
„Laser-FALCONEYE" holographic gauge-camera
sees DEFORMATION
and visualizes
STRESS
DISTRIBUTION
Extra
STRESS DISTRIBUTION
EXAMPLES
by digital-holographic interferometry

If you are interested, we would like to invite you to a personal TEA to our development laboratory!

(because, in our experience,
only on an interactive dicourse
is possible to confront
the new measurement needs
and the new opportunities)

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REFERENCES

(customers or cooperating partners at the following measurements)

FÉMALK

KÖMÉRŐ

bay Bay Zoltán Alkalmazott Kutatási Közhasznú Nonprofit Kft.

Budapesti Műszaki és Gazdaságtudományi Egyetem
HIDAK ÉS SZERKEZETEK TANSZÉK

WIGNER

TRAMPUS MÉRNÖKIRODA

RÁBA

MOL

eCon ENGINEERING

PRÍMAGÁZ

SIEMENS

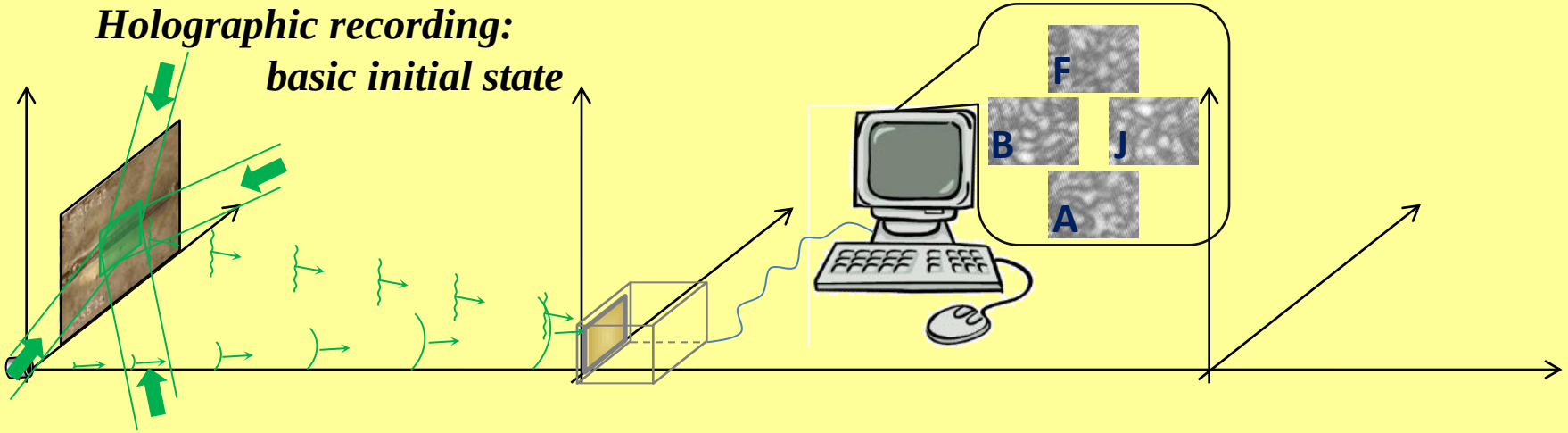
att ANYAGTUDOMÁNY ÉS TECHNOLÓGIA TANSZÉK
Budapesti Műszaki és Gazdaságtudományi Egyetem

MŰEGYETEM 1782
BUDAPESTI MŰSZAKI ÉS GAZDASÁGTUDOMÁNYI EGYETEM
GÉPÉSZMÉRNÖKI KAR
POLIMERTECHNIKA TANSZÉK

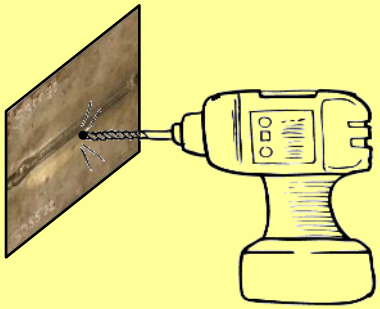
MISKOLCI EGYETEM
UNIVERSITY OF MISKOLC

ANYAGSZERKEZETTANI ÉS ANYAGTECHNOLÓGIAI INTÉZET

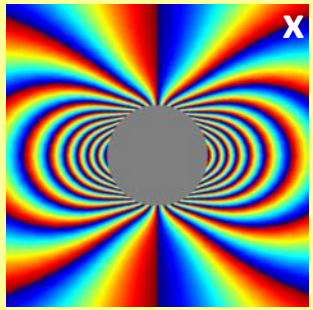
Holographic recording:
basic initial state

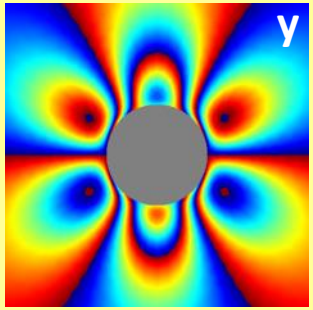


LOADING: blind-hole-drilling

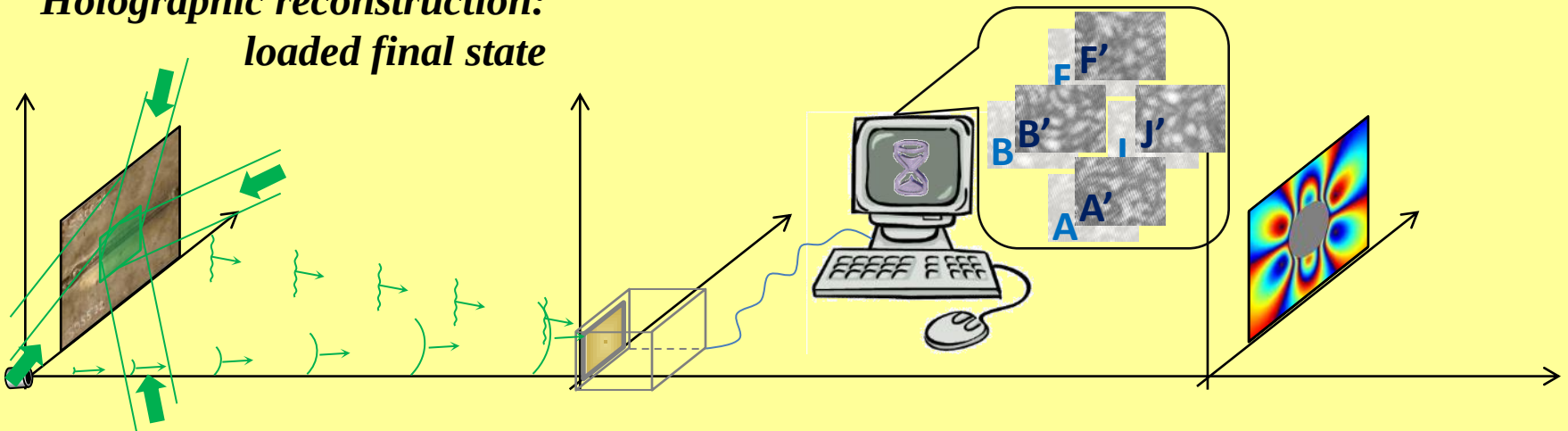


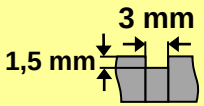
Residual stress measurement steps
- to illustrate
holographic interferometric
stress measurement

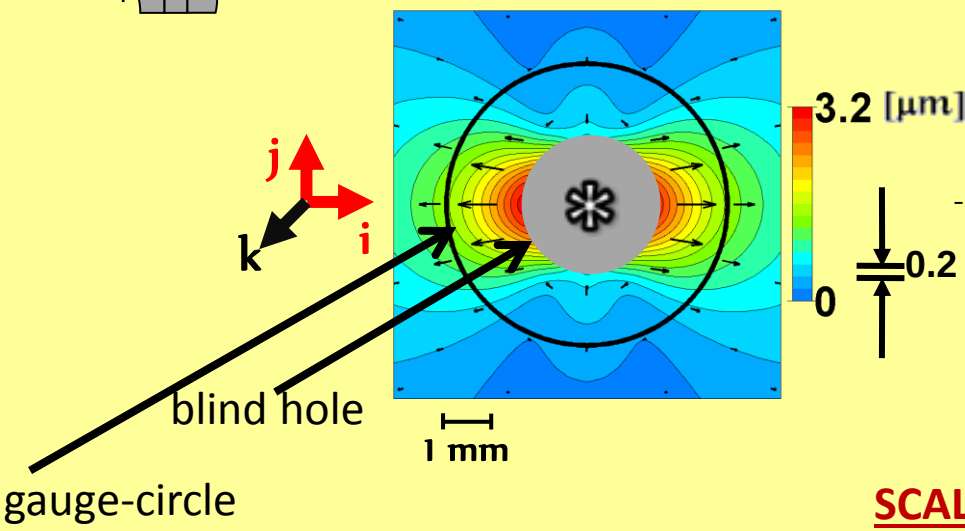


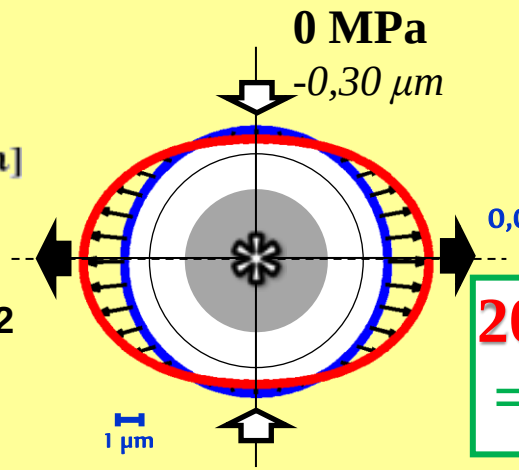


Holographic reconstruction:
loaded final state









deformation of gauge-circle into ellipse

200 MPa =
= 1,36 µm

SCALLING **(to stress)**

- or by **empirical** scale:
  obtained by a tensile machine
- or by **simulated** scale:
  by finite element modeling

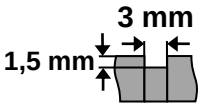
Residual stress measurement steps - to illustrate holographic interferometric stress measurement

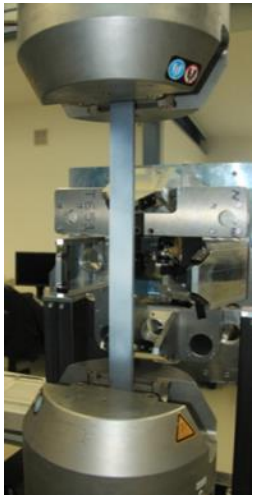
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/C. *Properties accessible from STRESS (DISTRIBUTION) CHANGE*

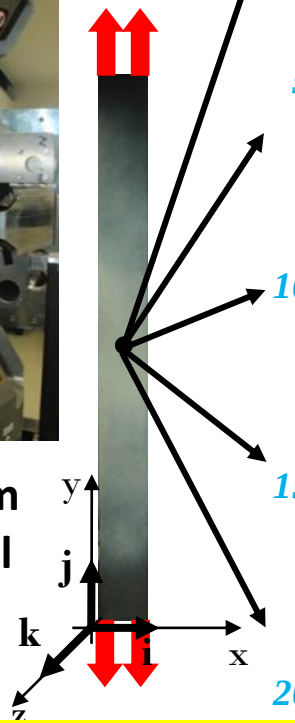
1. Actually formed stresses

1.1. LOAD-CARRYING CAPACITY

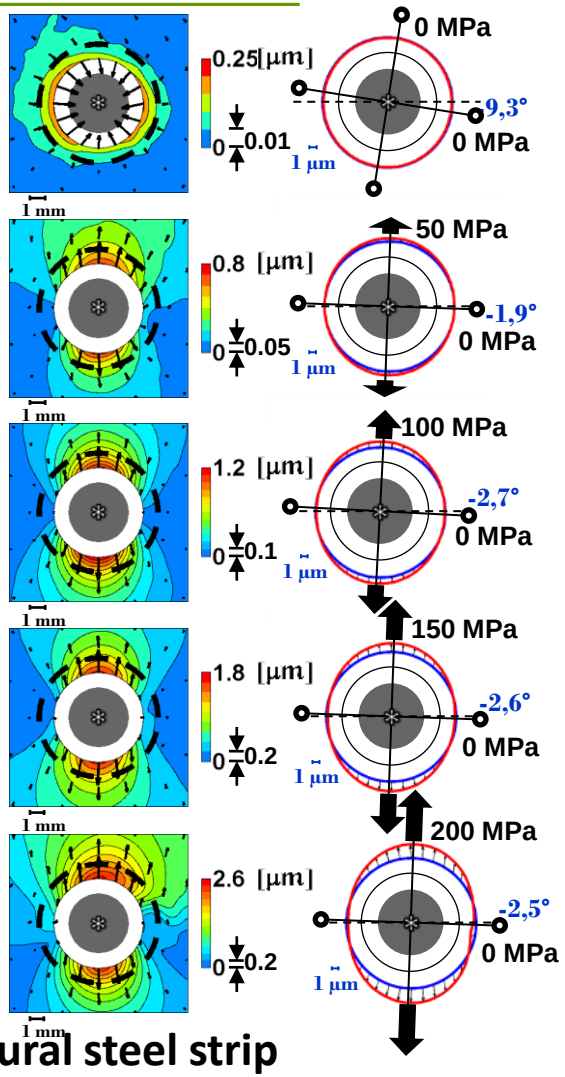




Strees from a universal testing machine



Stress following with a single drill-hole



Tensile stress change of a structural steel strip
- under load of tensile strength measurement

a. Empiric stress scale of structural steel

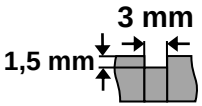
Stress increases correspondingly to the load

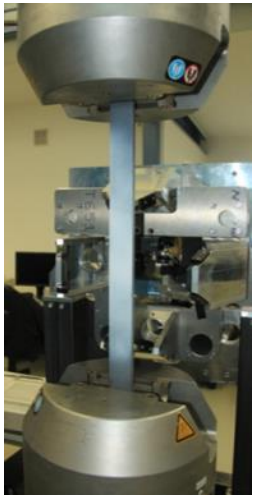
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/C. *Properties accessible from STRESS (DISTRIBUTION) CHANGE*

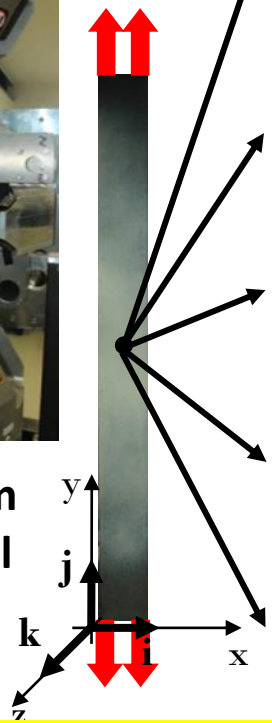
1. Actually formed stresses

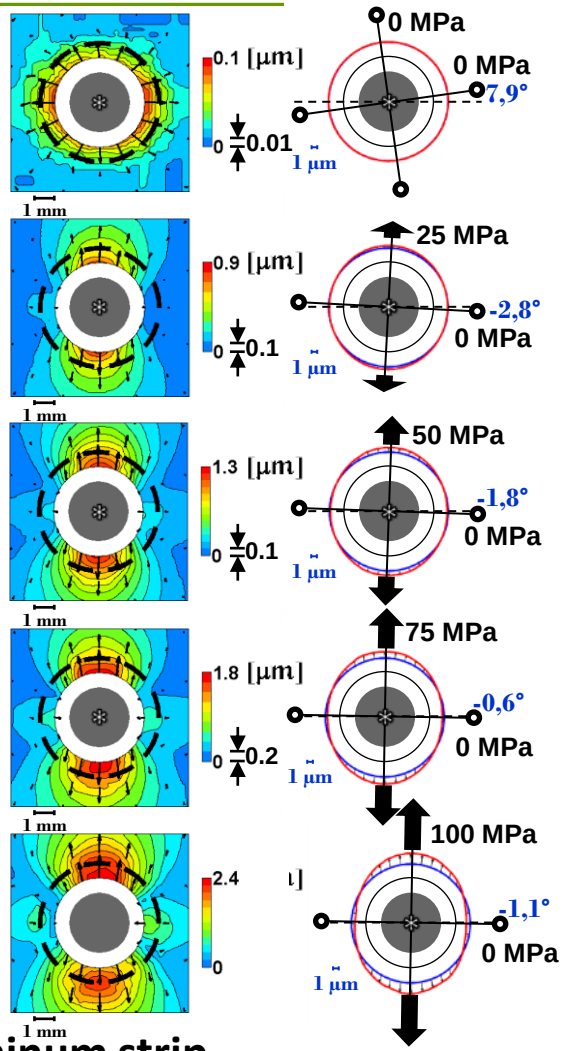
1.1. LOAD-CARRYING CAPACITY





Stress from a universal testing machine





Stress following with a single drill-hole

b. Empiric stress scale of aluminum (I-II.)

Stress increases correspondingly to the load

Tensile stress change of an aluminum strip

- under load of tensile strength measurement

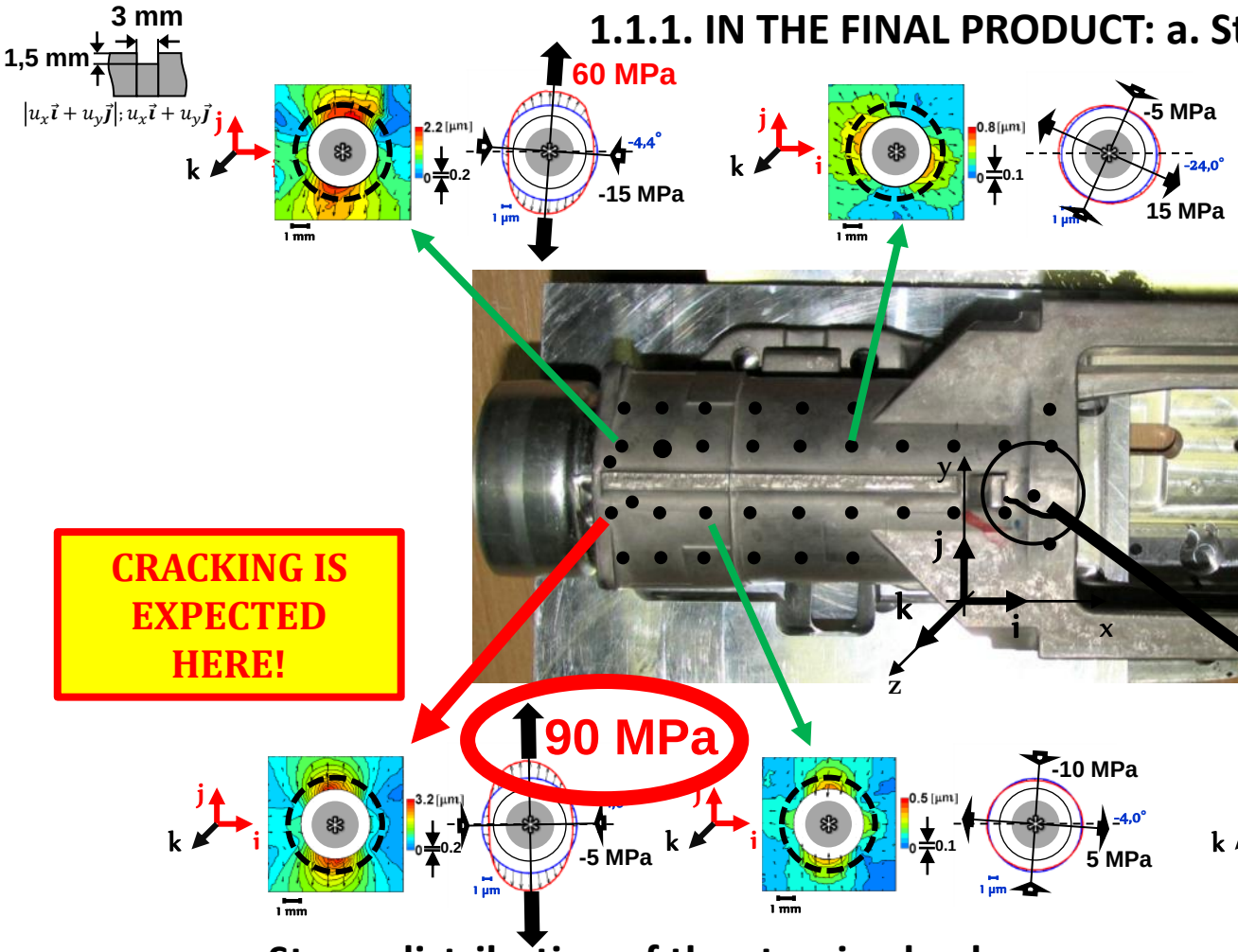
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.1. IN THE FINAL PRODUCT: a. Steering bush



Stress distribution of the steering bush

-for prediction of spots of cracks

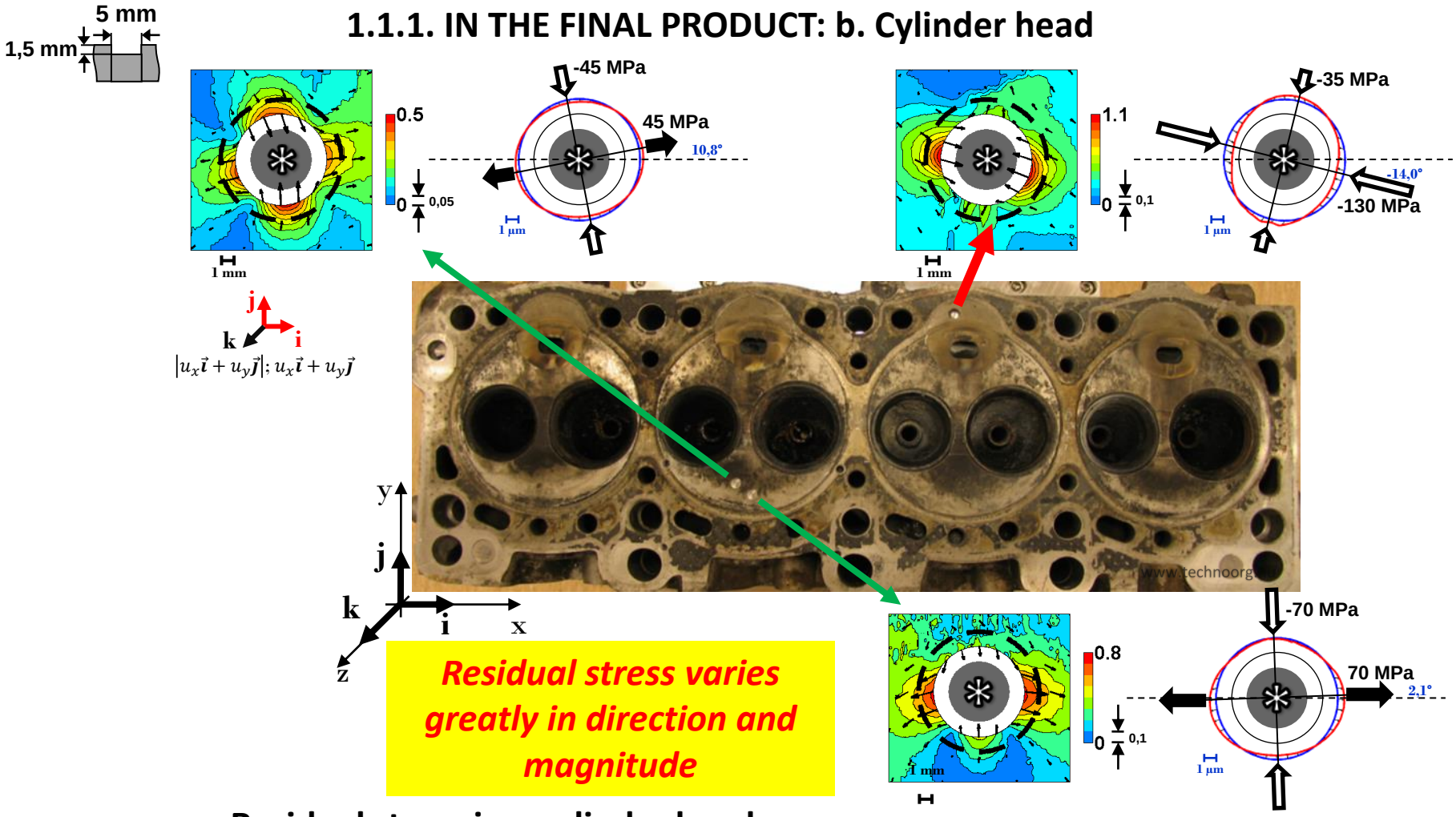
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.1. IN THE FINAL PRODUCT: b. Cylinder head



Residual stress varies greatly in direction and magnitude

Residual stress in a cylinder head

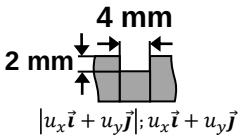
- for verification of the stress-free state

II. *Applied* DEFORMATION – *for diagnostic purposes*

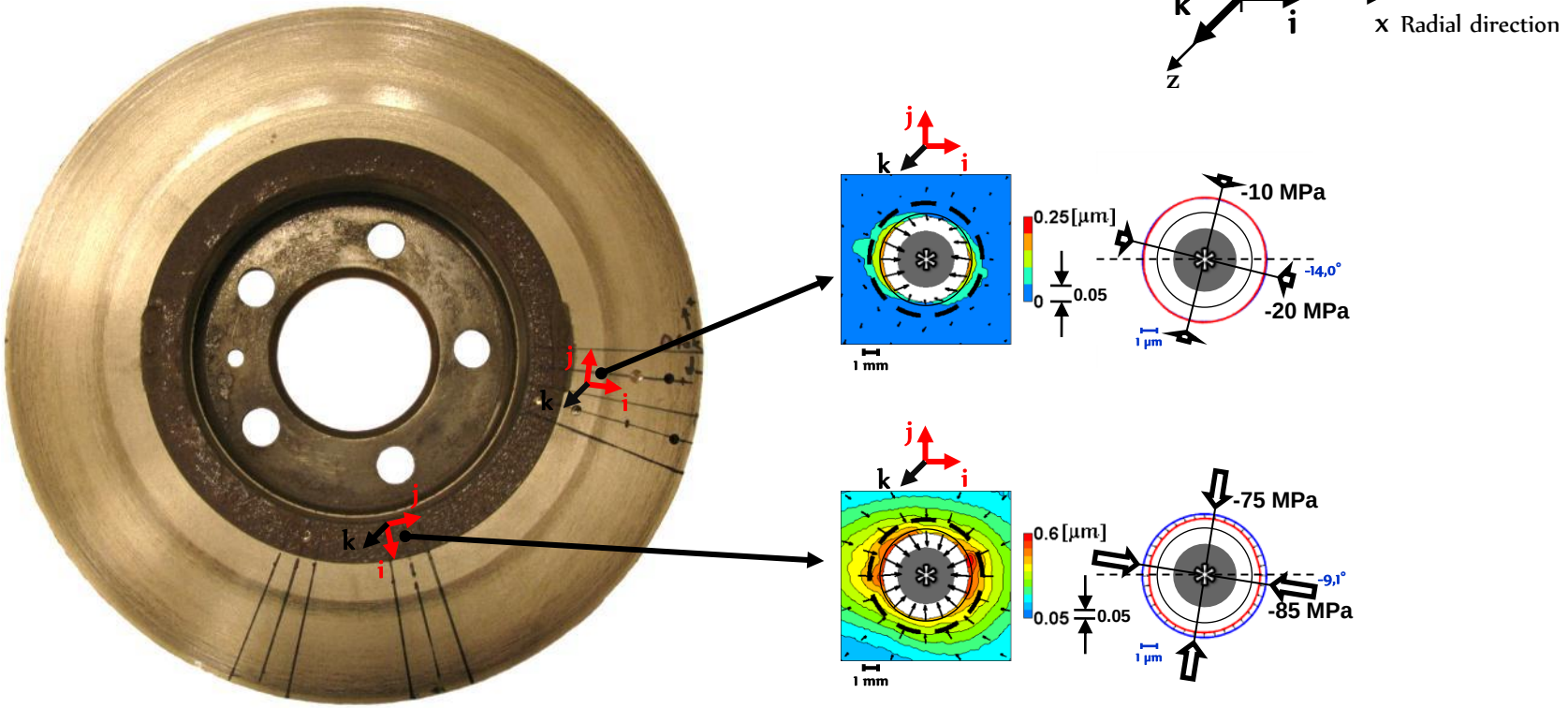
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY



1.1.1. IN THE FINAL PRODUCT: c. Brake disc



Residual stress in a brake disc

- for verification of the stress-free state

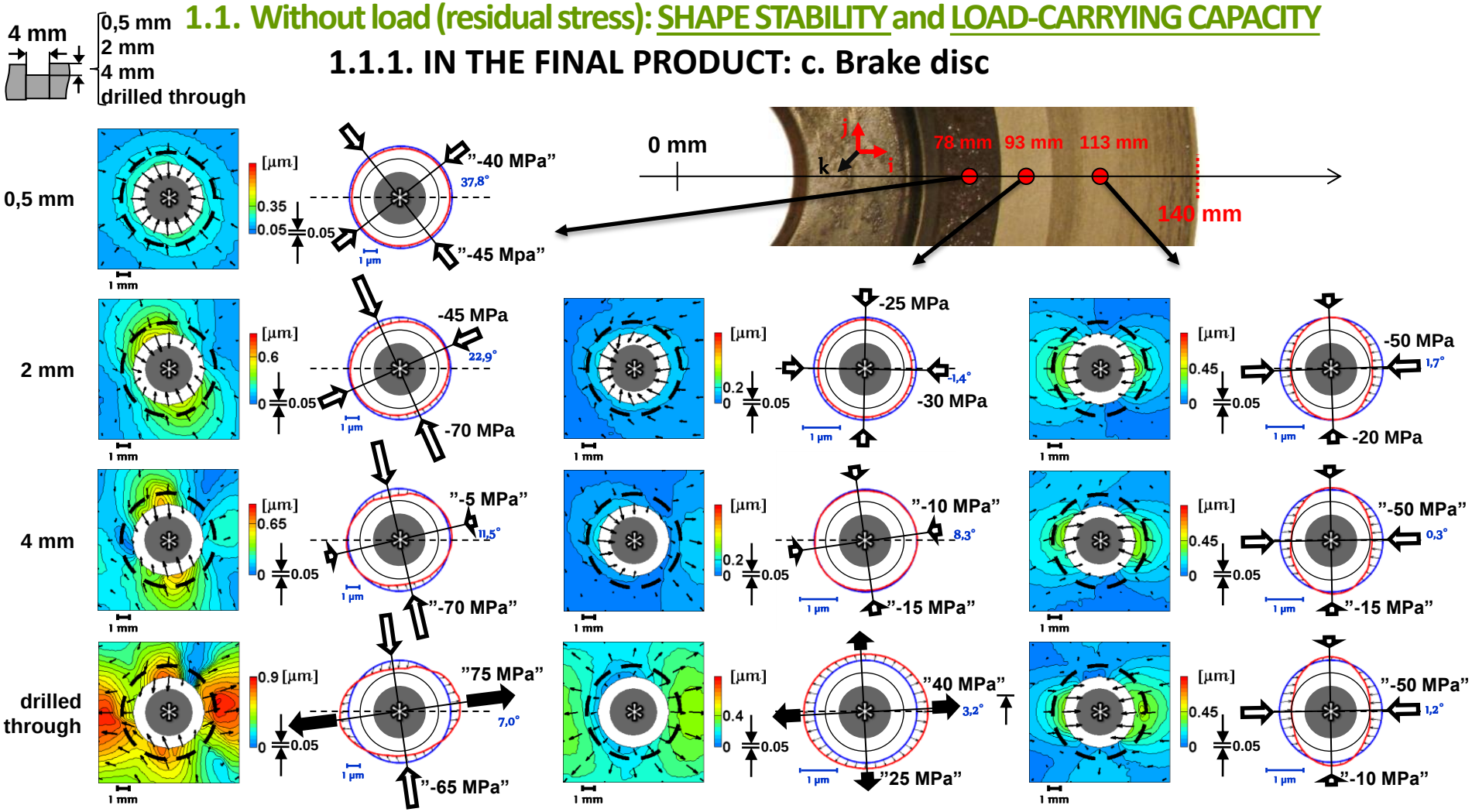
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.1. IN THE FINAL PRODUCT: c. Brake disc



Residual stress in a brake disc

- for verification of the stress-free state

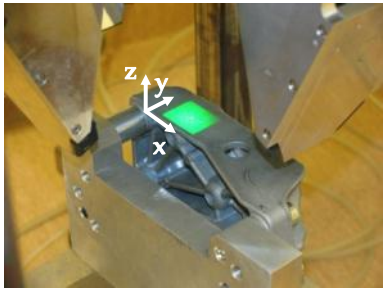
II. DIAGNOSZTIKAI CÉLLAL keltett mérési deformálásnál

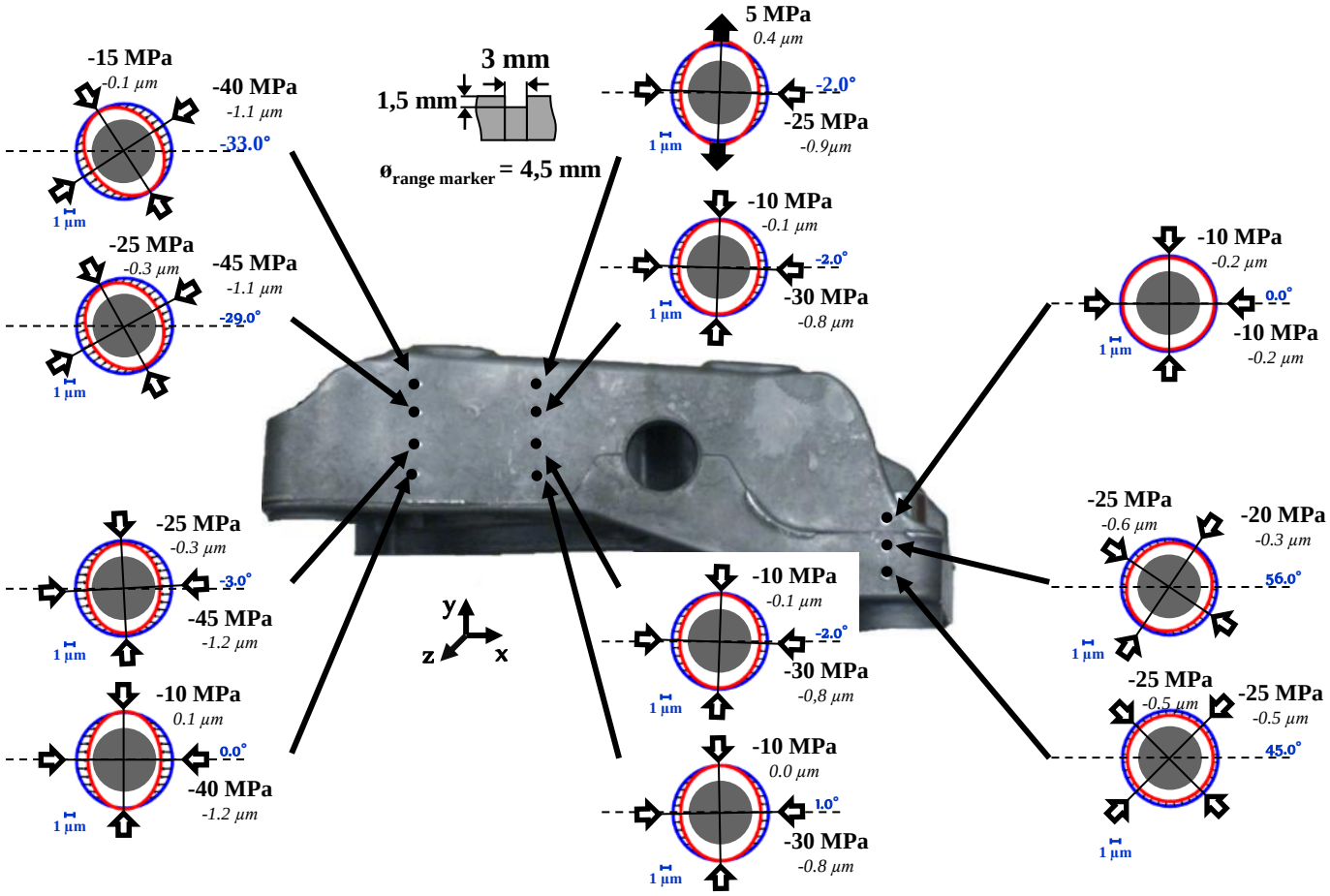
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.1. IN THE FINAL PRODUCT: d. Aluminum engine bracket





Residual stress distribution of a pressured cast on the surface

II. *Applied* DEFORMATION – *for diagnostic purposes*

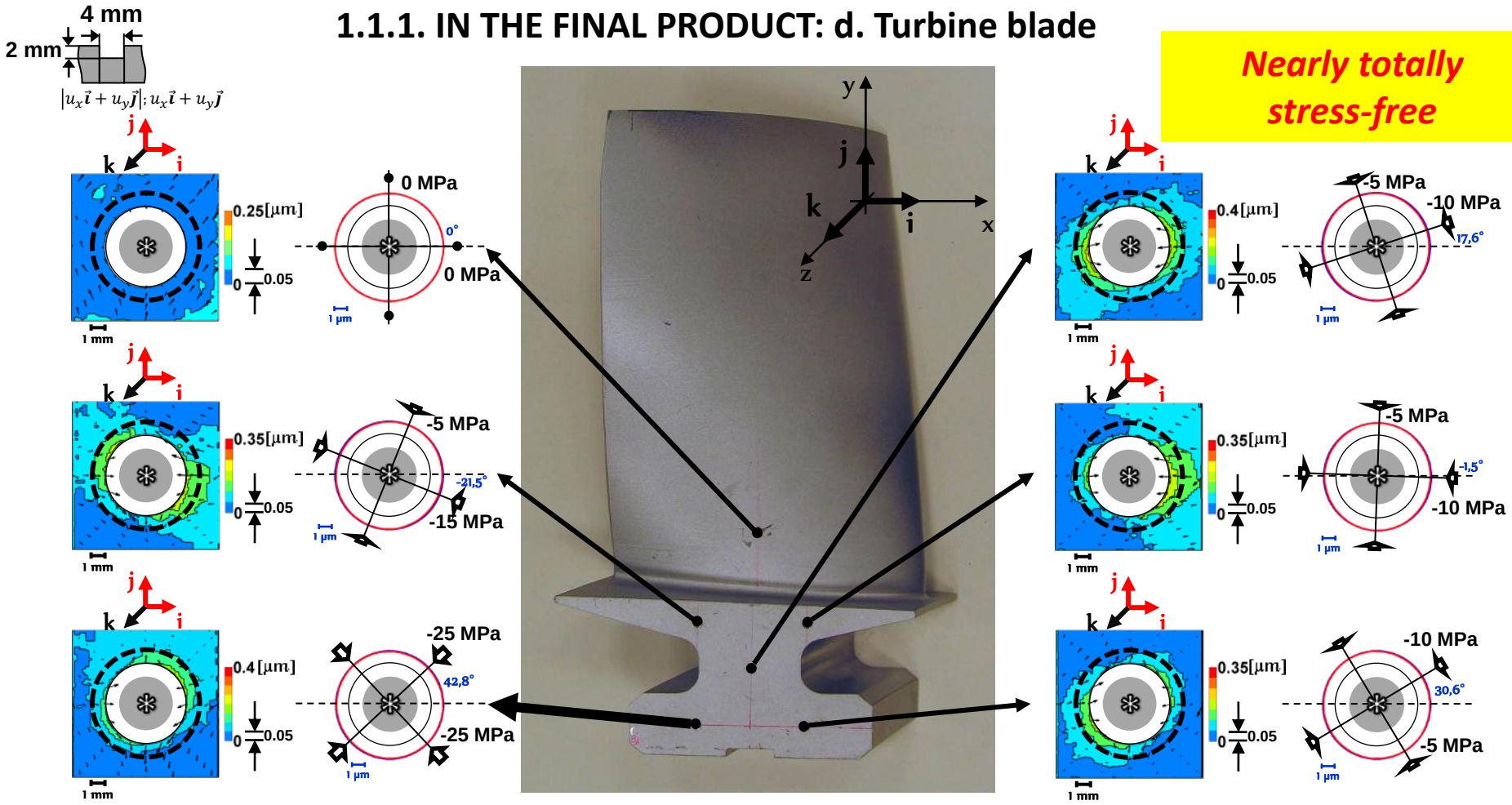
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.1. IN THE FINAL PRODUCT: d. Turbine blade

Nearly totally stress-free



Residual stress in a brake disc

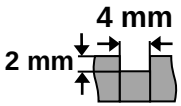
- for verification of the stress-free state

II. *Applied* DEFORMATION – *for diagnostic purposes*

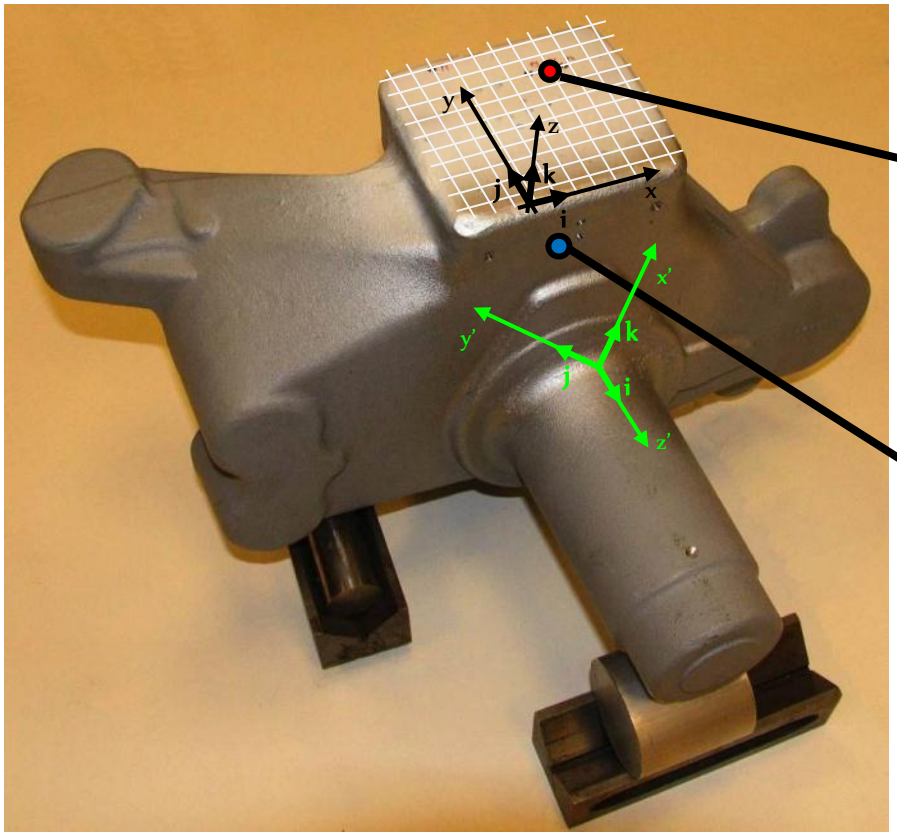
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

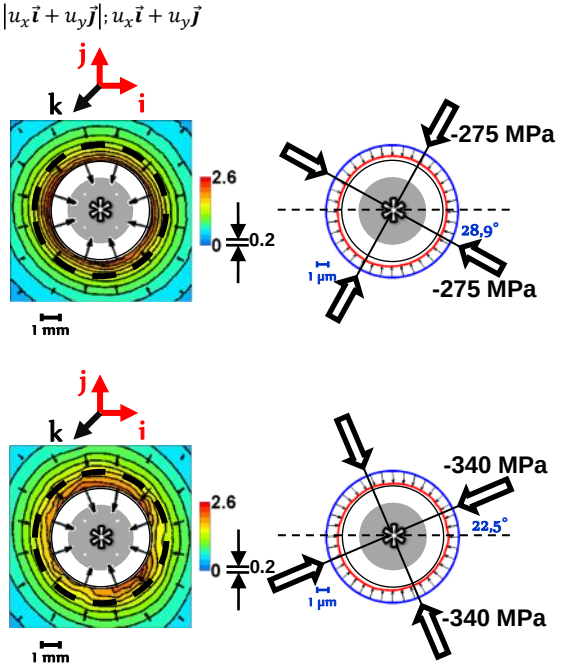
1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY



1.1.2. IN THE RAW MATERIAL: a. Wrought steel





Significant residual stress

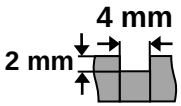
Residual stress in a block of wrought iron
- for verification of the stress-free state

II. *Applied* DEFORMATION – *for diagnostic purposes*

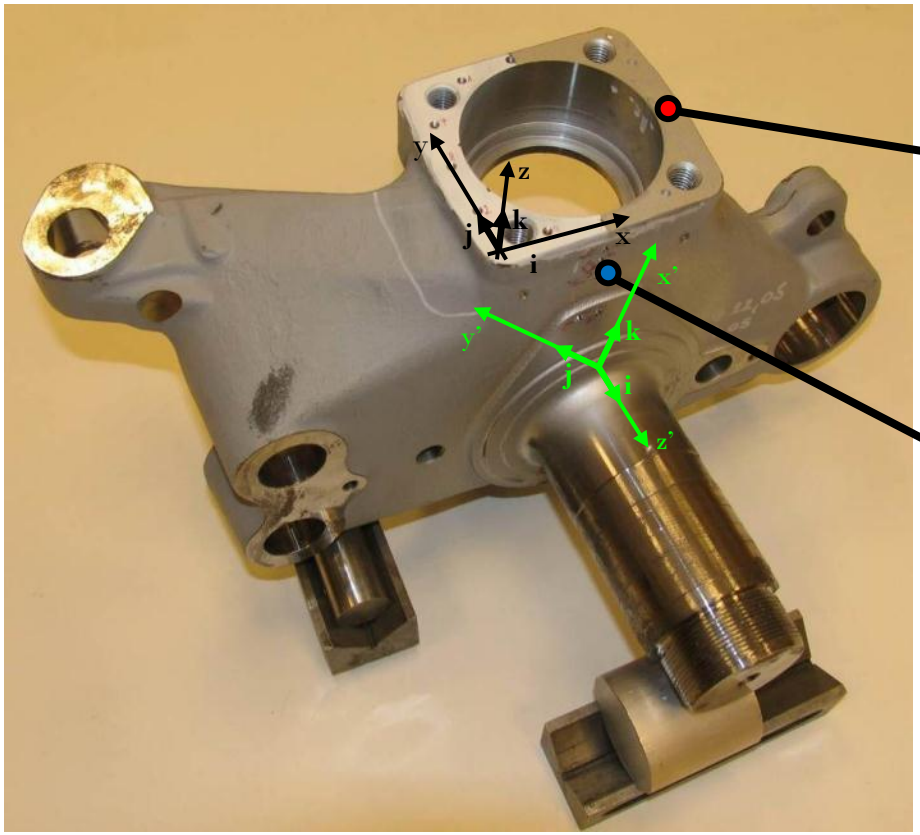
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

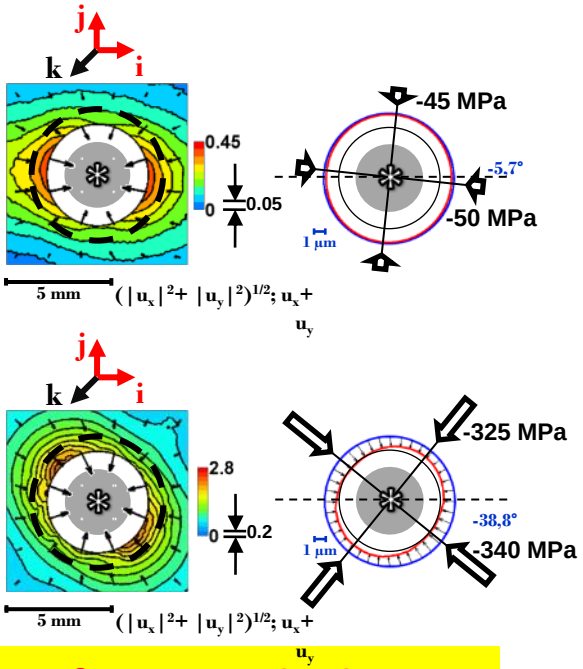
1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY



1.1.3. DURING MANUFACTURING: a. Etching





Significant residual stress in the sidewall

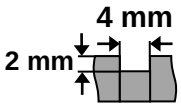
Stress of a stub axle formed by etching
- for verification of the stress-free state

II. *Applied* DEFORMATION – *for diagnostic purposes*

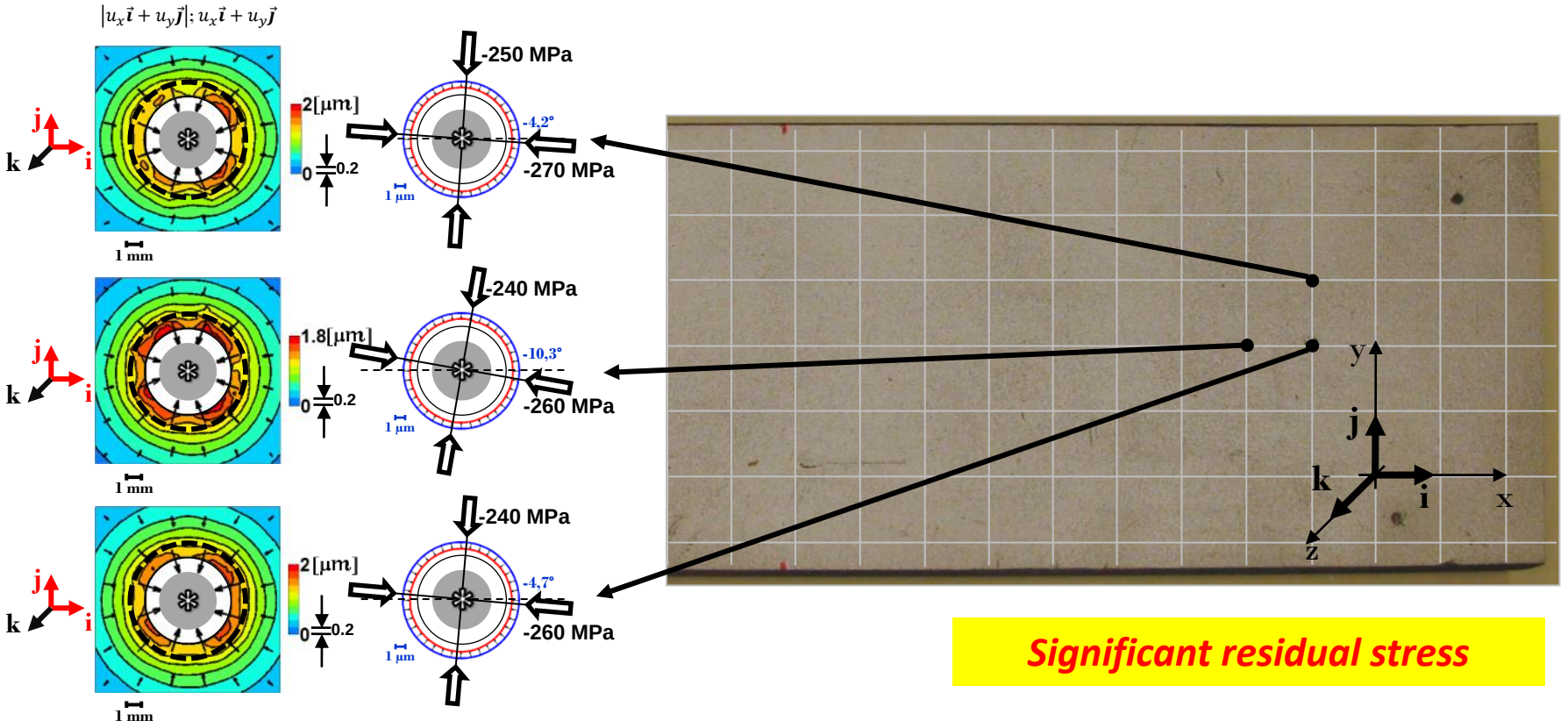
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY



1.1.2. IN THE RAW MATERIAL: b. Chrome steel block



Significant residual stress

Residual stress in an X20Cr13 steel block

- for verification of the stress-free state

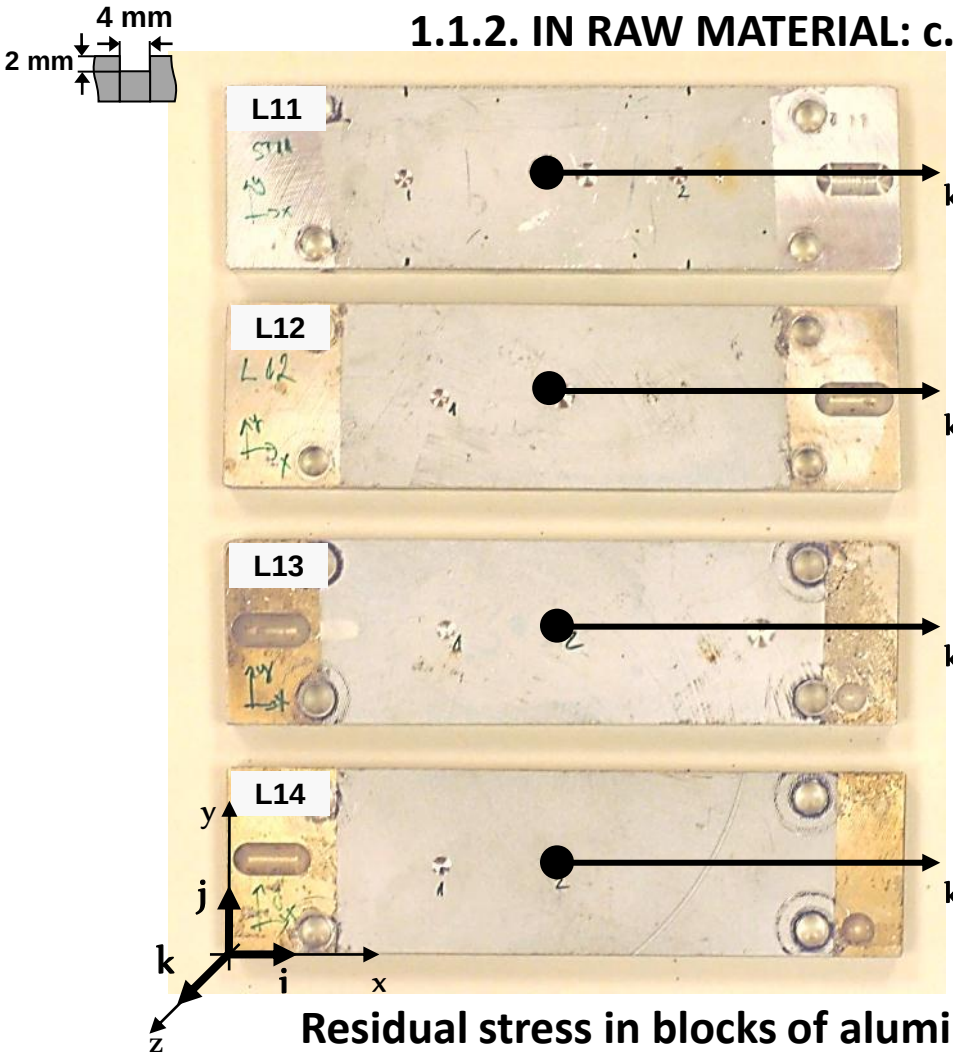
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.2. IN RAW MATERIAL: c. Aluminum with optimized heat treatment



Min. stress: best technology!

Max. stress

Residual stress in blocks of aluminum

- for optimizing the heat treatment

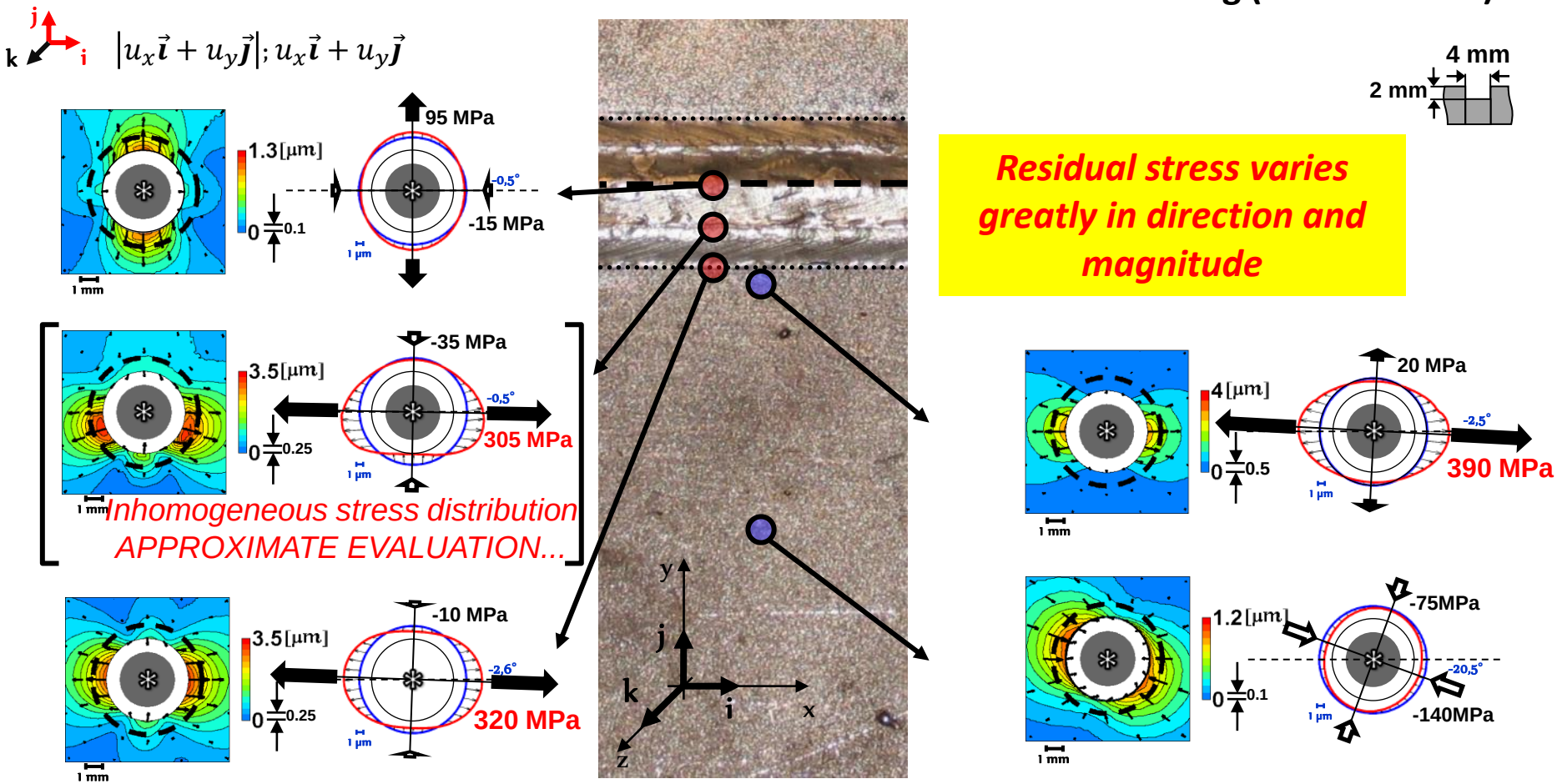
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: b. Welding (I – II – III – IV.)



Stress distribution of the welding seam and its surrounding area – for qualification of the welding technology

II. *Applied* DEFORMATION – *for diagnostic purposes*

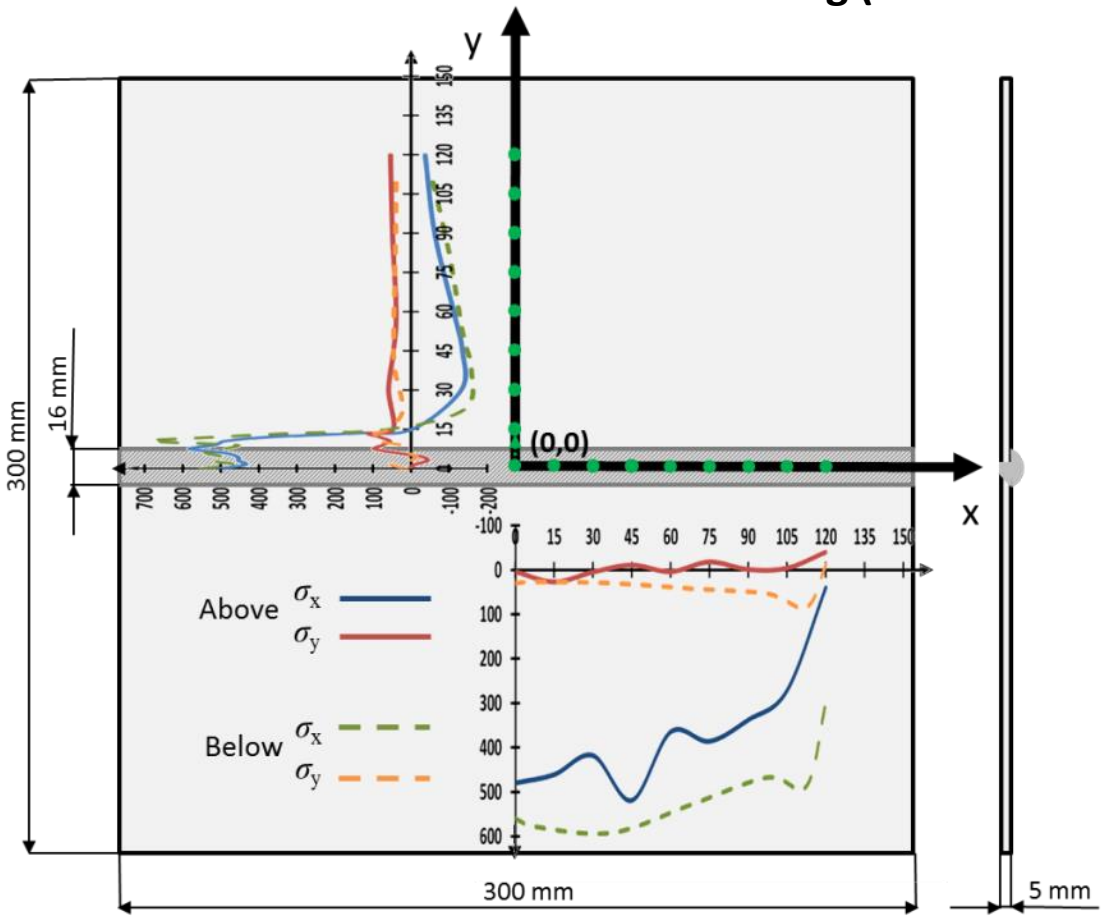
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: b. Welding (I' – II – III – IV.)

Residual stress varies greatly in magnitude



The stress distribution graph of the welding seam and its surrounding area in stainless steel - for qualification of the welding technology

II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

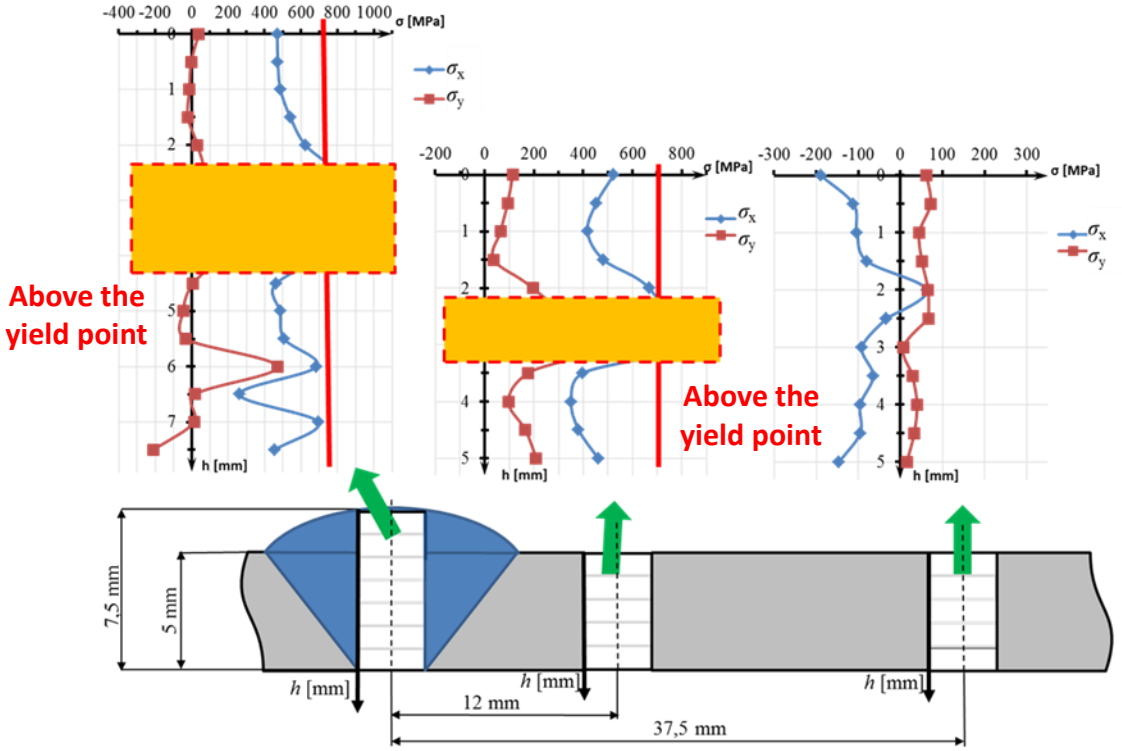
1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: b. Welding (I'' – II – III – IV.)

Residual stress varies greatly in magnitude

above the yield point, too!!



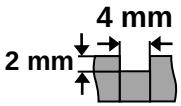
The *in depth* stress distribution graph of the welding seam and its surrounding area in stainless steel - for qualification of the welding technology

II. *Applied* DEFORMATION – *for diagnostic purposes*

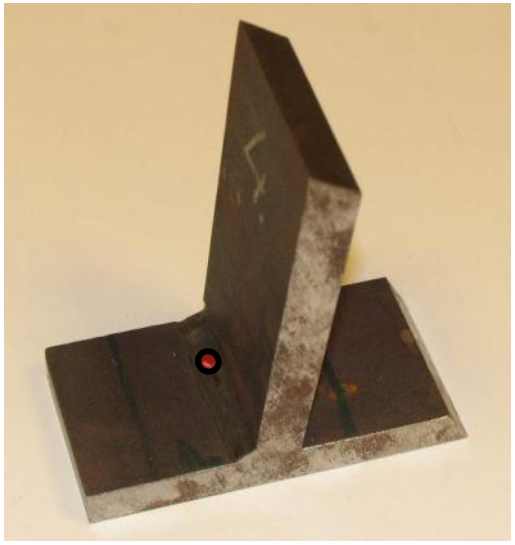
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

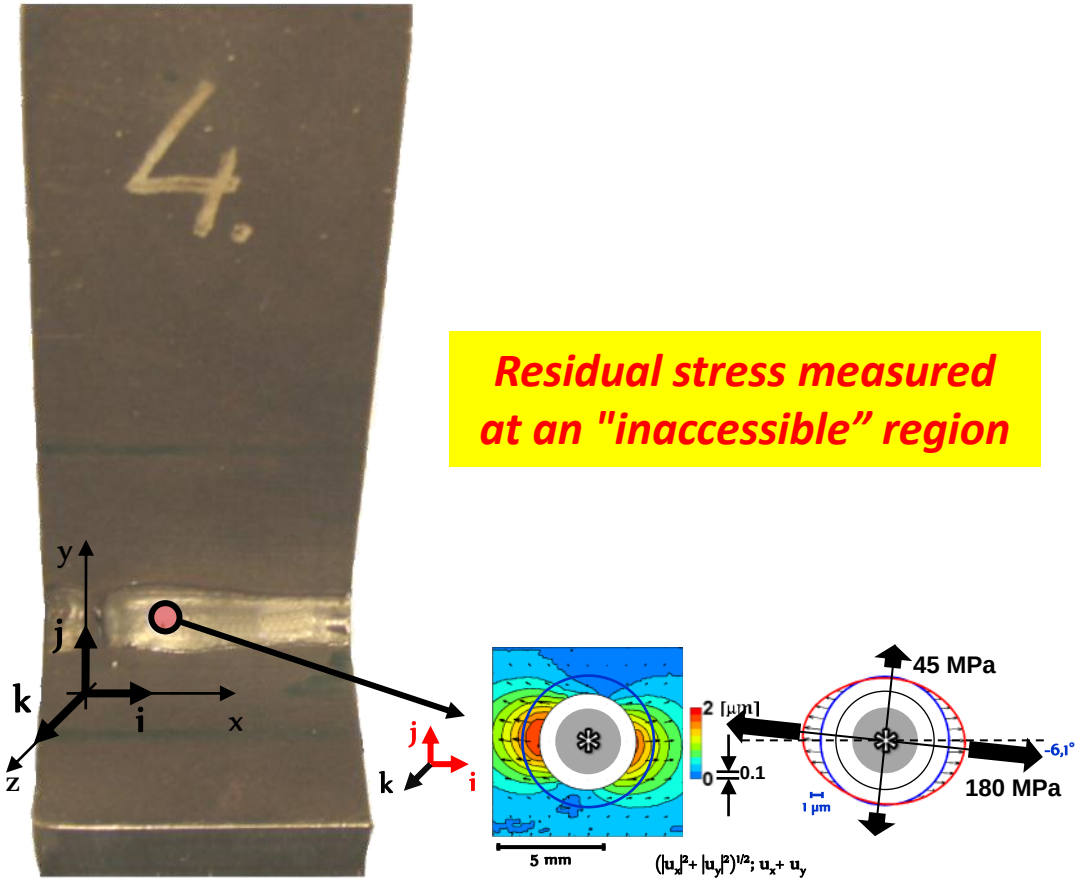
1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY



1.1.3. DURING MANUFACTURING: b. Welding (I – II – III – IV.)





Residual stress measured at an "inaccessible" region

Stress of corner weld (in one measuring point)

- for qualification of the welding technology

II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTR*

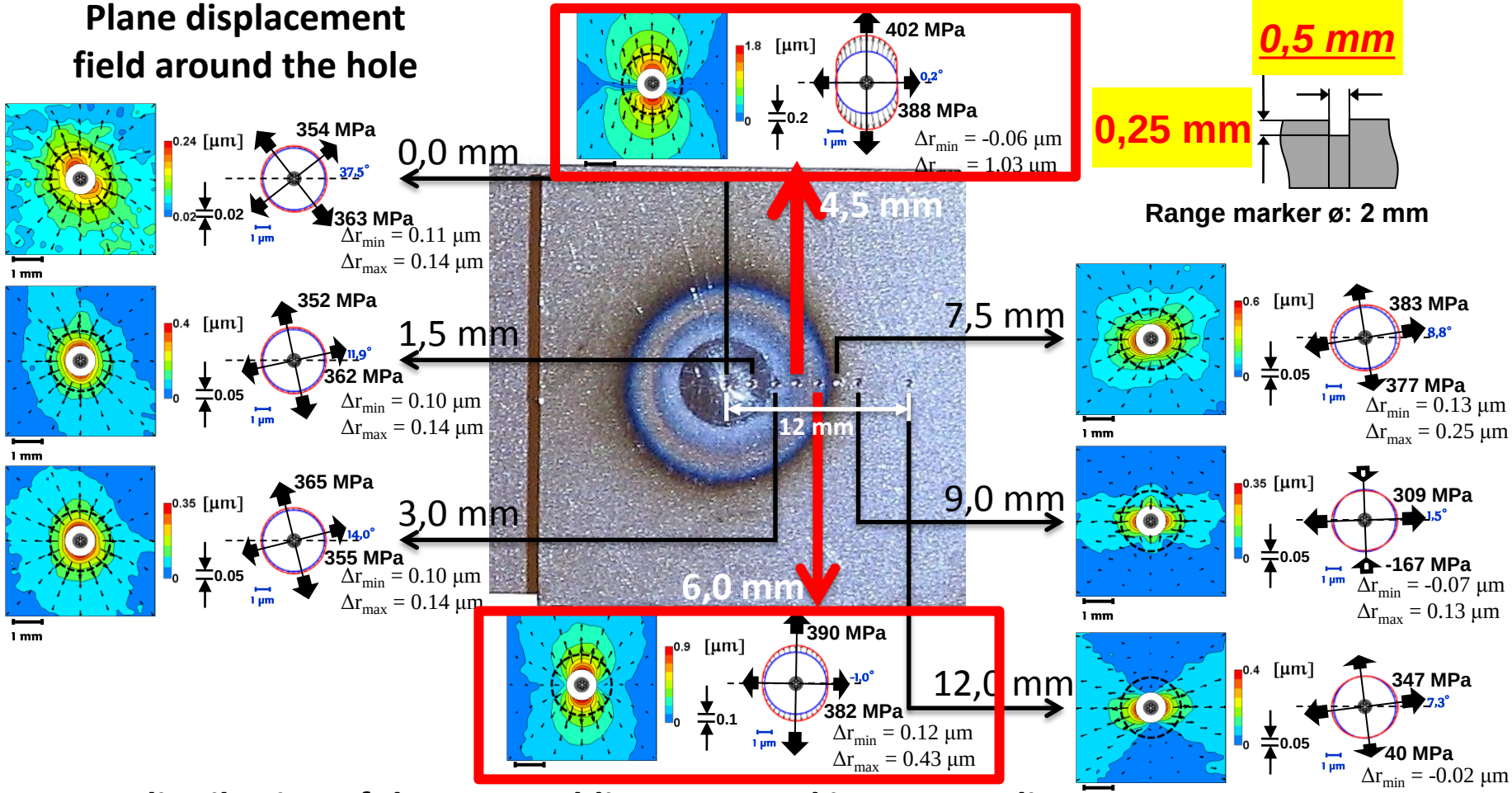
SEMI-NONDESTRUCTIVE with MINI-HOLE!!!

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY a

1.1.3. DURING MANUFACTURING: b. Spot welding (I – II' – III – IV.)

Plane displacement field around the hole



Stress distribution of the spot welding seam and its surrounding area

- for qualification of the welding technology

II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTR*

SEMI-NONDESTRUCTIVE with MINI-HOLE!!!

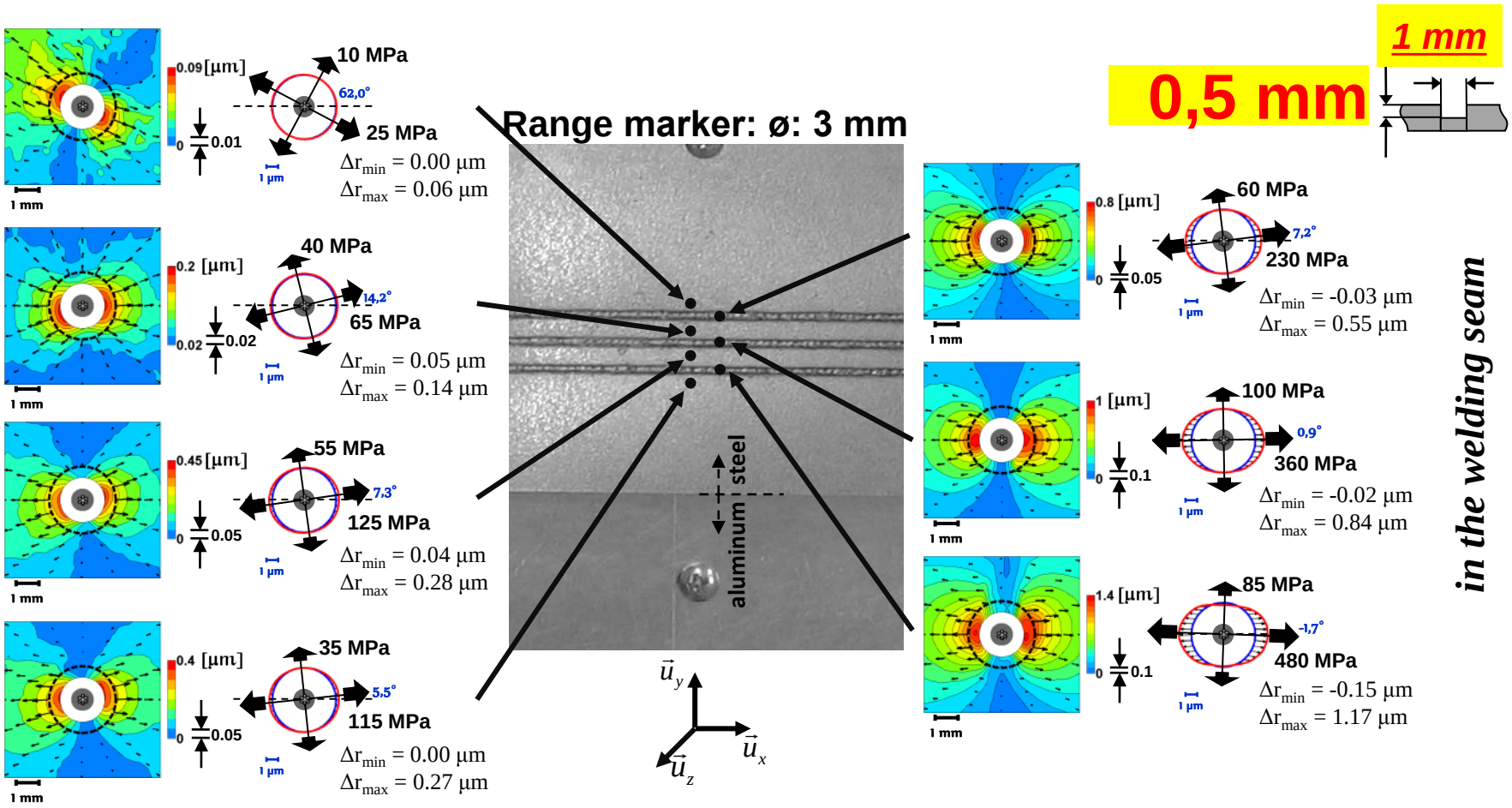
1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY a

1.1.3. DURING MANUFACTURING: b. Laser welding (I – II''' – III – IV.)

near and between the welding seam, respectively

in the welding seam



Stress distribution of the laser welding of welded steel and aluminum plate - for qualification of the welding technology

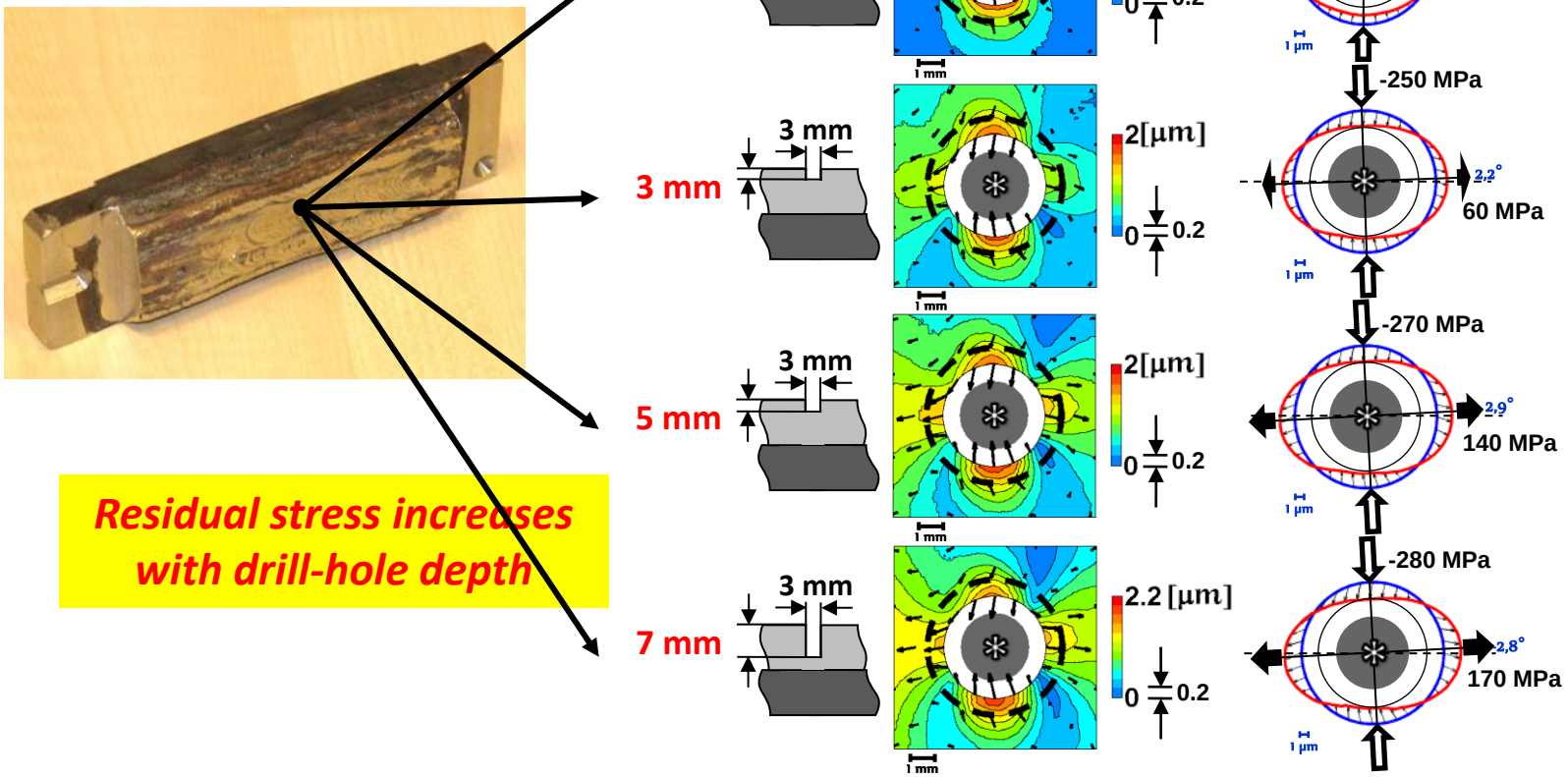
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: b. Welding (I – II – IIIa – IV.)



Residual stress increases with drill-hole depth

Stress distribution of the deposited layer of deposition welding and the substrate - for qualification of the welding technology (Ia.)

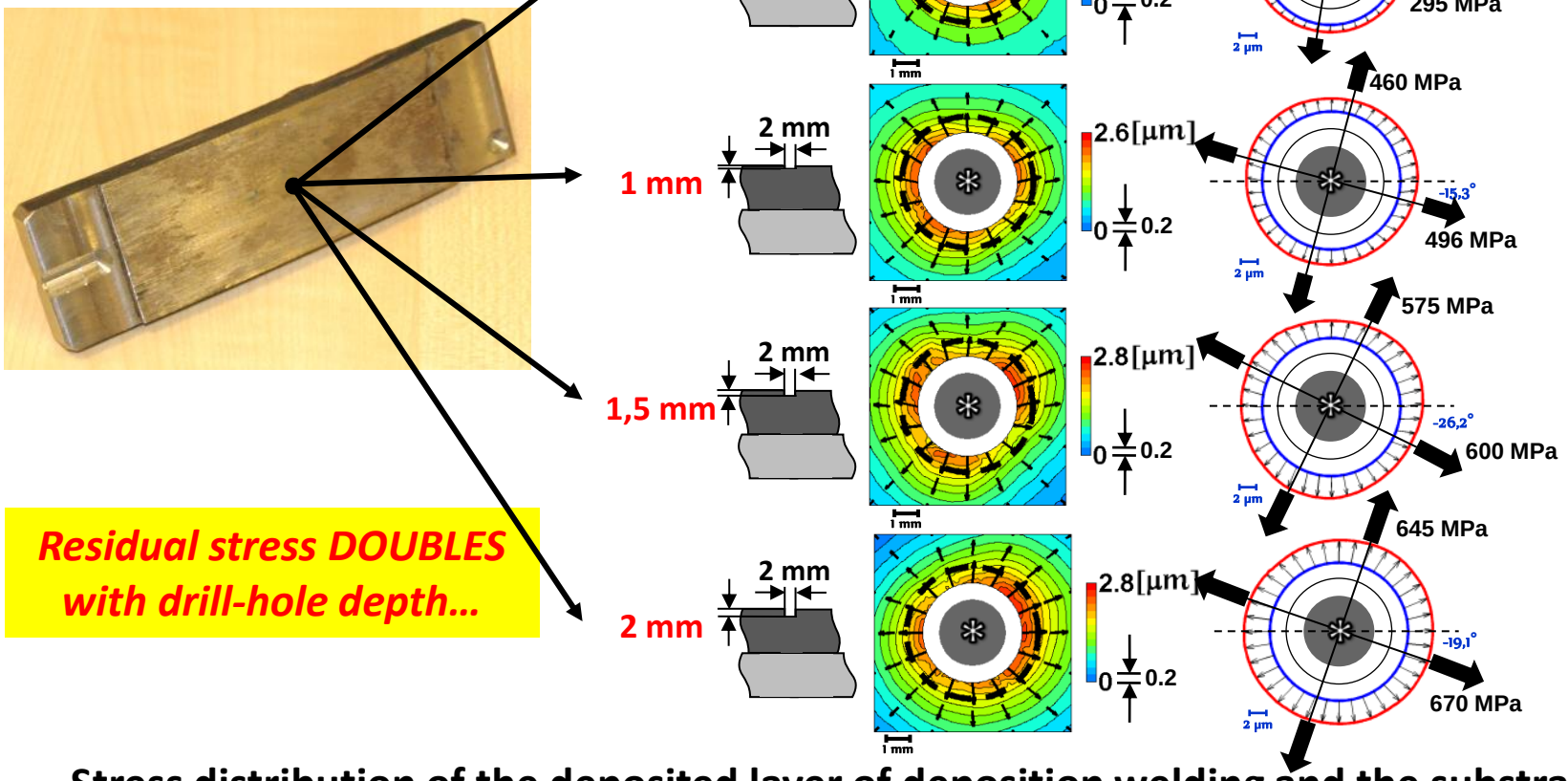
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: b. Welding (I – II – IIIb – IV.)



Residual stress DOUBLES with drill-hole depth…

Stress distribution of the deposited layer of deposition welding and the substrate - for qualification of the welding technology (Ib.)

II. *Applied* DEFORMATION – *for diagnostic purposes*

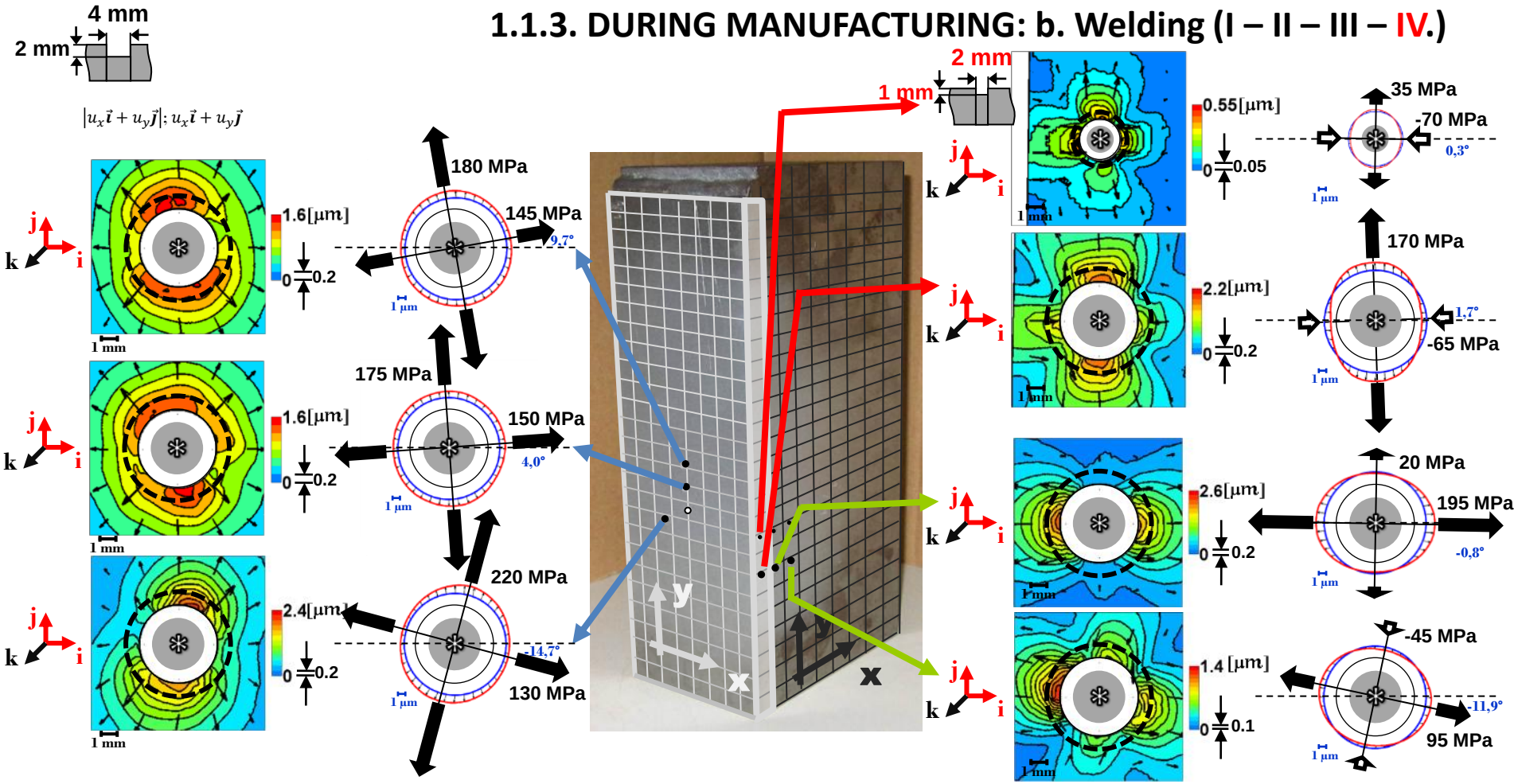
II/B. *Properties accessible from STRESS (DISTRIBU*

Residual stress varies greatly in direction and magnitude

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: b. Welding (I – II – III – IV.)



Stress distribution of the deposited layer of deposition welding and the substrate - for qualification of the welding technology (II.)

A COMPLEX STRESS EXAMPLE:

WELDED HOLLOW SECTION

STRESS DISTRIBUTION
ON THE SURFACE
+ IN DEPTH, TOO…

II. *Applied* DEFORMATION – *for diagnostic purpose*

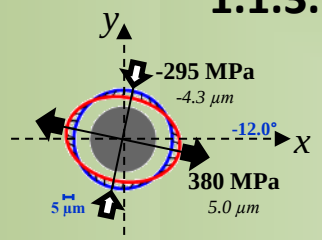
Non-welded side

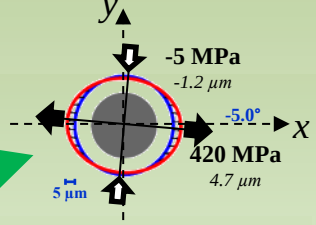
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

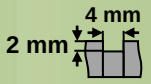
1. Actually formed stress

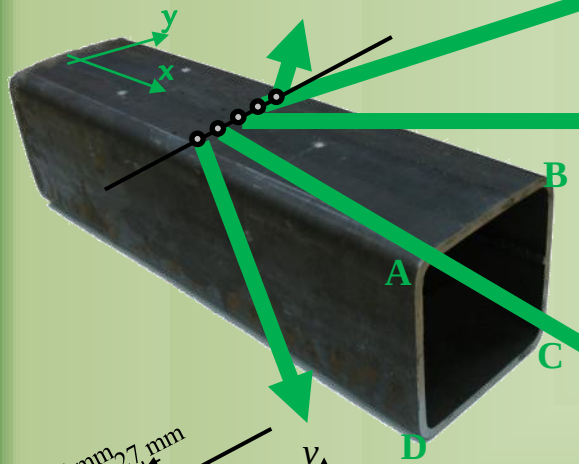
1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: c. Hollow section

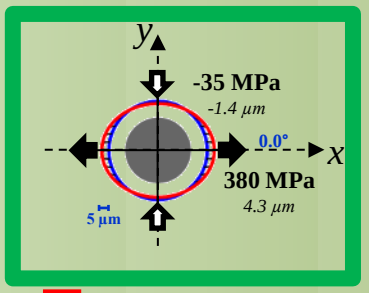




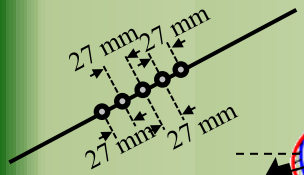


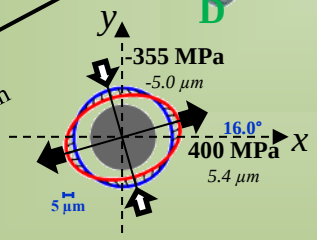


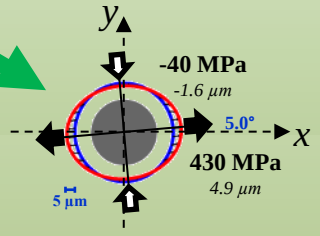
IN THE MIDDLE
IN THE CENTER



in depth measurement to follow







The distribution of residual stress along a cross-line on the surface of the hollow section - on the non welded side

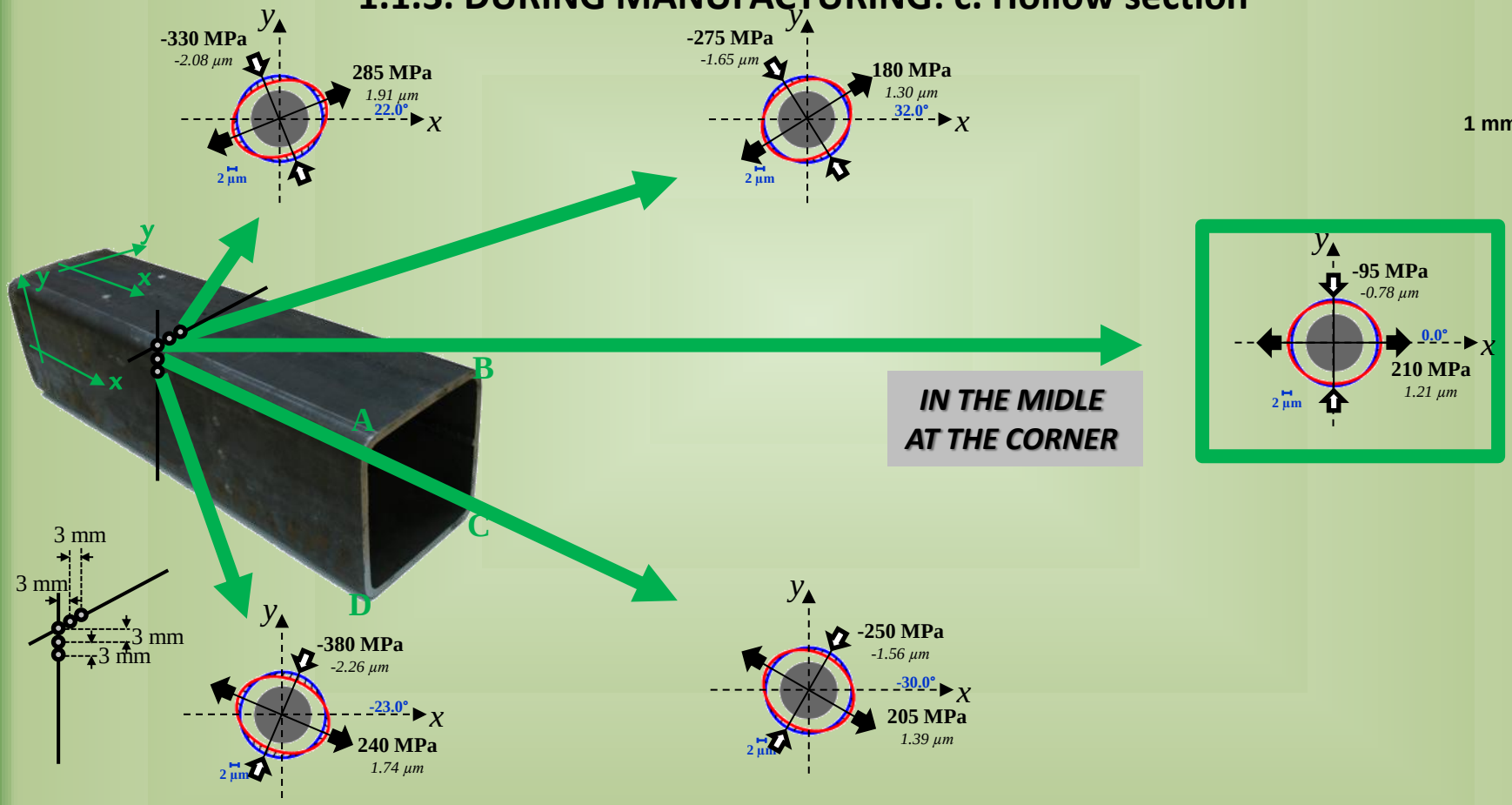
Around the corner

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: c. Hollow section



The distribution of residual stress along a cross-line on the surface of the hollow section - around the corner

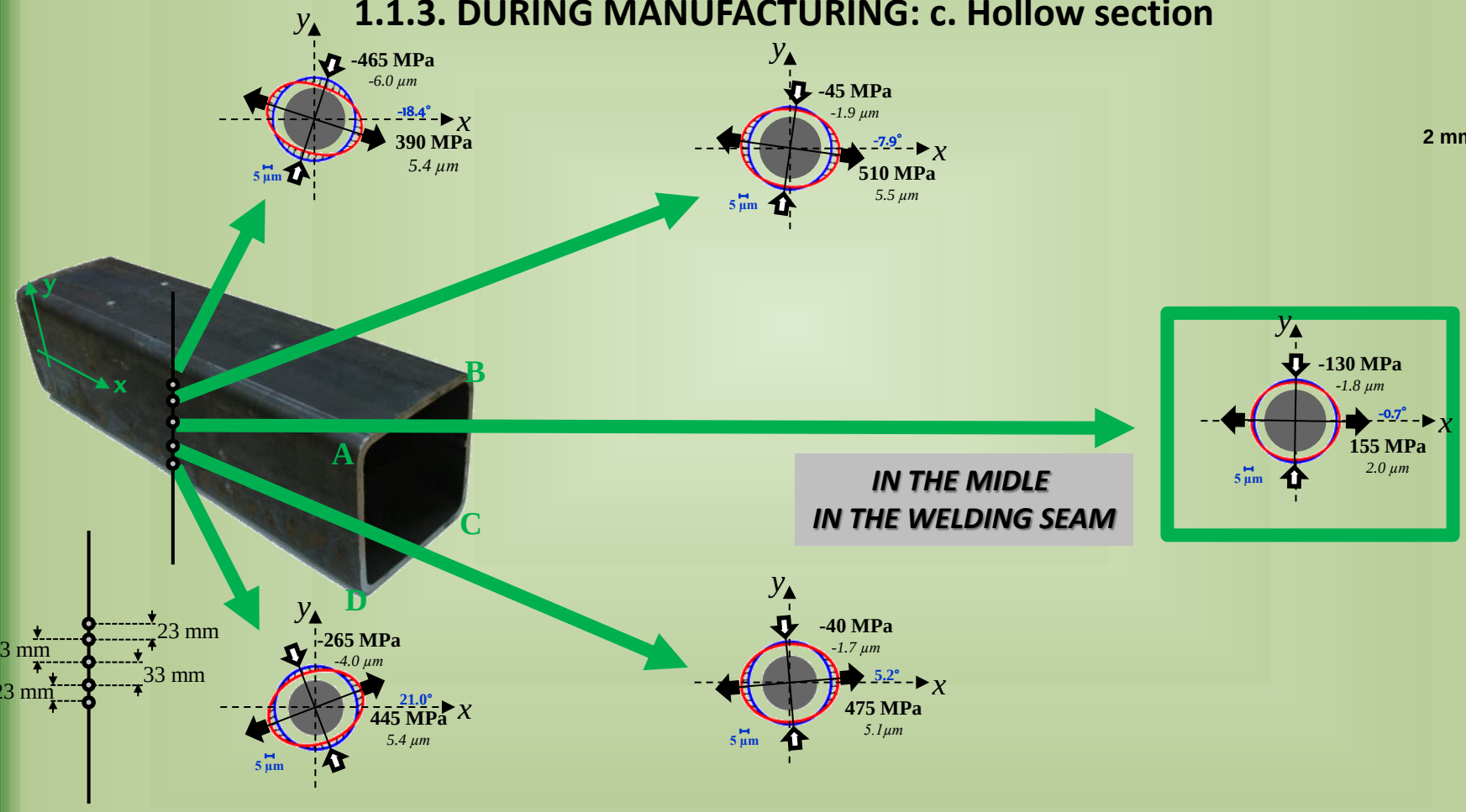
Welded side

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: c. Hollow section



The distribution of residual stress along a cross-line on the surface of the hollow section - on the welded side

II. *Applied* DEFORMATION – *for diagnostic purposes*

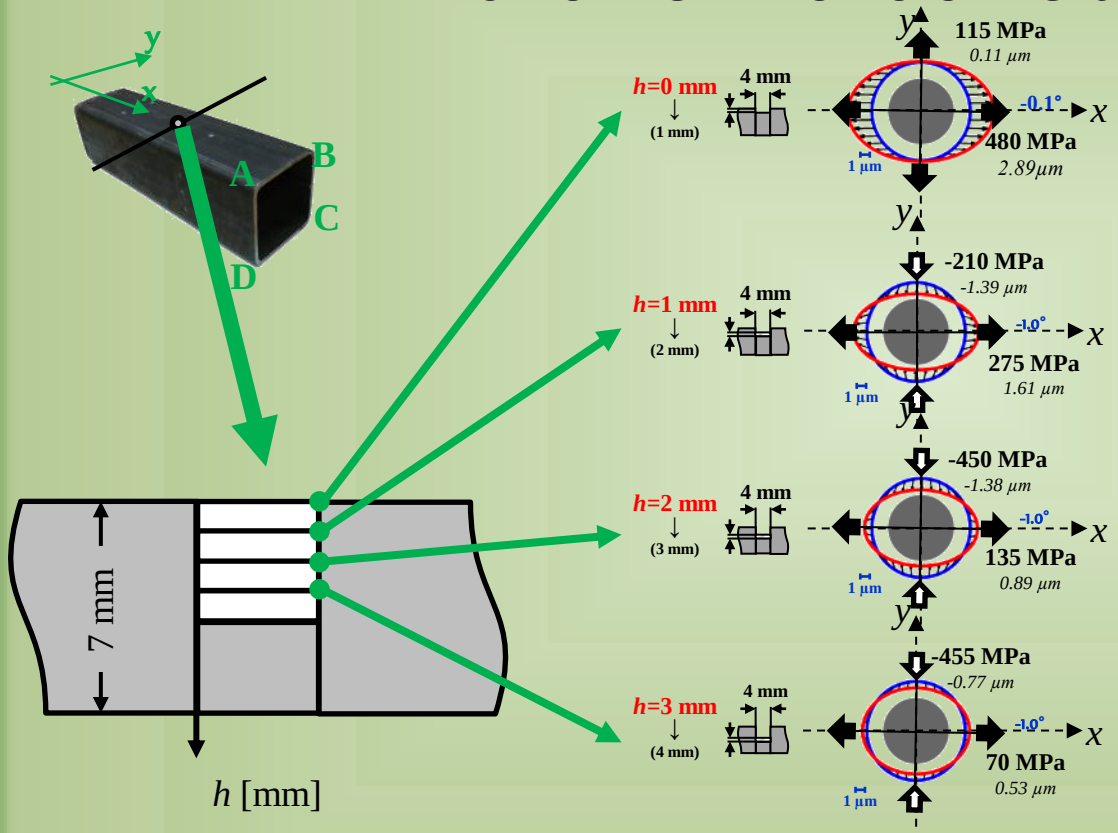
Non-welded side

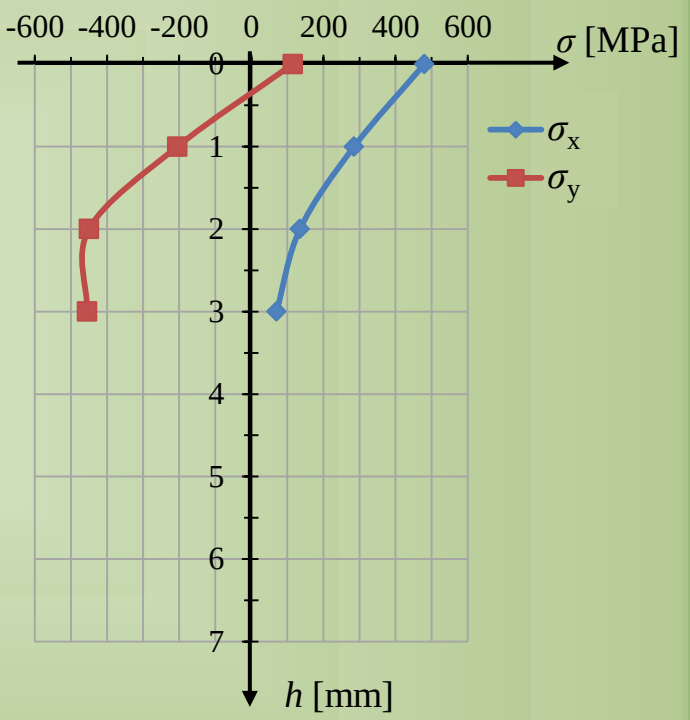
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: c. Hollow section





The distribution of residual stress in depth on the non welded side (by PROGRESSIVE DRILLING):

from above

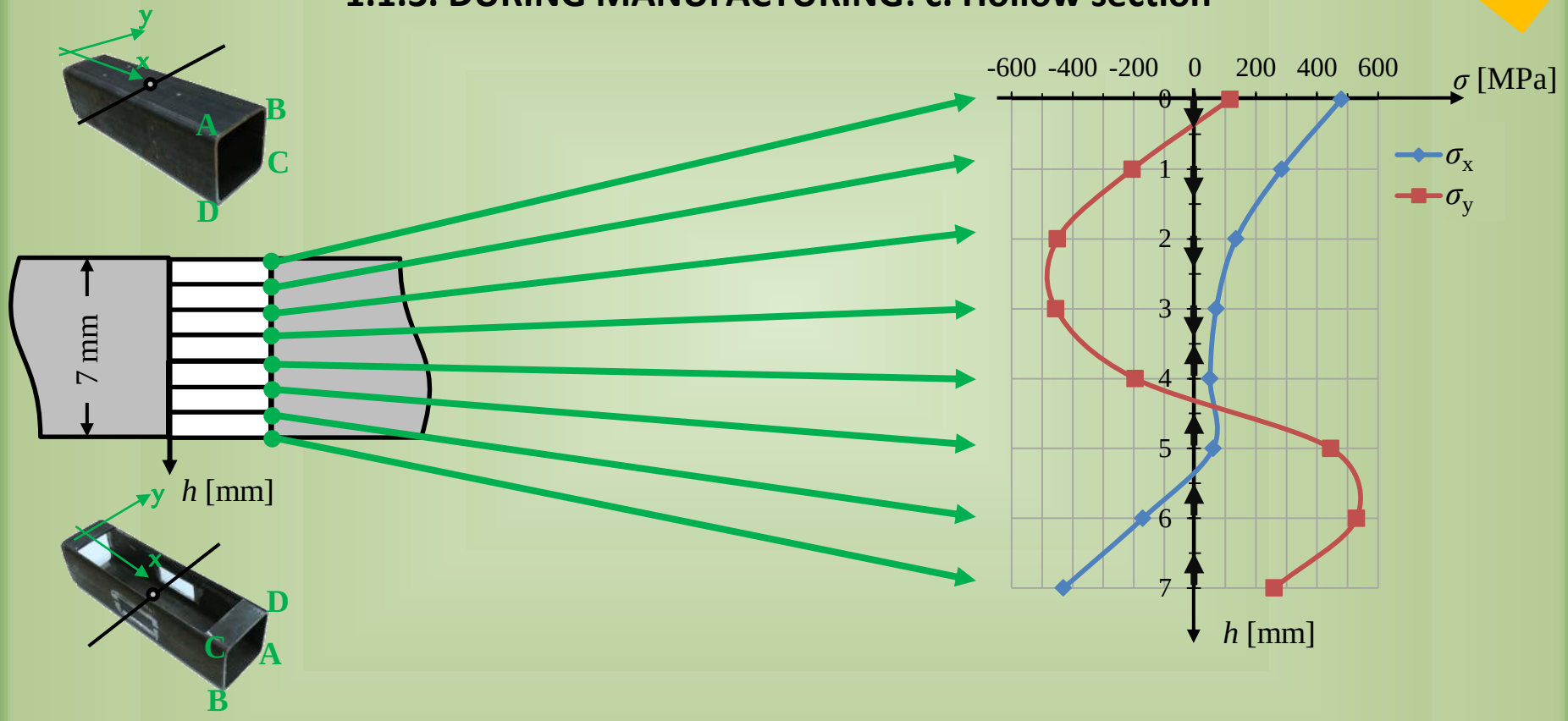
Non-welded side from both sides

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: c. Hollow section



The distribution of residual stress in depth on the non welded side

from above and below: TOTAL IN DEPTH DISRIBUTION!

II. *Applied* DEFORMATION – *for diagnostic purposes*

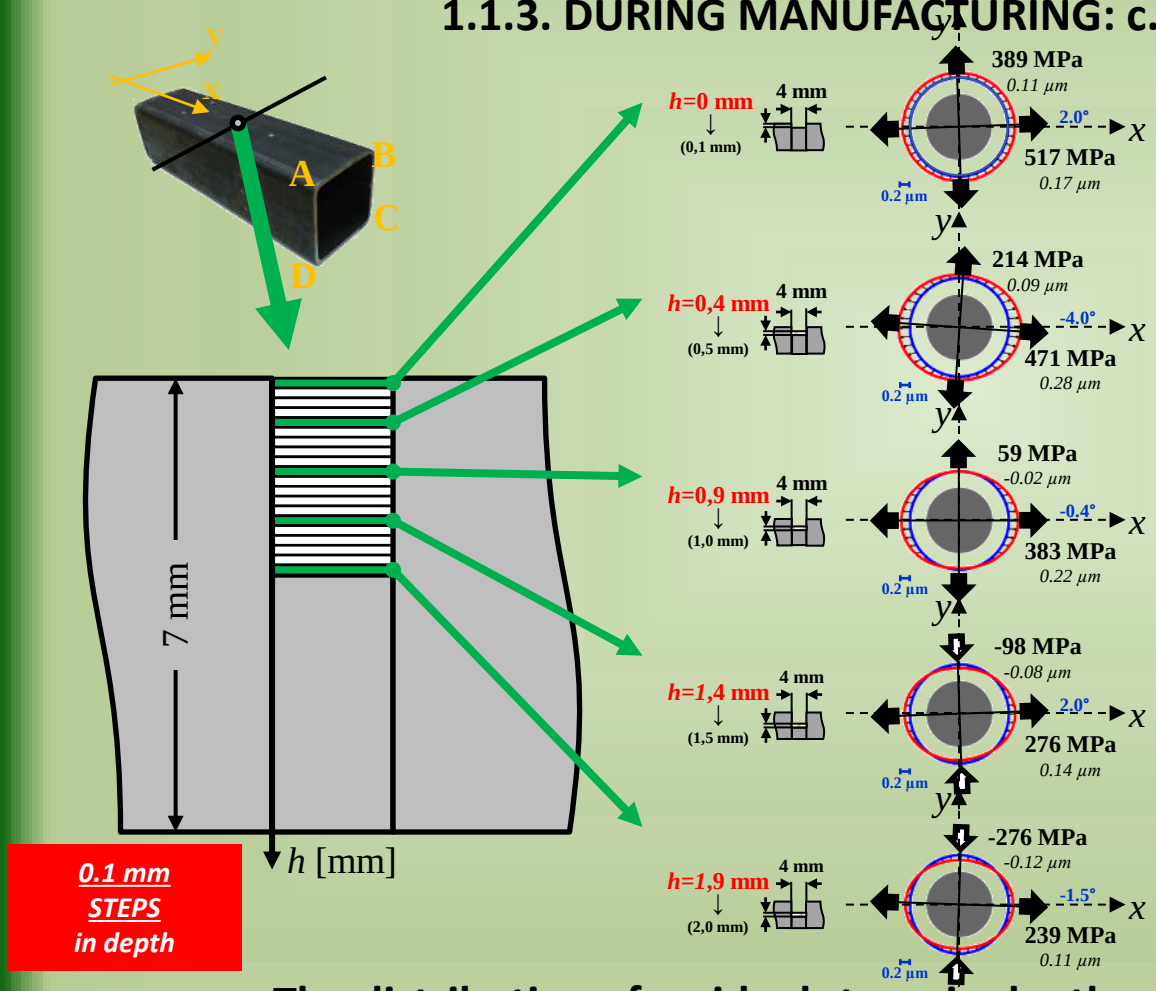
Non-welded side high resolution

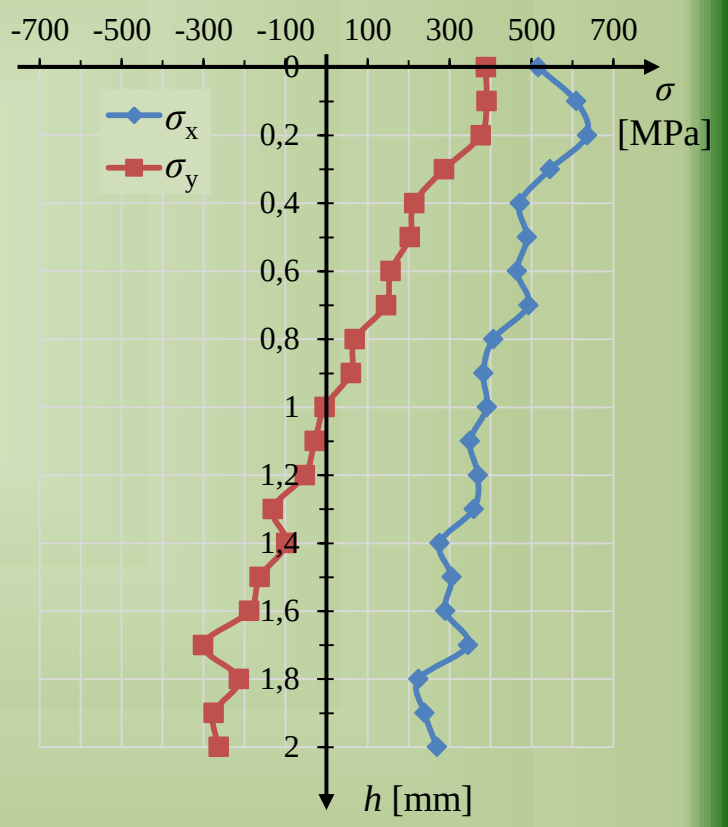
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACITY

1.1.3. DURING MANUFACTURING: c. Hollow section





The distribution of residual stress in depth on the non welded side incrementally by extra fine steps

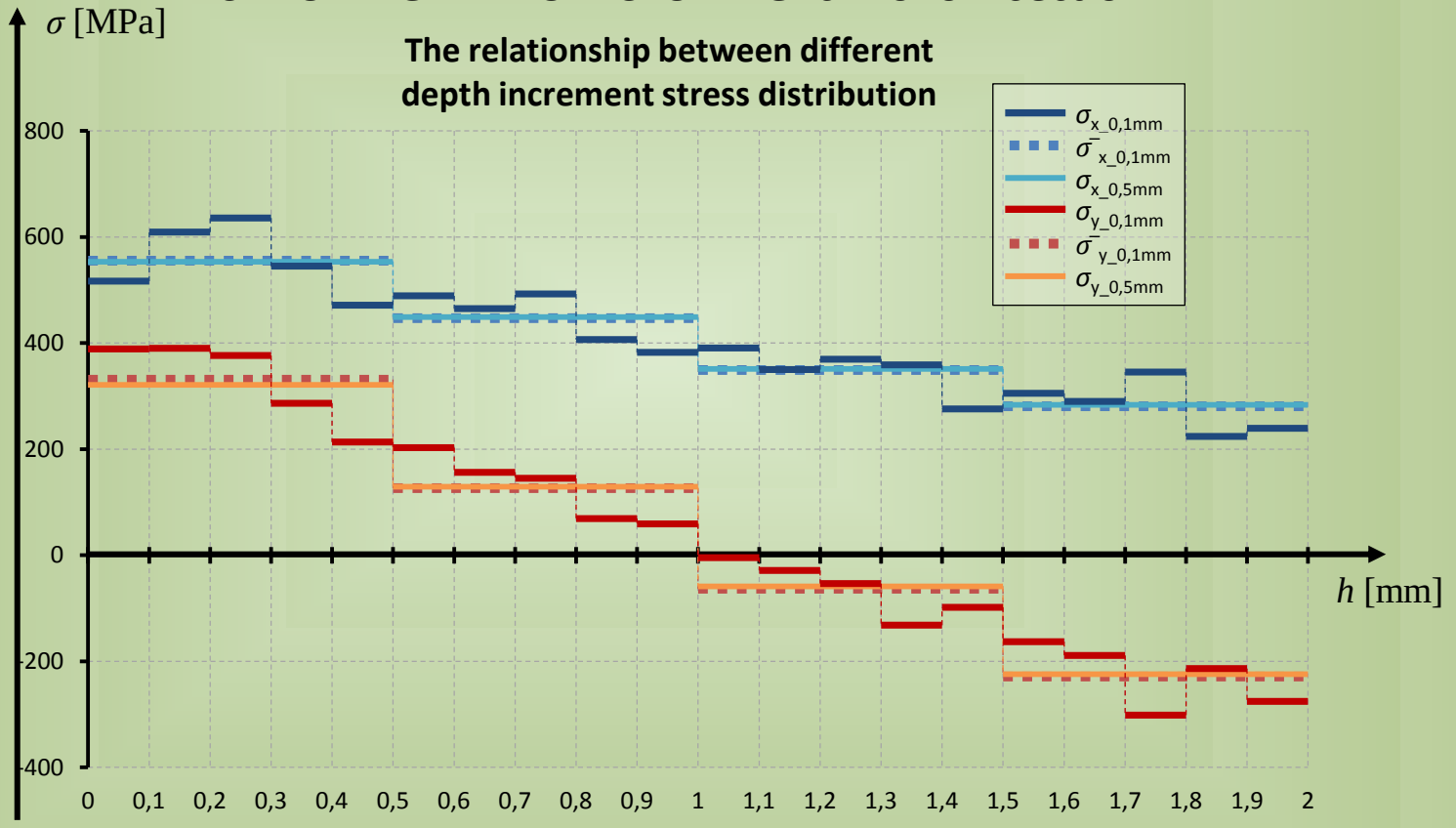
Non-welded side
high resolution

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.1. Without load (residual stress): SHAPE STABILITY and LOAD-CARRYING CAPACI

1.1.3. DURING MANUFACTURING: c. Hollow section



The distribution of residual stress in depth on the non welded side

the average of smaller steps is equal to the biger ones

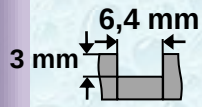
NON-METALIC EXAMPLES

II. *Applied* DEFORMATION – *for diagnostic purposes*

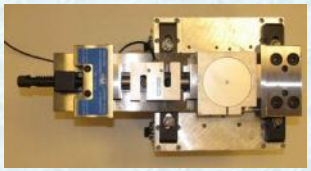
II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

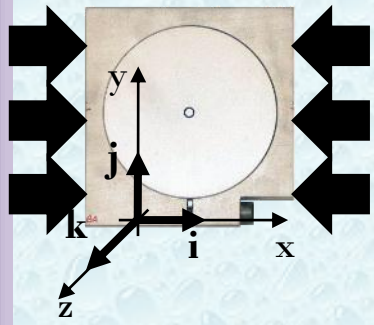
1.2. With load

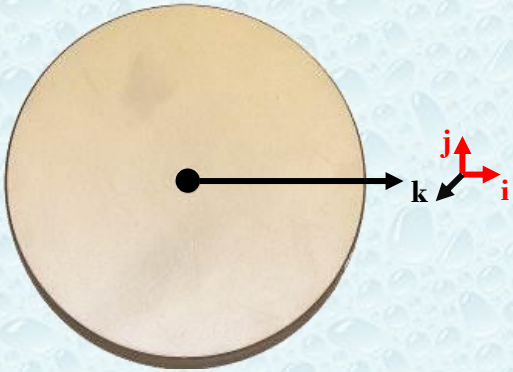


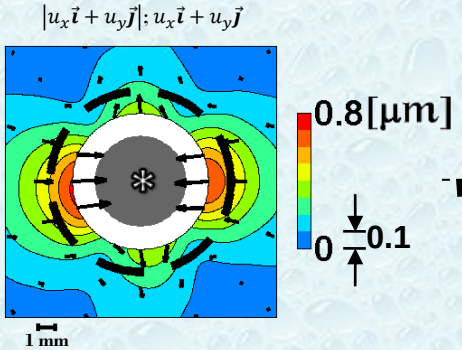
c. Compressed glass disc

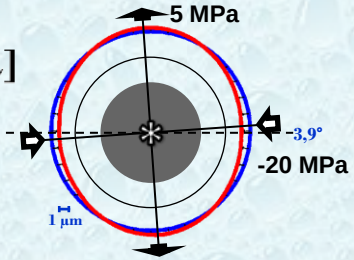


41 kN (-18 MPa)









Measured stress nearly equal to the load

Strain distribution of a glass substrate for thin films under load in different spots

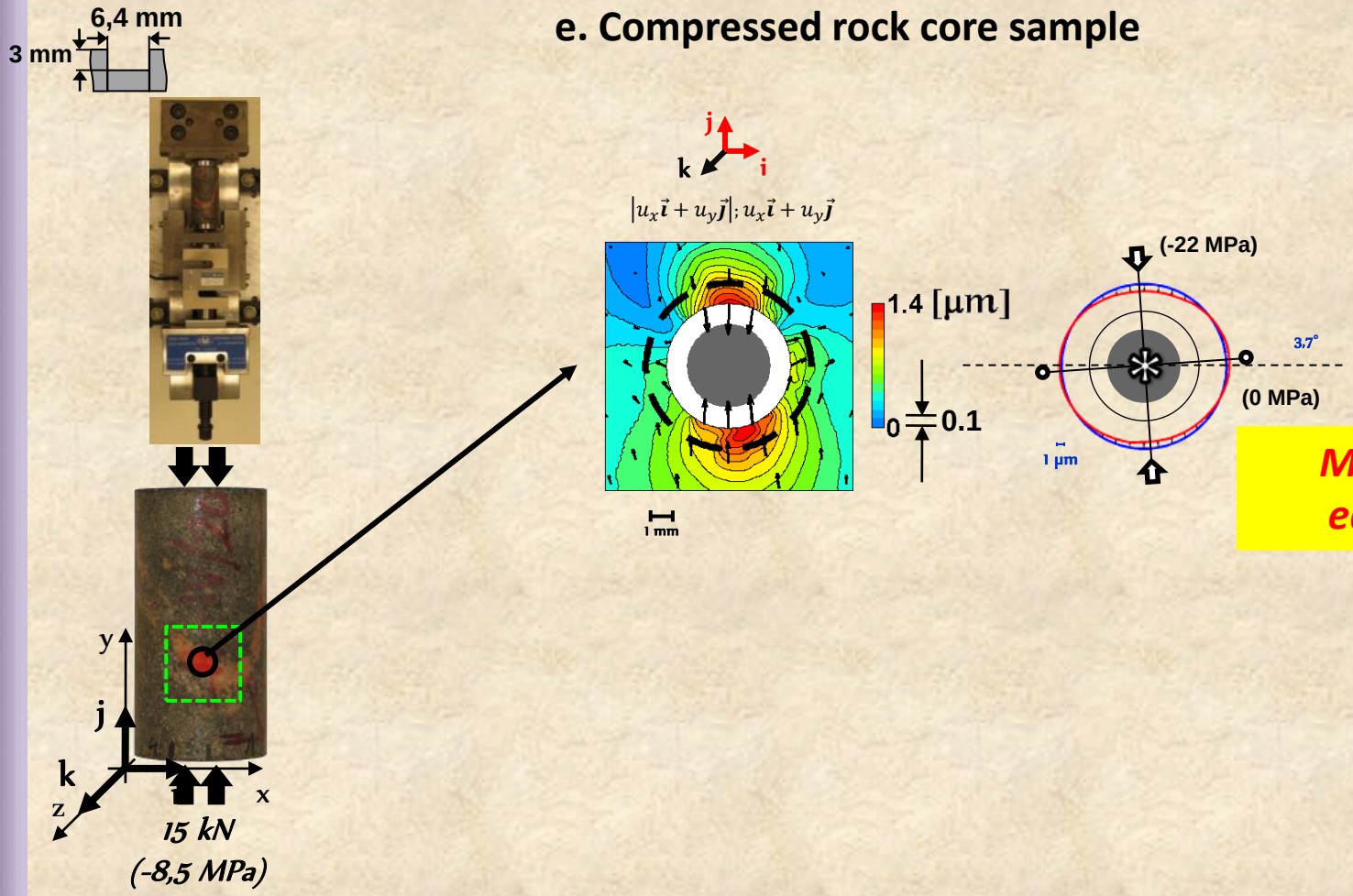
II. *Applied* DEFORMATION – *for diagnostic purposes*

II/B. *Properties accessible from STRESS (DISTRIBUTION)*

1. Actually formed stress

1.2. With load

e. Compressed rock core sample



Measured stress equals the load

Stress of a compressed rock core sample (in one sample point)