NAFEMS

A Common Sense Approach to Stress Analysis and Finite Element Modeling

February 28th, 2008

Agenda

A Common Sense Approach to Stress Analysis and Finite Element Modeling

February 28th, 2008

8am PST (Los Angeles) / 11am EST (New York) / 4pm GMT (London)

- Welcome & Introduction (Overview of NAFEMS Activities)
  - Matthew Ladzinski, NAFEMS North America
- A Common Sense Approach to Stress Analysis and Finite Element Modeling
  - Bob Johnson BSc MSc NRA MIMechE CEng, DAMT Limited
- Q&A Session
  - Panel
- Closing

Ladzinski

Johnson

THE INTERNATIONAL ASSOCIATION
FOR THE ENGINEERING ANALYSIS
COMMUNITY

An Overview of NAFEMS NA Activities

Matthew Ladzinski
NAFEMS
North American Representative

Planned Activities in North America

- Webinars
  - New topic each month!
    - AUTOSIM Update
    - Applied Element Methods
    - Managing FEA in the Design Process
  - Recent webinars:
    - The Interfacing of FEA with Pressure Vessel Design Codes (CCOPPS Project)
    - Multiphysics Simulation using Directly Coupled-Field Element Technology
    - Methods and Technology for the Analysis of Composite Materials
    - Simulation Process Management
    - Simulation-supported Decision Making (Stochastics)
    - Simulation Driven Design (SDD) Findings

To register for upcoming webinars, or to view a past webinar, please visit: www.nafems.org/events/webinars

Planned Activities in North America

- Events
  - Practical Stress Analysis & Finite Element Methods *with* Bob Johnson
    - An opportunity to ensure that your organization gets maximum benefit from using FEA
    - Three-day Training Course
    - April 30th – May 2nd, 2008 in Troy, MI
    - Only a few open seats are still available
    - www.nafems.org/events

Planned Activities in North America

NAFEMS NA 2008 Regional Summit

NAFEMS 2020 Vision of Engineering Analysis and Simulation

- ***NAFEMS 2020*** will bring together the leading visionaries, developers, and practitioners of CAE-related technologies and business processes
- Goal: Provide attendees with the best "food for thought and action" to deploy CAE over the next several years
- Location: Embassy Suites Hotel & Convention Center, Hampton, Virginia
- Date: October 29-31, 2008

Call for Papers Now Open!

For more information, visit:

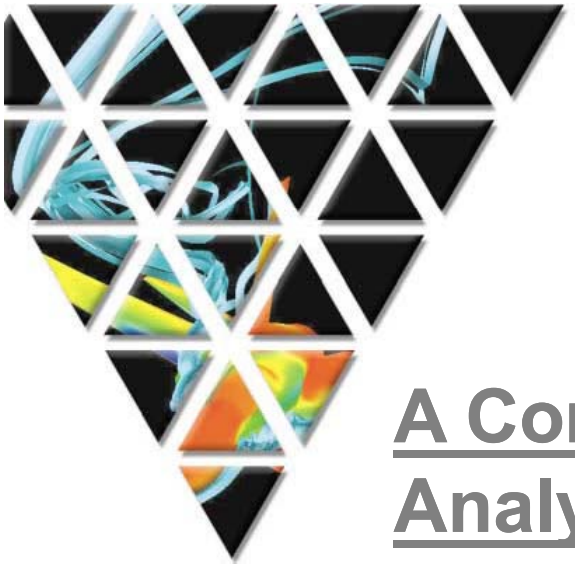
www.nafems.org/nafems2020

Other NAFEMS Activities

- NAFEMS Simulation Data Management Working Group (SDMWG) – name tbd
  - www.nafems.org/tech/sdmwg

- NAFEMS NA eNews Update
  - Monthly newsletter containing information on upcoming NAFEMS NA activities
  - Can be downloaded at: www.nafems.org/regional/north_america/enews

- Email from NAFEMS



A Common-Sense Approach to Stress Analysis and Finite Element Modelling

A NAFEMS Webinar organised by Matthew Ladzinski of NAFEMS Limited (North America).

Matthew.Ladzinski@NAFEMS.Org

Presented by Bob Johnson BSc MSc NRA MIMechE CEng
DAMT Limited, UK

bj@damt.co.uk

DESIGN
ANALYSIS
MODELLING
TECHNOLOGIES

A Common-Sense Approach to Stress Analysis and Finite Element Modelling

Aims:

- Achieve a modern-day balance between hand calcs and FEA
- Provide a number of “must-have” formulas for stress analysis
- Provide a summary of the technique of Free-Body Diagrams
- Practical advice for best use of FEA for realistic solutions
- Constraints that gives minimal support & worst-case stresses

CONTENTS:

- INTRODUCTION
- PLANET EARTH
- FORCES and MOMENTS
- TYPES OF STRESS
- PRINCIPAL STRESSES
- FREE-BODY DIAGRAMS
- KARABINER FEA (Open Gate)
- DETERMINATE or INDETERMINATE?
- KARABINER FEA (Closed Gate)
- MINIMAL CONSTRAINT METHODS IN FEA
- QUESTIONS and CLOSE

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INTRODUCTION:

INTRODUCTION:

Win! Win! Win!

Exclusive Race Day Champagne Breakfast • Grandstand seats on the Mall • Post Race Party

Once again we are offering the chance for two lucky people to join us on Race Day at the Flora London Marathon on 22nd April 2007.

After an exclusive Champagne Breakfast reception at 'The Avenue' in St. James's you will stroll down to the Mall and take your seats at the Grandstand Finish. After you have thrilled to the elite battle, the club runners, the fancy dress and Uncle Tom Cobley coming across the line take a well earned rest. Then, in the evening, you can slip on your glad rags and step out with the Flora London Marathon team, the Elite winners and celebrities at the Flora London Marathon Post Race Party.

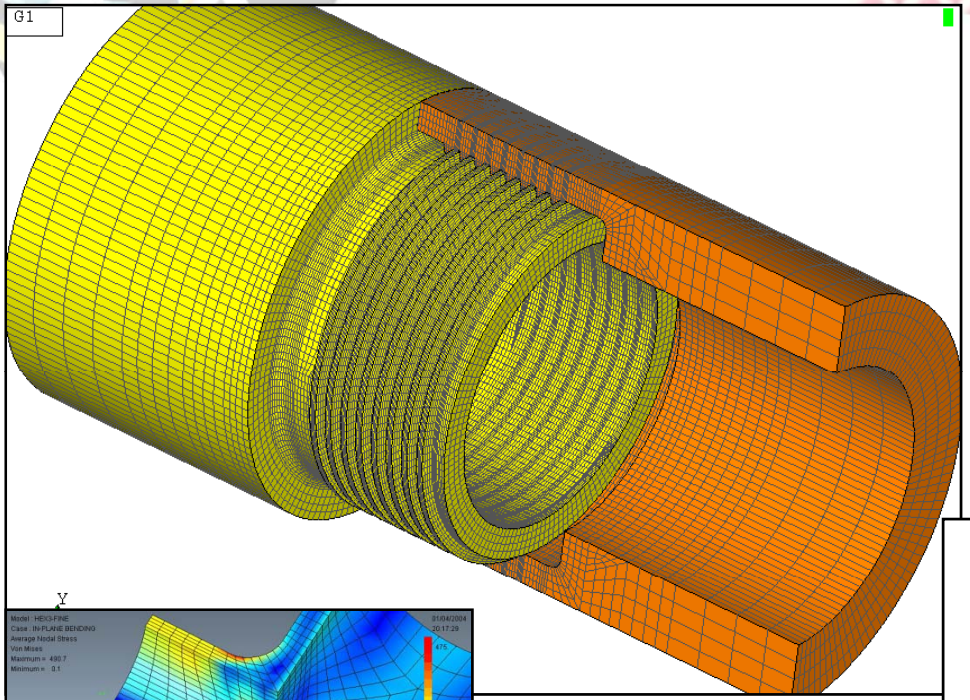
To be in with a chance of winning this superb prize all you need do is send us a postcard with your caption for our Dalek photo. Easy to think of a better one than us!

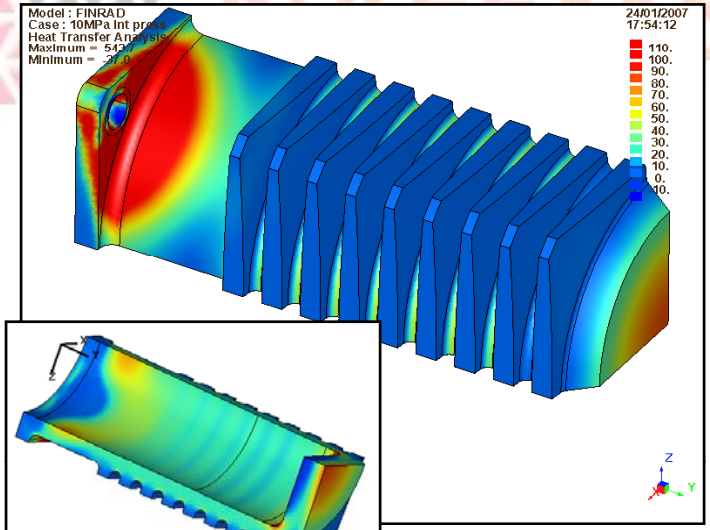
The funniest entry will be printed in The Flora London Marathon Official Programme and tickets for race day will be dispatched to the lucky winners.

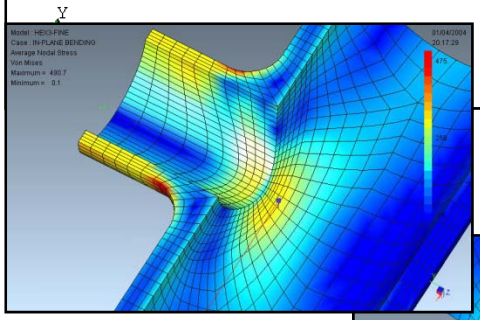
Send your entry on a postcard to:
Caption Competition
Flora London Marathon
PO Box 1234
London
SE1 0XT

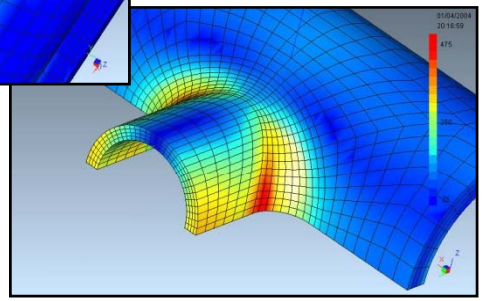
Remember to include your full name, address and telephone number.

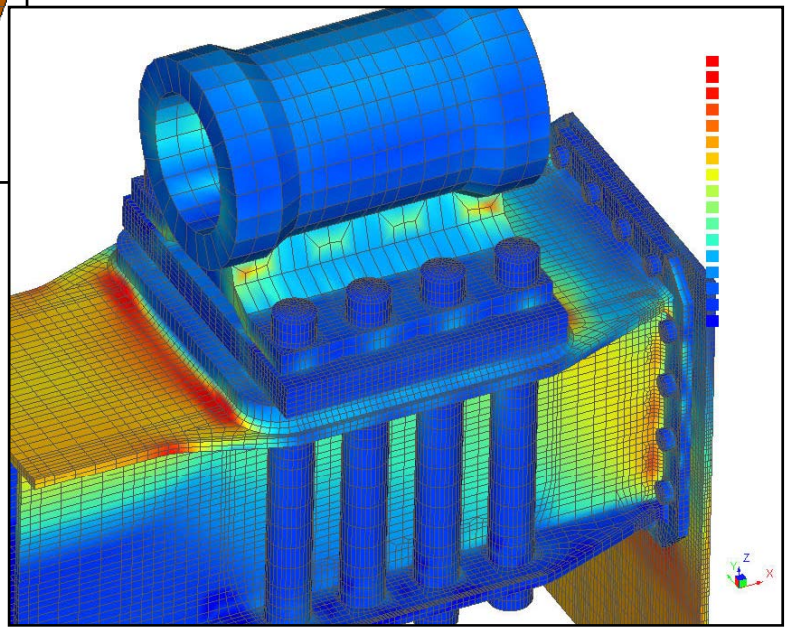
INTRODUCTION:











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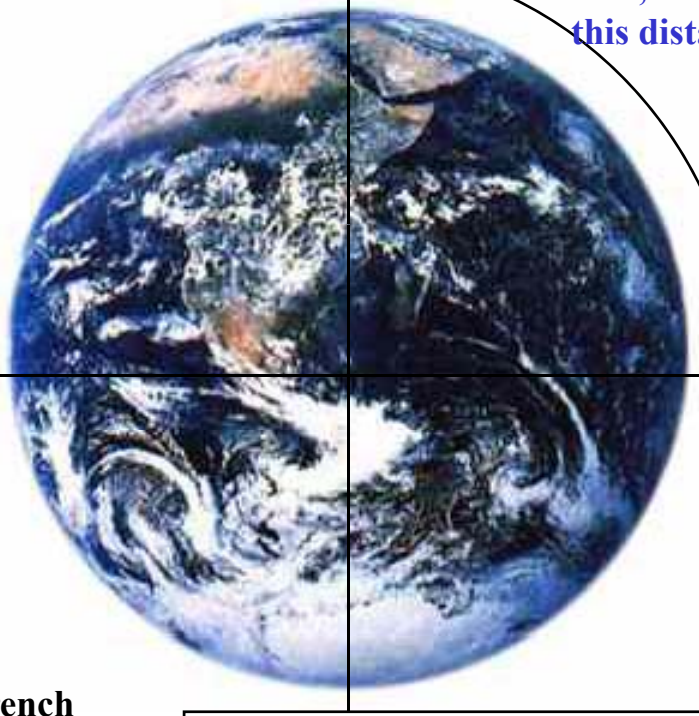
PLANET EARTH:

Polar Radius	= 6356.8km
Equatorial Radius	= 6378.2km
Mean Radius	= 6371.0km (3960miles)
Surface Area	= 5.101E14 m^2
Volume	= 1.083E21 m^3
Mass	= 5.977E24 kg
Mean Density	= 5517 kg/m^3
Gravity at Surface	= 9.80665 m/s^2 (standard 45deg)
Rotational speed	= 465 m/s (at the equator)
Sun orbit velocity	= 29,780 m/s (mean speed)
Inclination	= 23 27 (equator to ecliptic)
Greatest Height	= 8847.7m (29,028ft) Mt Everest
Greatest Depth	= 11,033m (35,960ft) Marianas Trench
Land Area	= 148.8E6 km^2 (5.747E7 $miles^2$)
Ocean Area	= 361.3E6 km^2 (13.95E7 $miles^2$)

$$\frac{0.25 \times (2 \times \pi \times 6{,}371{,}000)}{10{,}000{,}000} = 1.00075\text{m}$$

One metre defined as $1/10{,}000{,}000^{th}$ of this distance*



Composition of Atmosphere (by vol)	
N_2 78.09%	O_2 20.95%
Ar 0.93%	CO_2 0.03%

**One metre defined as 1,650,763.73 wavelengths of the krypton-86 atom*

PLANET EARTH:

QUANTITY	DIMENSIONAL SYMBOL
Mass	M
Length	L
Time	T
Force	F

S.I. UNITS

	UNIT	SYMBOL
Base Units	kilogram	kg
	metre	m
	second	s
	newton	N

An *absolute* system because the measurement of the base quantity mass is independent of it's environment

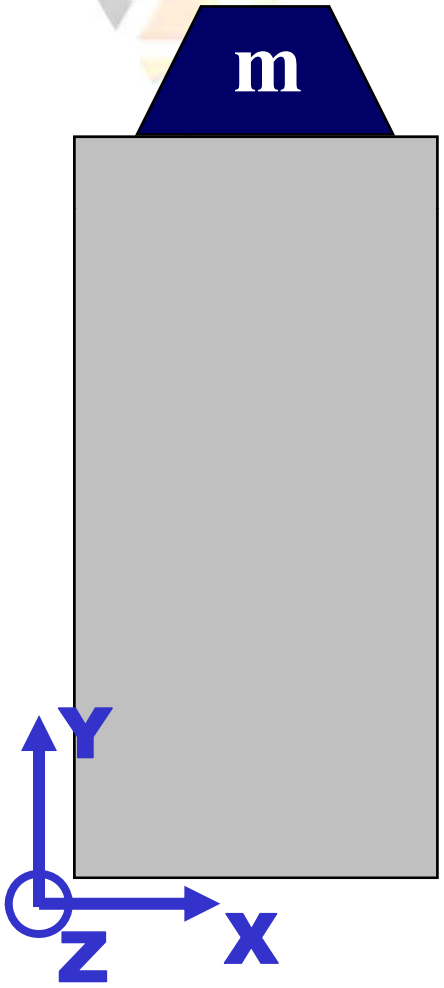
U.S. UNITS

	UNIT	SYMBOL
	slug	-
Base Units	foot	ft
	second	sec
	pound	lb

A *gravitational* system because the base quantity force is the *weight* acting on a standard mass (at sea level and 45deg latitude)

PLANET EARTH:

$g = 9.81 m/s^2$



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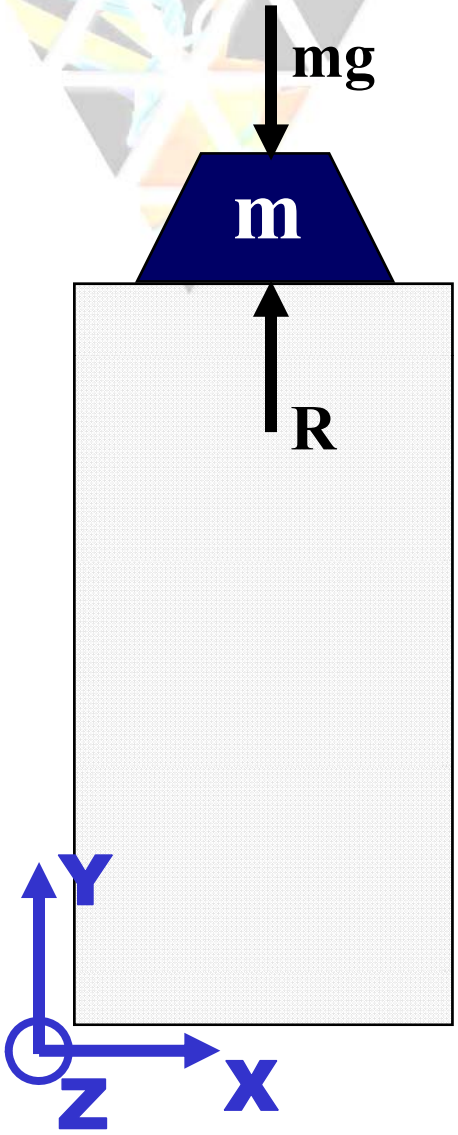

$g = 9.81 m/s^2$

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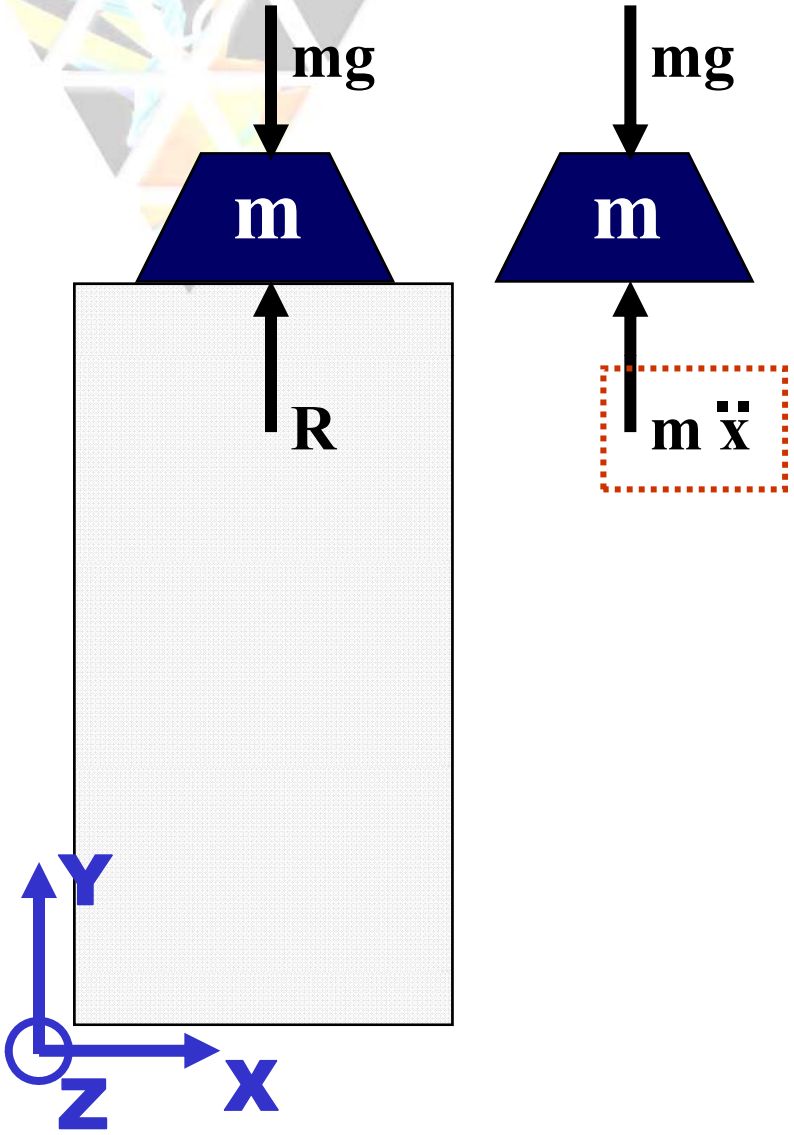

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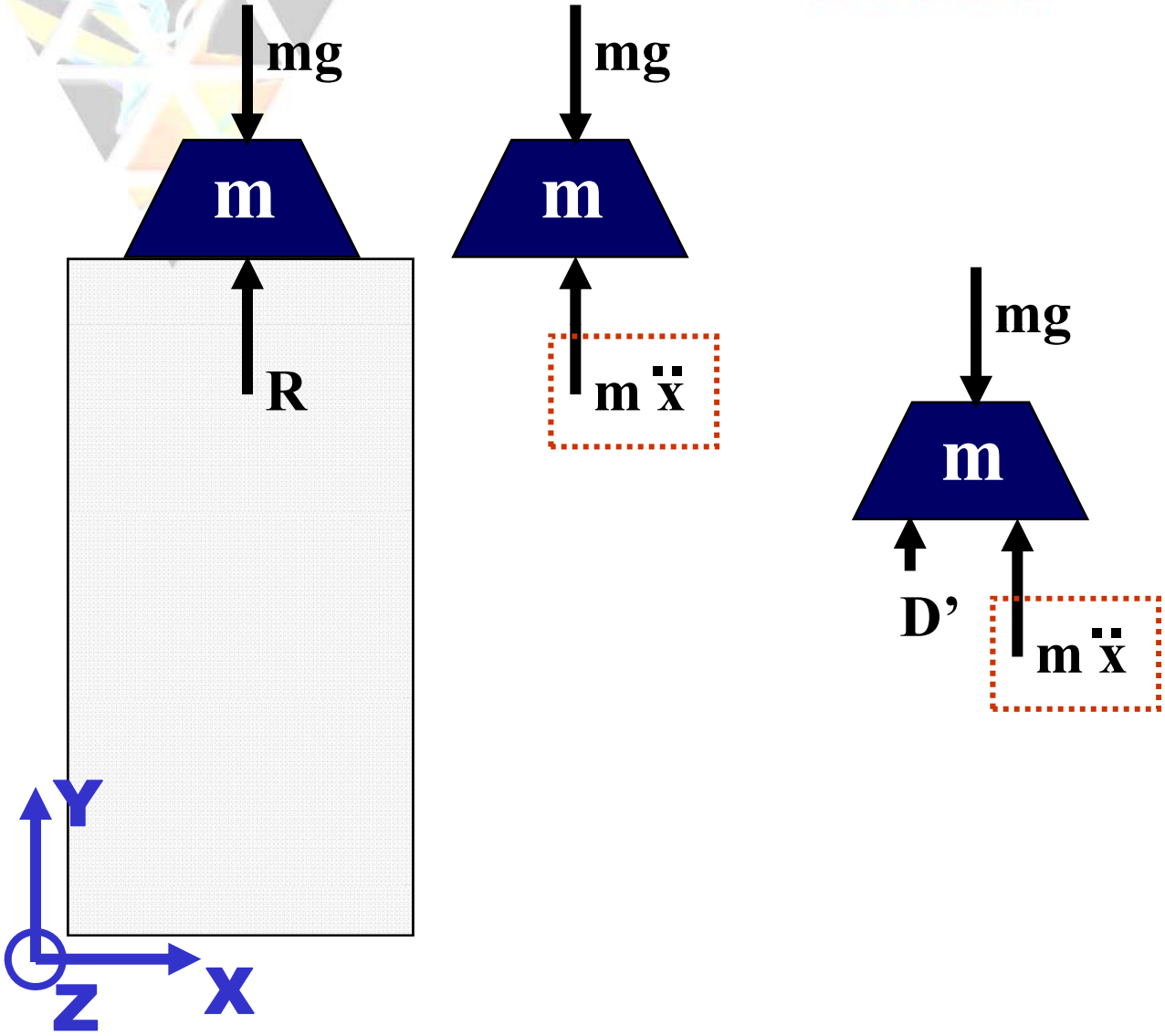

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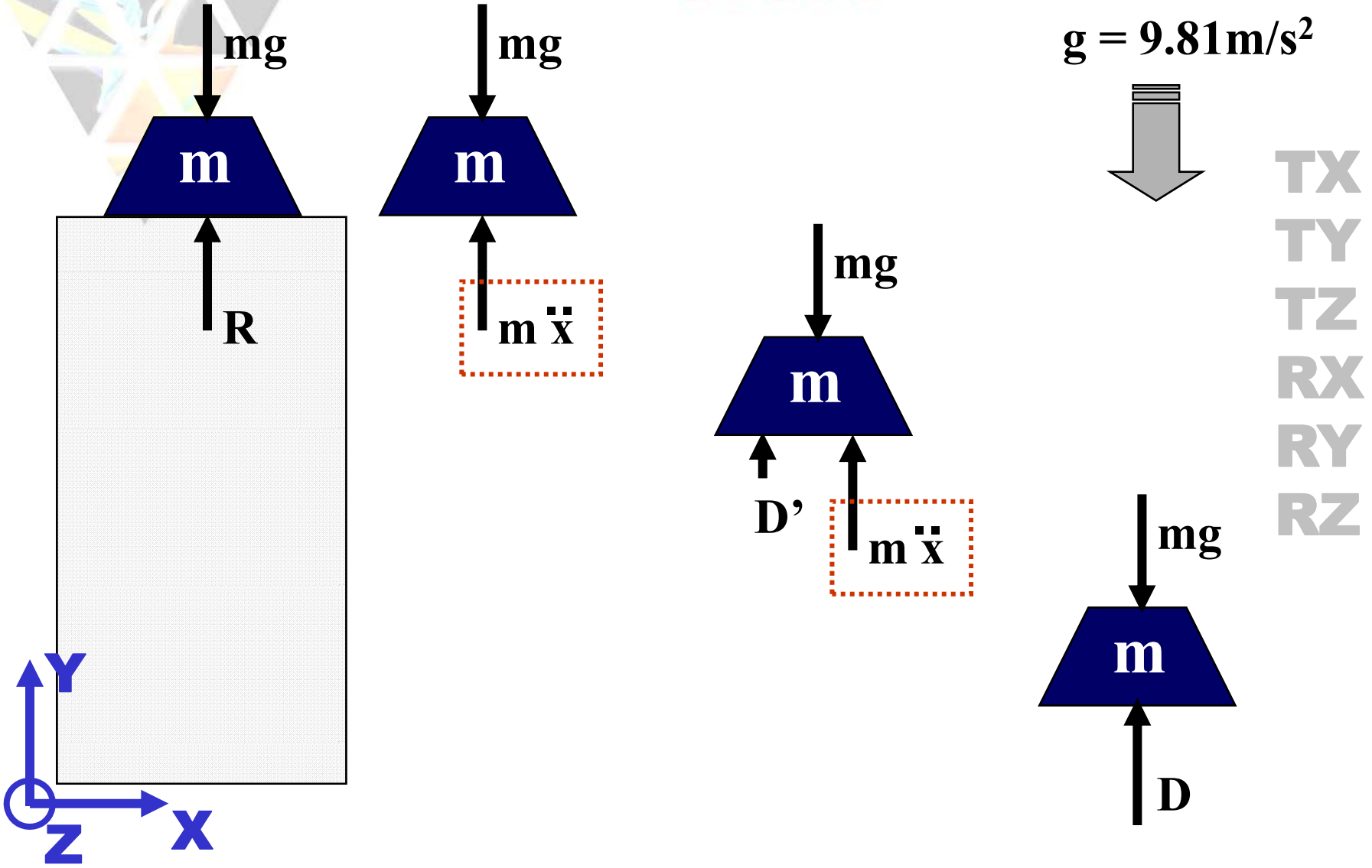

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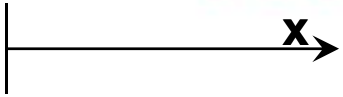

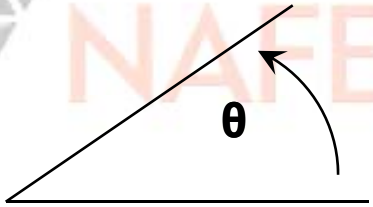

QUANTITY	LINEAR	ANGULAR
Time	t	t
Distance	x	θ
Velocity	$\dot{x}$	$\dot{\theta}$
Acceleration	$\ddot{x}$	$\ddot{\theta}$
Inertia	M	$I \quad (\Sigma Mr^2)$
"Effort"	$F = M\ddot{x}$	$T = I\ddot{\theta}$
Momentum	$M\dot{x}$	$I\dot{\theta}$
Kinetic Energy	$\frac{1}{2} M\dot{x}^2$	$\frac{1}{2} I\dot{\theta}^2$

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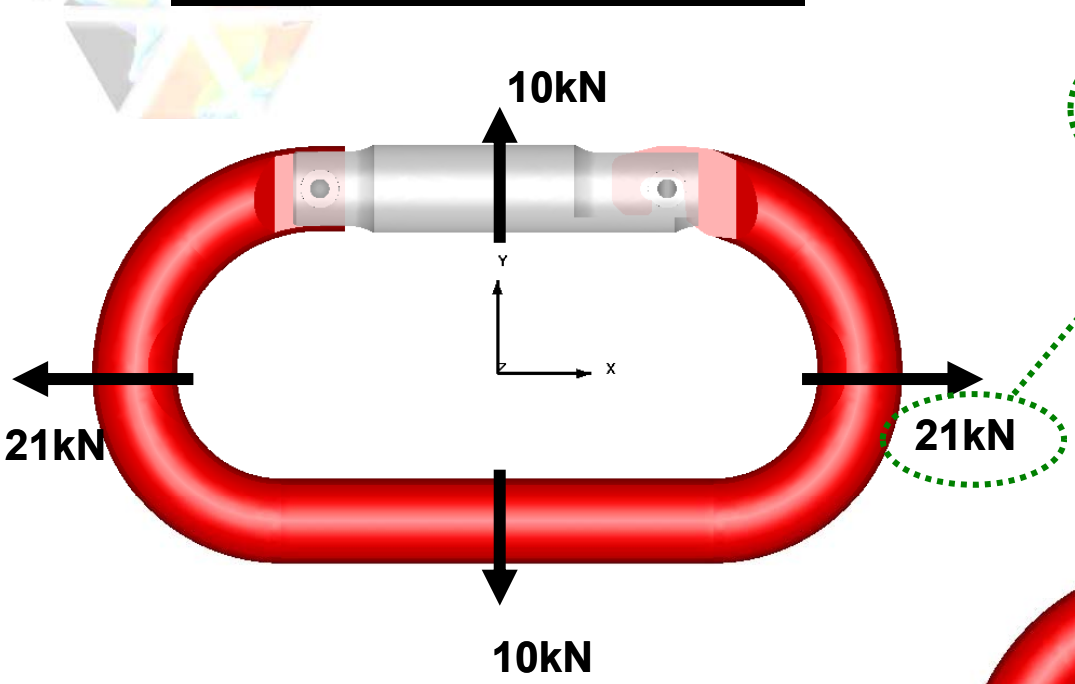
FORCES and MOMENTS:

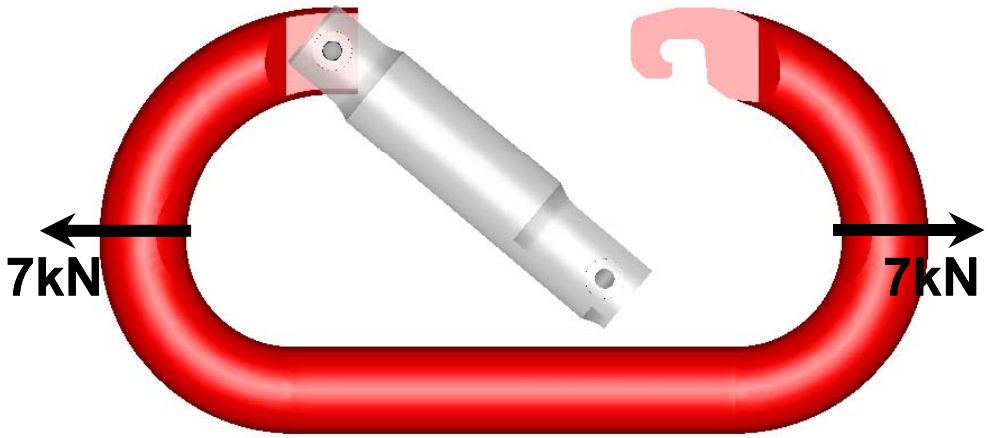
FORCES and MOMENTS:

21kN Closed Gate Rating



2.14 tonnes
4720 lbsf

7kN Open Gate Rating



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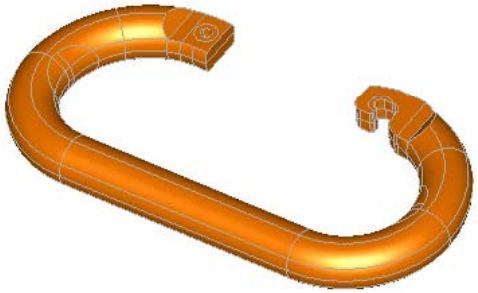
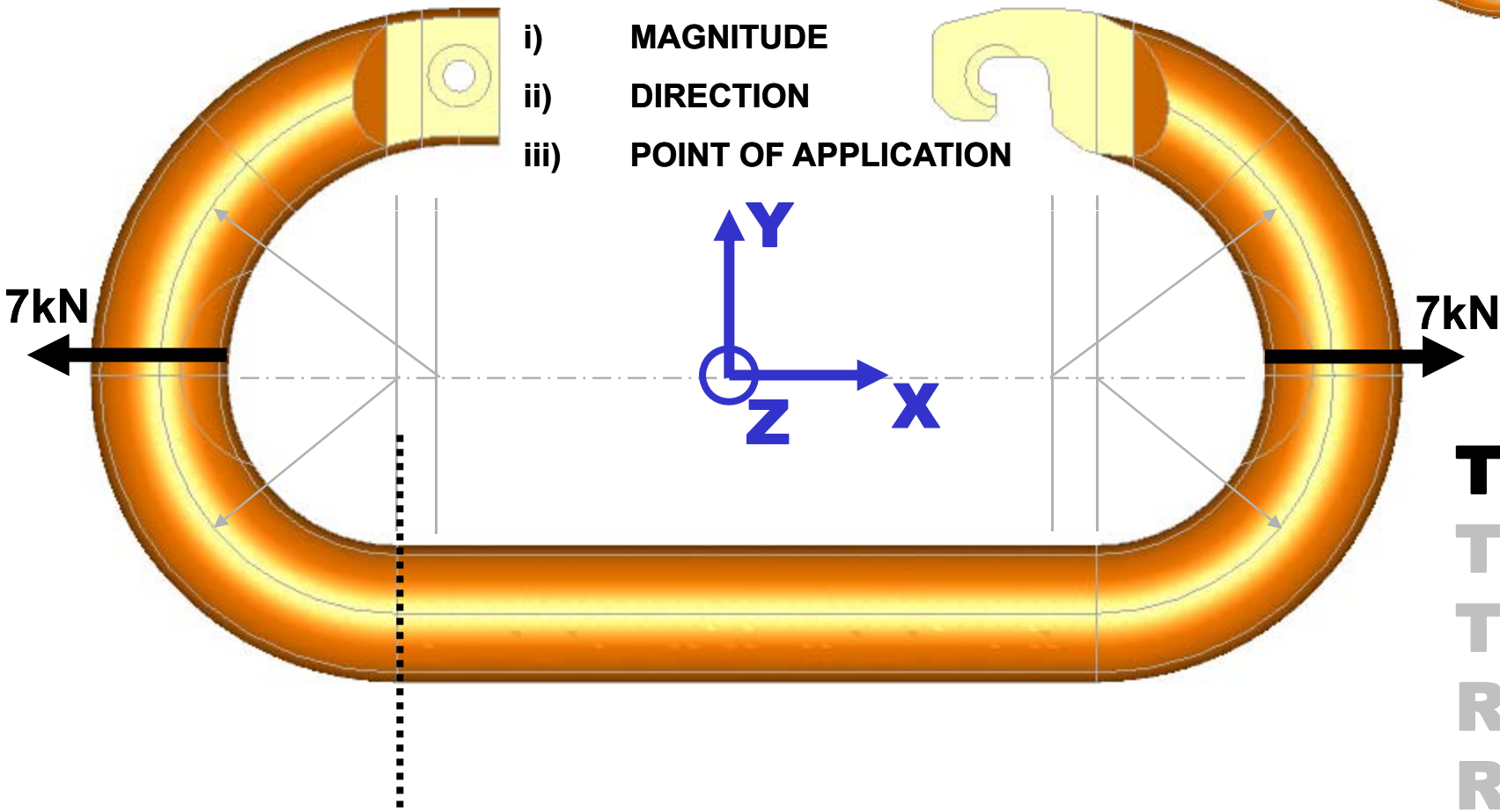


DEFINITION OF A FORCE:

i) MAGNITUDE

ii) DIRECTION

iii) POINT OF APPLICATION



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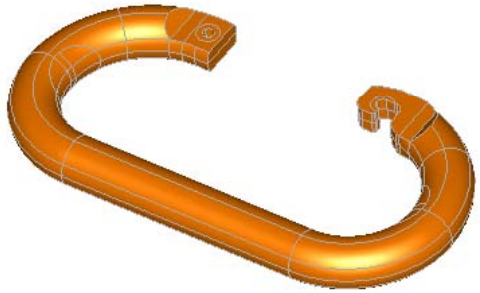
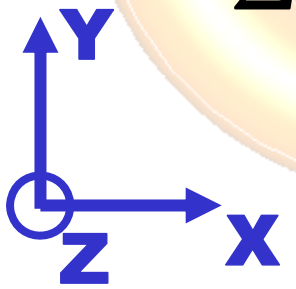


FORCES	MOMENTS
$\sum Fx=0$	$\sum Mx=0$
$\sum Fy=0$	$\sum My=0$
$\sum Fz=0$	$\sum Mz=0$



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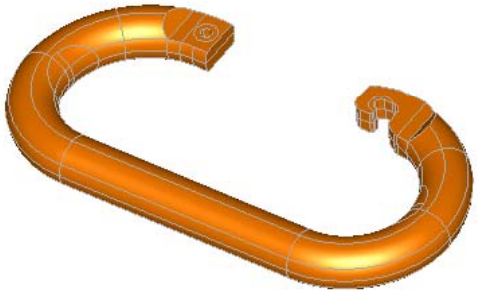

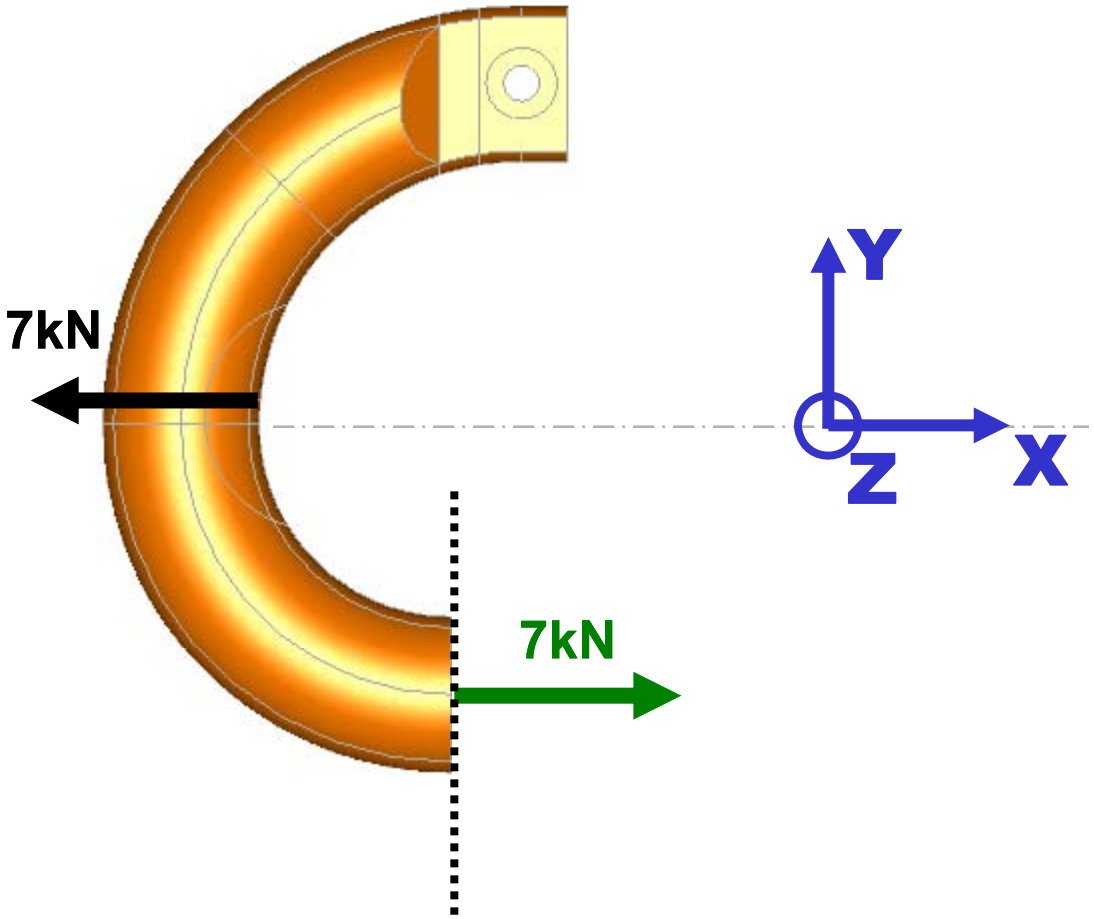

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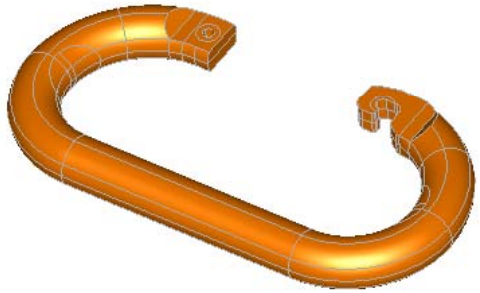


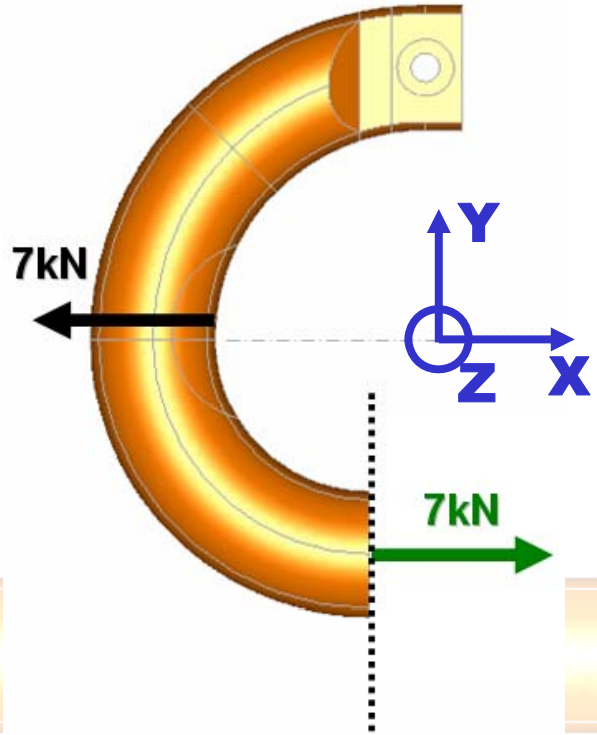
FORCES

$\sum Fx=0$

7000 – 7000 = 0

$\sum Fy=0$

$\sum Fz=0$

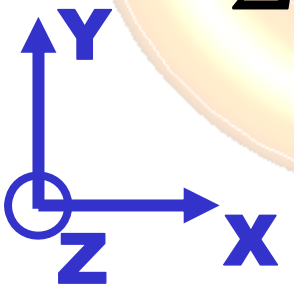


MOMENTS

$\sum Mx=0$

$\sum My=0$

$\sum Mz=0$



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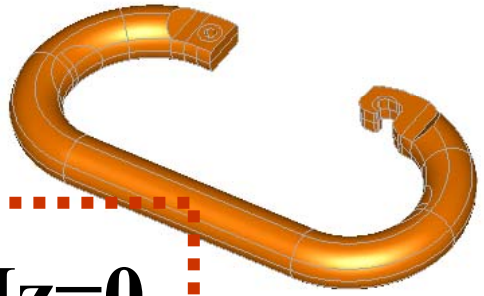
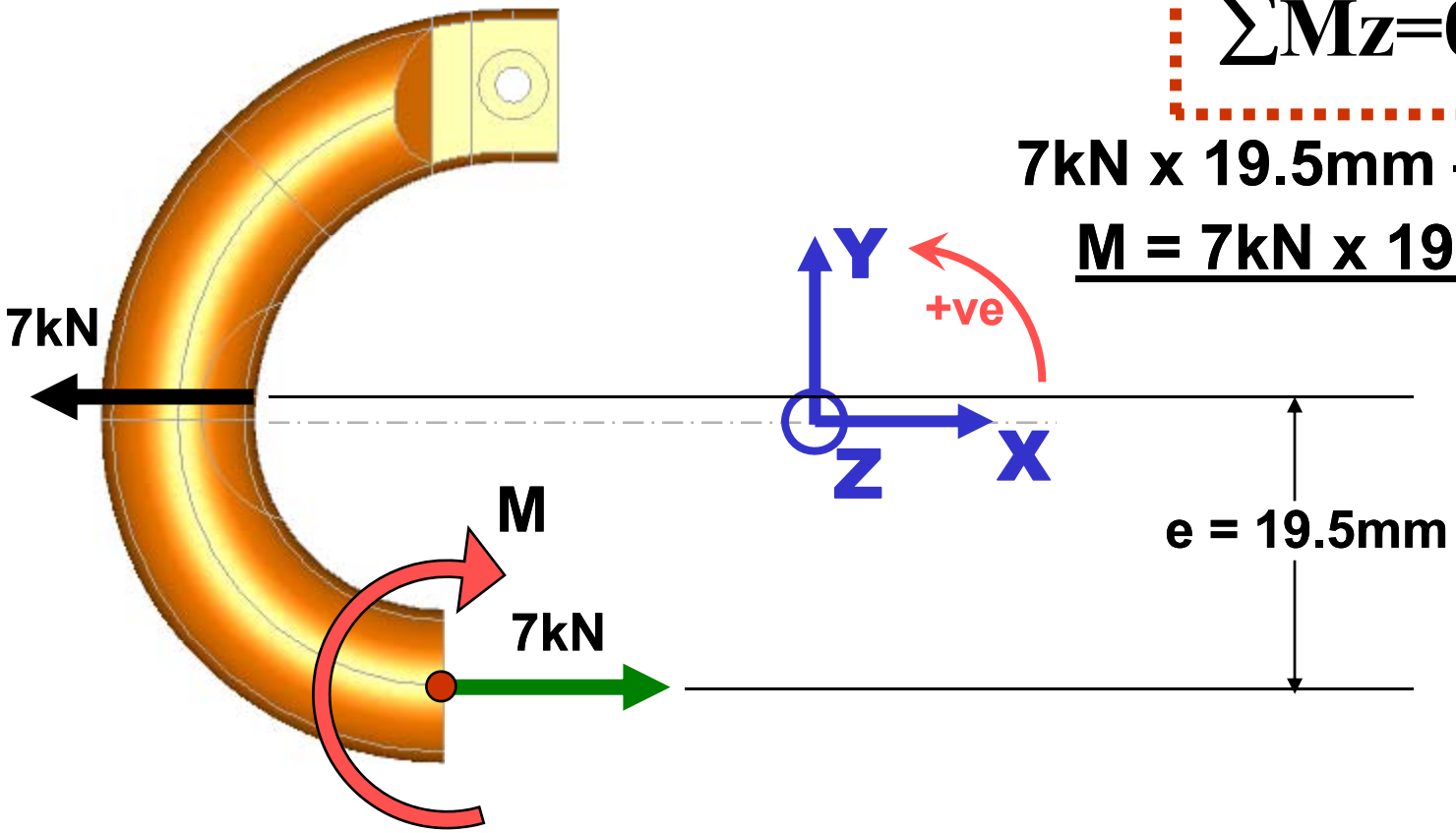


$\sum Mz=0$

7kN x 19.5mm – M = 0

M = 7kN x 19.5mm



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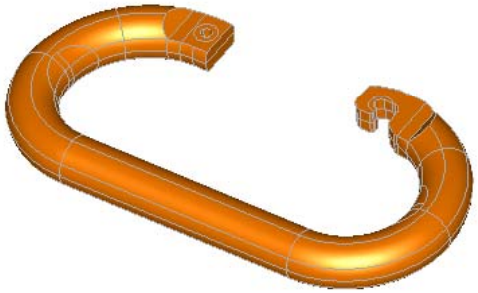

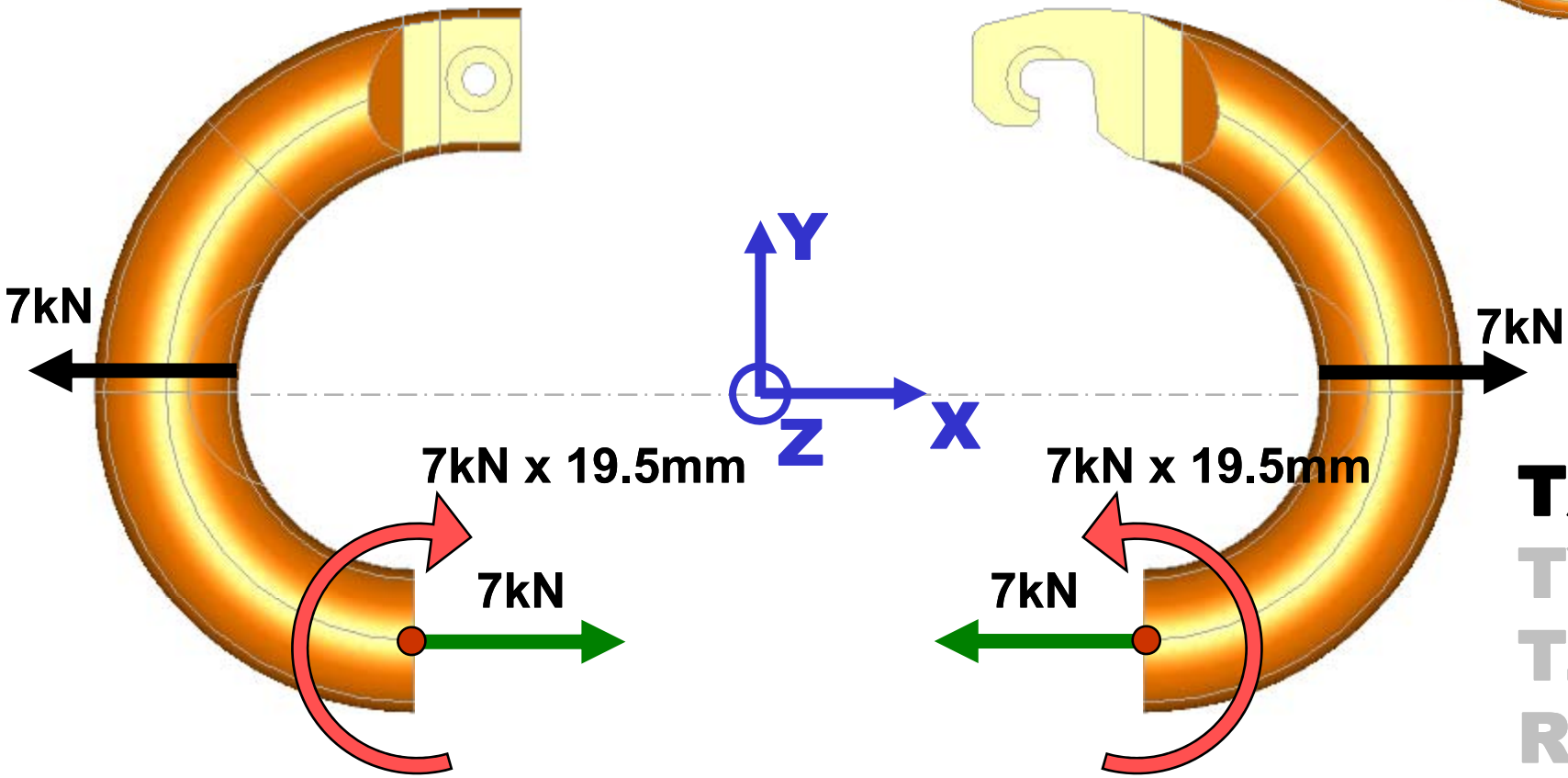

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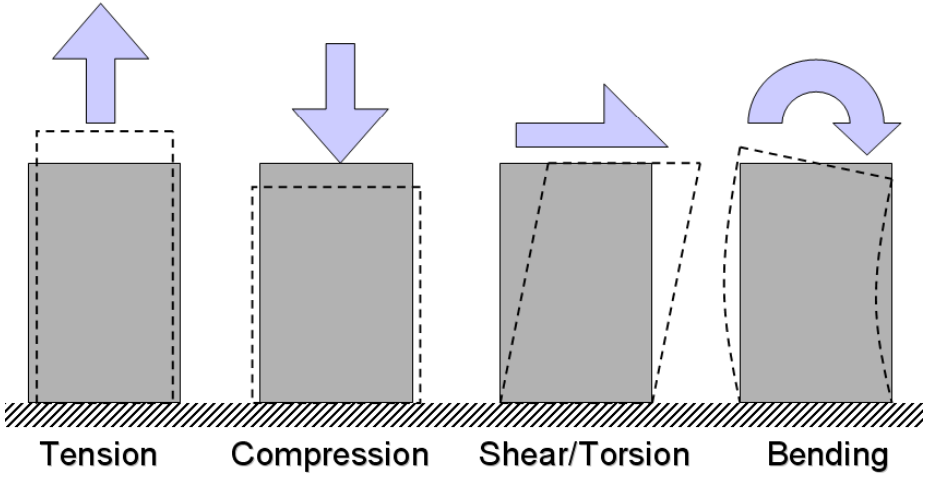
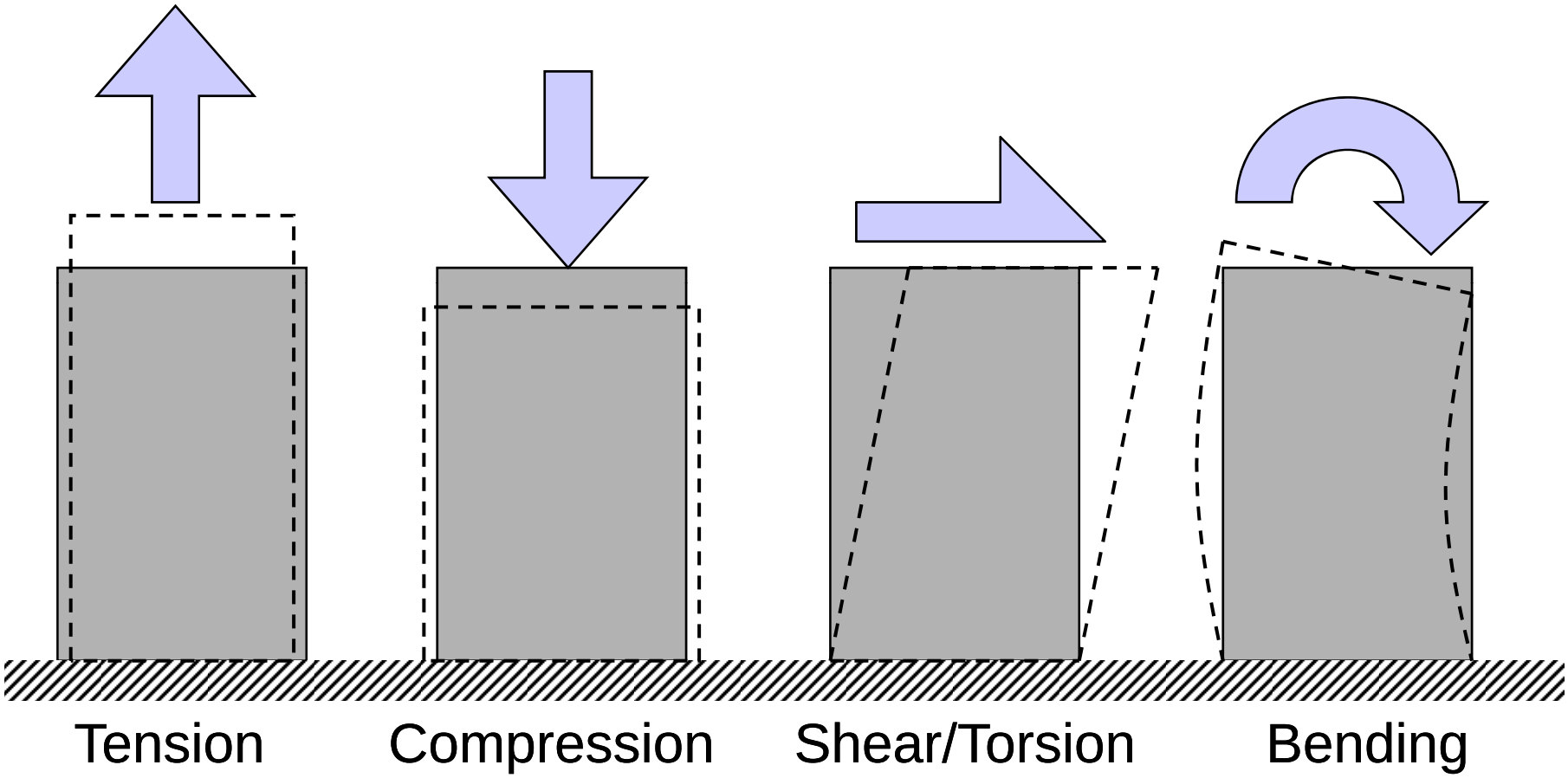


TYPES of STRESS:



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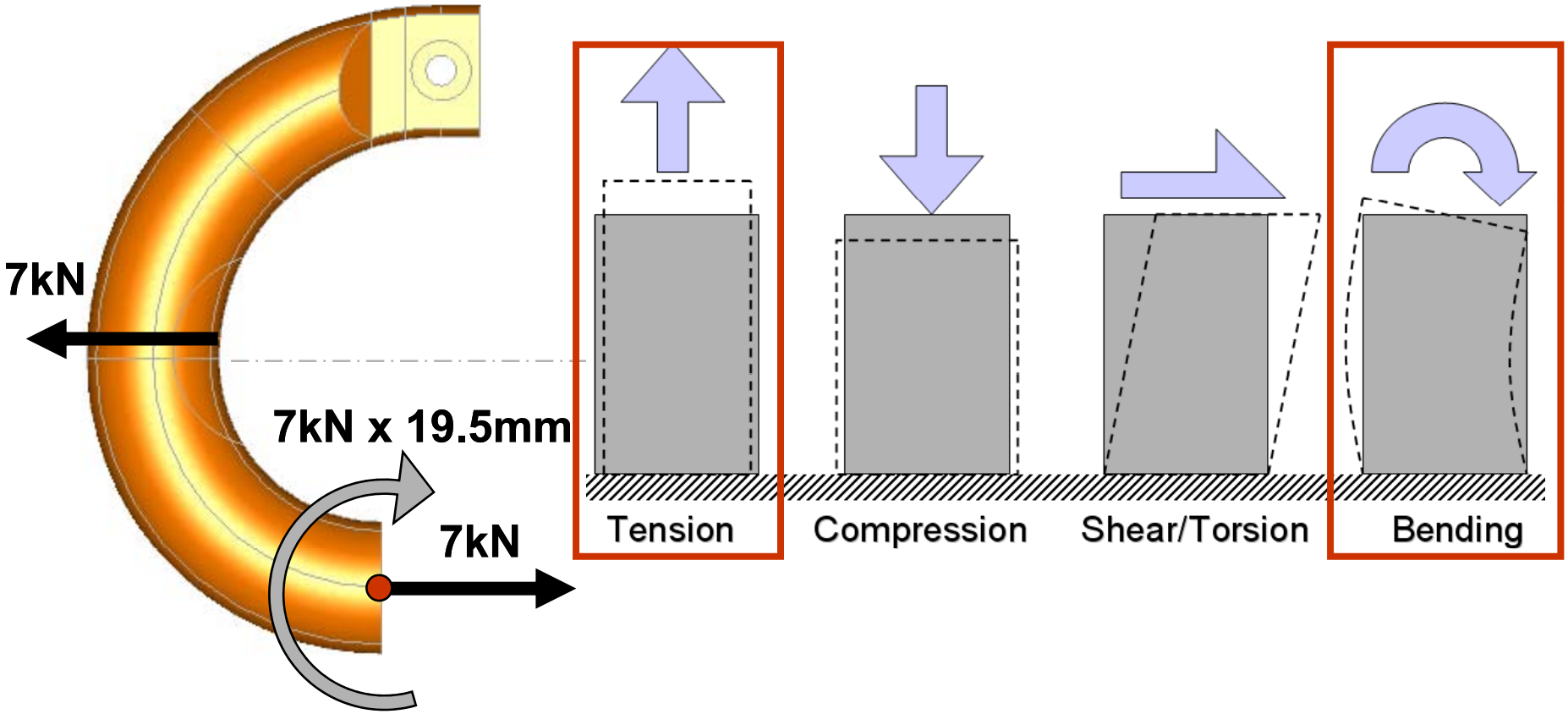

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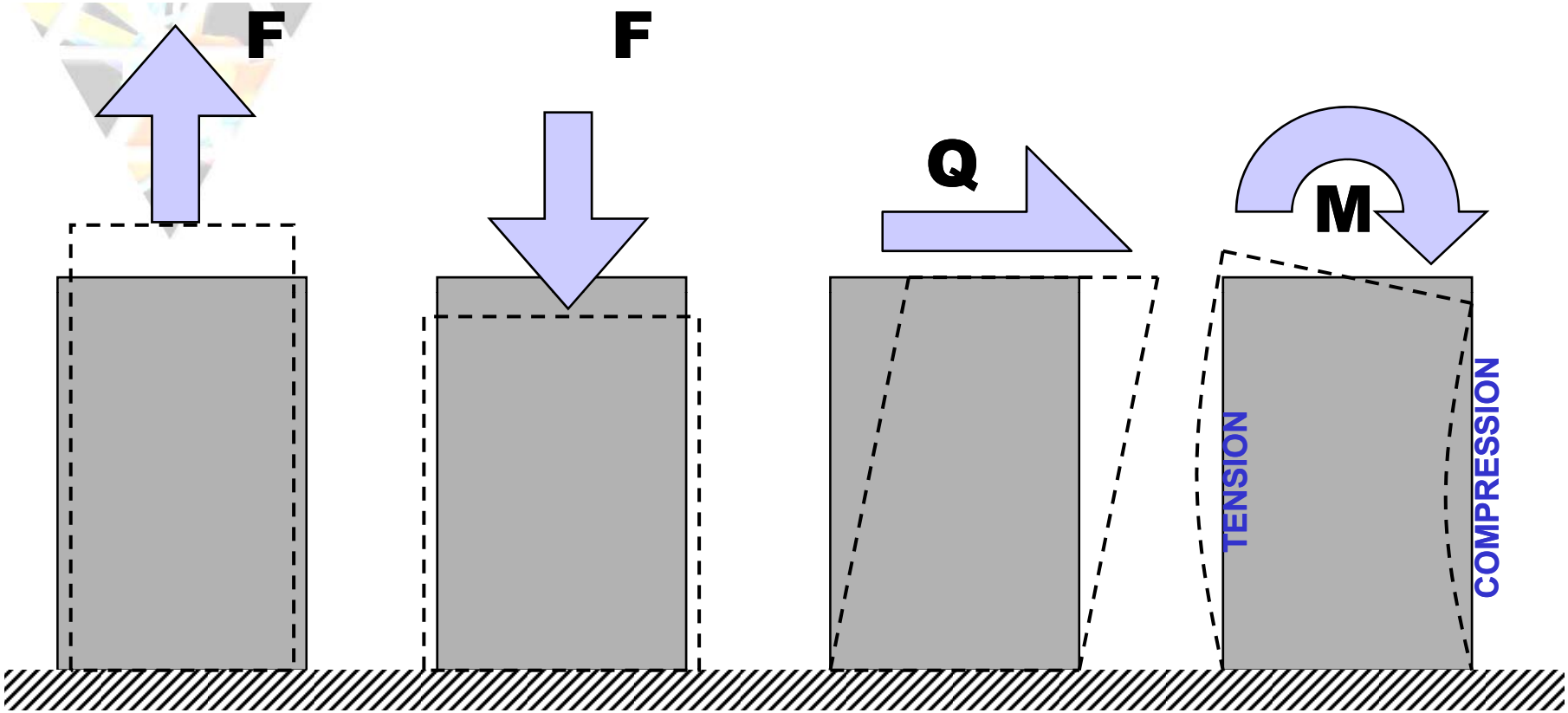


Tension
POSITIVE

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

Compression
NEGATIVE

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

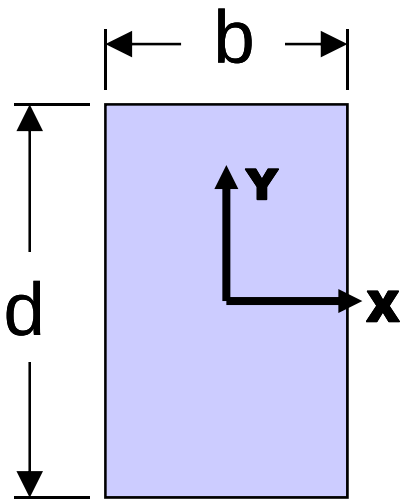
Shear/Torsion

$$\sigma_{av} = \frac{Q}{A}$$

Bending

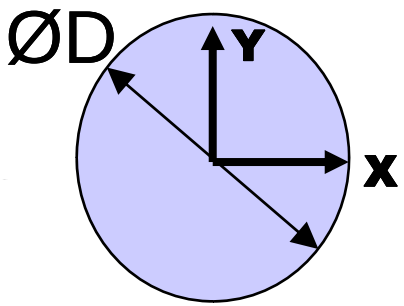
$$\sigma = \frac{My}{I}$$

TYPES of STRESS:



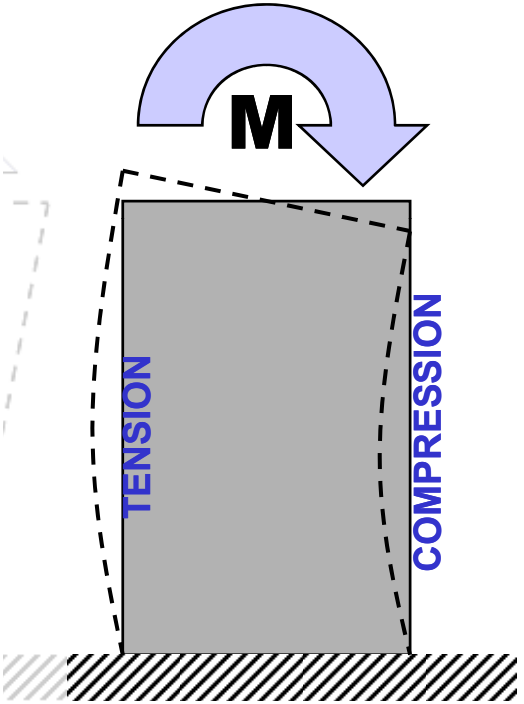
$$I = \frac{bd^3}{12}$$

$$y = d/2$$



$$I = \frac{\pi D^4}{64}$$

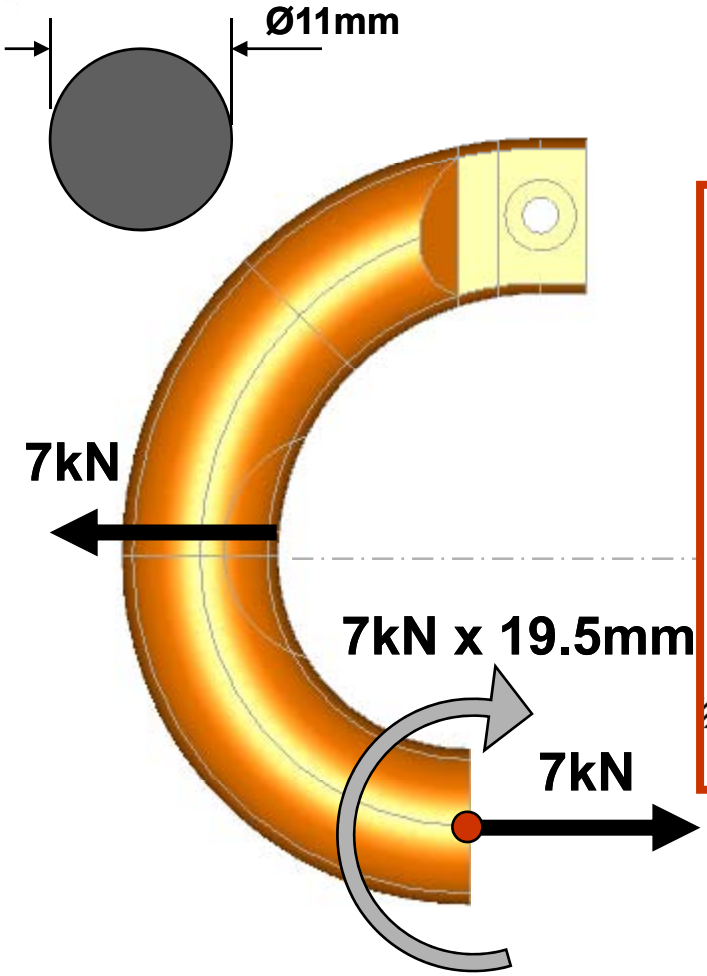
$$y = D/2$$



Bending

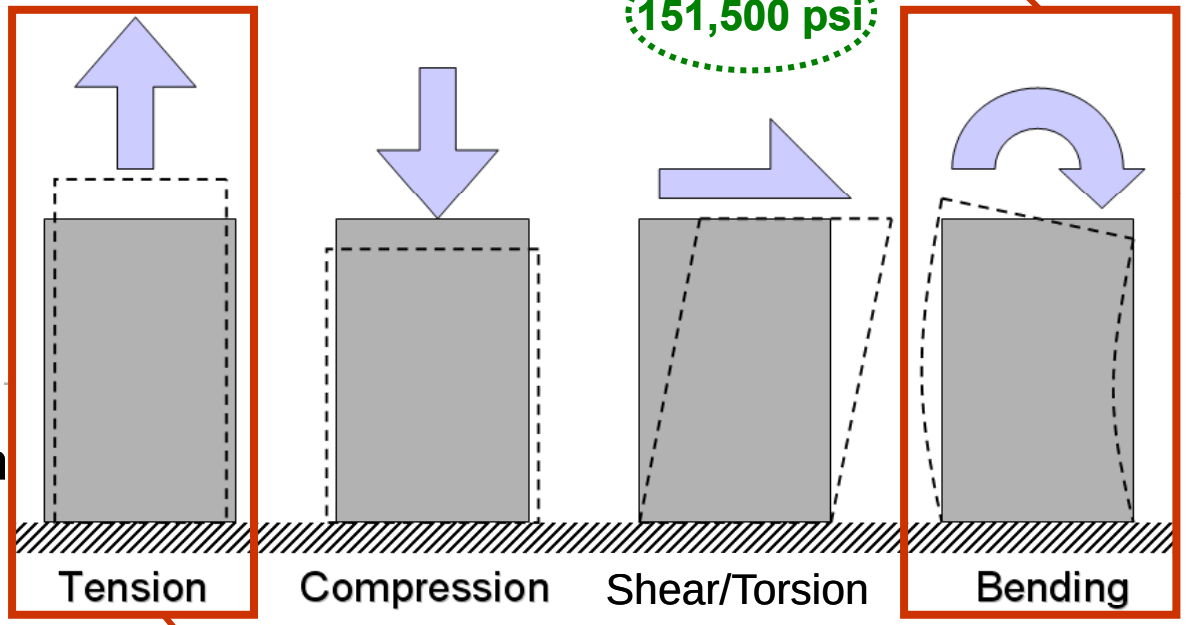
$$\sigma = \frac{My}{I}$$

TYPES of STRESS:



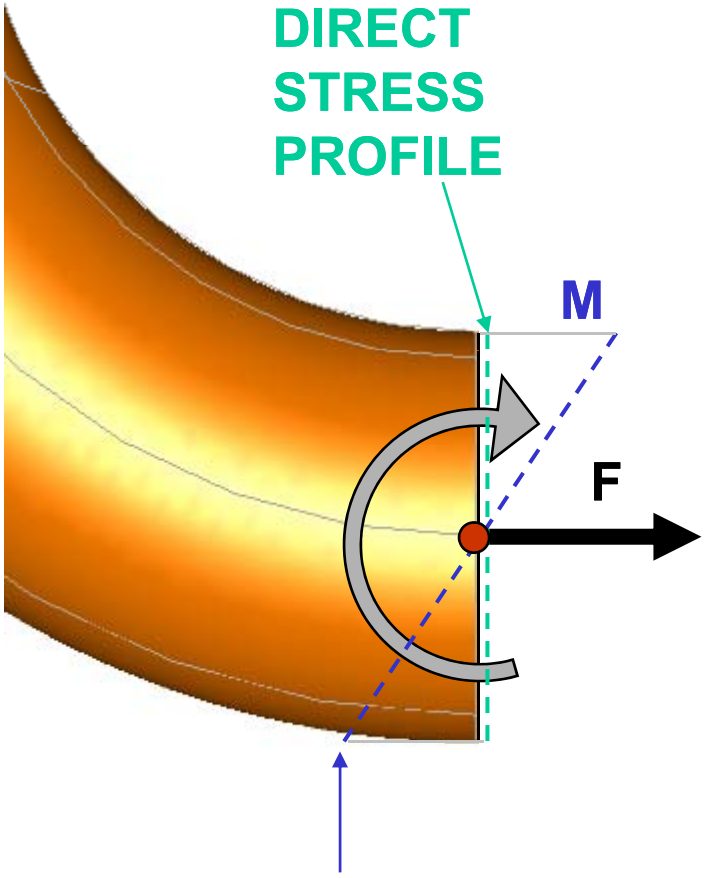
$$\sigma = \frac{My}{I} = \frac{\text{MOMENT}\ 7000 \times 19.5 \times 5.5}{\pi(11)^4/64} = 1045\text{MPa}$$

151,500 psi

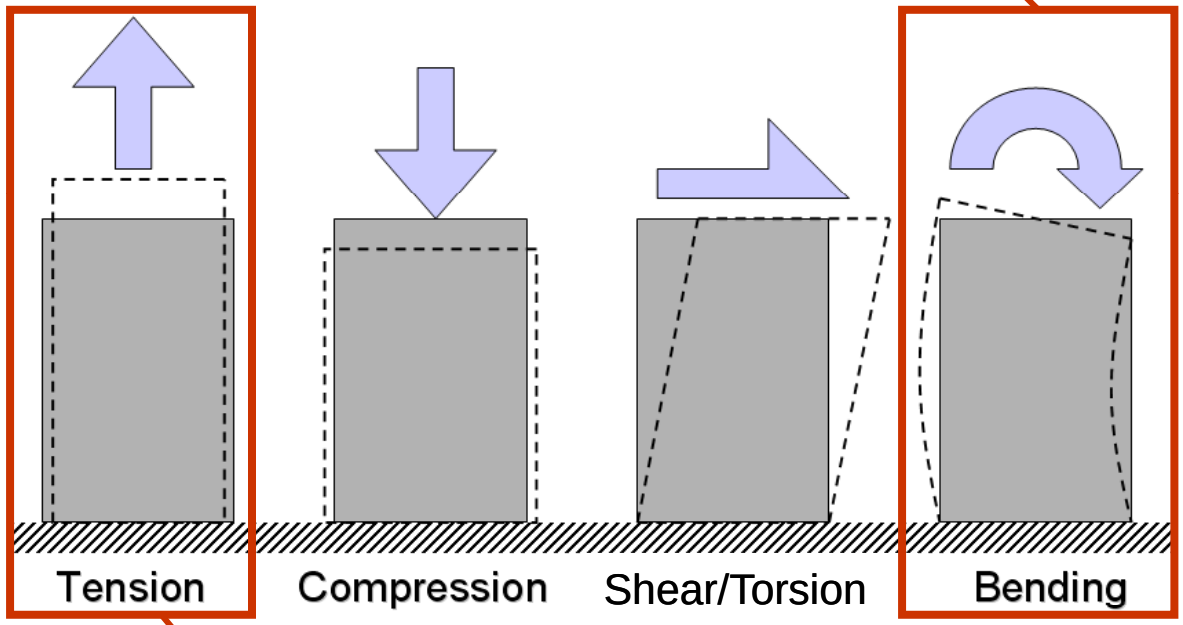


$$\sigma = \frac{F}{A} = \frac{7000}{\pi(11)^2/4} = 74\text{MPa}$$

TYPES of STRESS:

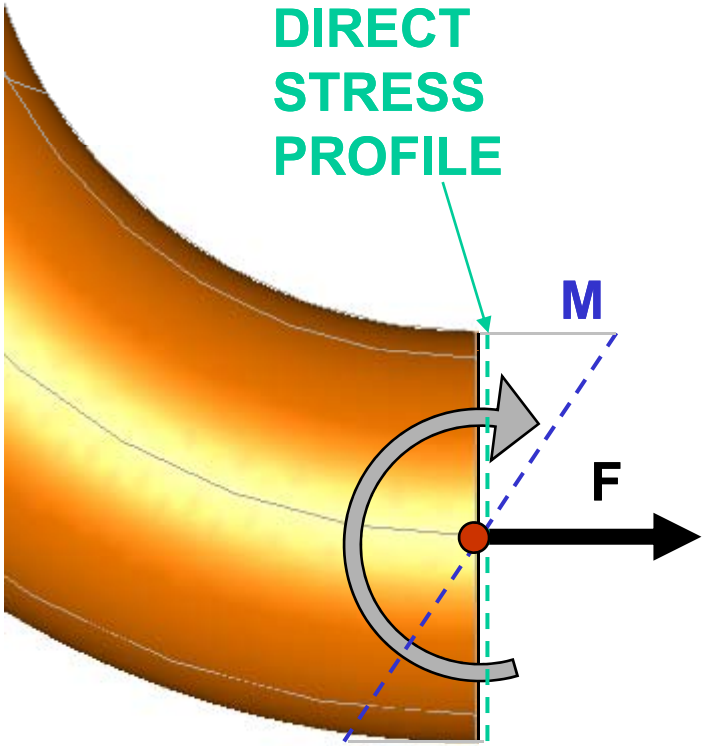


$$\sigma = \frac{My}{I} = \frac{\text{MOMENT } 7000 \times 19.5 \times 5.5}{\pi(11)^4/64} = 1045\text{MPa} \quad (+/-)$$

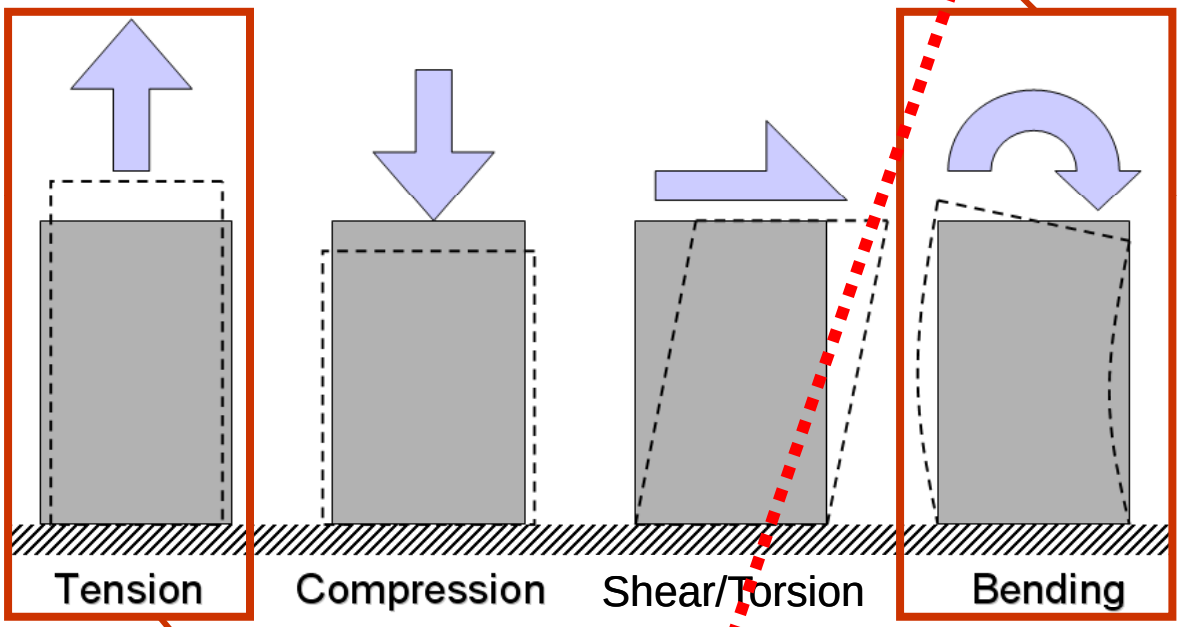


$$\sigma = \frac{F}{A} = \frac{7000}{\pi(11)^2/4} = 74\text{MPa}$$

TYPES of STRESS:



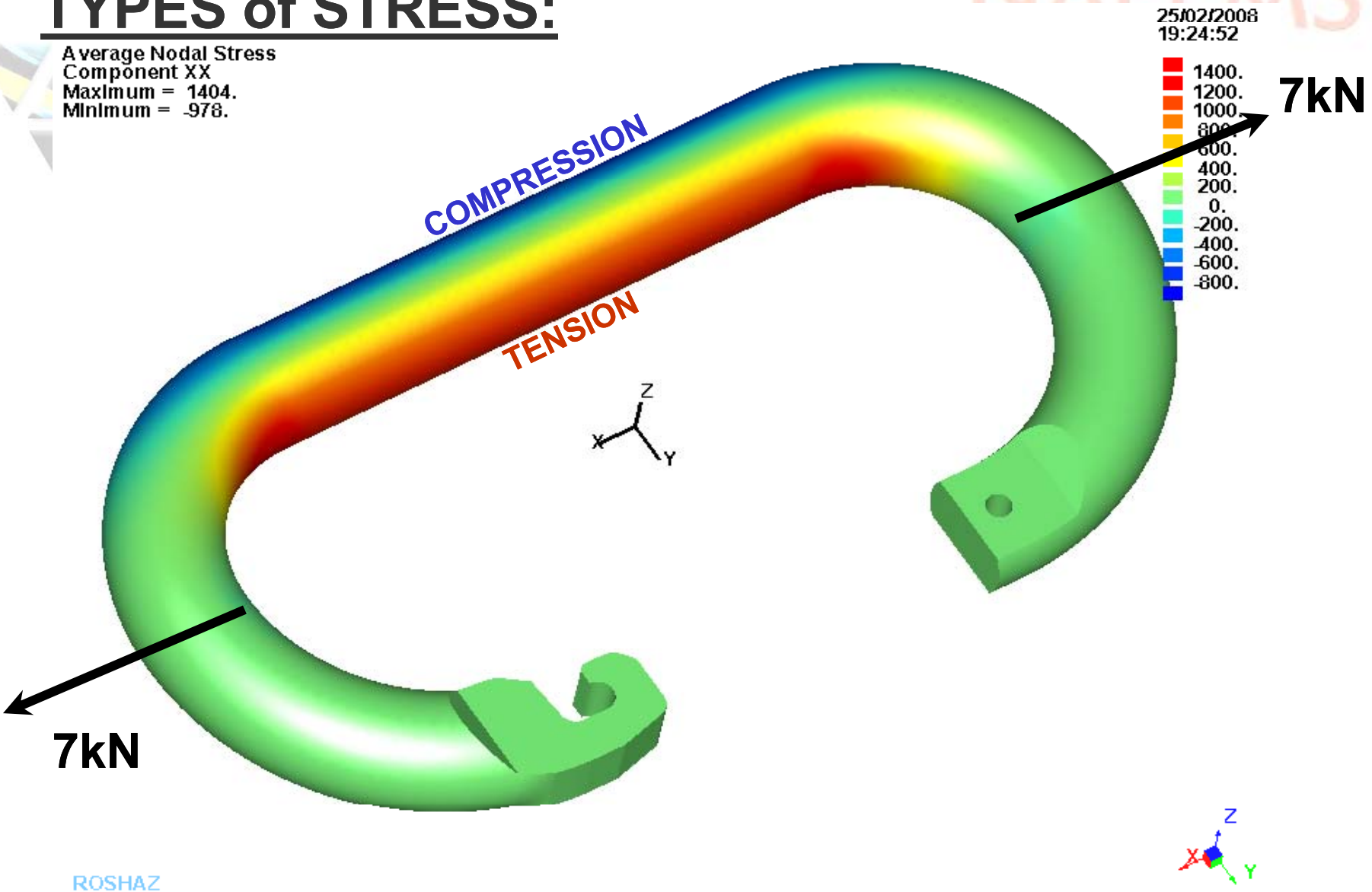
$$\sigma = \frac{My}{I} = \frac{\text{MOMENT}}{\pi(11)^4/64} = \frac{7000 \times 19.5 \times 5.5}{} = 1045\text{MPa}$$



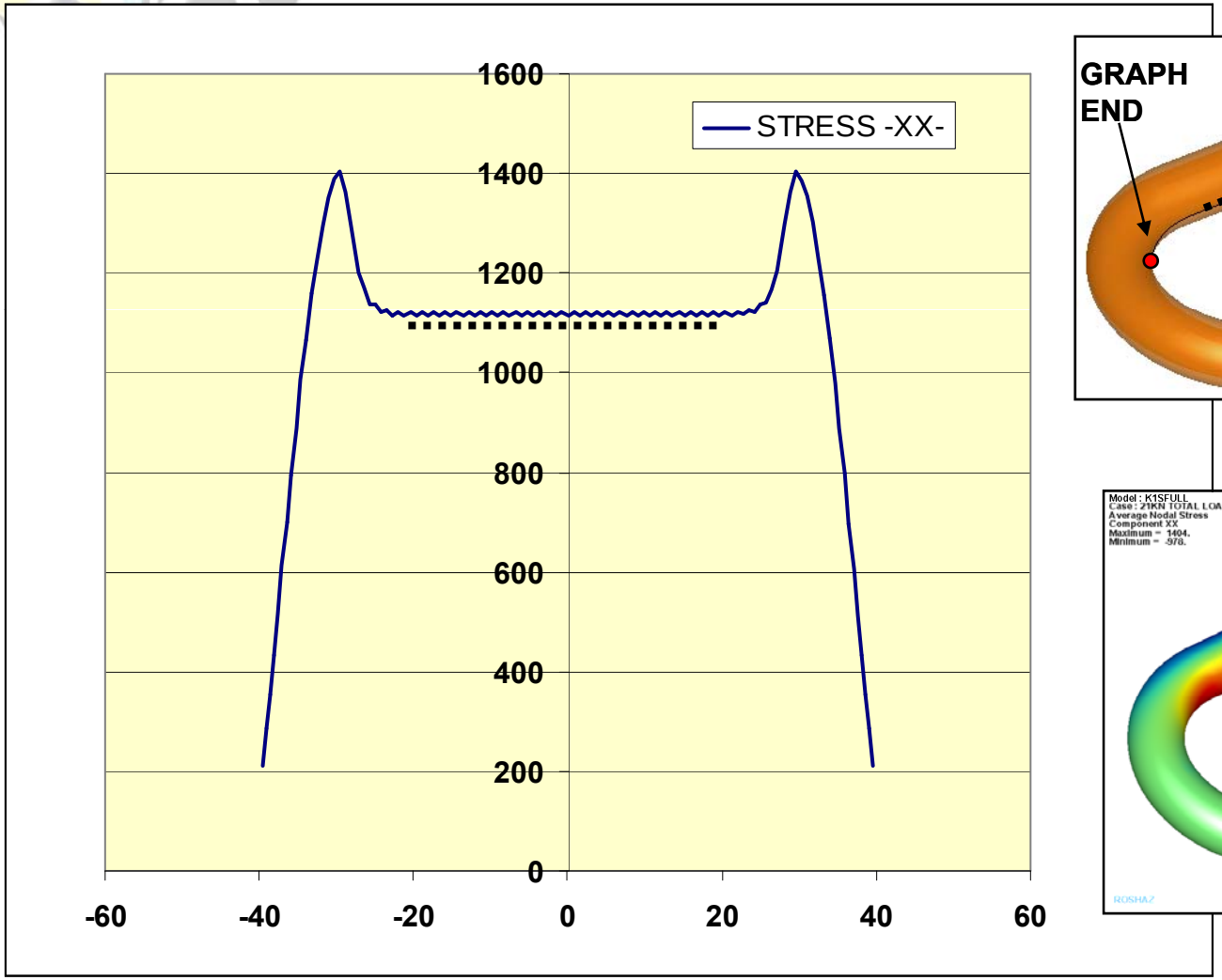
$$\sigma = \frac{F}{A} = \frac{7000}{\pi(11)^2/4} = 74\text{MPa}$$

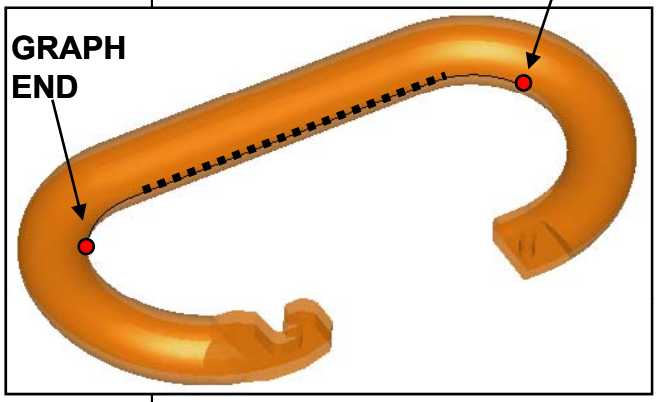
7%

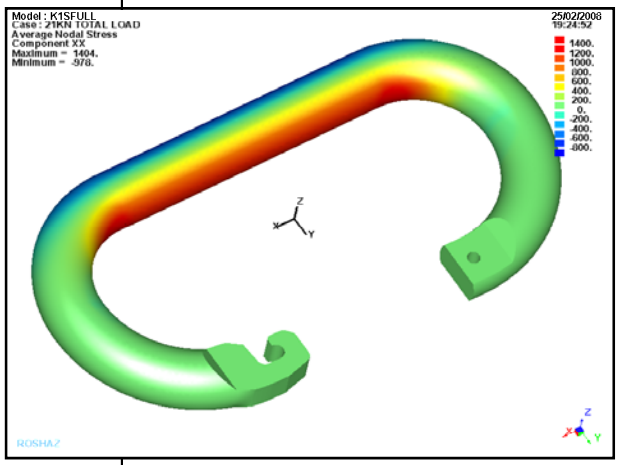
TYPES of STRESS:



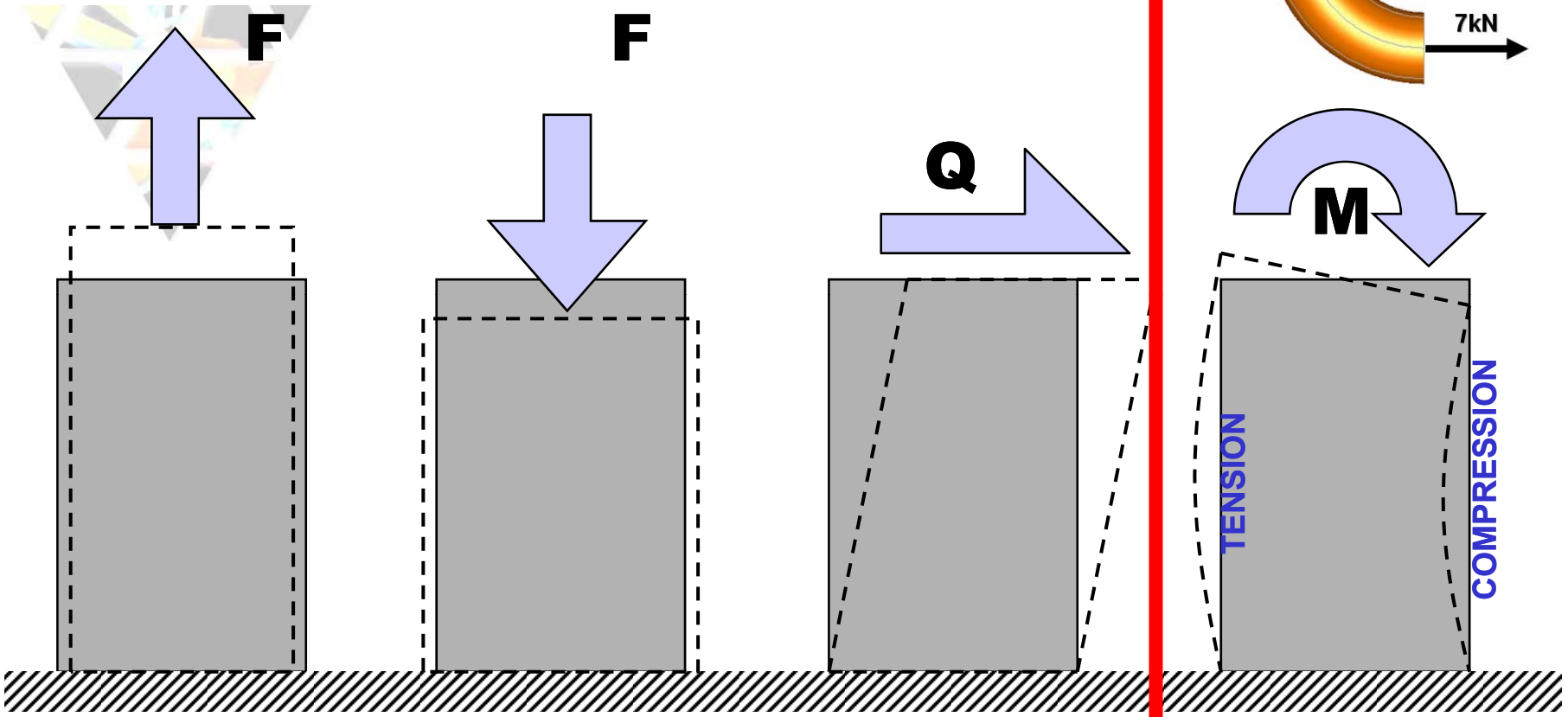
TYPES of STRESS:







TYPES of STRESS:



Tension
POSITIVE

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

Compression
NEGATIVE

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

Shear/Torsion

$$\sigma_{av} = \frac{Q}{A}$$

Bending

$$\sigma = \frac{My}{I}$$

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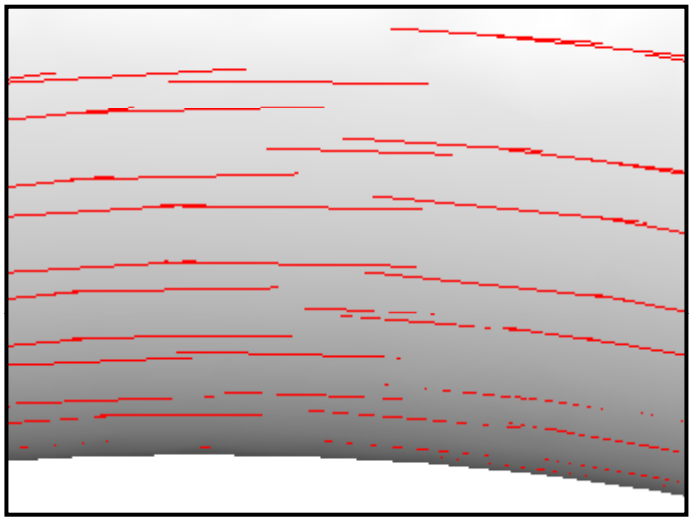
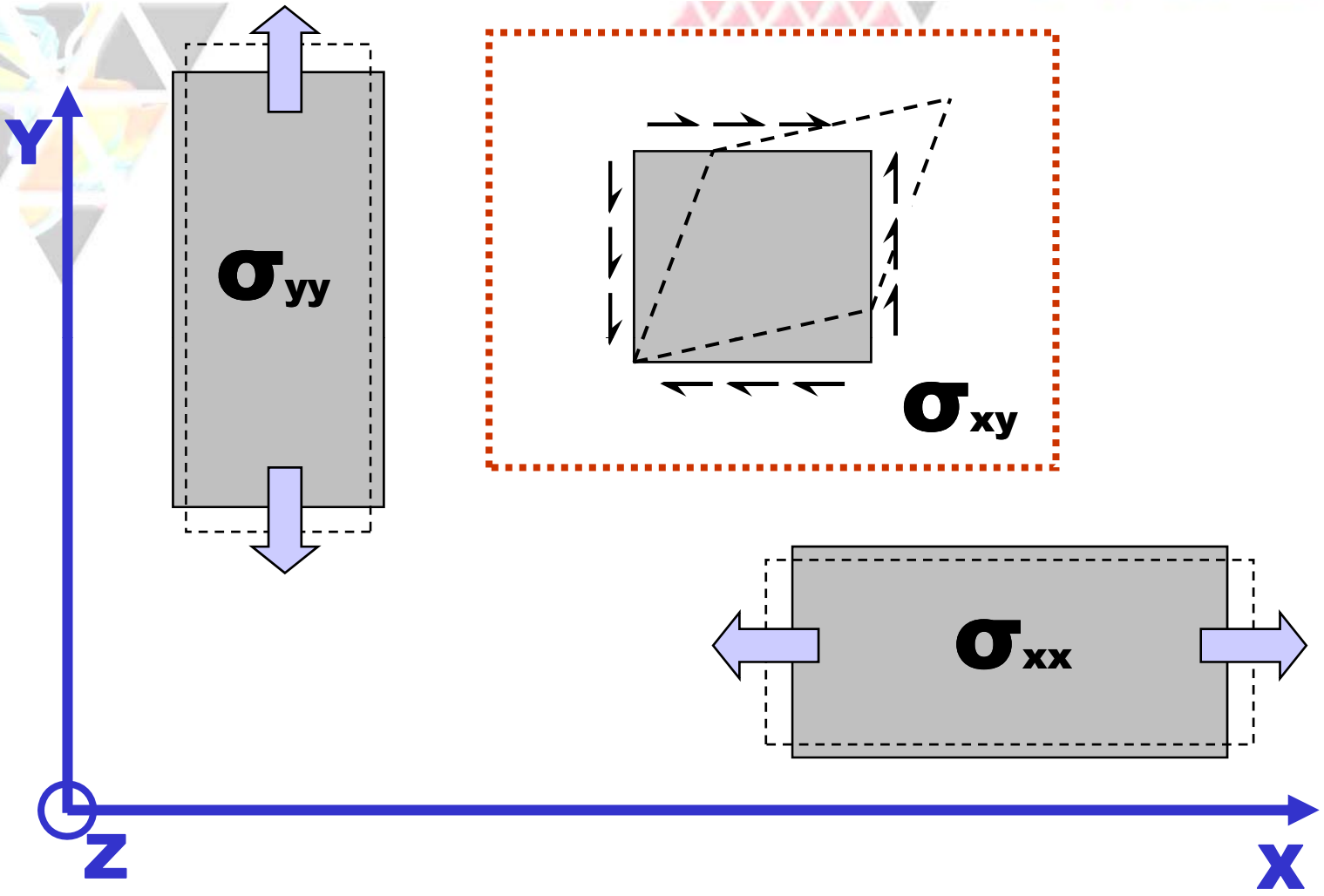
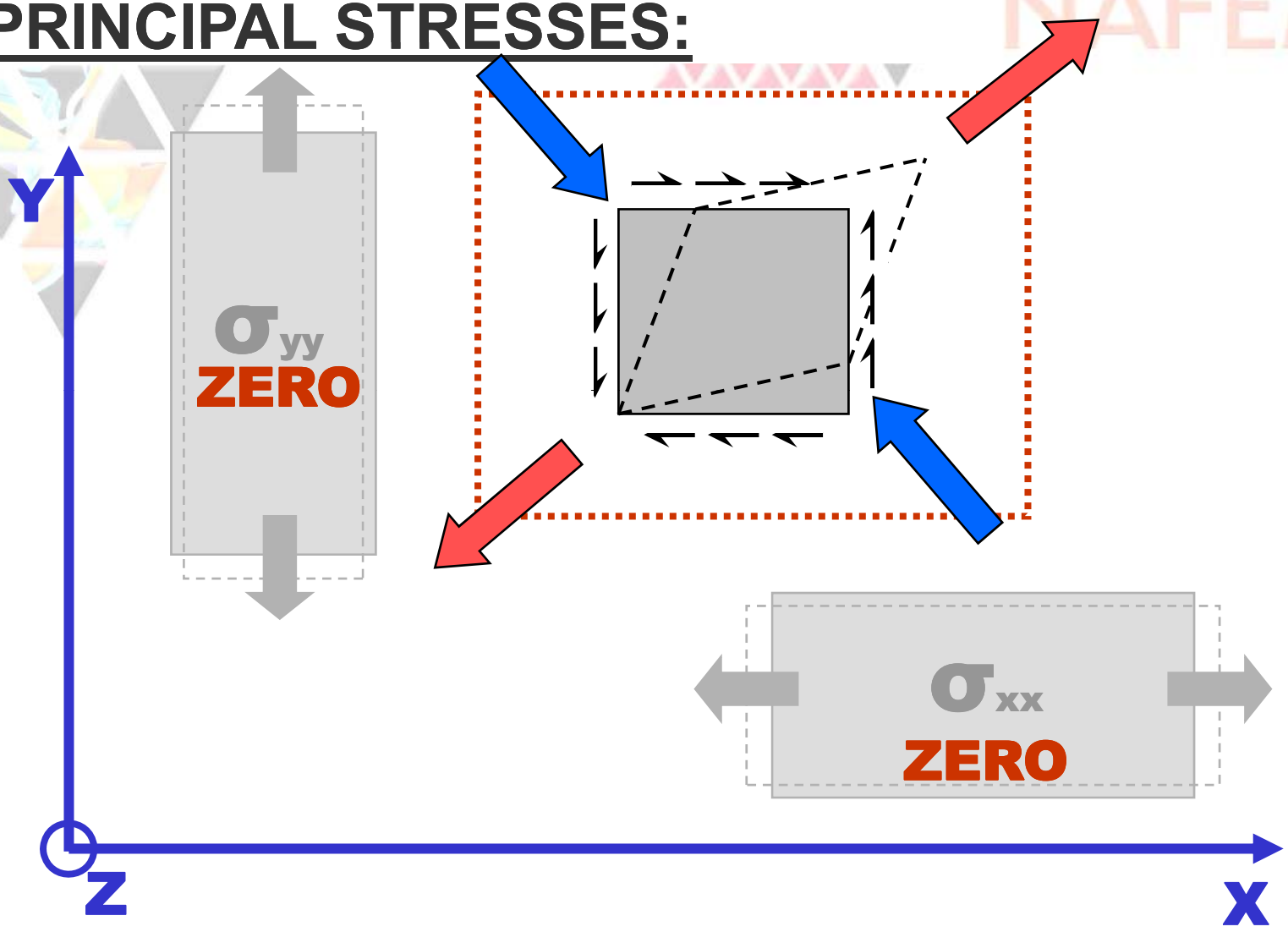
- •QUESTIONS and CLOSE



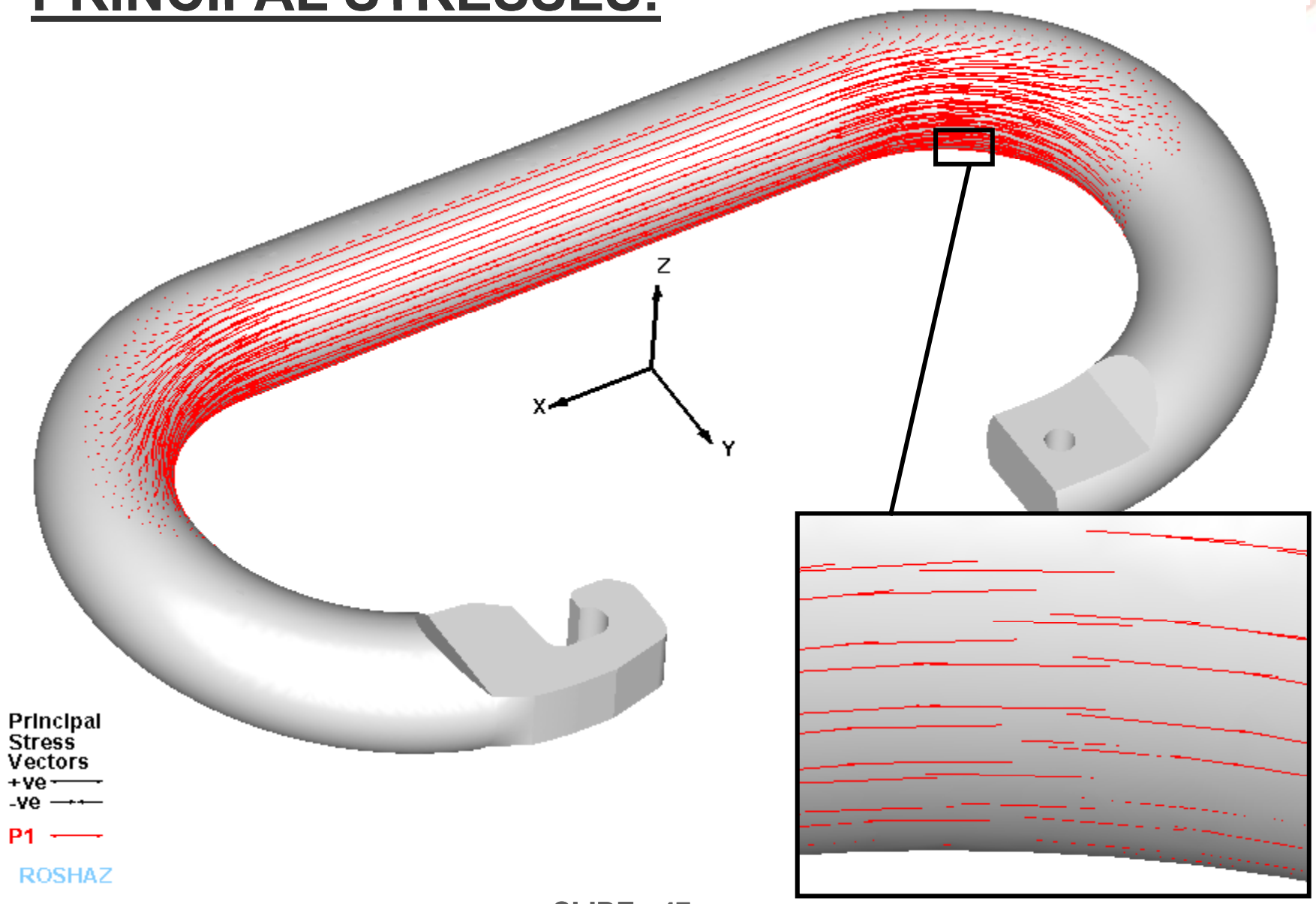
PRINCIPAL STRESSES:



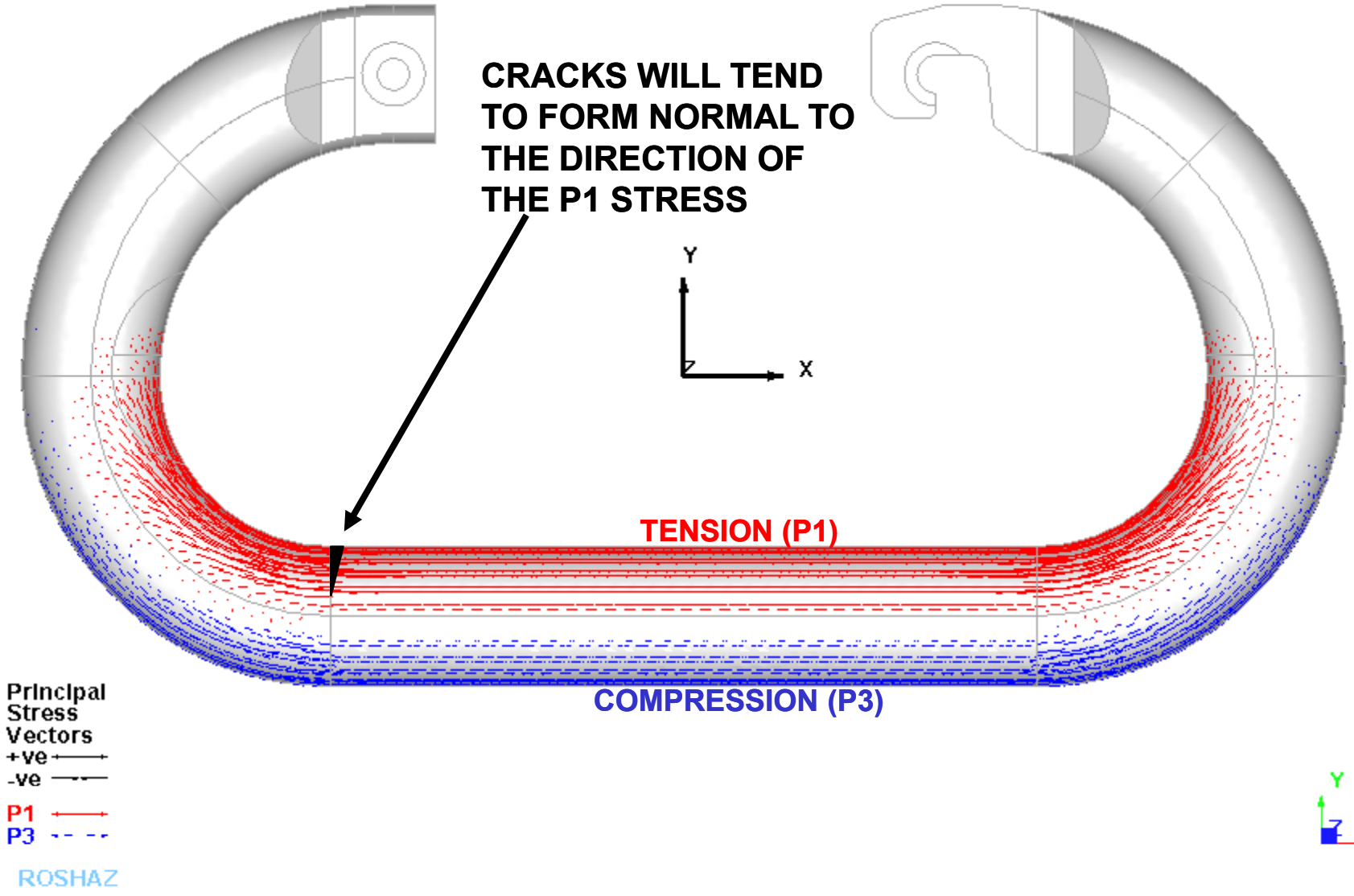
PRINCIPAL STRESSES:



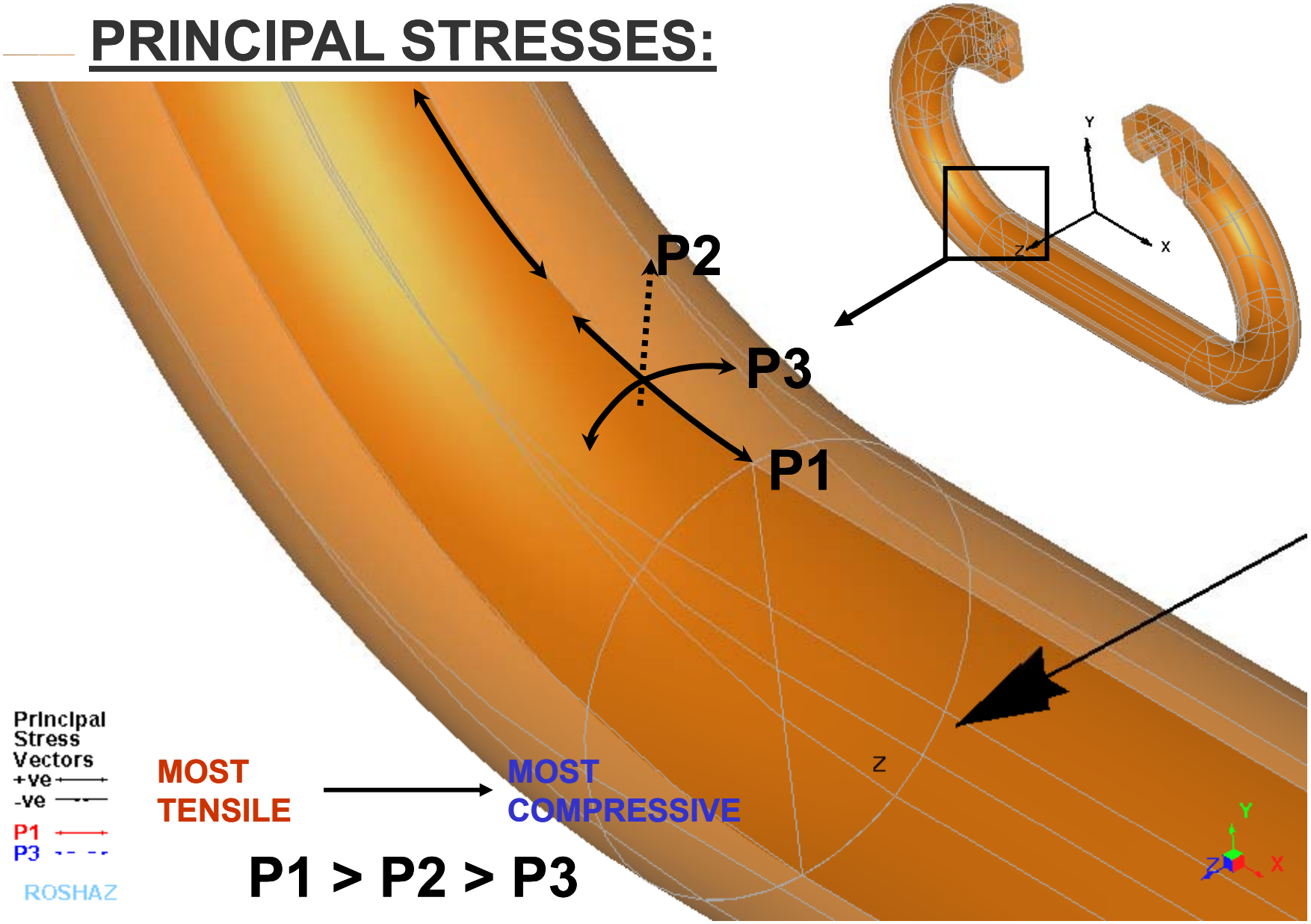
PRINCIPAL STRESSES:



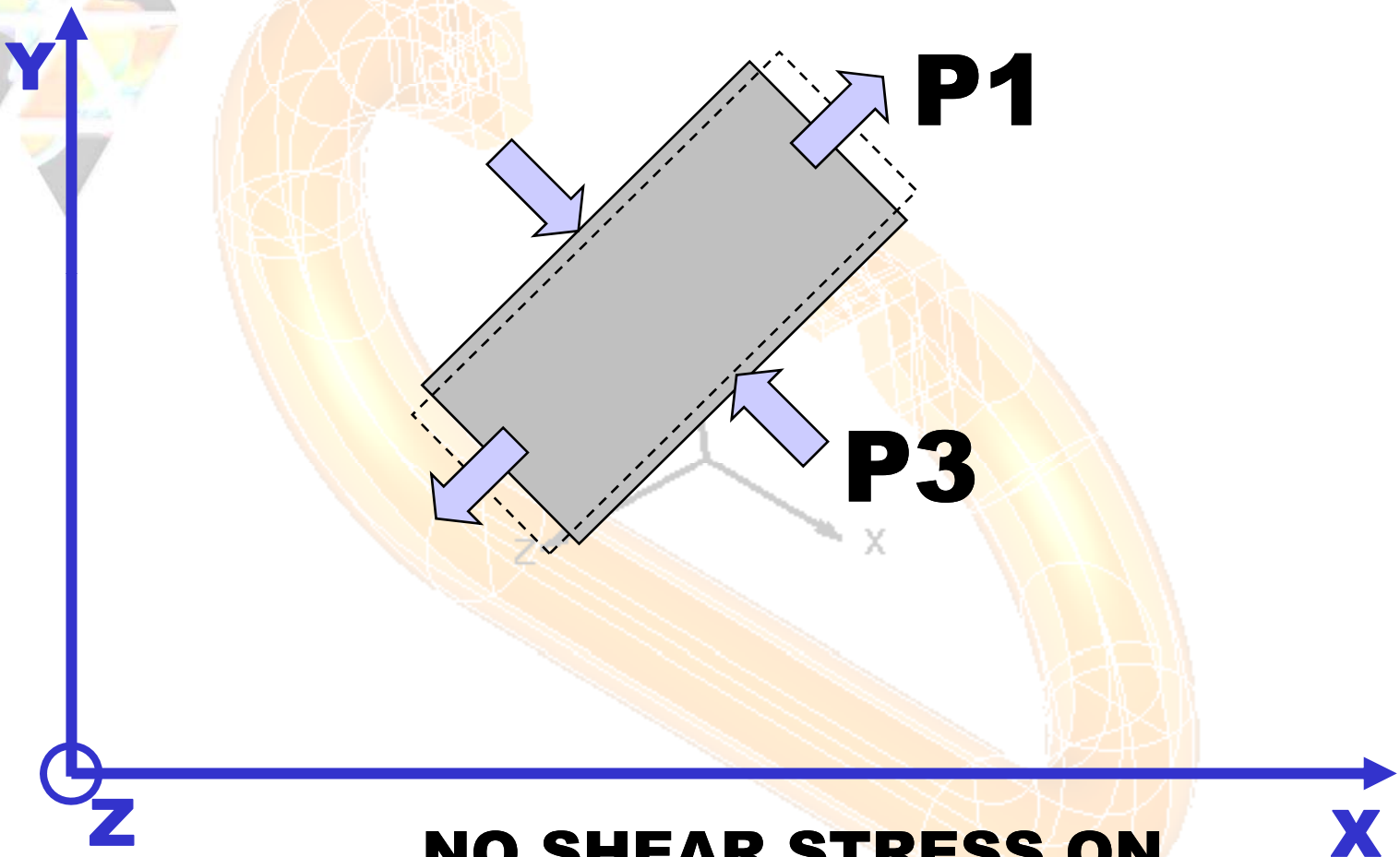
PRINCIPAL STRESSES:



PRINCIPAL STRESSES:



PRINCIPAL STRESSES:



NO SHEAR STRESS ON PRINCIPAL PLANES

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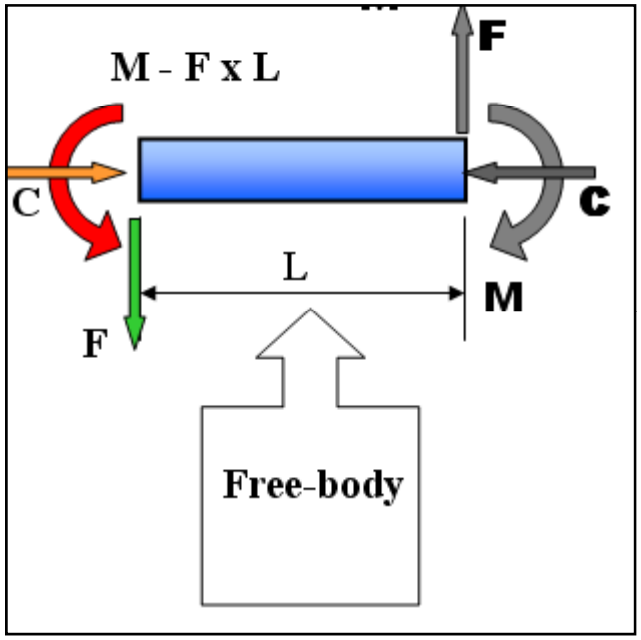
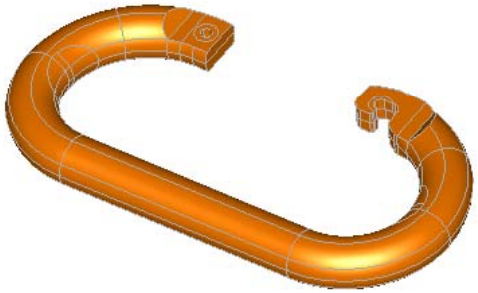
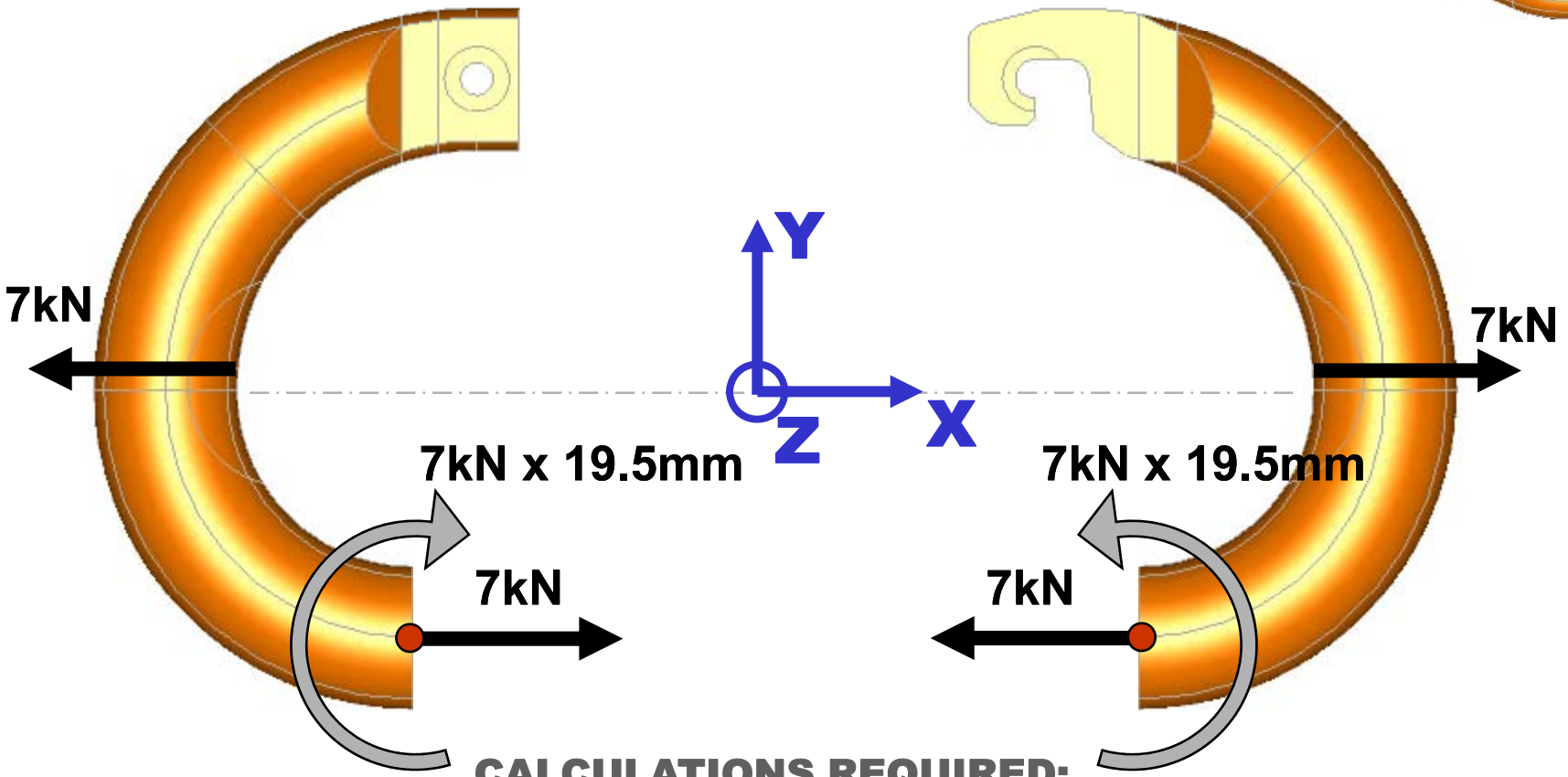


FREE-BODY DIAGRAMS:

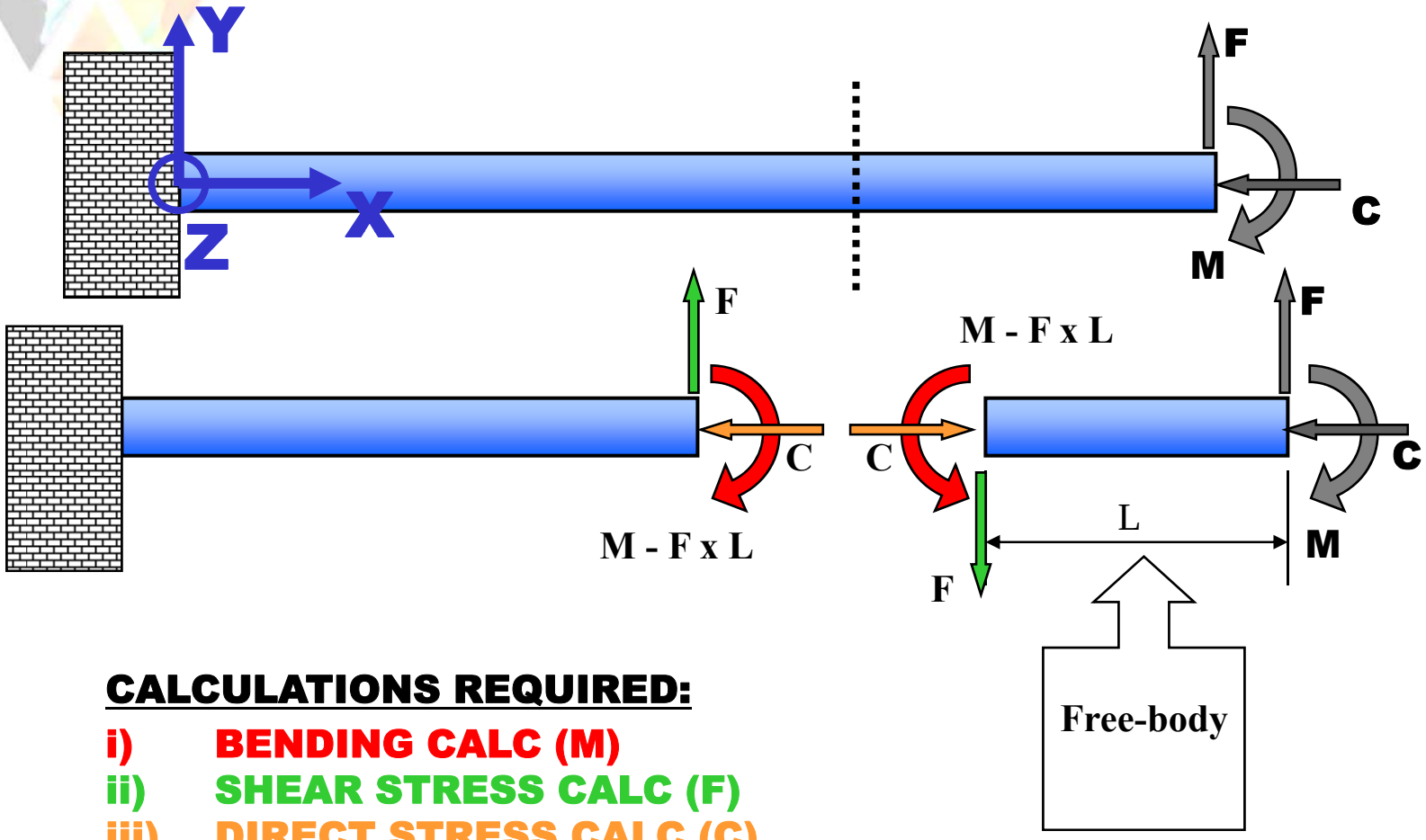




CALCULATIONS REQUIRED:

i) **BENDING CALC (M=7kNx19.5mm)**
ii) **DIRECT STRESS CALC (7kN)**

FREE-BODY DIAGRAMS:



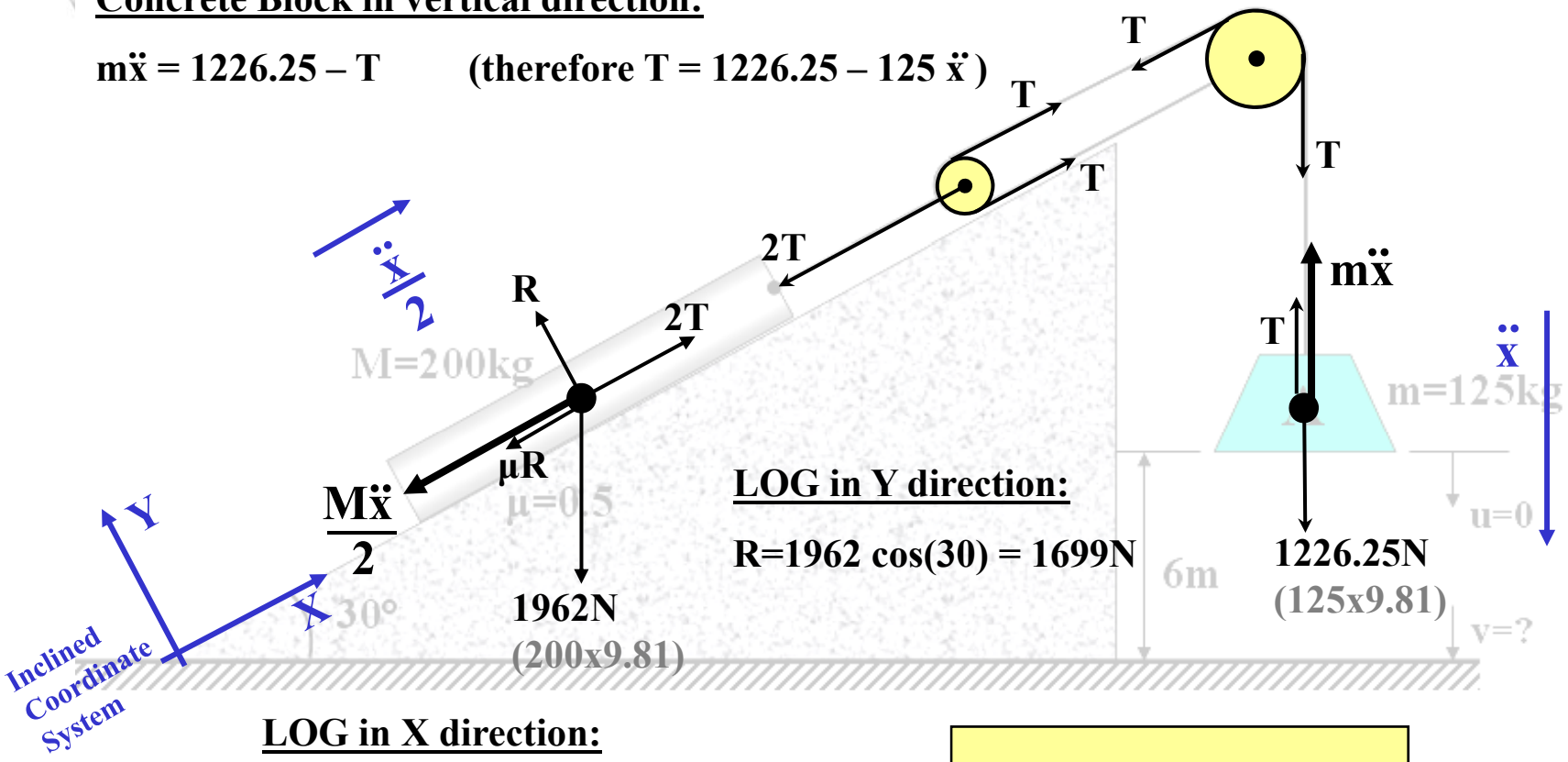
CALCULATIONS REQUIRED:

i) **BENDING CALC (M)**
ii) **SHEAR STRESS CALC (F)**
iii) **DIRECT STRESS CALC (C)**

FREE-BODY DIAGRAMS:

Concrete Block in vertical direction:

$m\ddot{x} = 1226.25 - T$ (therefore $T = 1226.25 - 125\ \ddot{x}$)



LOG in Y direction:

$R = 1962 \cos(30) = 1699N$

LOG in X direction:

$\frac{M\ddot{x}}{2} = 2T - 1962 \sin(30) - 849.5$ … > …. $\frac{M\ddot{x}}{4} = T - 490.5 - 424.75$

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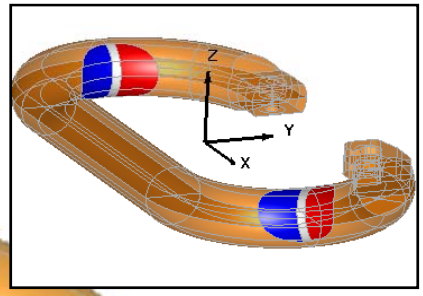
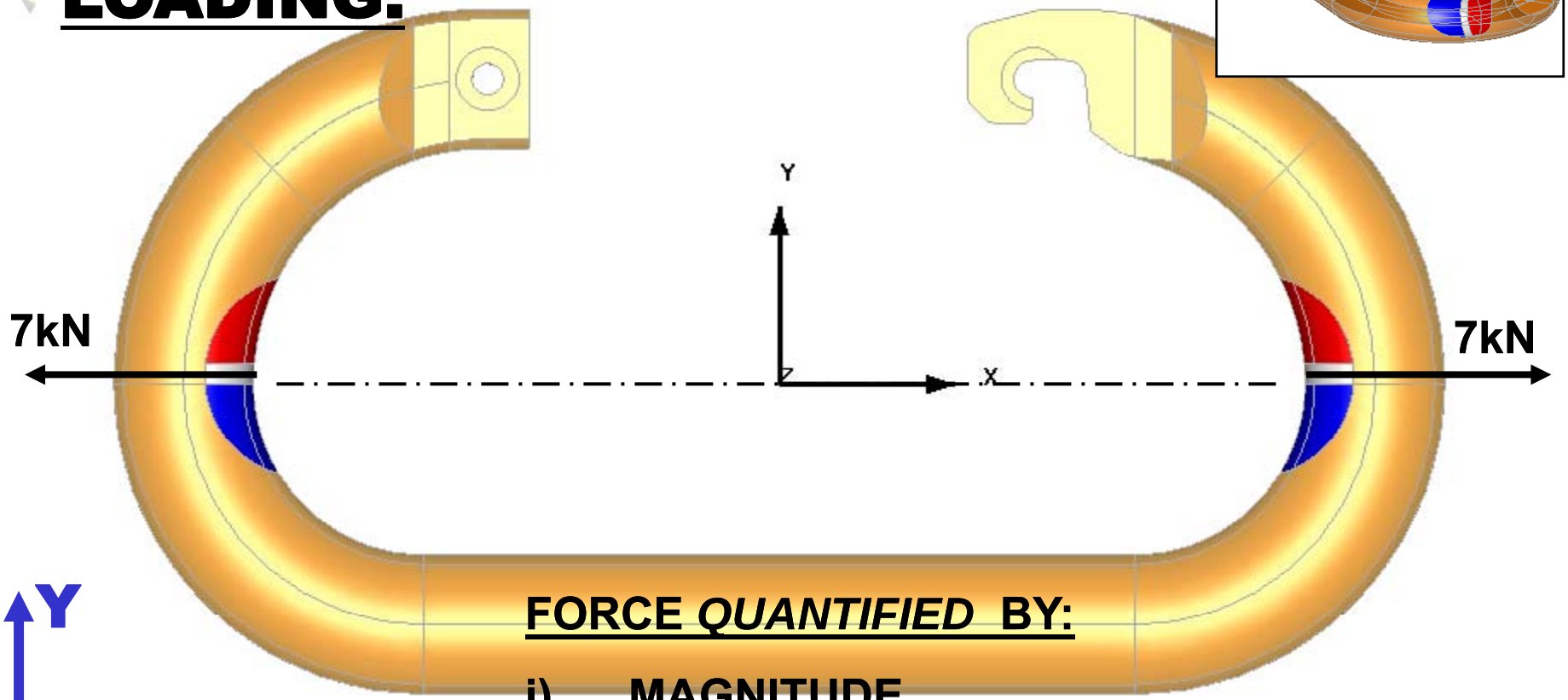
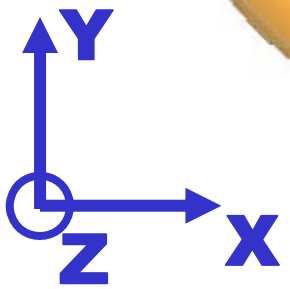
KARABINER FEA (open gate):

LOADING:







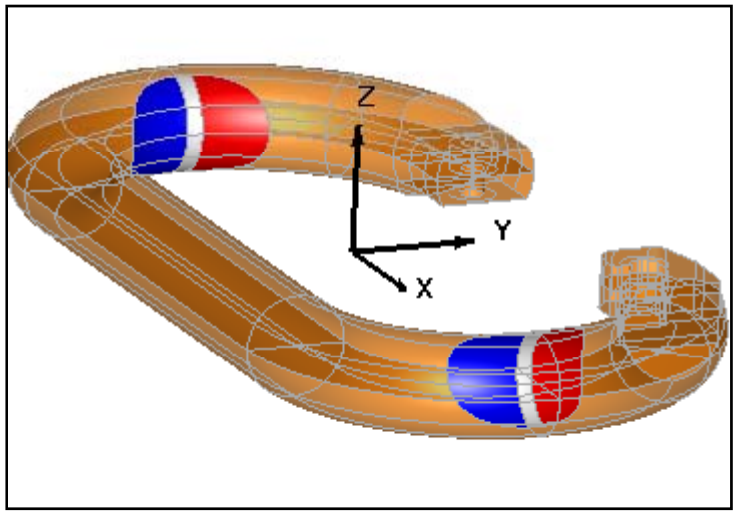
FORCE *QUANTIFIED* BY:

i) **MAGNITUDE**

ii) **DIRECTION**

iii) **POINT OF APPLICATION**

KARABINER FEA (open gate):



7kN

39.83MPa

95.58MPa

44.99MPa

Y
Z
X

ROSHAZ

FORCE *QUANTIFIED* BY:

Fx
Fy

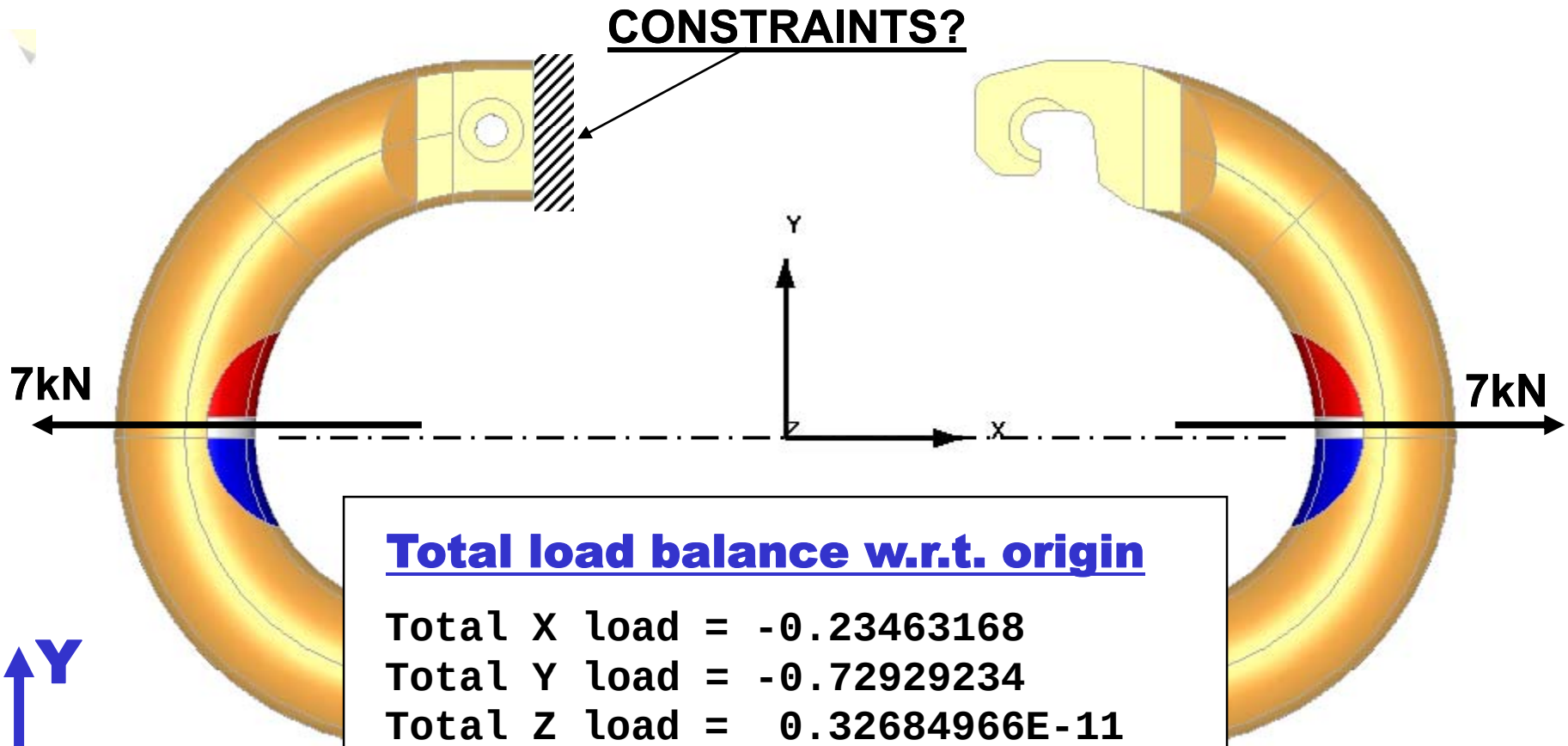
i) **MAGNITUDE**

ii) **DIRECTION**

Mz

iii) **POINT OF APPLICATION**

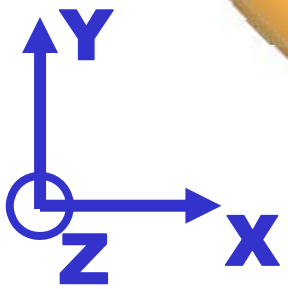
KARABINER FEA (open gate):



Total load balance w.r.t. origin

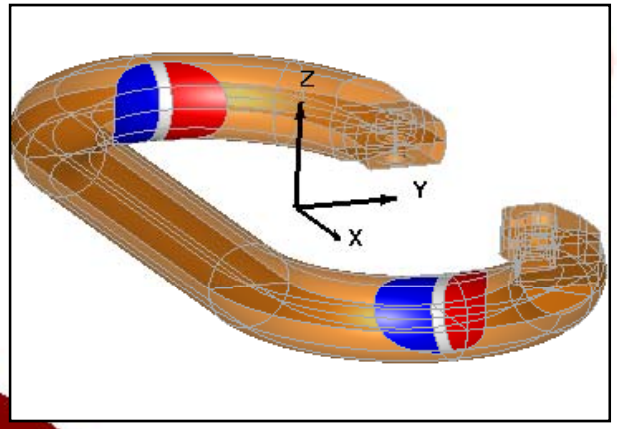
```
Total X load = -0.23463168
Total Y load = -0.72929234
Total Z load =  0.32684966E-11

Total X moment =  0.19089799E-11
Total Y moment =  0.48650861E-10
Total Z moment =   9.5877061
```



ROSHAZ

KARABINER FEA (open gate):



WITNESS MARK TO
APPLIED PRESSURES

Minimum Principal
Maximum = 47.4
Minimum = -978.0

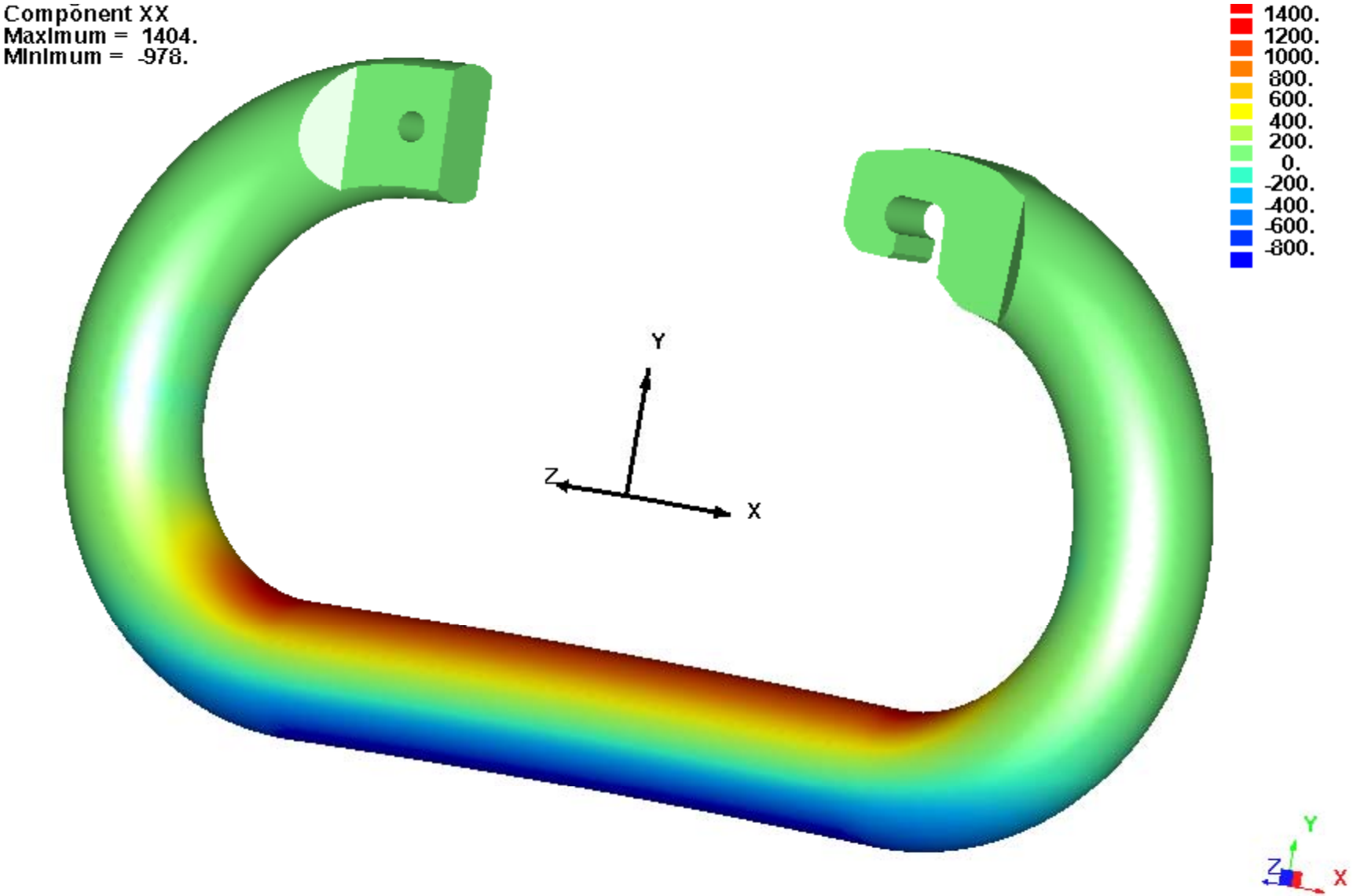
Z
Y
X

0.
-50.
-100.
-150.
-200.
-250.
-300.
-350.
-400.
-450.
-500.

ROSHAZ

Z
Y
X

KARABINER FEA (open gate):



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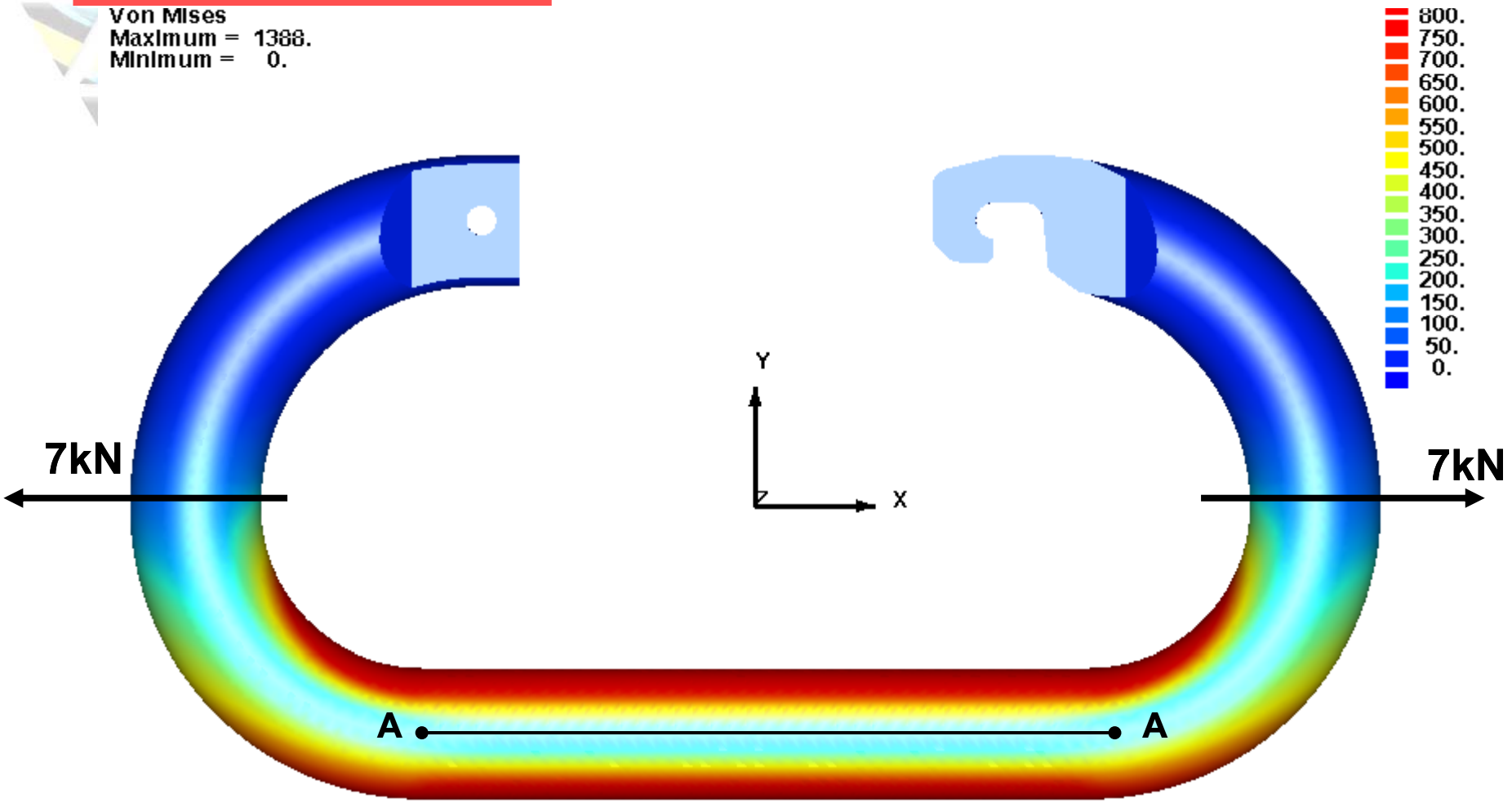
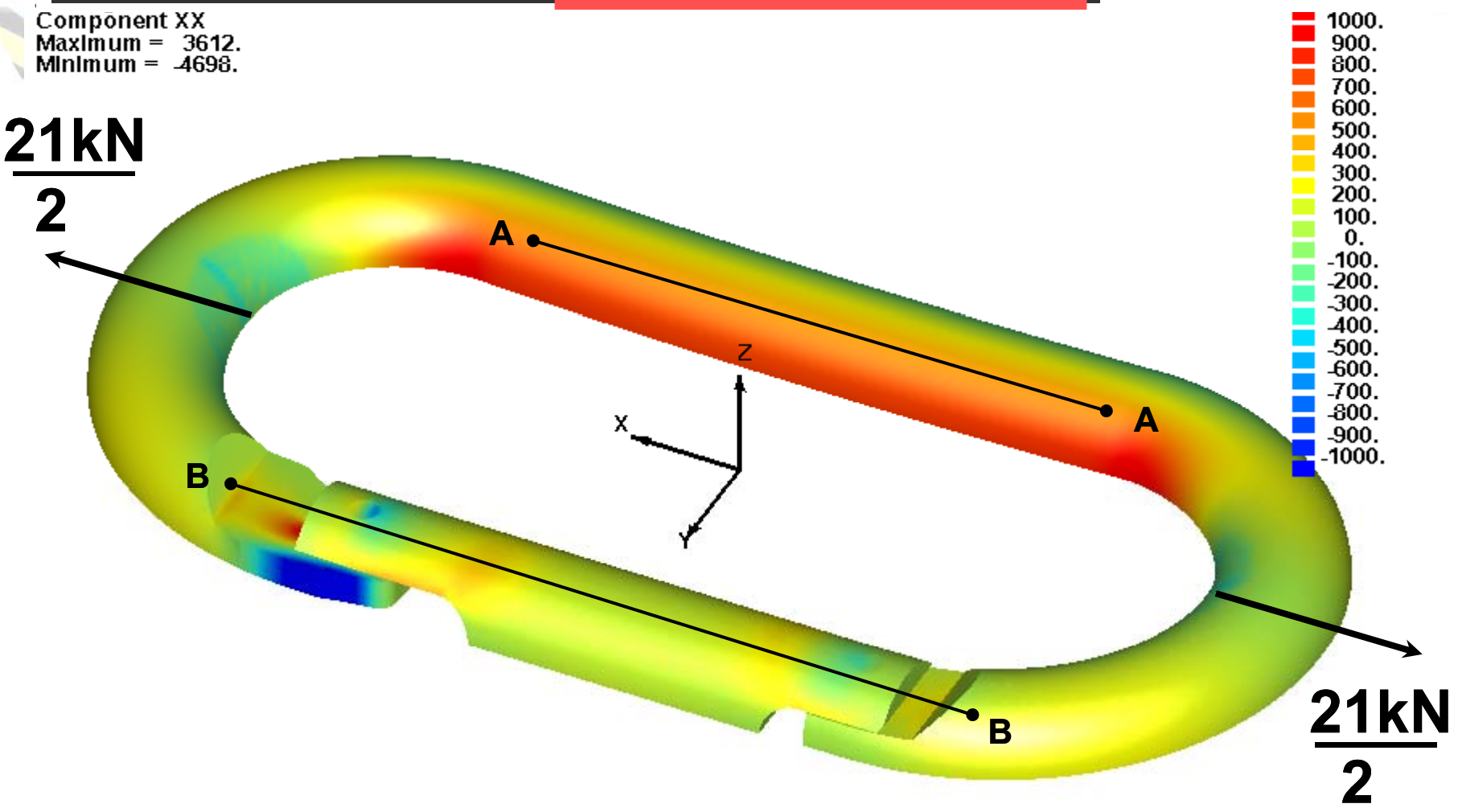
DETERMINATE or INDETERMINATE?

DETERMINATE or INDETERMINATE?



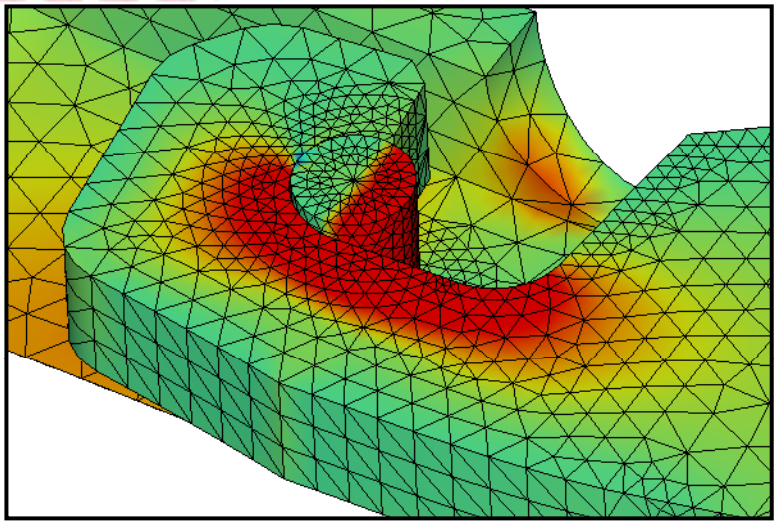
von Mises stress

DETERMINATE or INDETERMINATE?



Cartesian XX stress

CONTENTS:



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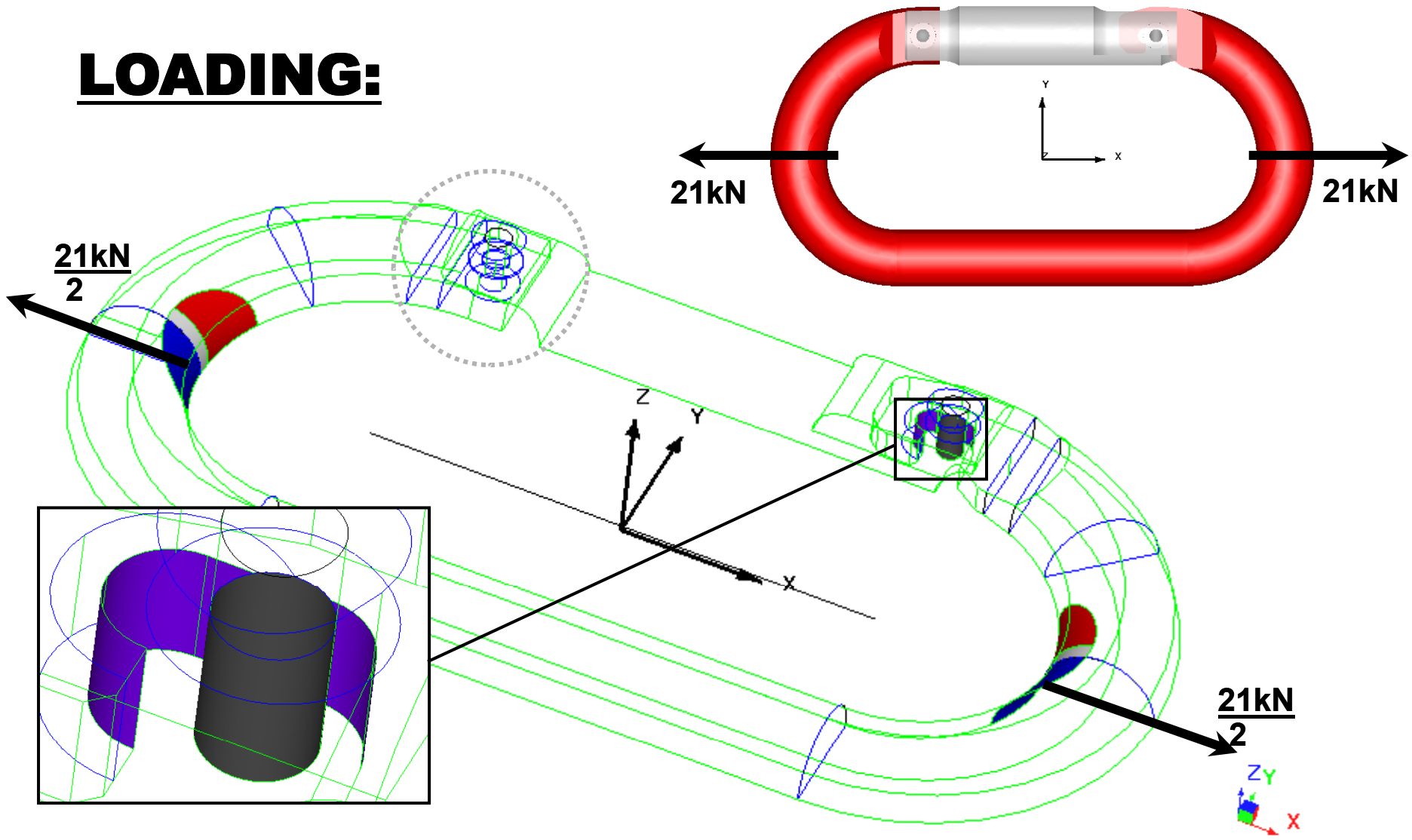
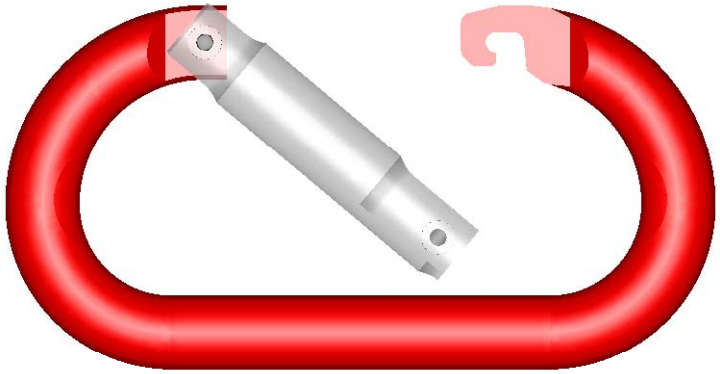
KARABINER FEA: (closed-gate)

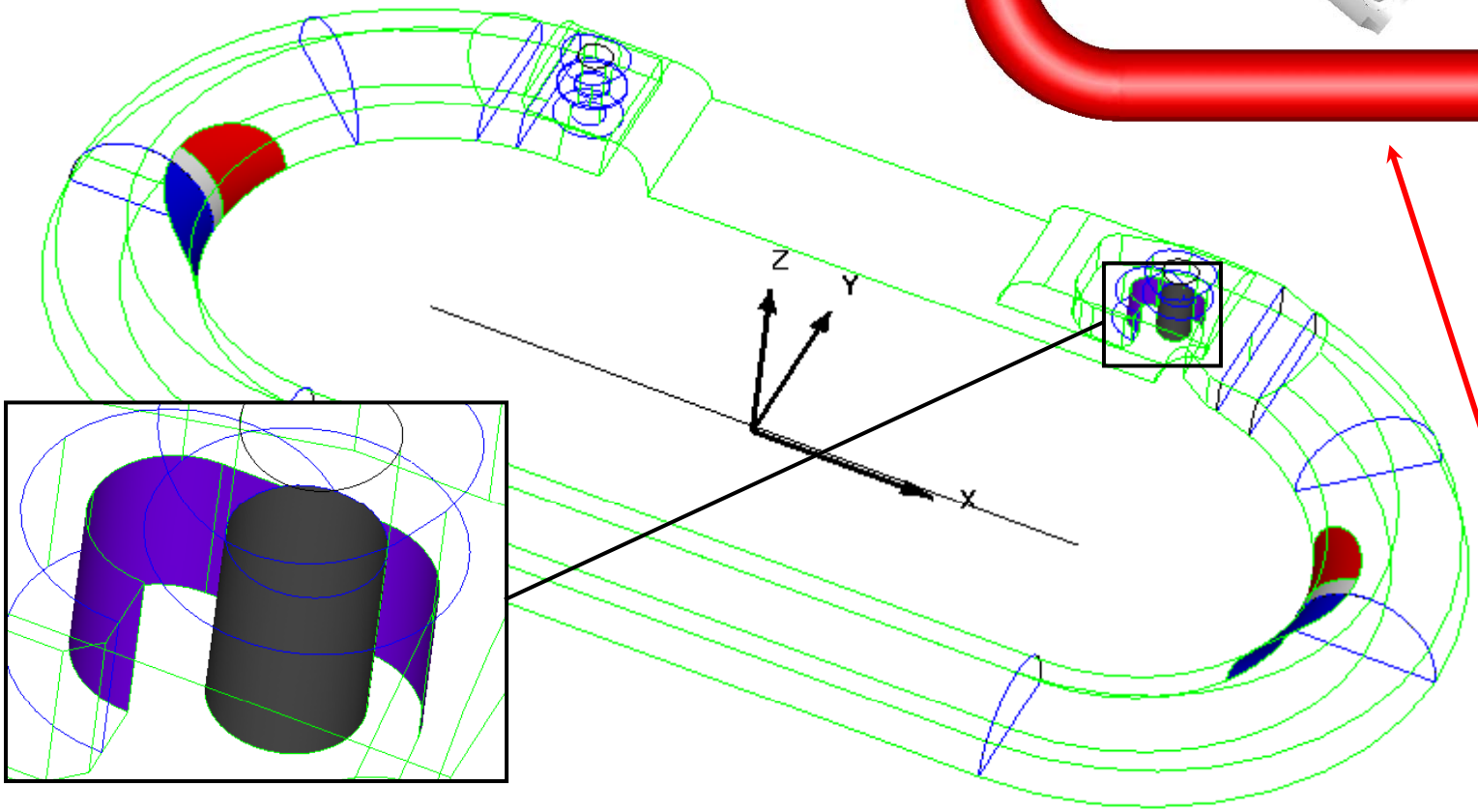
LOADING:



KARABINER FEA: (closed-gate)

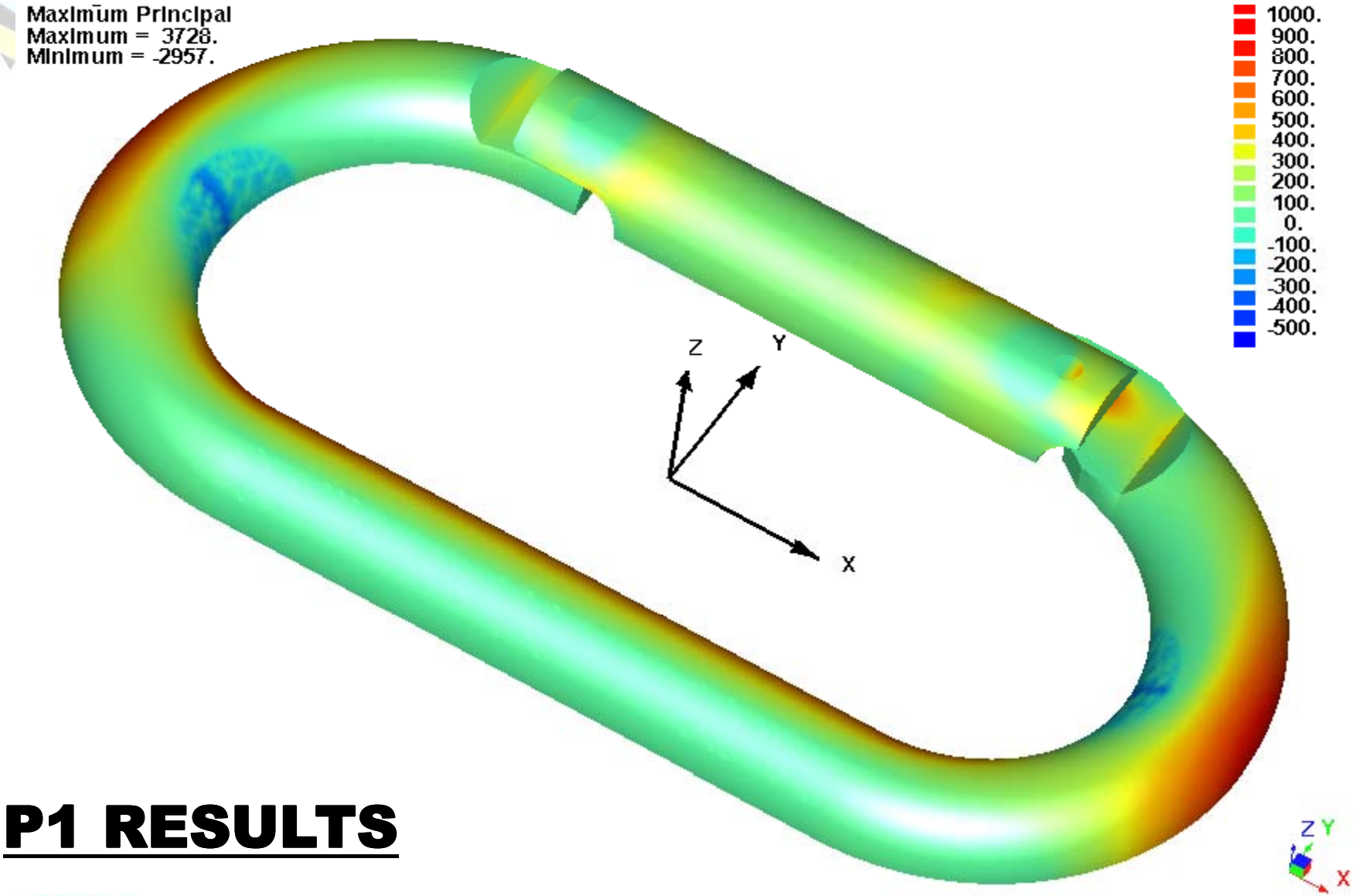
CONSTRAINTS:





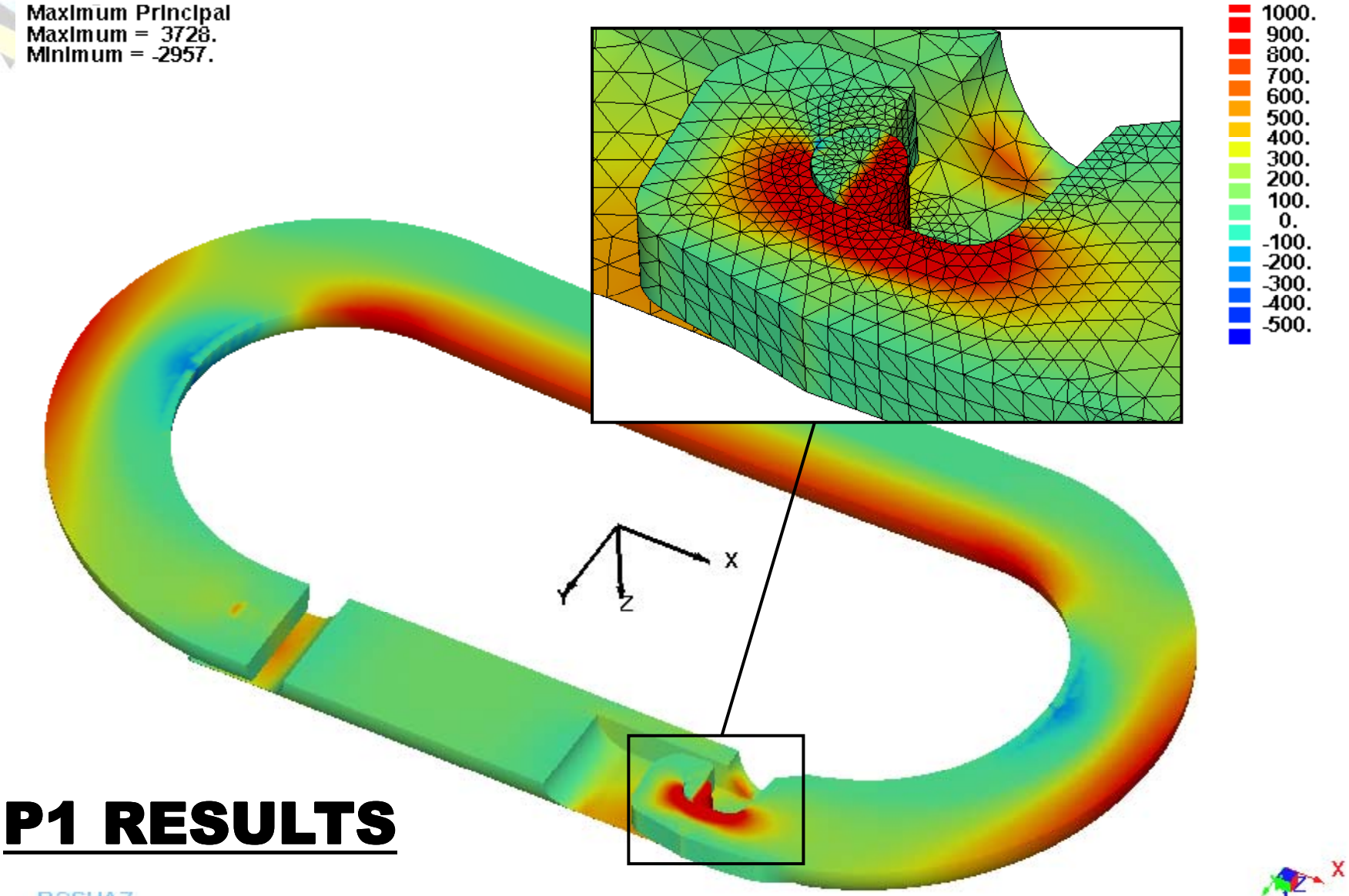
TX
TY
TZ
RX
RY
RZ

KARABINER FEA: (closed-gate)



P1 RESULTS

KARABINER FEA: (closed-gate)



P1 RESULTS

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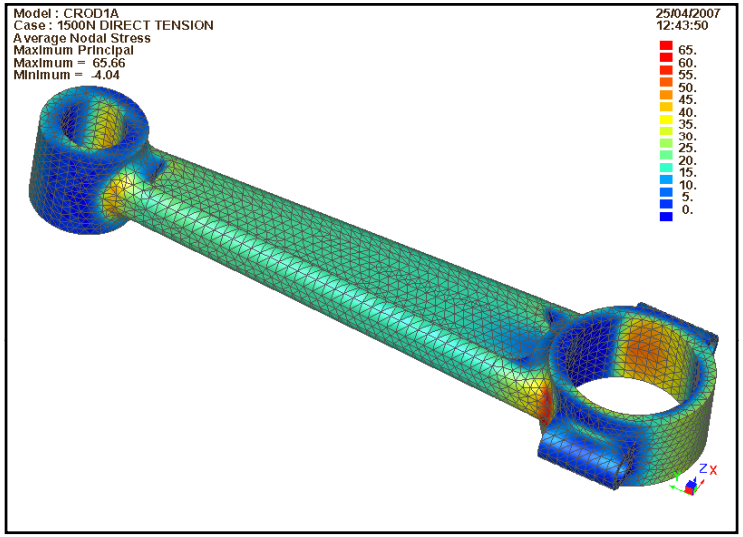

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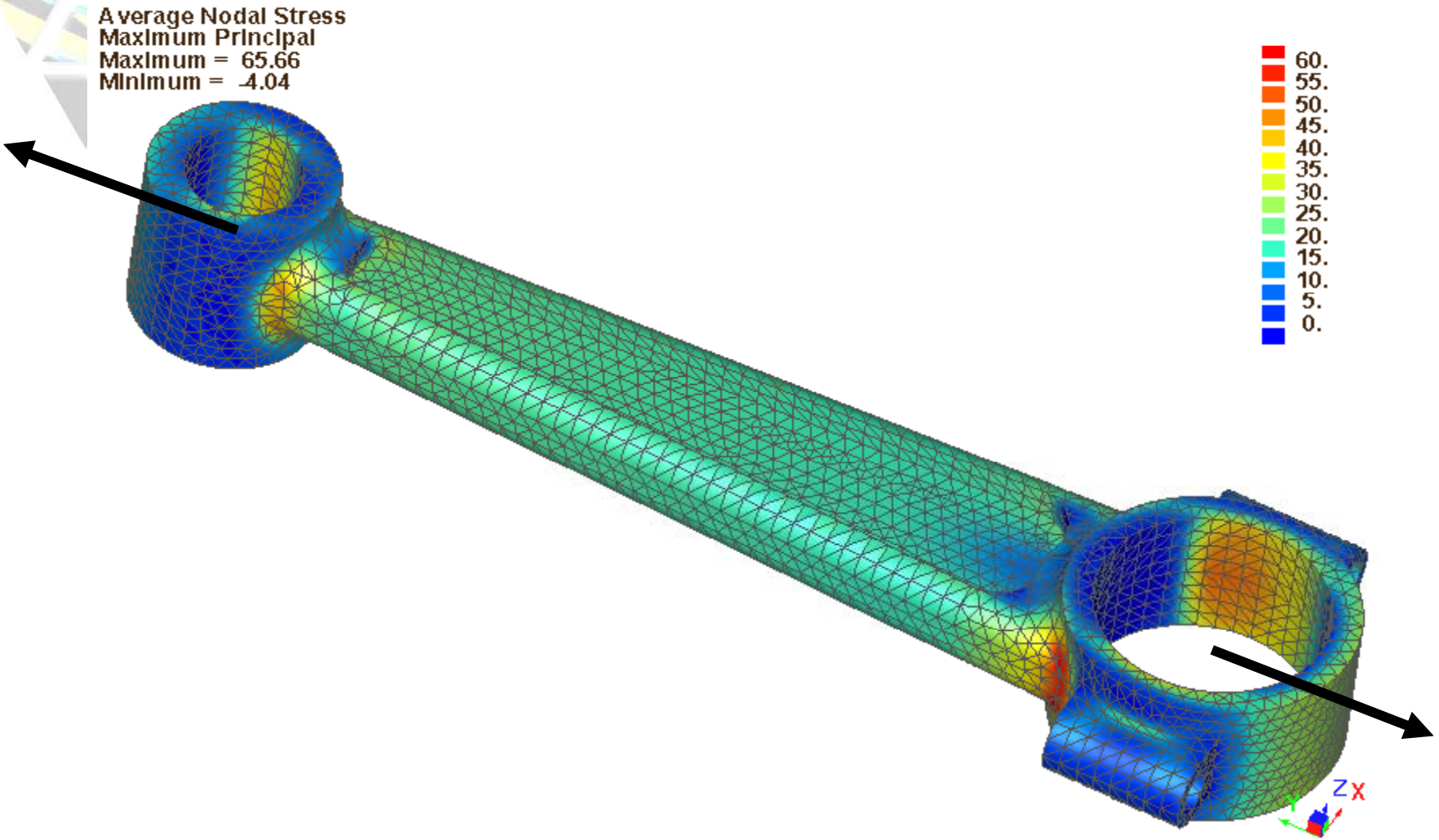
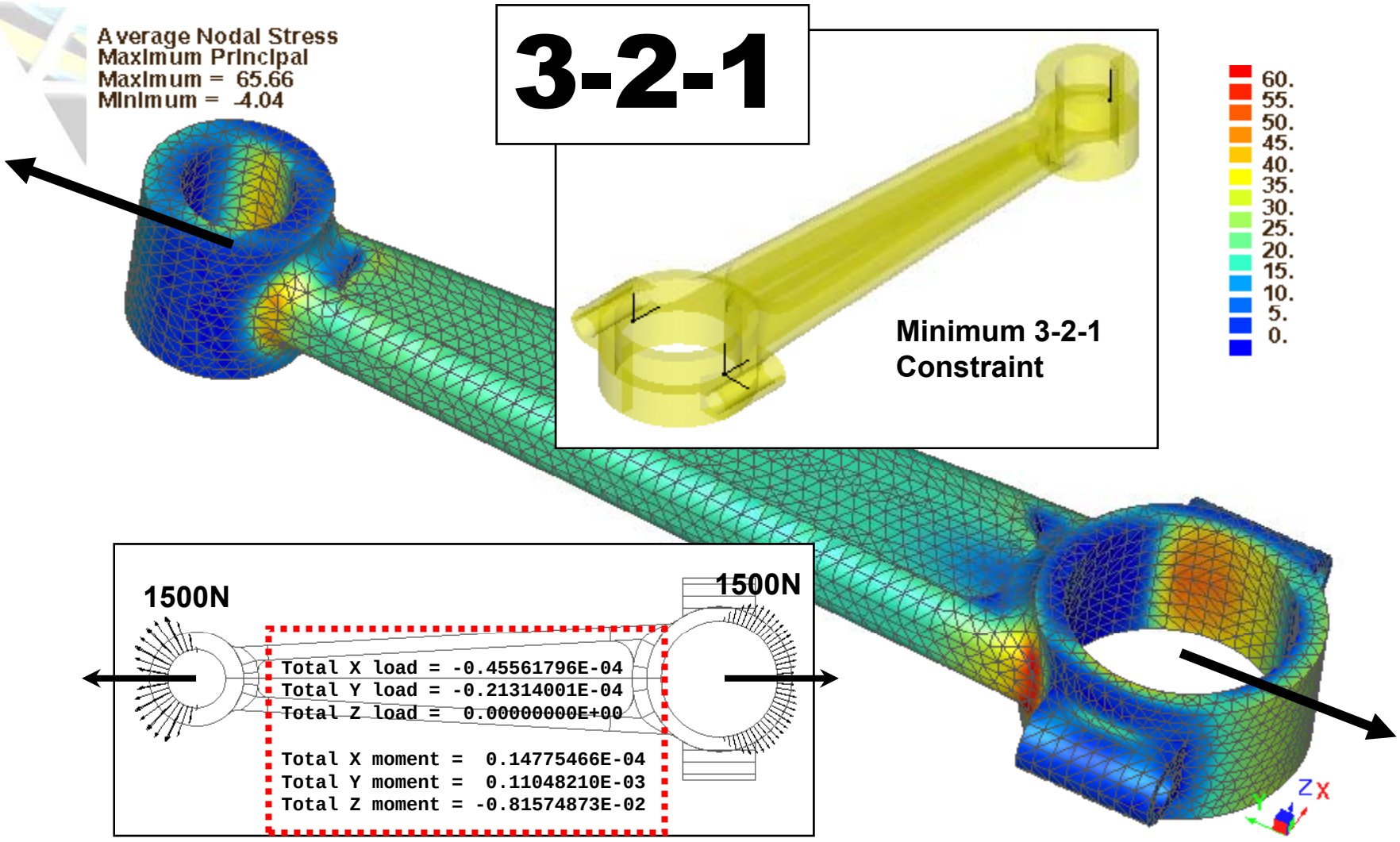
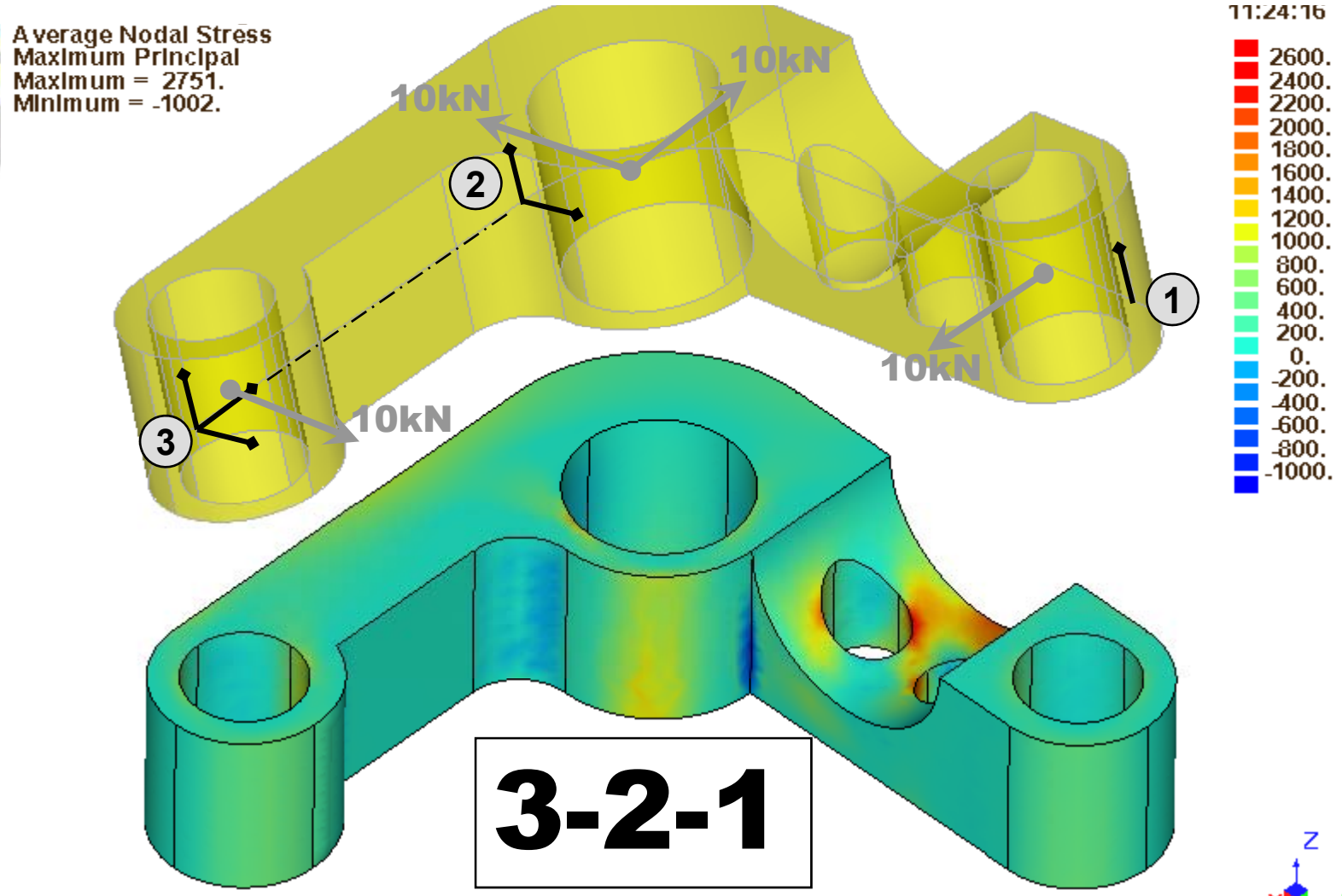
MINIMAL CONSTRAINT METHODS IN FEA:



MINIMAL CONSTRAINT METHODS IN FEA:

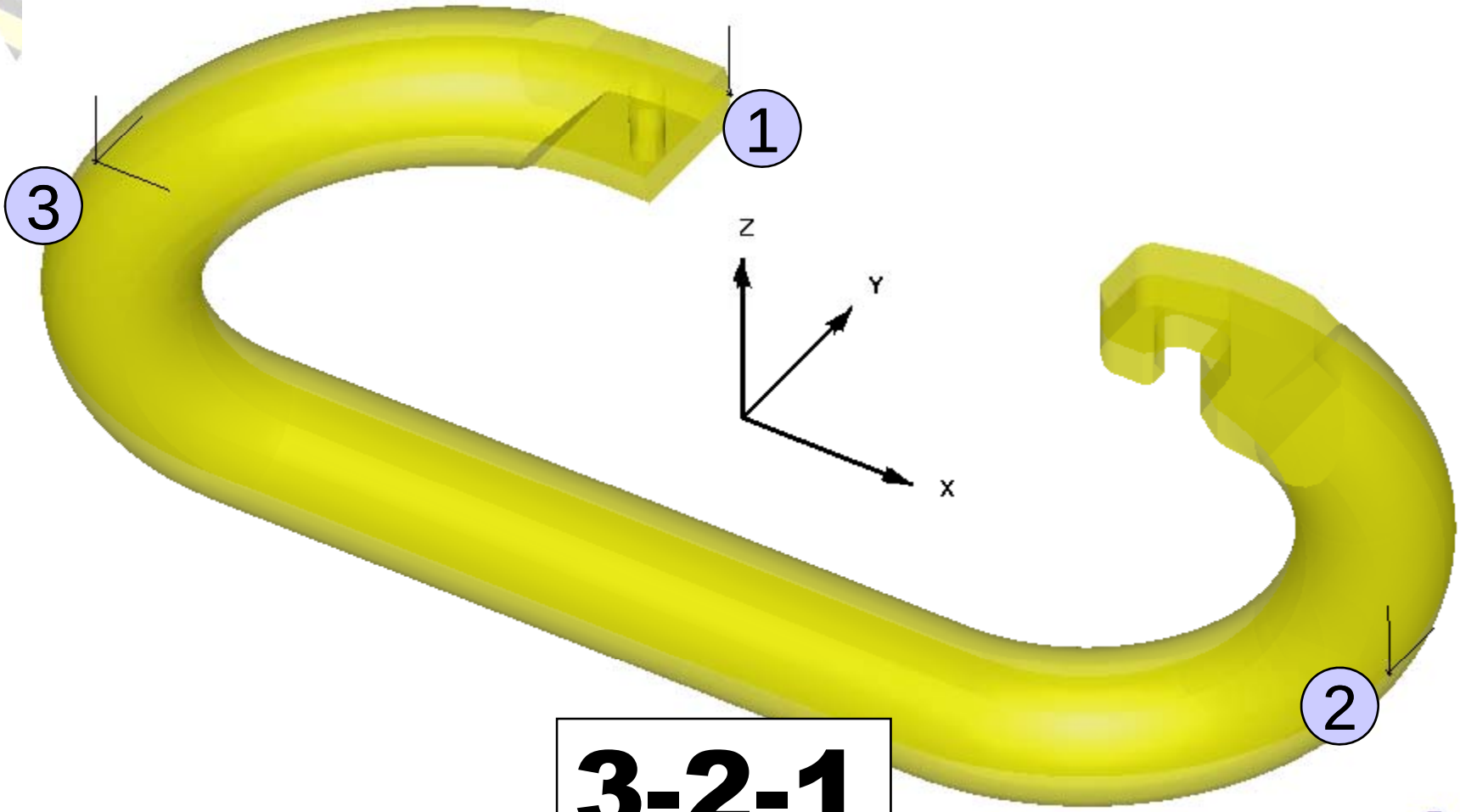


MINIMAL CONSTRAINT METHODS IN FEA:



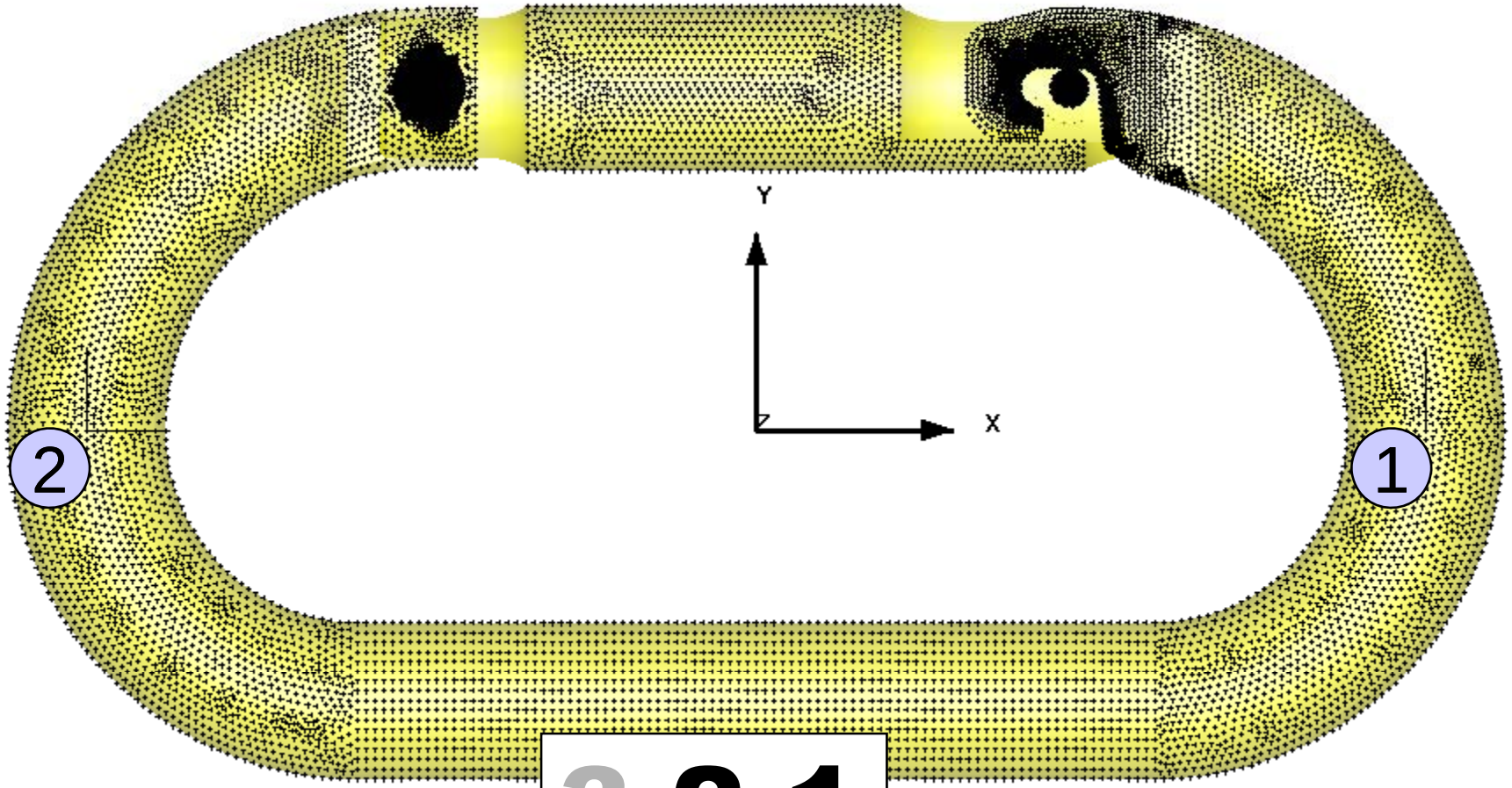
Balanced Loading and Minimum Constraint in 3D – Crank

MINIMAL CONSTRAINT METHODS IN FEA:



Balanced Loading and Minimum Constraint in 3D – Full model of Karabiner

MINIMAL CONSTRAINT METHODS IN FEA:



Balanced Loading and Minimum Constraint in 3D – Half model of Karabiner

ROSHAZ

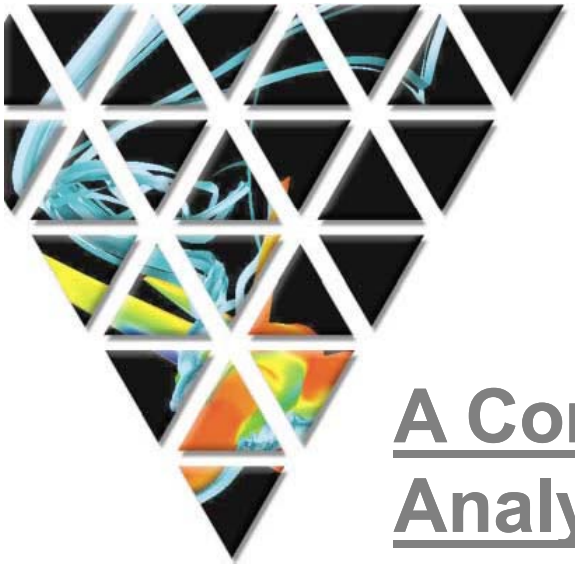
MINIMAL CONSTRAINT METHODS IN FEA:

No Symmetry	1 plane of symmetry	2 planes of symmetry	3 planes of symmetry
Balanced Loading	Balanced Loading	Balanced Loading	Balanced Loading
3-2-1	**3-2-1** *(2D Plane Stress/Strain)*	**3-2-1** *(2D Axi-symmetric)*	**3-2-1**
6 global freedoms	3 global freedoms	1 global freedom	0 global freedoms

A Common-Sense Approach to Stress Analysis and Finite Element Modelling

Aims:

- Achieve a modern-day balance between hand calcs and FEA
- Provide a number of “must-have” formulas for stress analysis
- Provide a summary of the technique of Free-Body Diagrams
- Practical advice for best use of FEA for realistic solutions
- Constraints that gives minimal support & worst-case stresses



A Common-Sense Approach to Stress Analysis and Finite Element Modelling

A NAFEMS Webinar organised by Matthew Ladzinski of NAFEMS Limited (North America).

Matthew.Ladzinski@NAFEMS.Org

Presented by Bob Johnson BSc MSc NRA MIMechE CEng
DAMT Limited, UK

bj@damt.co.uk

DESIGN
ANALYSIS
MODELLING
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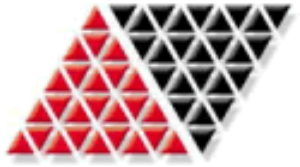

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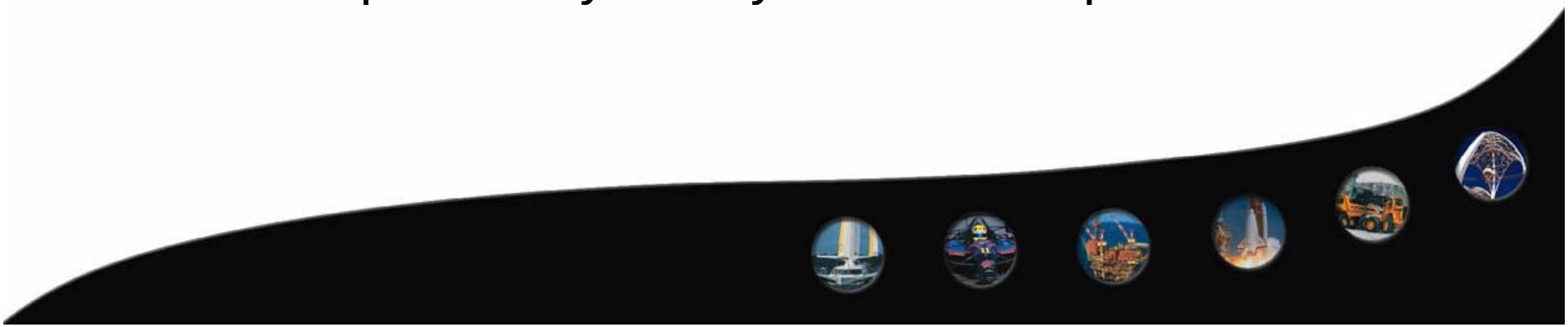
Q&A Session

Using the Q&A tool, please submit any questions you may have for our panel.



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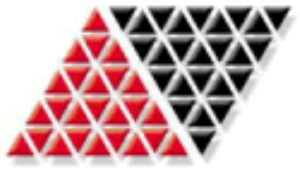

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Thank you!

matthew.ladzinski@nafems.org