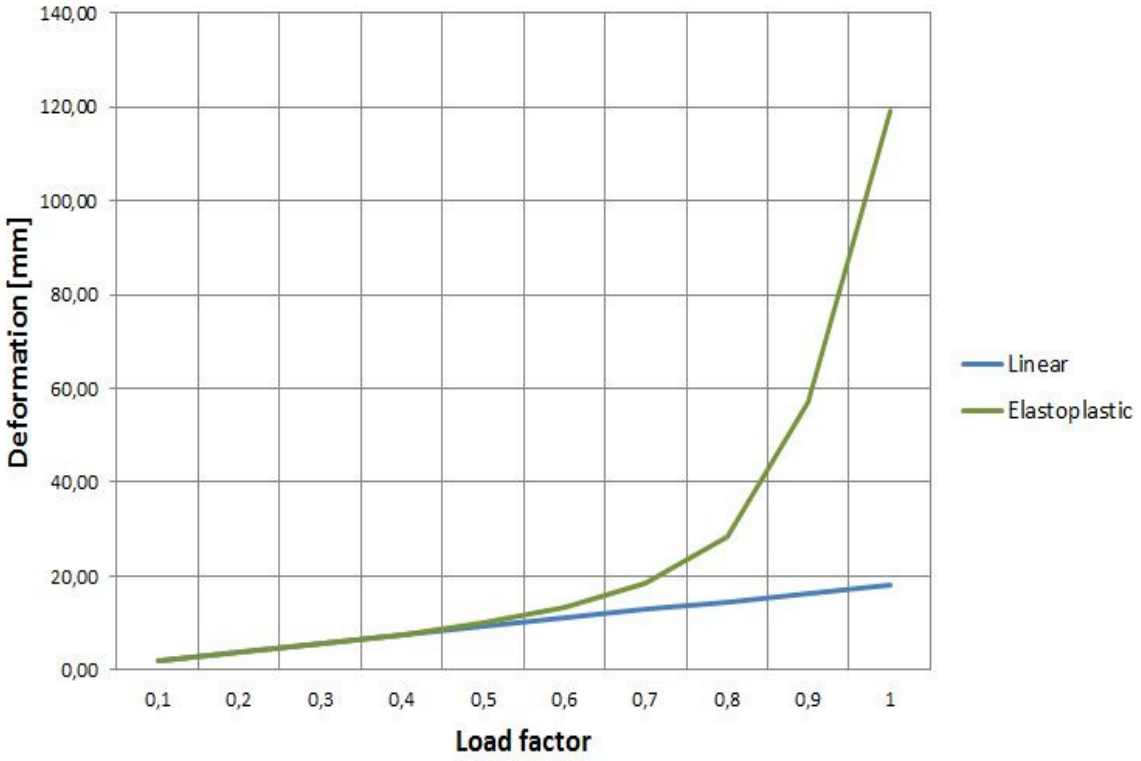


Theory of Non-Linearity

Example: Manhole Cover

Comparison Linear Analysis with Elastoplastic analyses





Theory of Non-Linearity

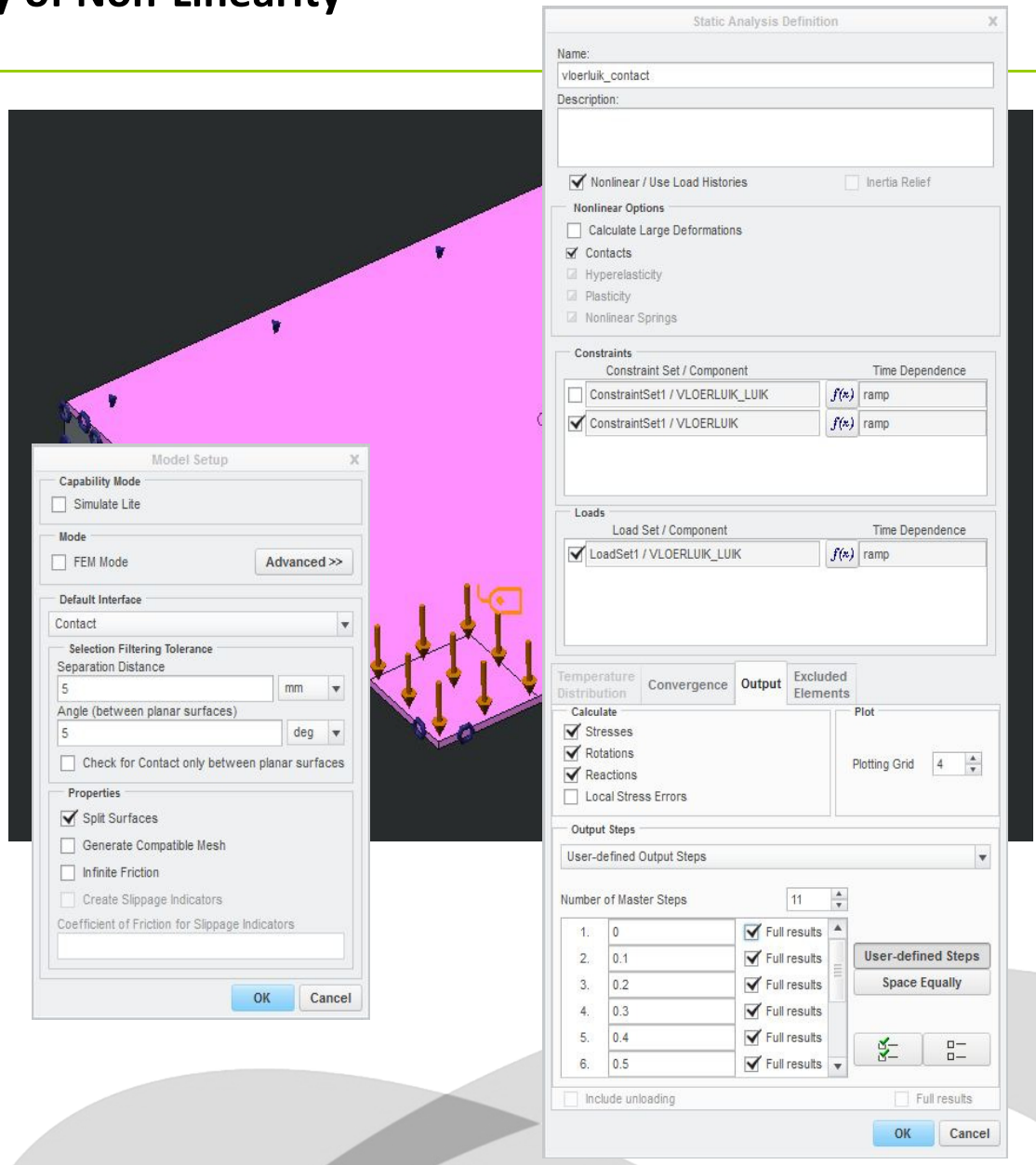
Constraint Non-Linearity: Contact

Characteristics:

- Contact acts as a constraint in one direction
- Number of load steps dependent on situation
- At each load step the contact situation will be evaluated

When to use Contact:

- When contact issues are expected which cannot be captured with constraints
- When contact values are needed (i.e. contact forces, contact area, contact pressure, …)

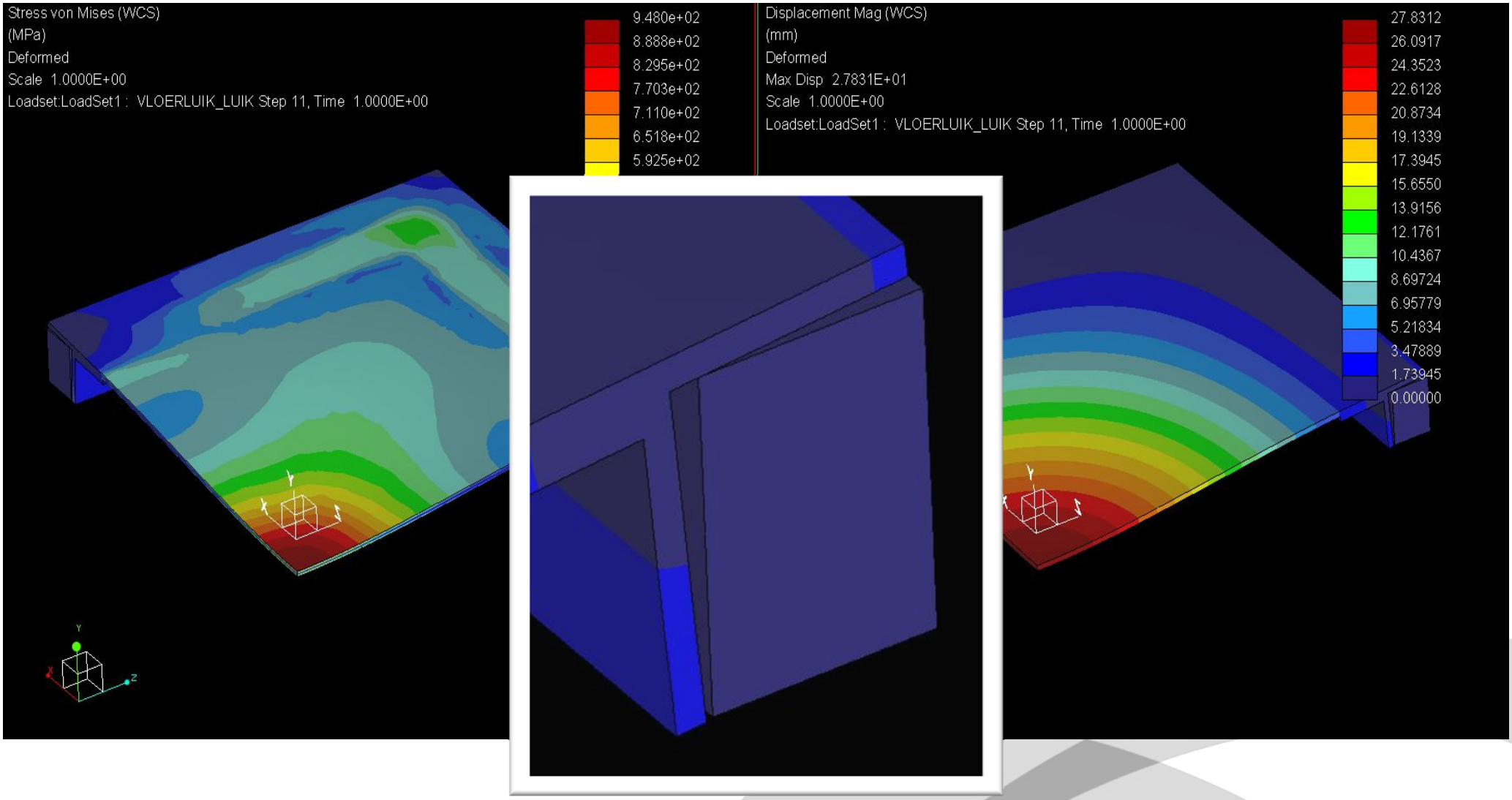


ce masters
a pezy group company

Results Non-Linear Contact

Max. VM stress = 948 MPa

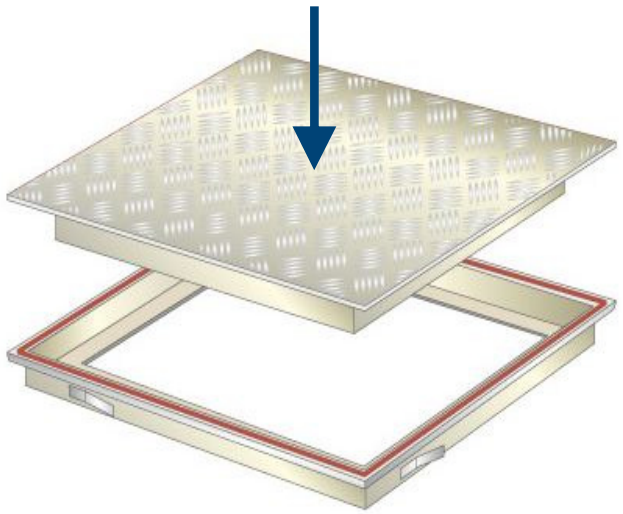
Max. Displacement = 27,8 mm

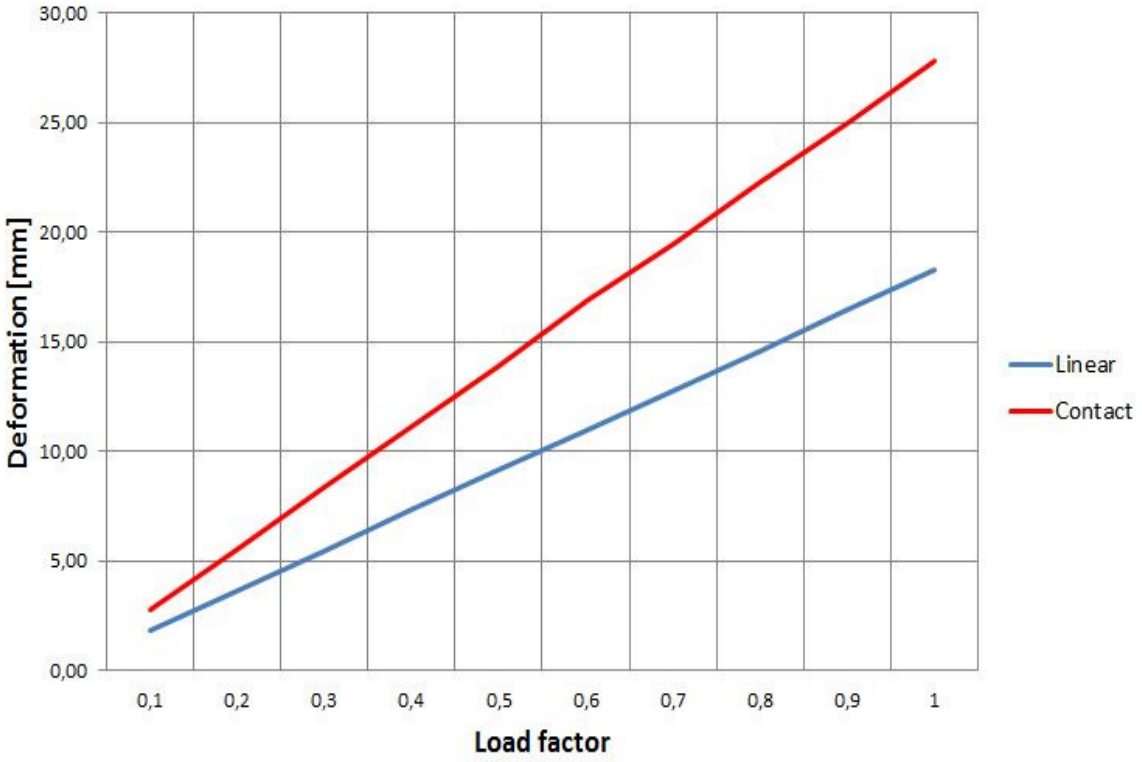


Theory of Non-Linearity

Example: Manhole Cover

Comparison Linear Analysis with Contact analyses

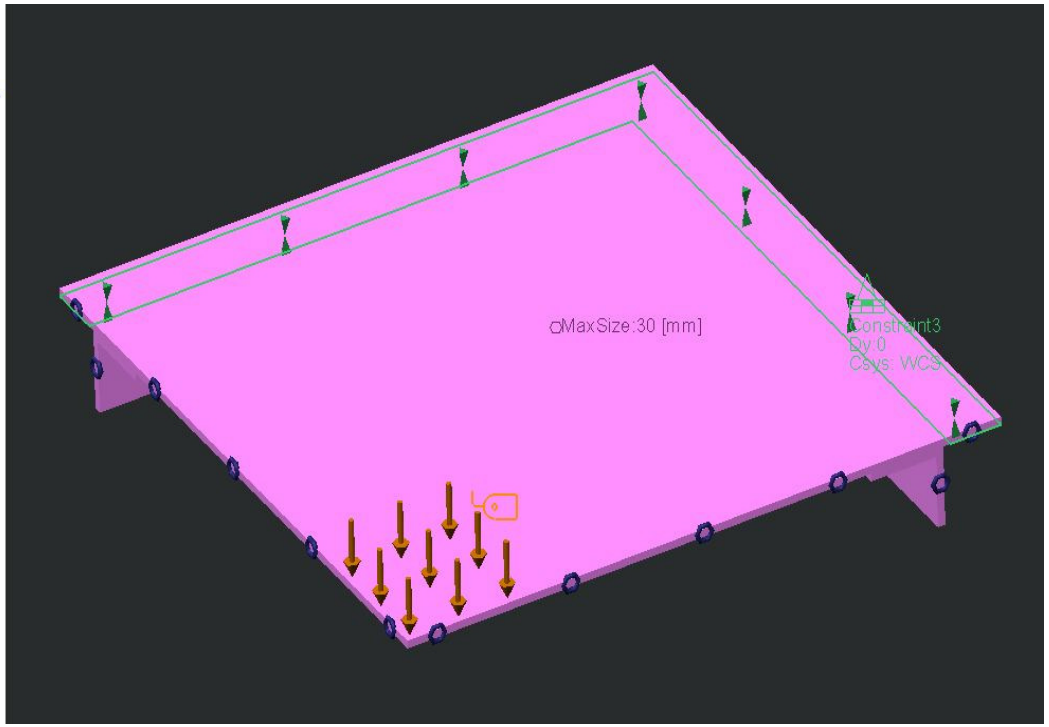




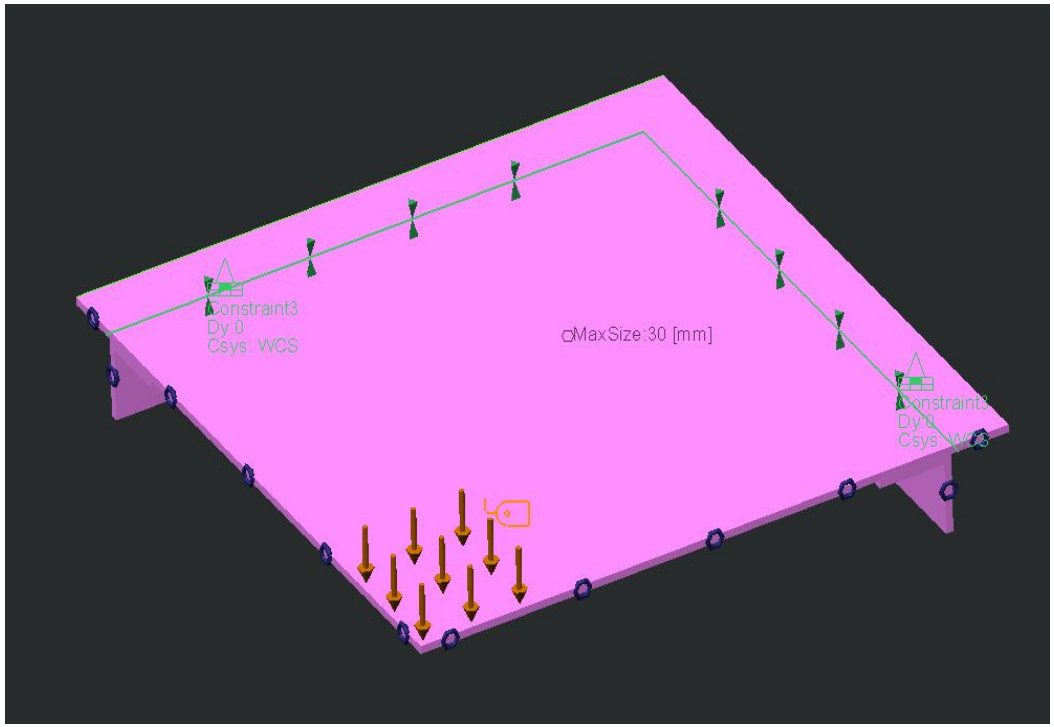
ce masters
a pezy group company

Theory of Non-Linearity

Linear alternative for Non-Linear contact analysis → modified constraint



Surface constraint

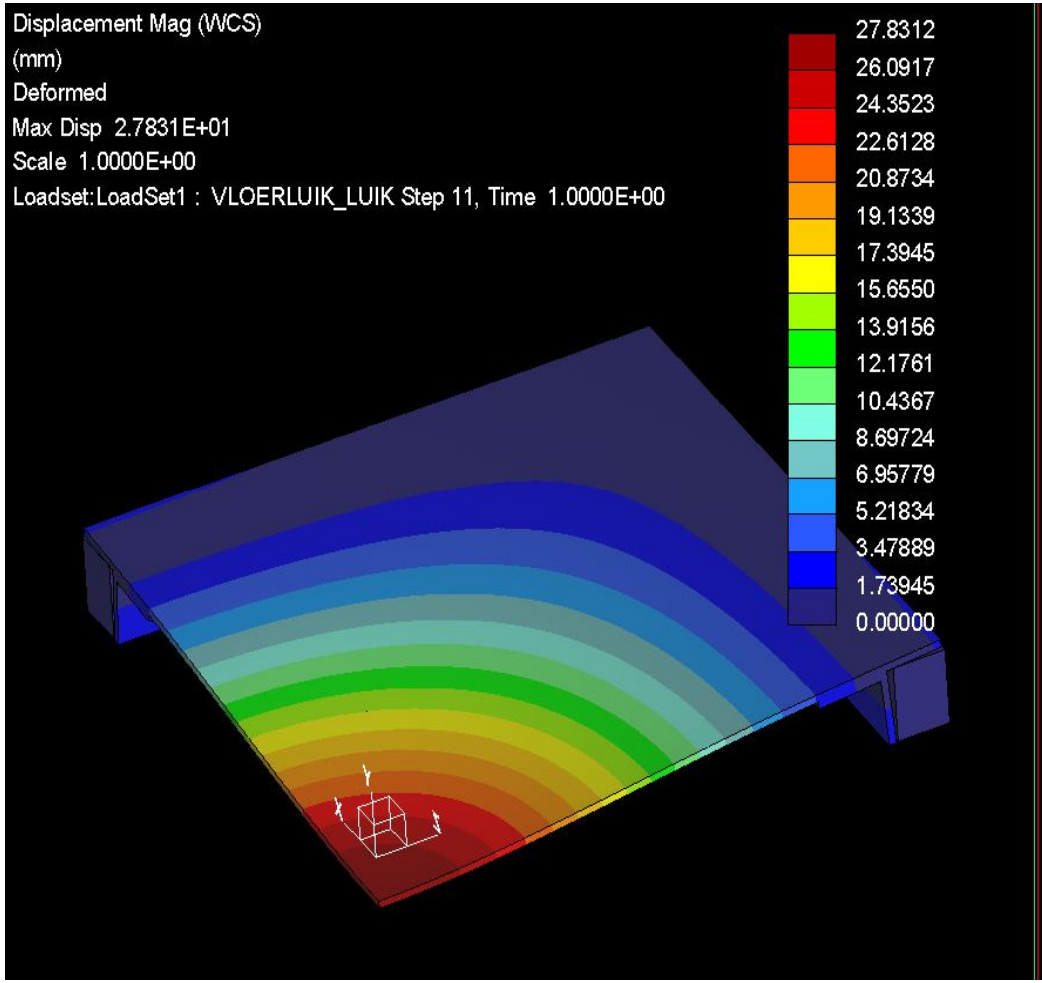


Edge constraint

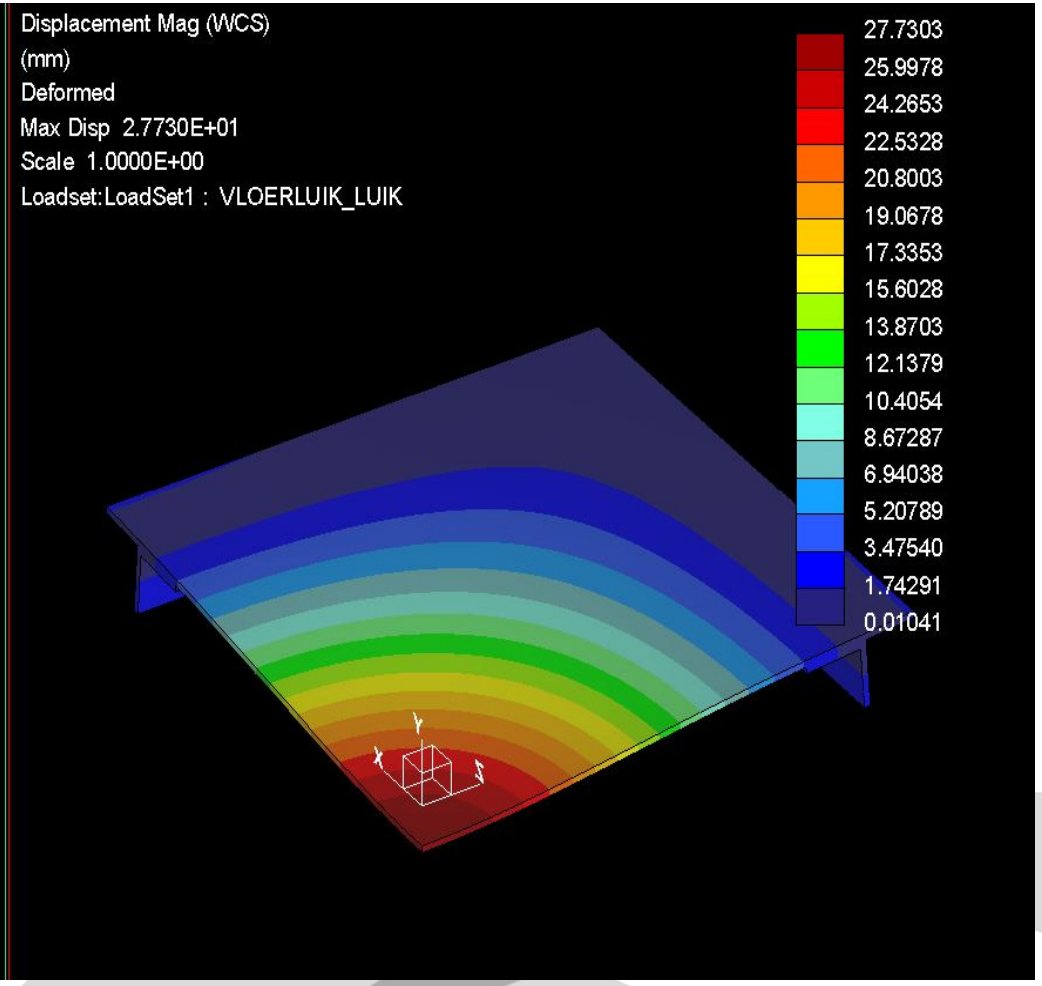
ce masters
a pezy group company

Theory of Non-Linearity

Non-Linear contact analysis



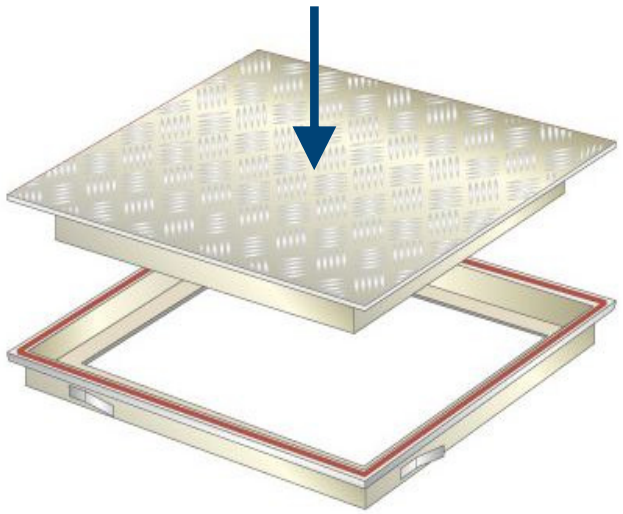
Linear analysis with edge constraint

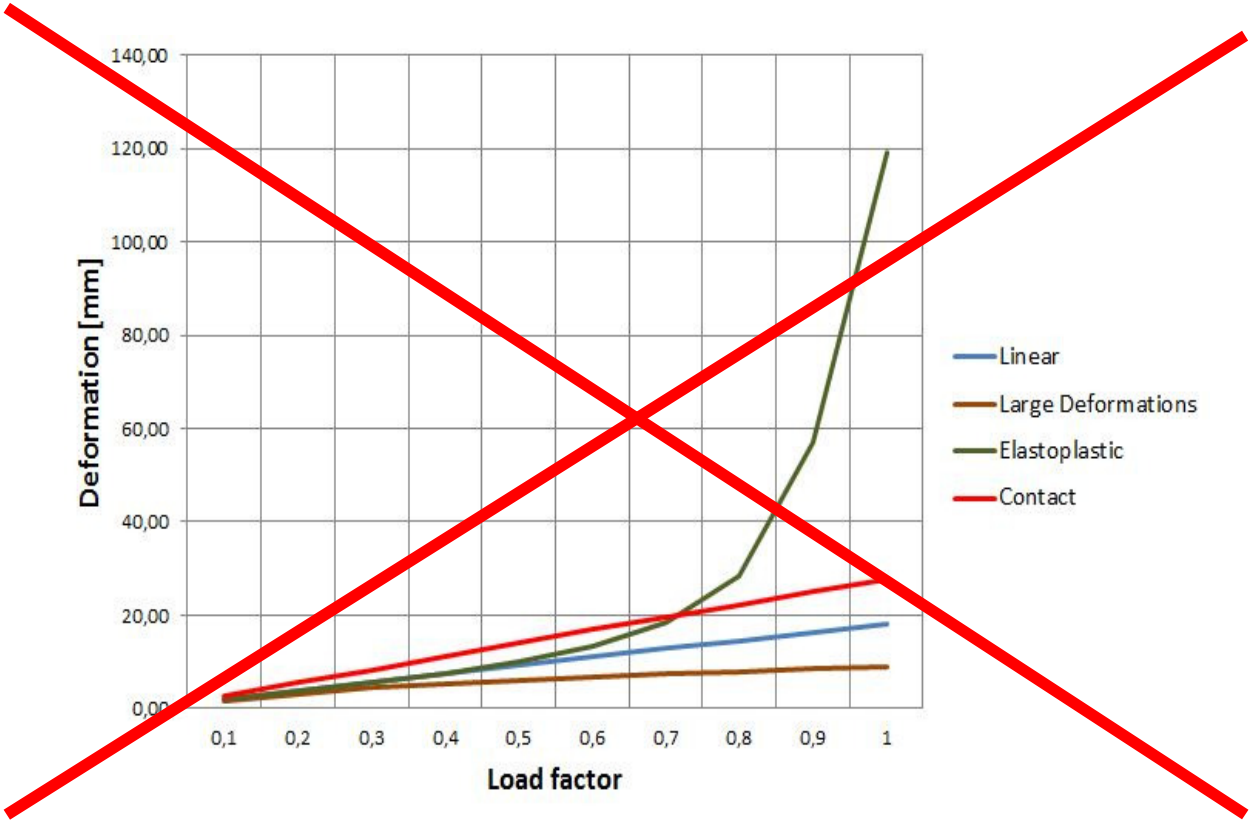


Theory of Non-Linearity

Example: Manhole Cover

Comparison Linear Analysis with
all separated Non-Linear Analyses





Which one is correct?

None of the above!

ce masters
a pezy group company

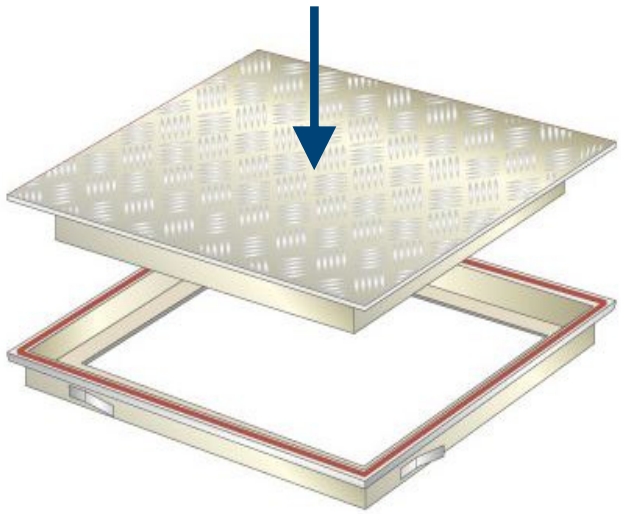
Combining Non-Linearities with Creo Simulate 2.0

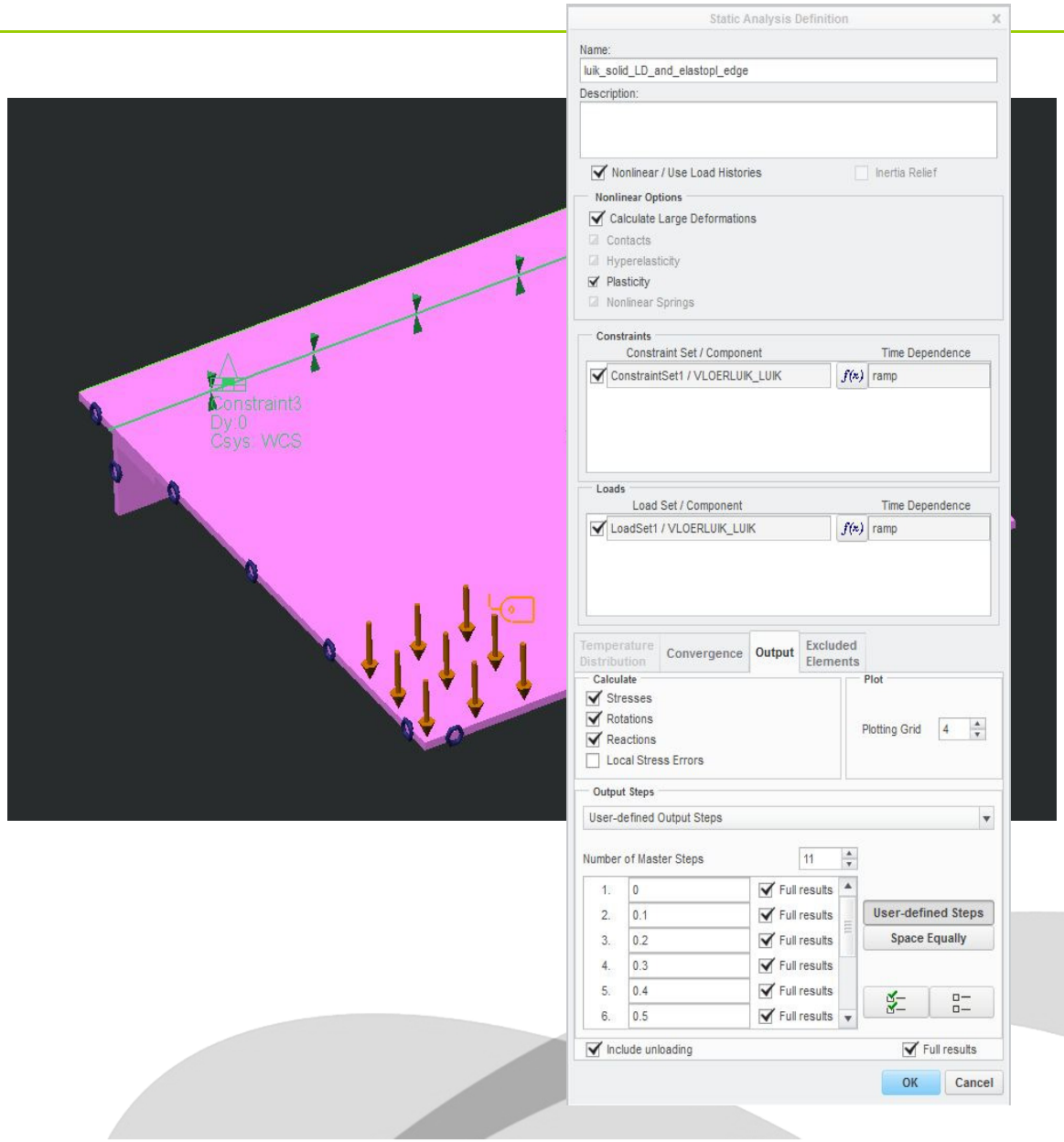
Previous analyses show that all Non-Linearities are occurring at the same time:

Large Displacements

Elastoplastic Material

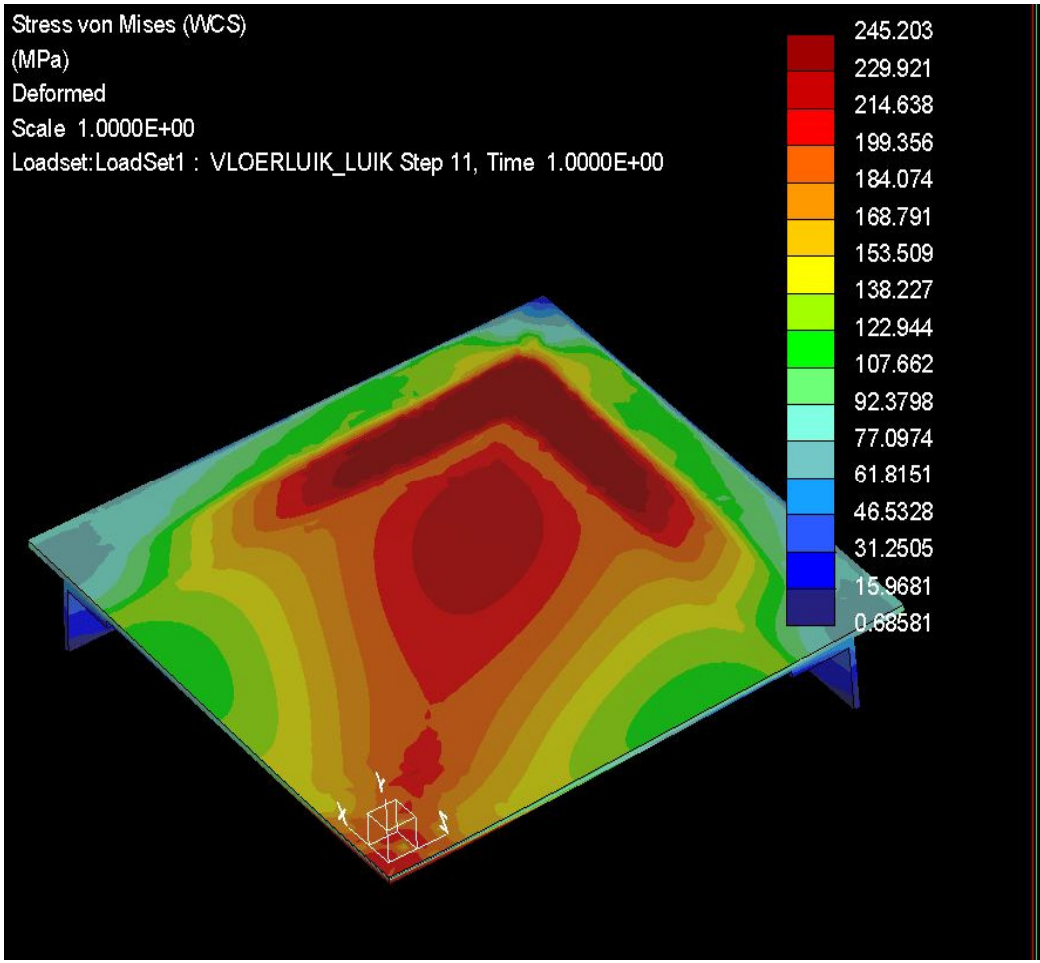
Contact



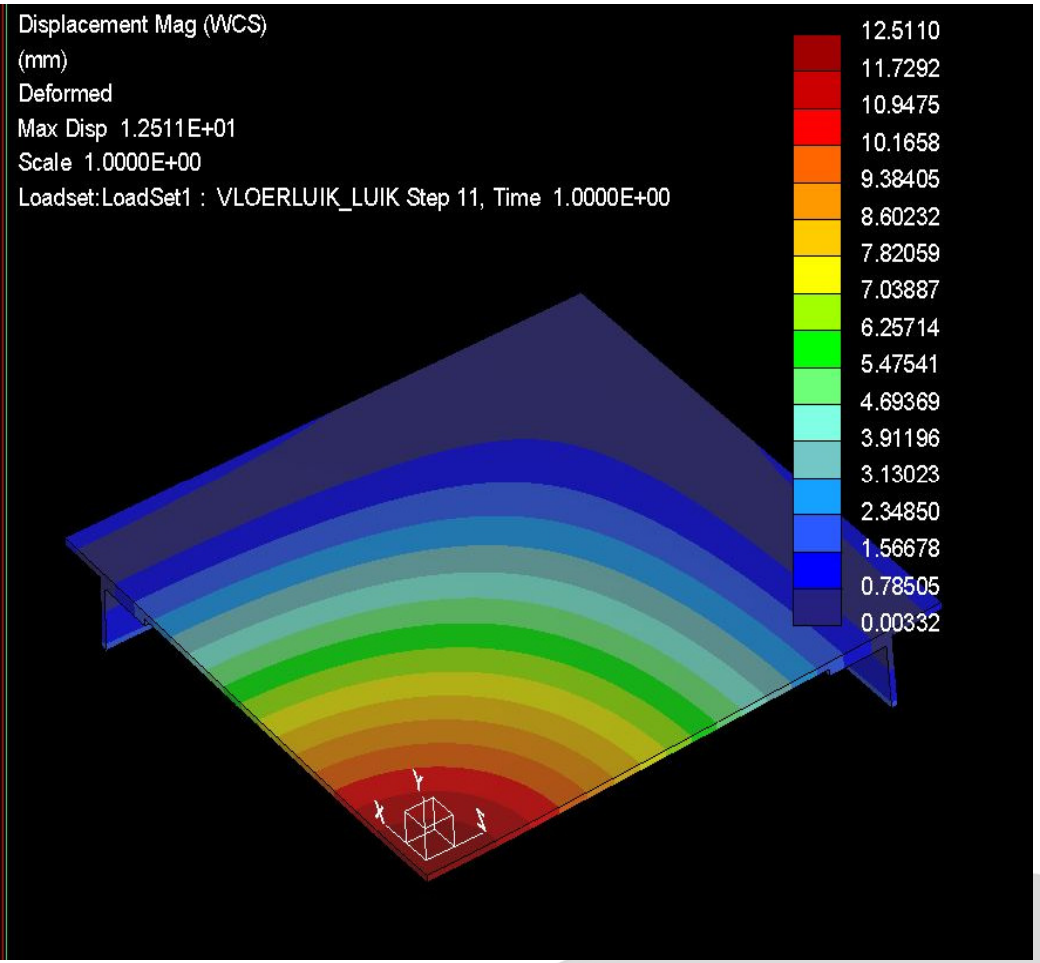


Results combined Non-Linearities

Max. VM stress = 245,2 MPa



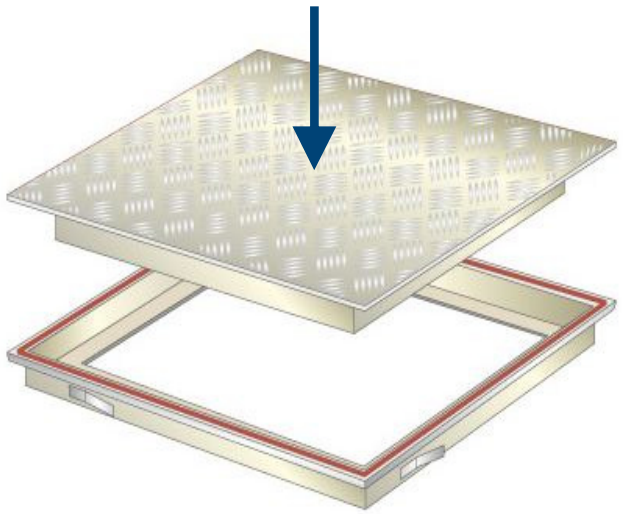
Max. Displacement = 12,5 mm

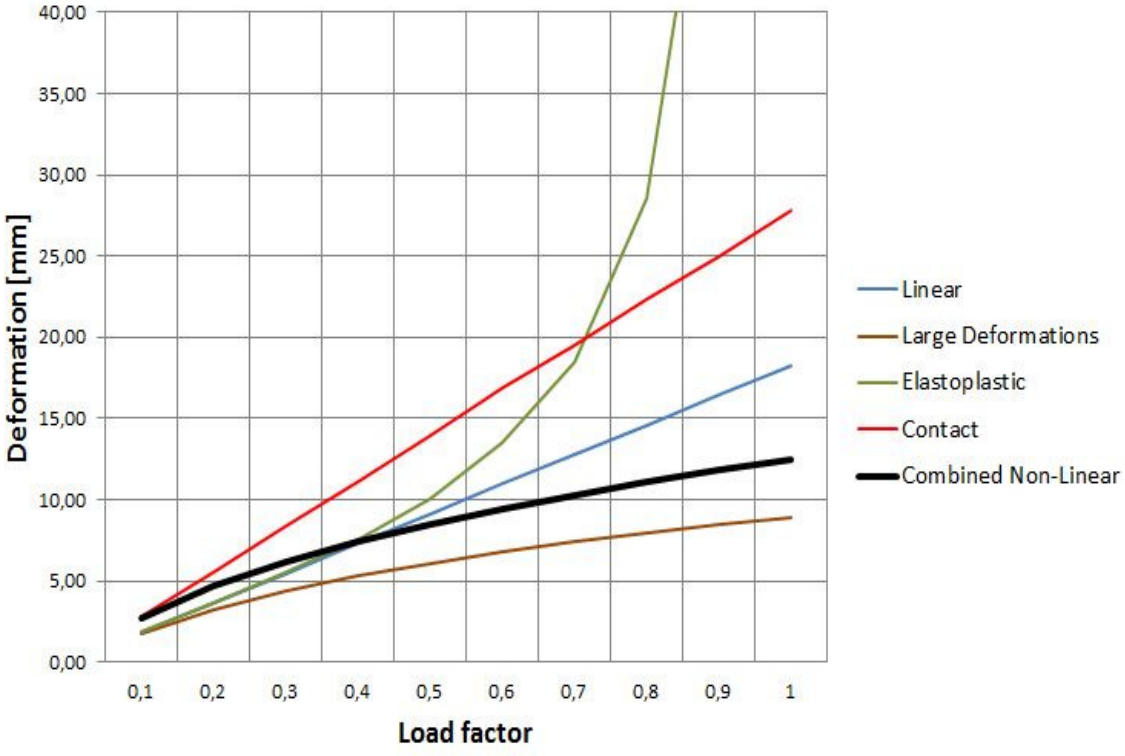


Combining Non-Linearities with Creo Simulate 2.0

Example: Manhole Cover

Comparison Linear Analysis with
all separated Non-Linear Analyses

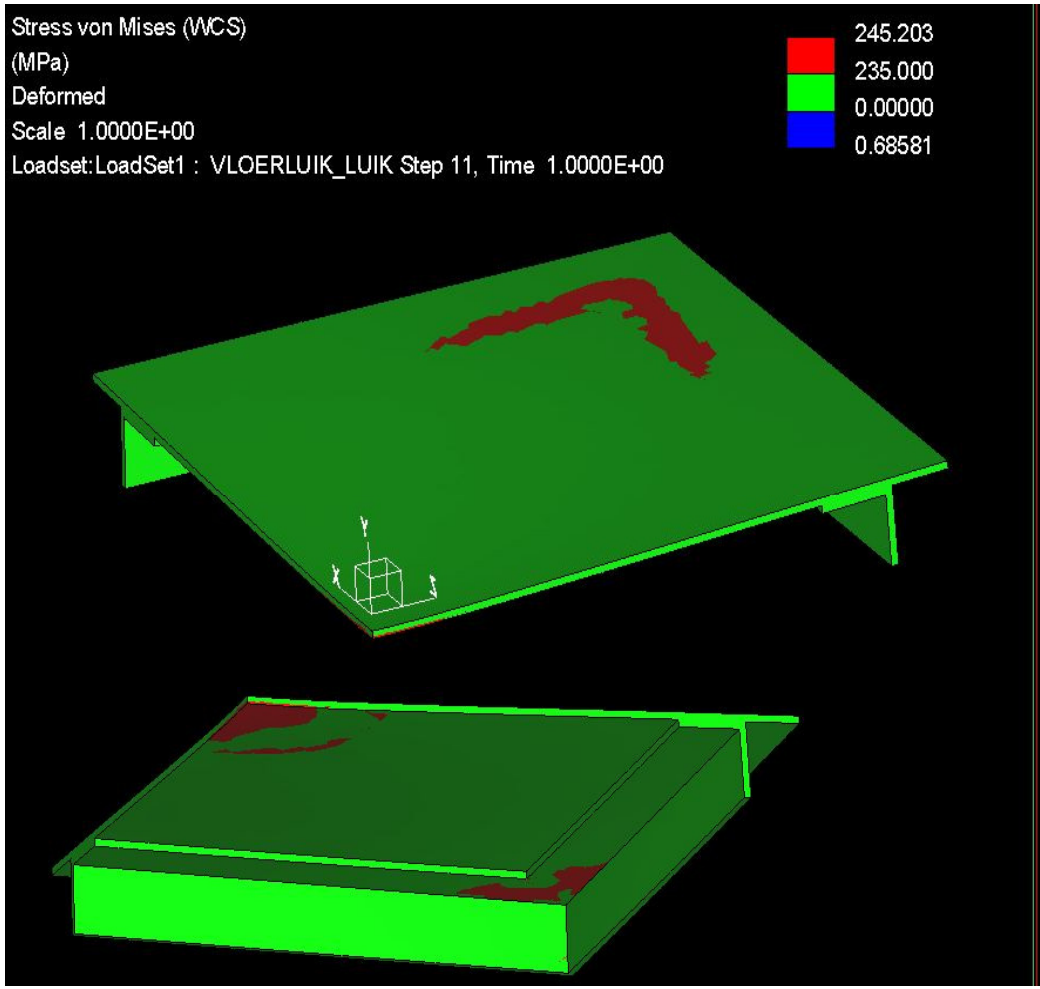




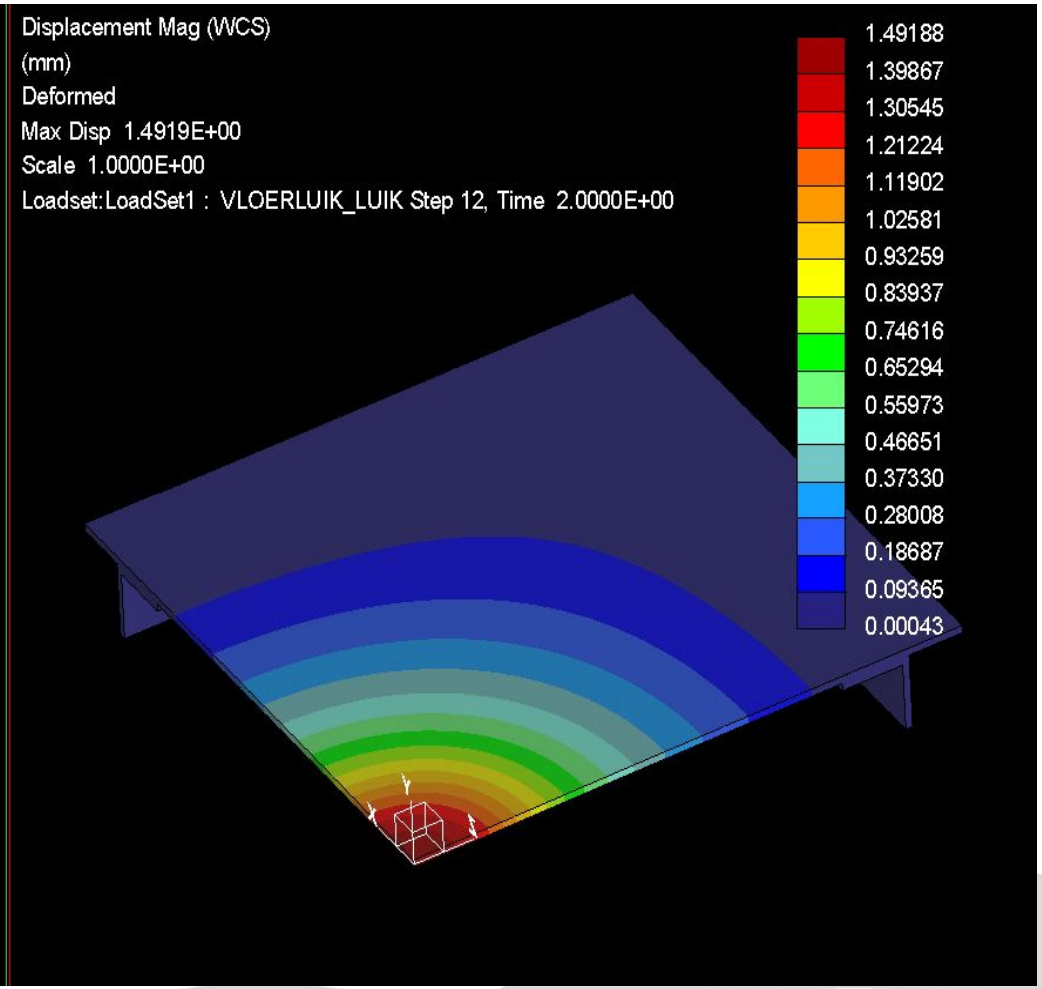
ce masters
a pezy group company

Results combined Non-Linearities

Red areas: stresses exceed Yield limit (plasticity)



Permanent Plastic Displacement = 1,5 mm (after un-loading)



ce masters

a pezy group company

Examples of Non-Linear Analyses

Helmet and Clip

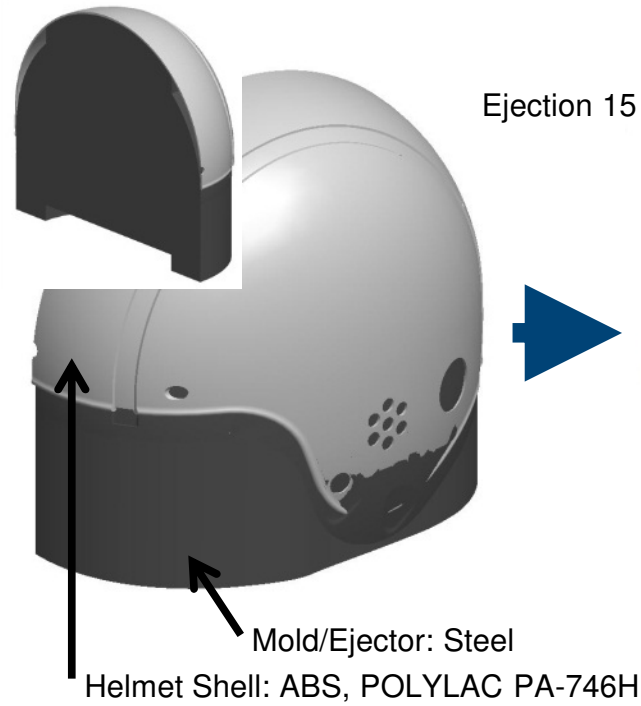
www.egghelmets.com

Questions:

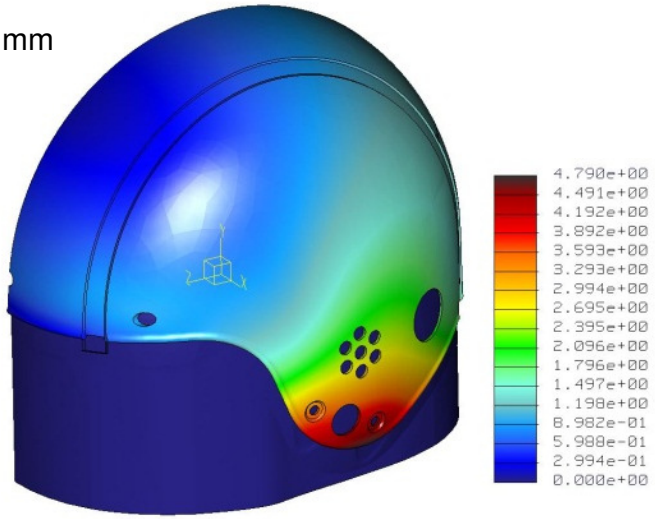
- Can the ABS outer shell be ejected from the mold?
- Does the clip work and survive impact tests?

Ejection of ABS helmet outer shell

- Quasi static approach; incremental ejection steps
- Contact analysis for each ejection step

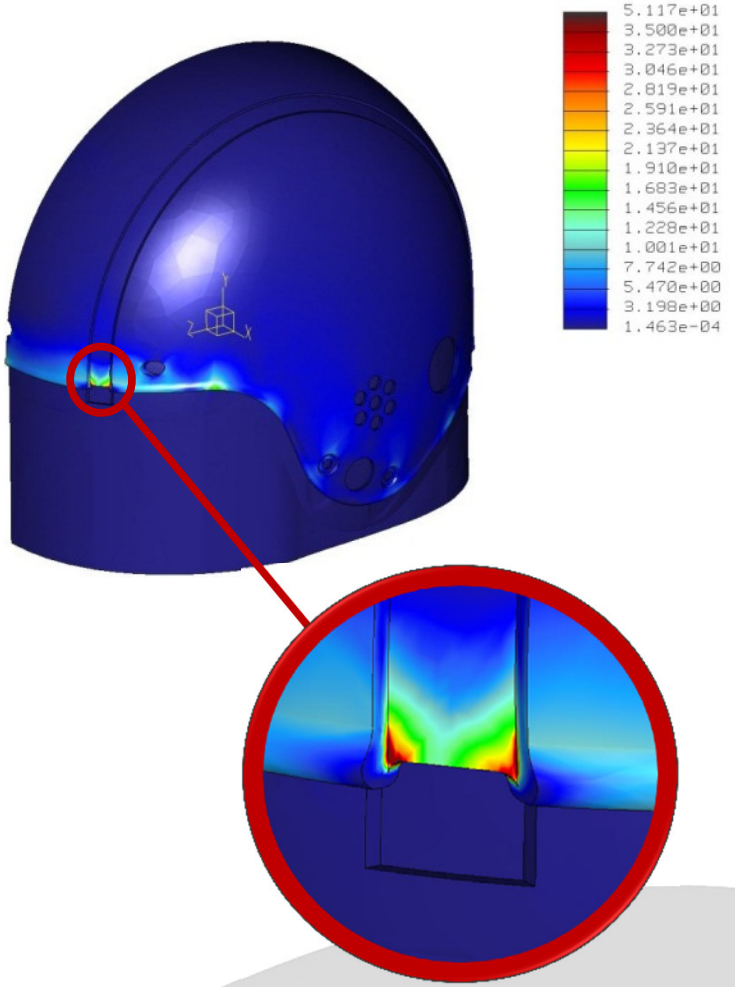


Ejection 15 mm



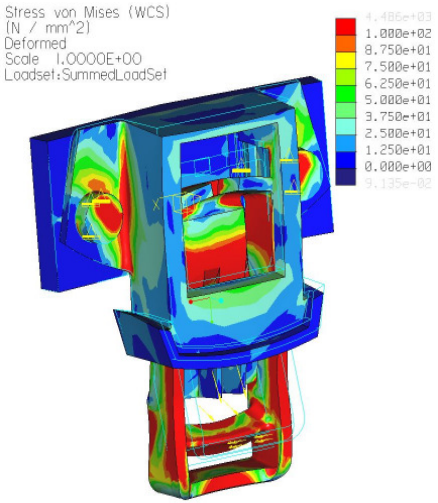
Displacements

Von Mises stresses



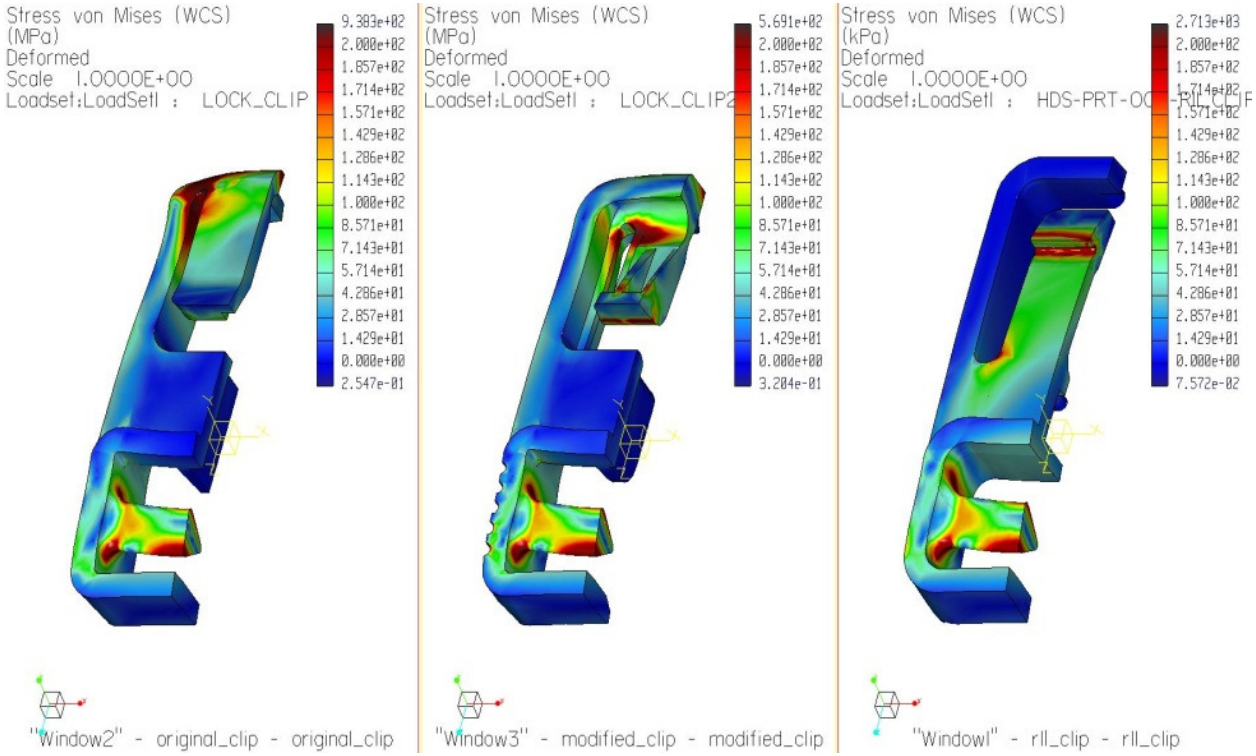
Contact analyses for different clip concepts

- Initial clip design didn't pass the test
- Comparison of different clip concepts



Initial clip

Different clip concepts



ce masters

a pezy group company

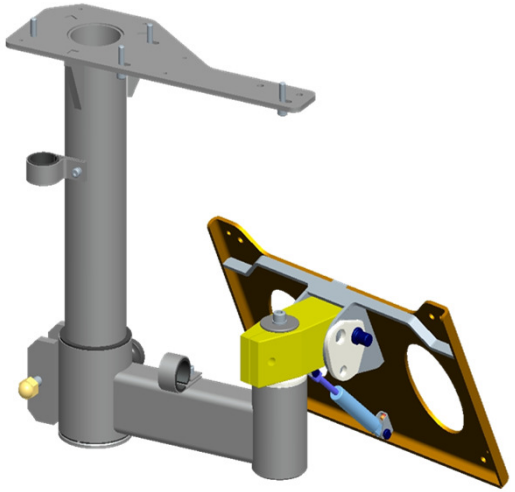
Examples Advanced Dynamic Analyses

Mounting Equipment for Communication Devices

www.thalesgroup.com

Questions:

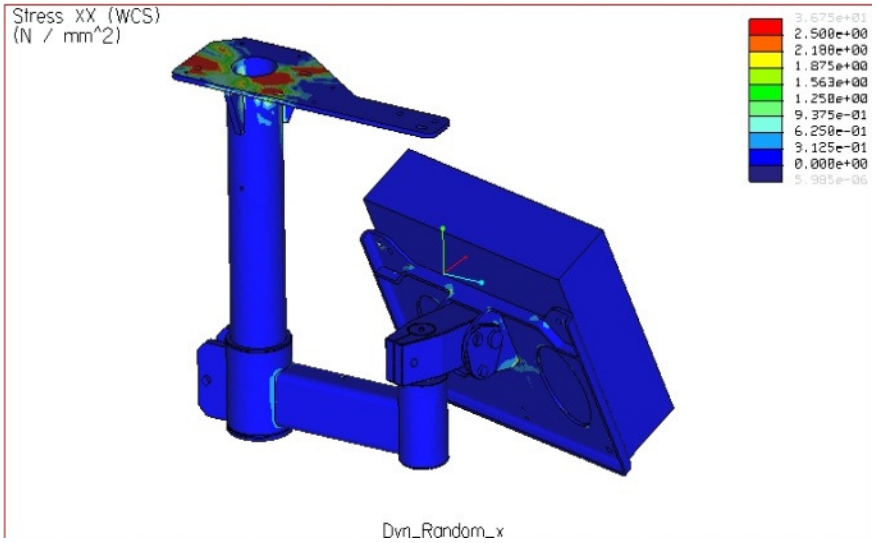
- Does the structure survive vibrations with specific Power Spectral Density diagrams?
- Does the structure survive shock impact?

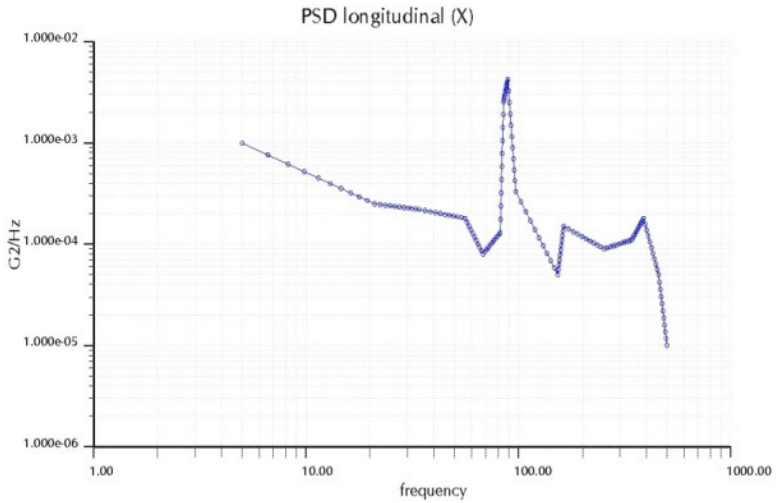


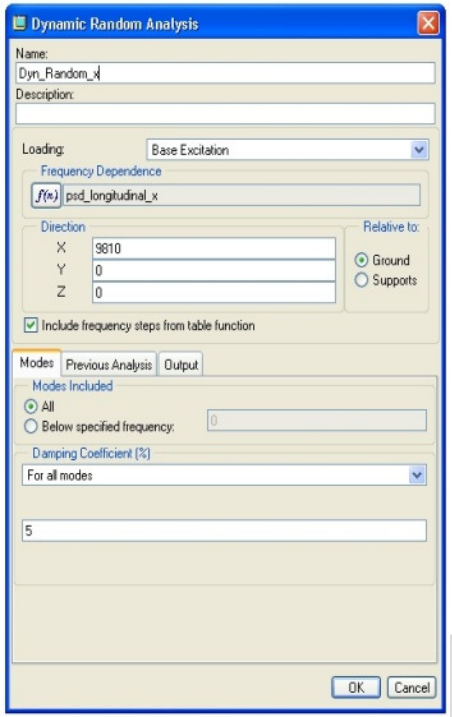
Dynamic Random Analysis

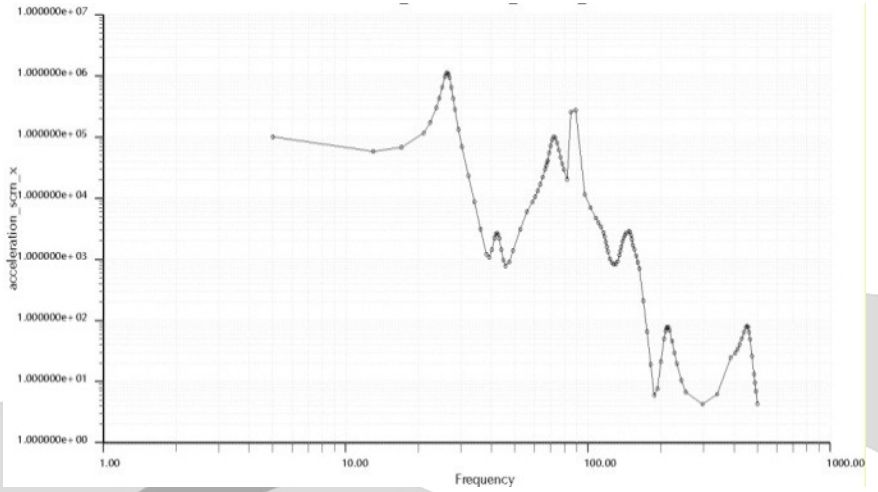
Characteristics:

- Calculate Eigen Frequencies
- Dynamic Random Analysis for 3 orthogonal directions





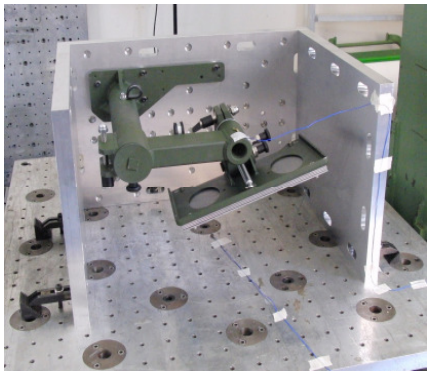


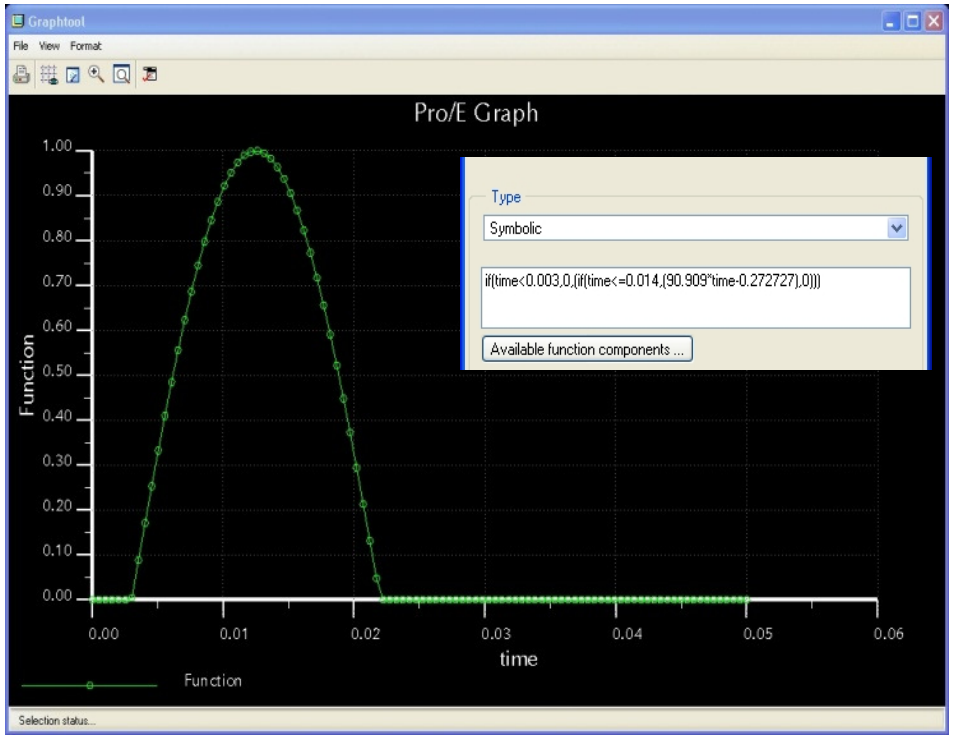


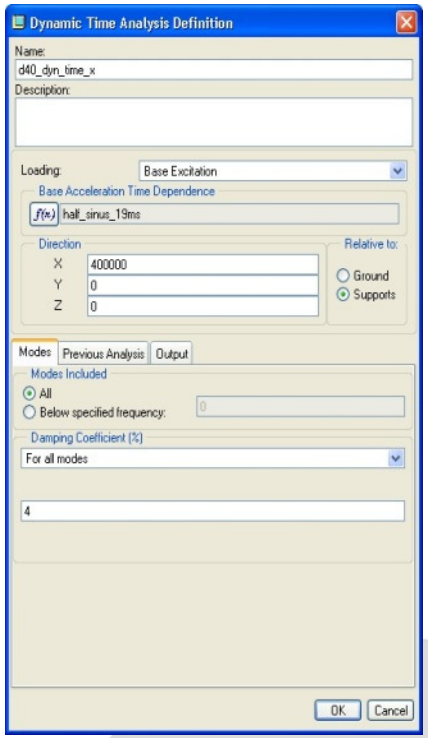
Dynamic Time Analysis (Shock)

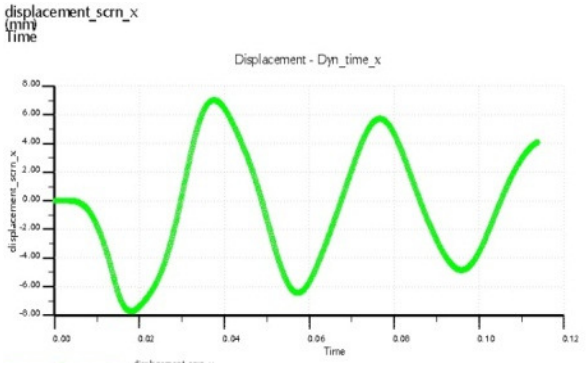
Characteristics:

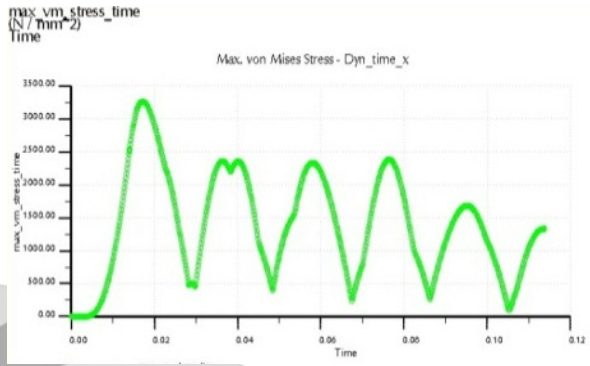
- Calculate Eigen Frequencies
- Dynamic Time Analysis for 3 orthogonal directions











ce masters

a pezy group company

Thank you for your attention!

ce masters
a pezy group company

Modeling & Simulation tiles