# IN-LINE INSPECTION OF HOT-ROLLED STEEL PRODUCTS BY HEAT FLUX THERMOGRAPHY

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FOERSTER

**FOP Spring Conference 2015**
**Gothenburg**

SWEDISH SOCIETY FOR NONDESTRUCTIVE TESTING

# AGENDA

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- Typical defects on hot-rolled steel surfaces
- Non-destructive testing by magnetic particle inspection (MPI)
- Principle and inspection setup for inductive thermography
- Inspection steps
- Heat flux thermography
- Conclusion

# CRACKS

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# CRACKS: MICROGRAPHS

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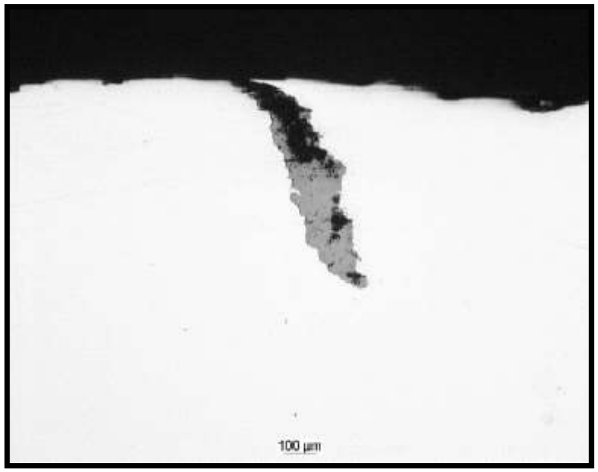


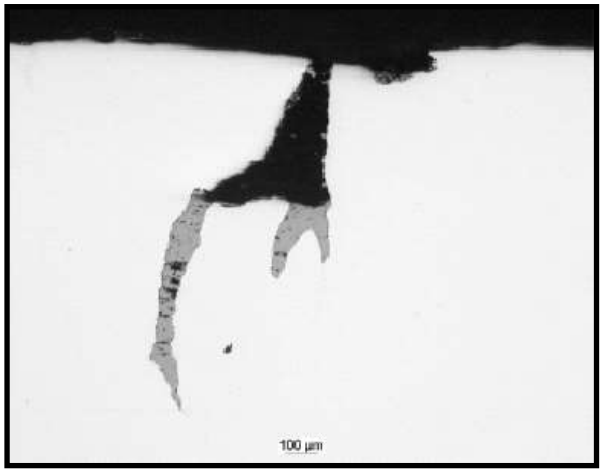


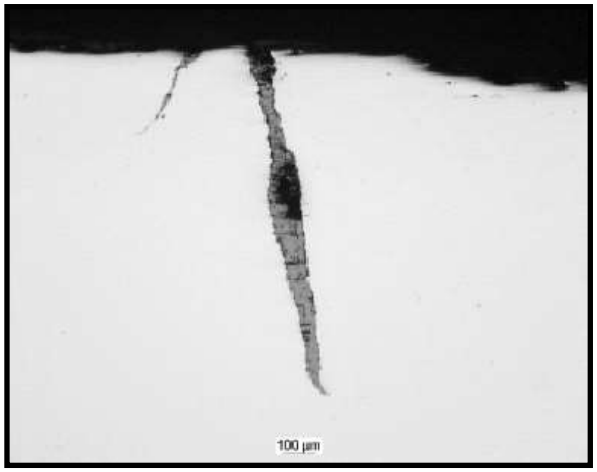


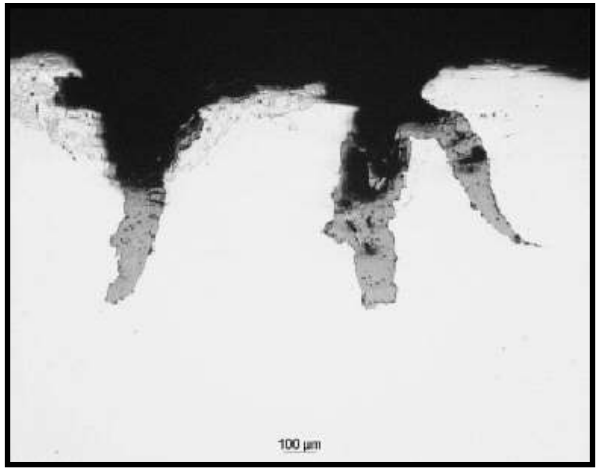


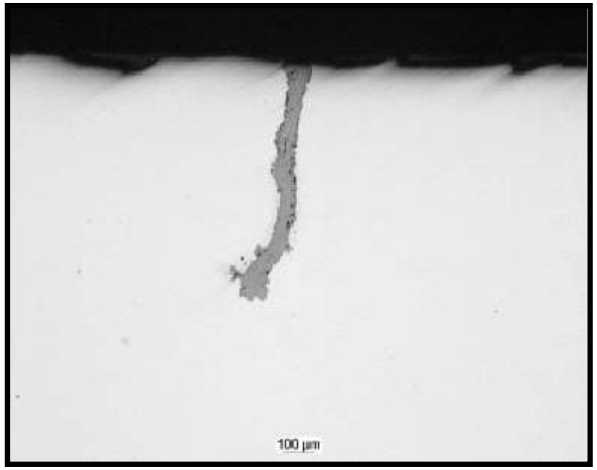

# SHELLS

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# MAGNETIC PARTICLE INSPECTION

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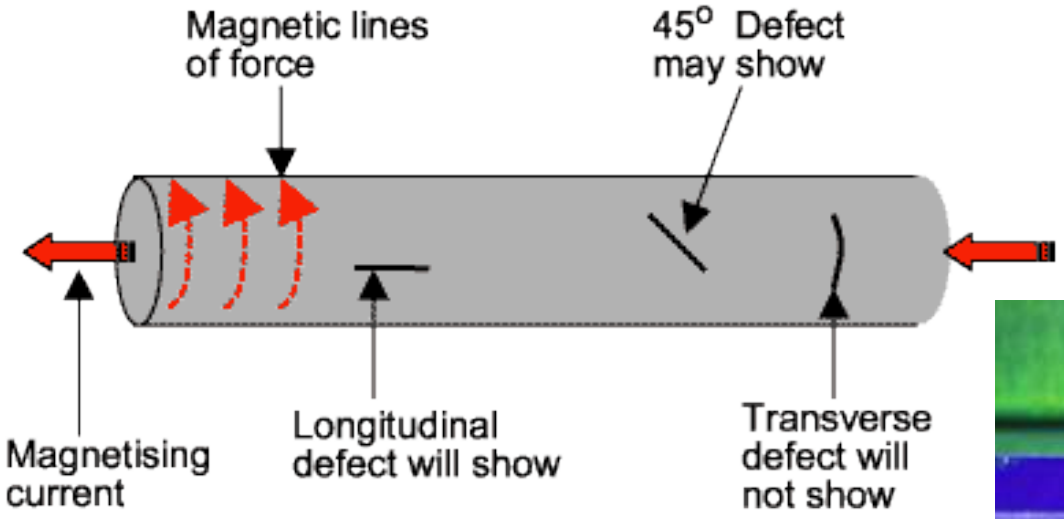


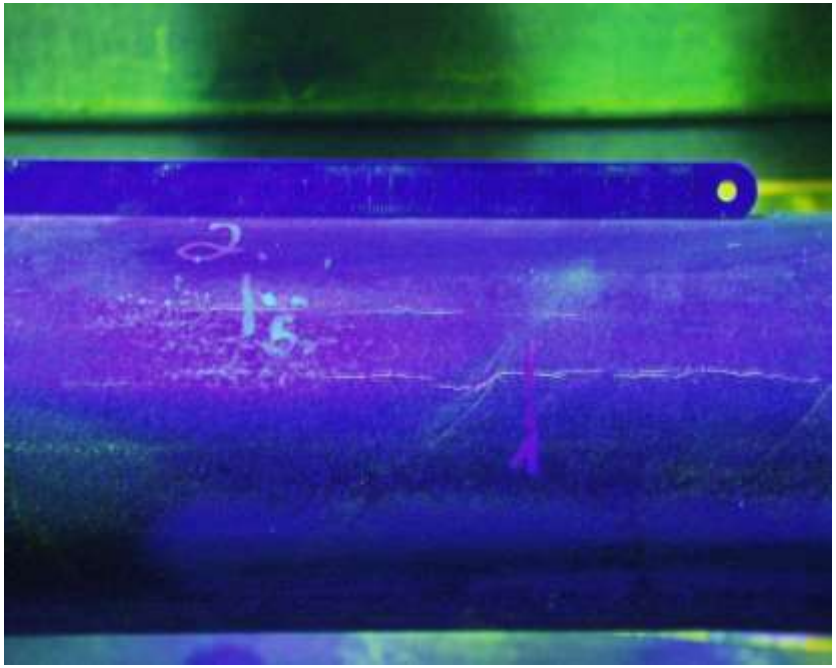

# MAGNETIC PARTICLE INSPECTION: LIMITATIONS

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Degree of automation

- Test results depend on the individual operator
- Limitation of inspection speed
- Depth identification and discrimination is not possible
  → High false indication rates
- Lack of detailed documentation
- No Level 2 integration possible

- Working environment
  - Large space requirements
  - Difficult working conditions regarding UV-lighting and chemical handling
  - Used solvents affect the environmental safety
  - Additional working steps (demagnetizing, cleaning)

# PRINCIPLE:
# INDUCTIVE THERMOGRAPHY

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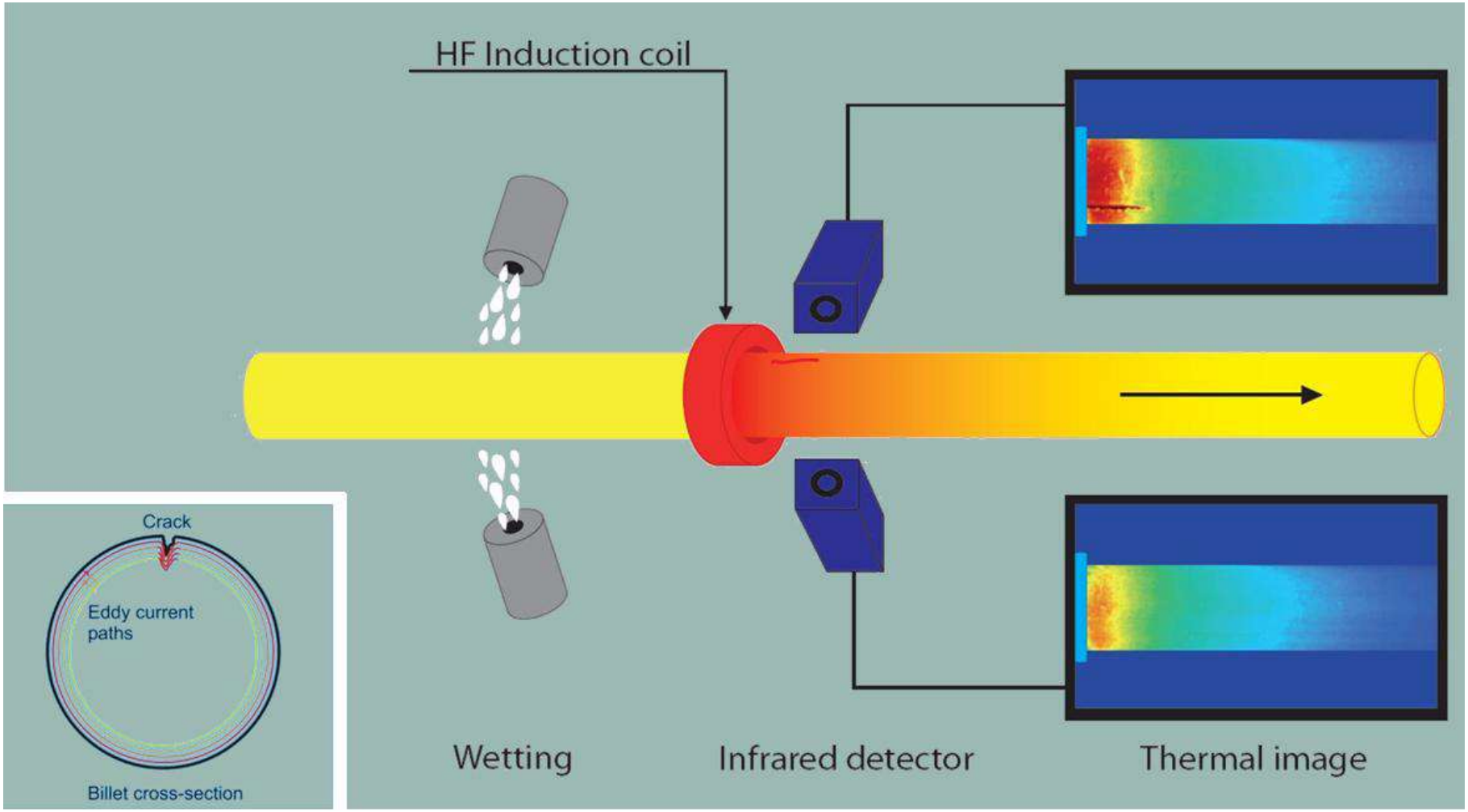

# TEST EQUIPMENT

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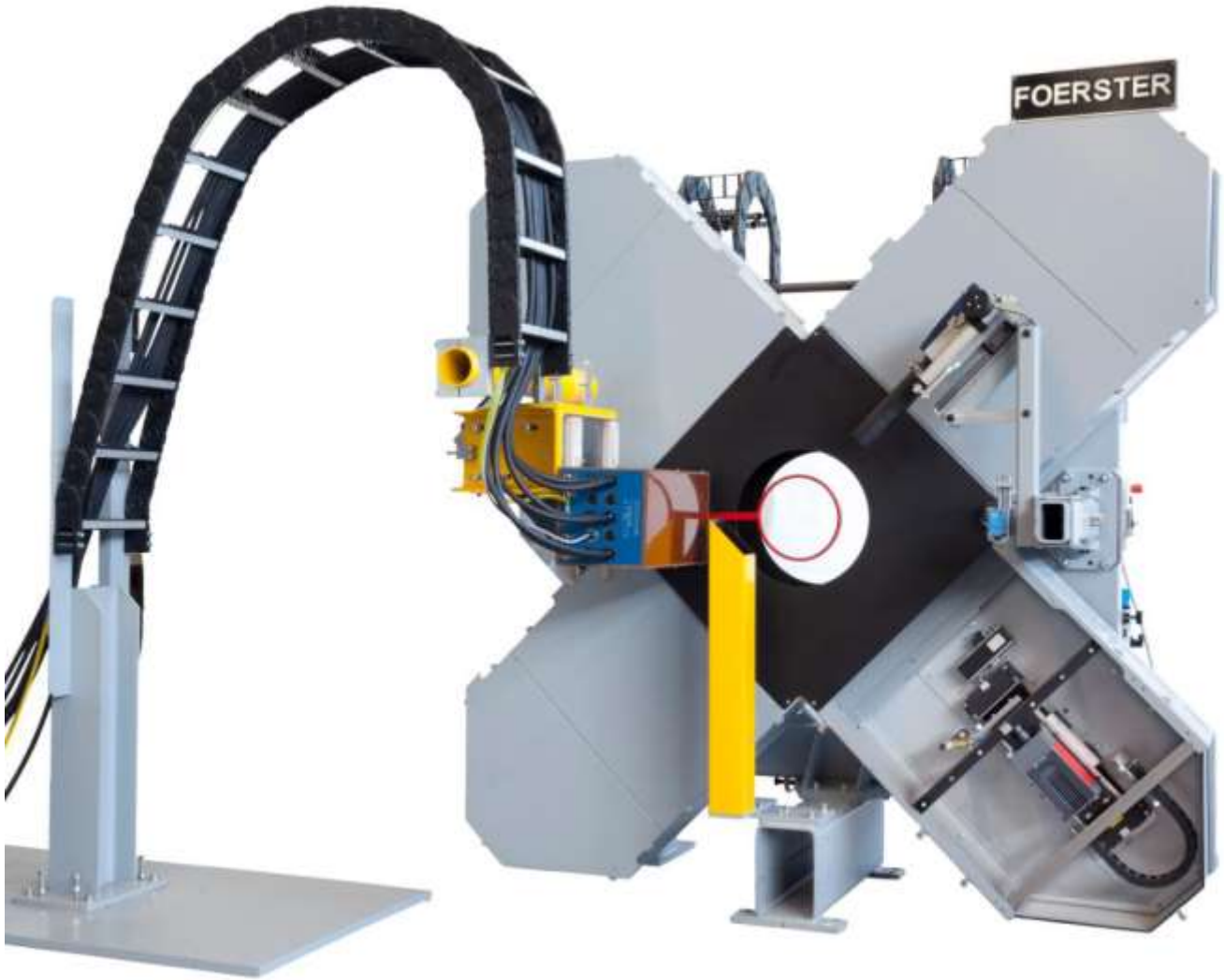

# STEP 1: WETTING

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# EMISSIVITY OF STEEL WITH A THIN WATER FILM

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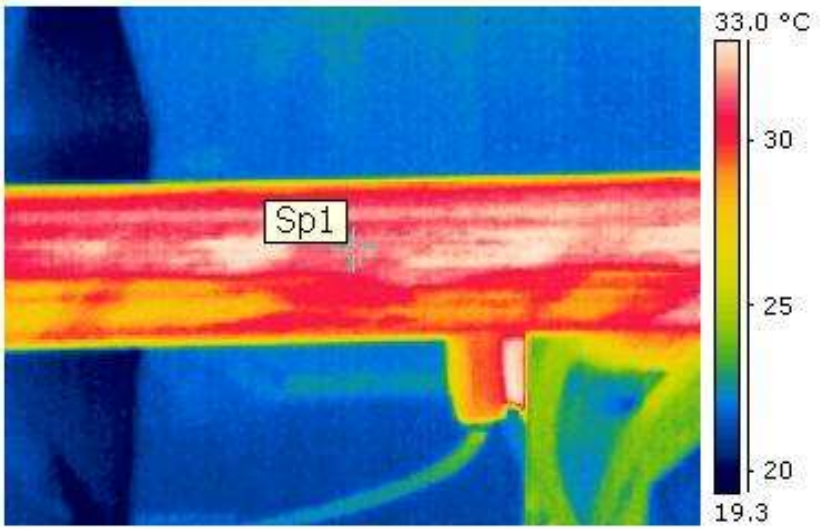
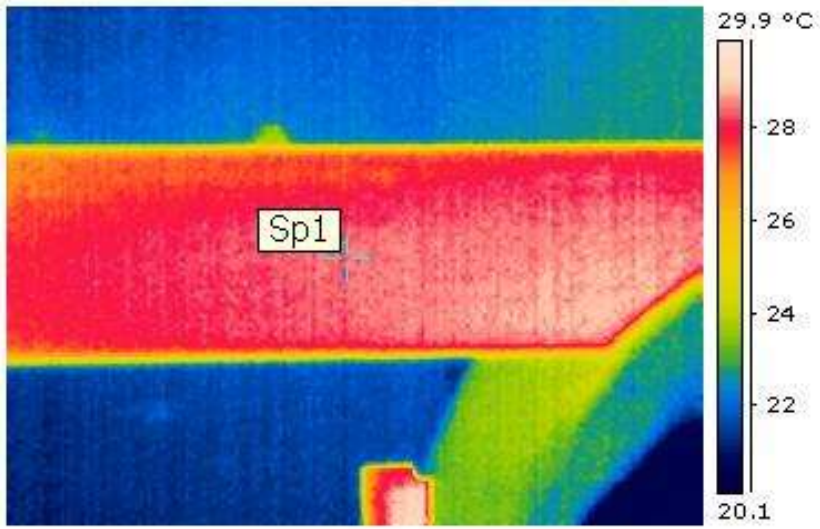



Without water:

Local variation of emissivity




With water:

Homogenous emissivity

$\varepsilon \approx 0.95$

# STEP 2: HEATING

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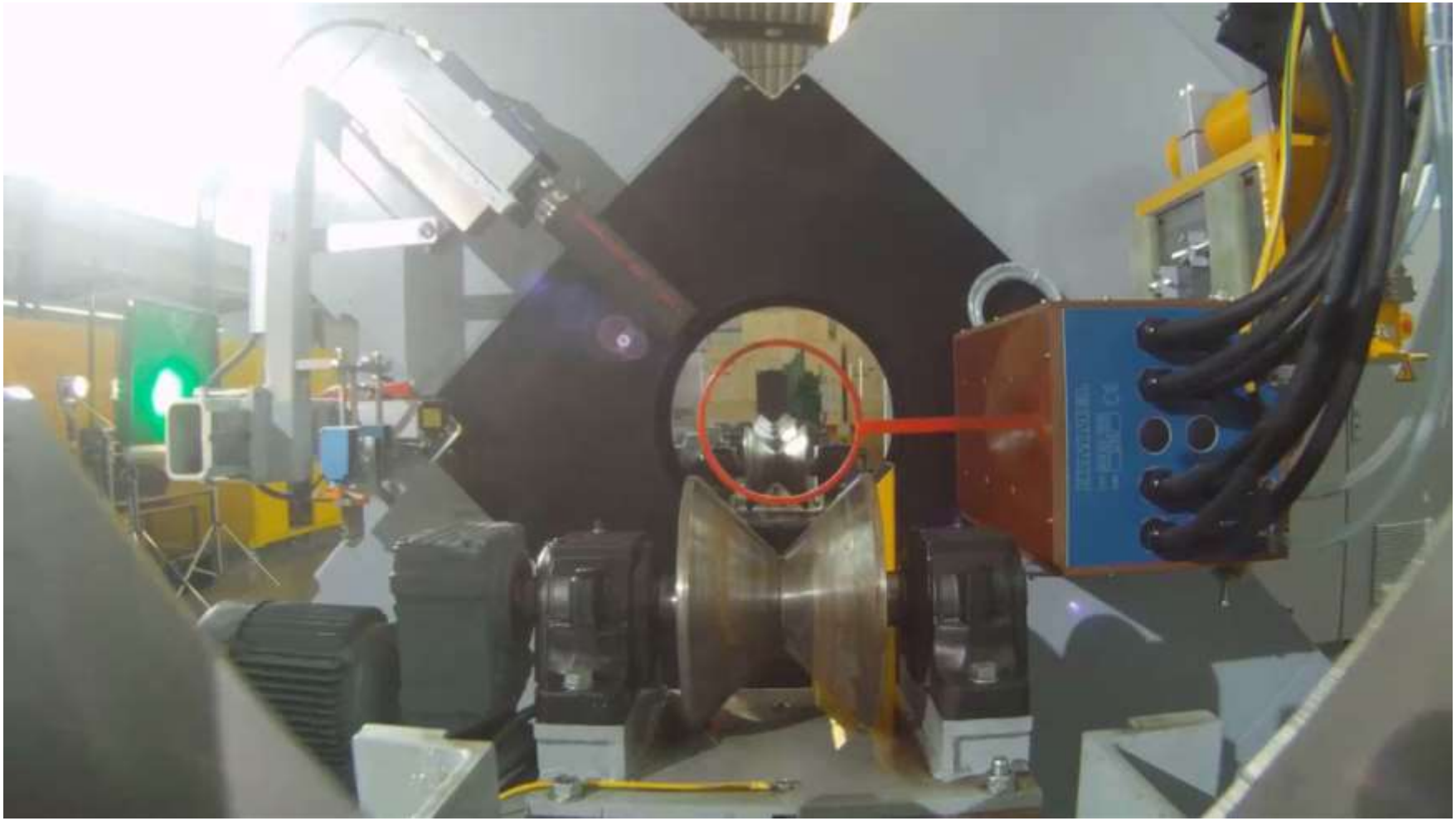

# TEMPERATURE INCREASE IN PRESENCE OF A FLAW

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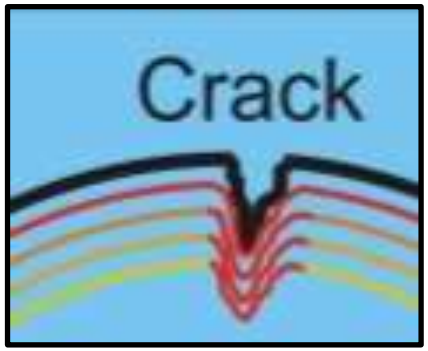


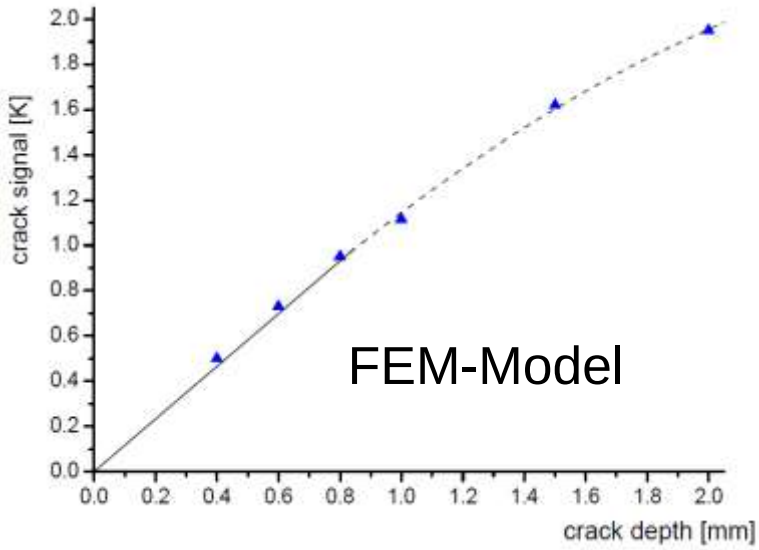


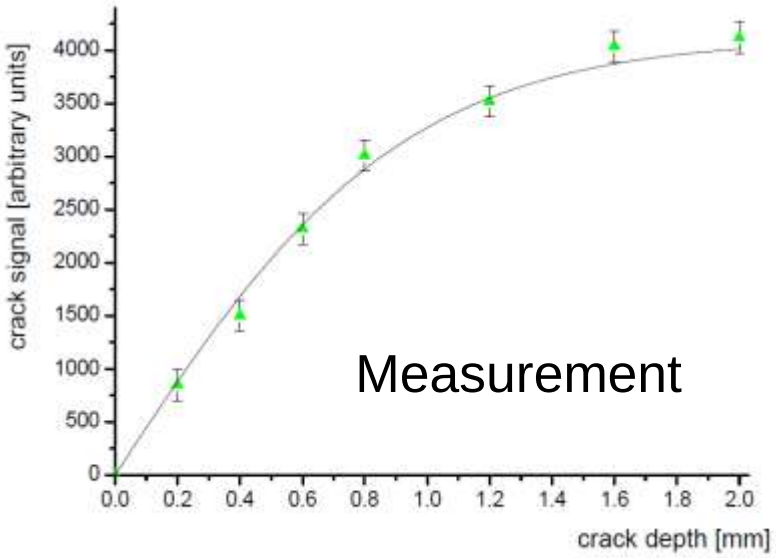

# STEP 3: IMAGE AQUISITION

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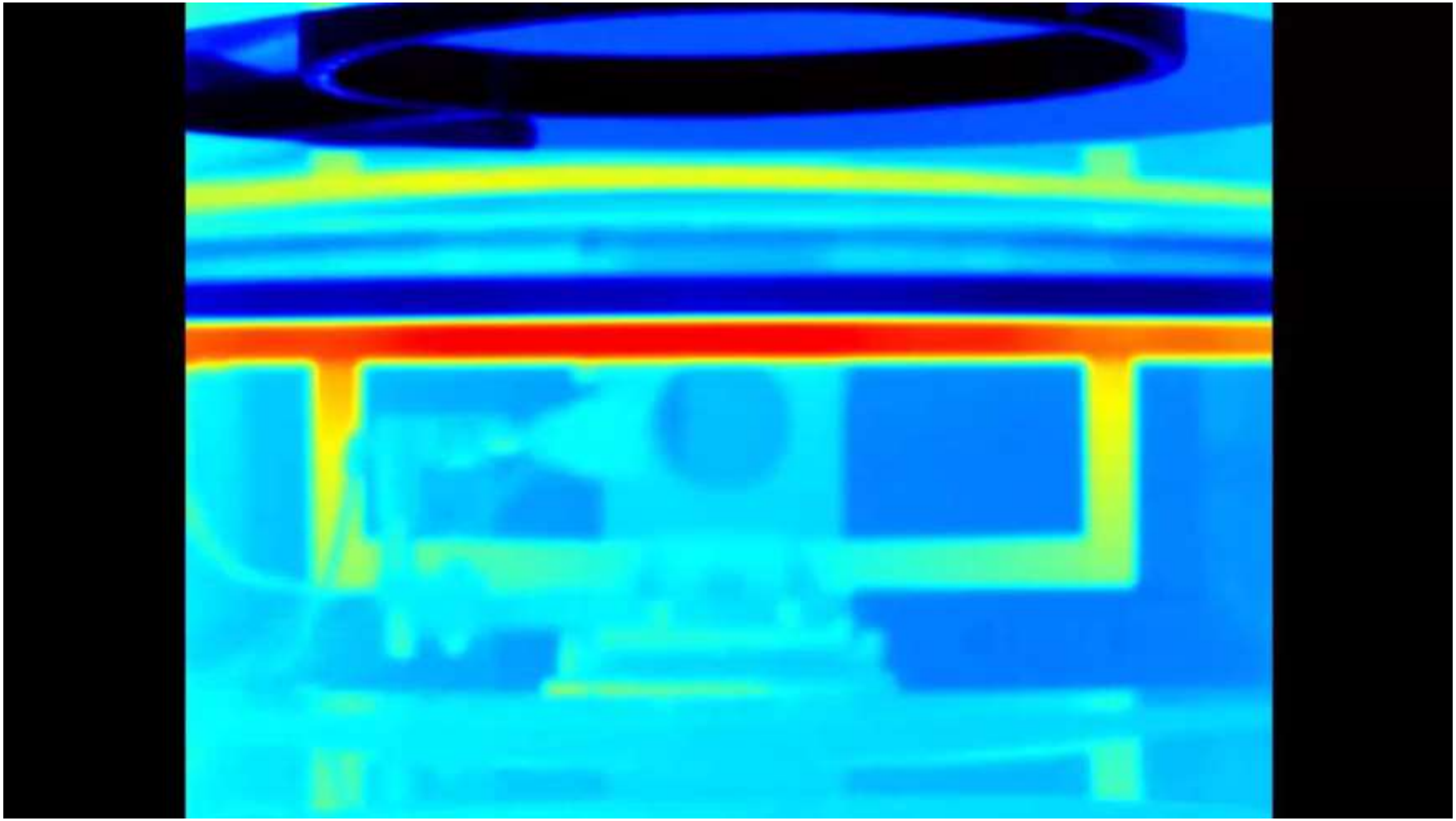

# THERMAL IMAGE

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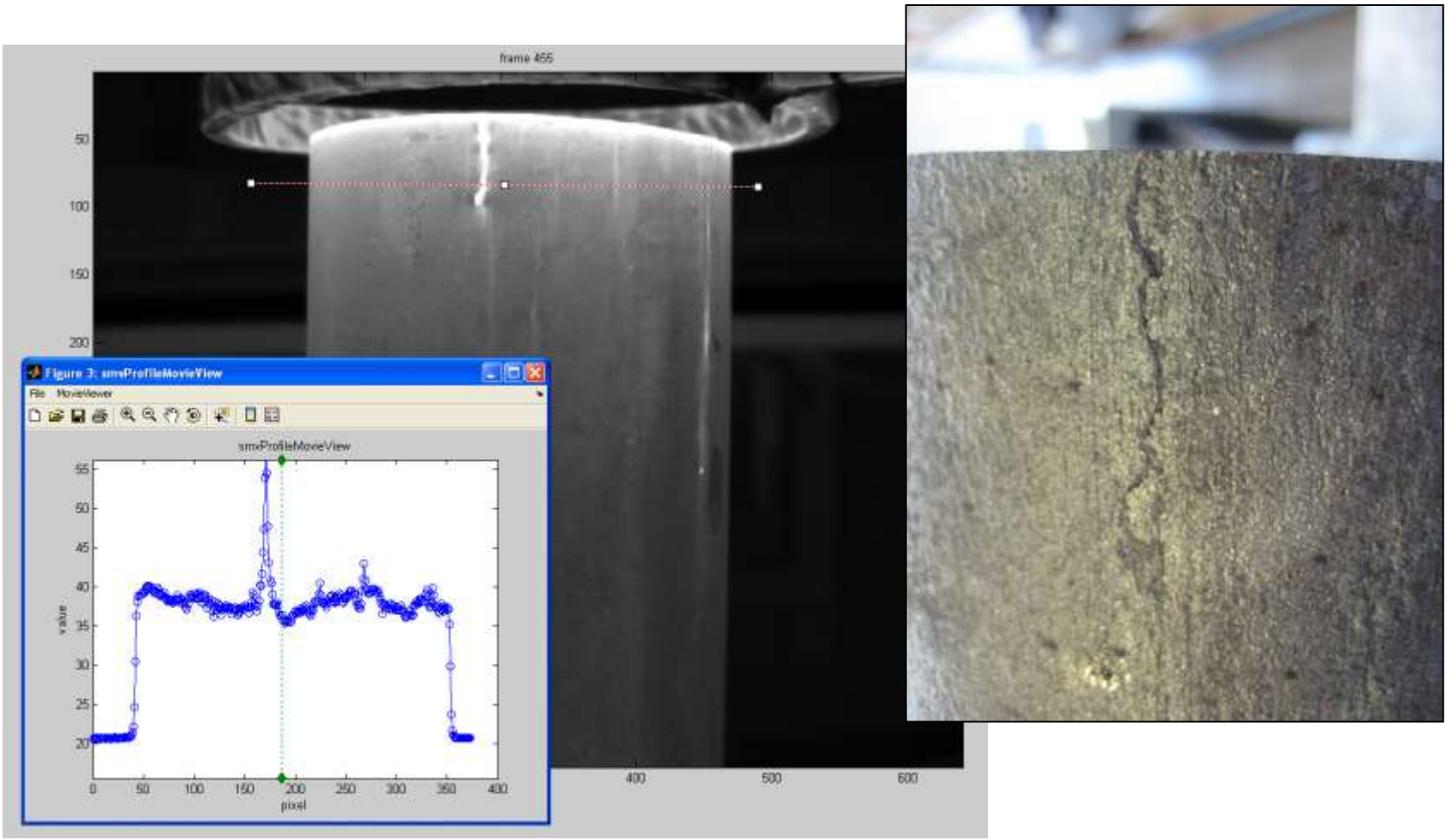

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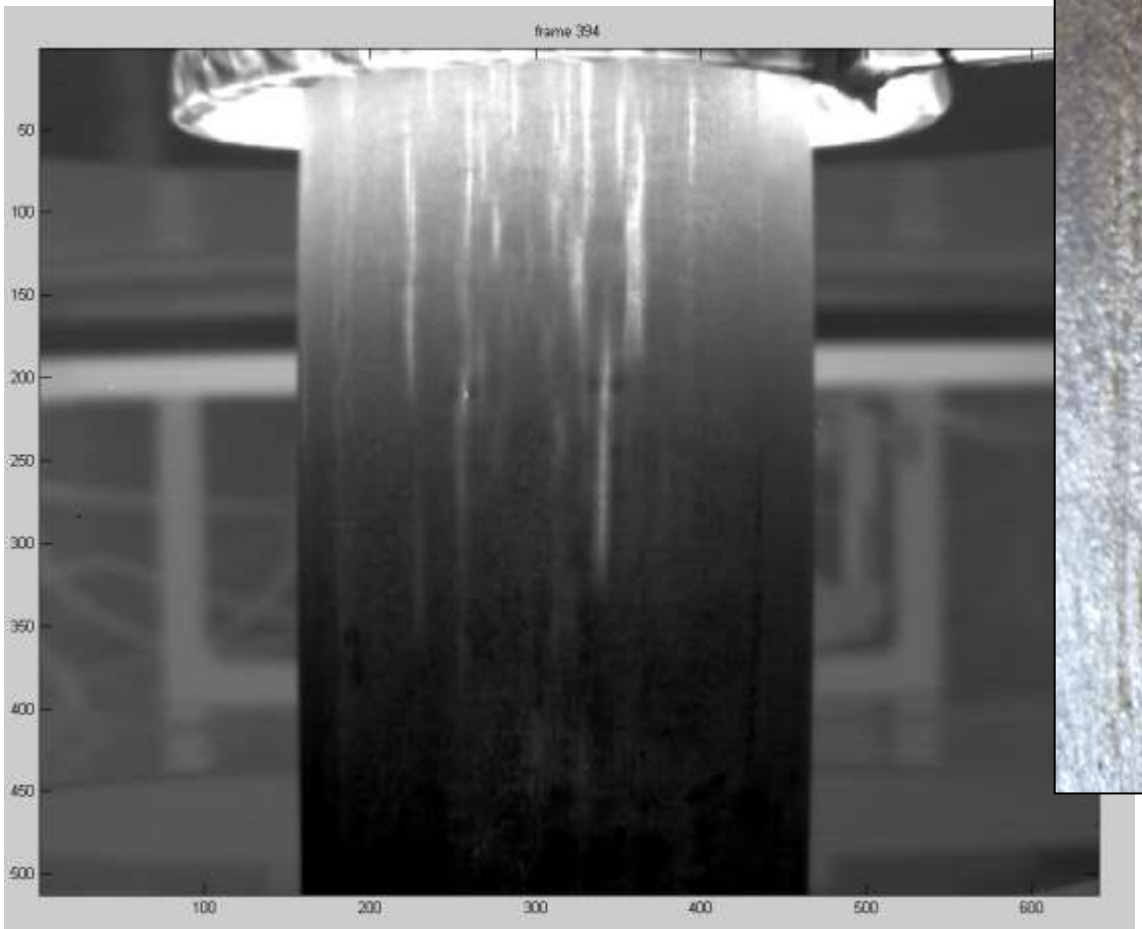


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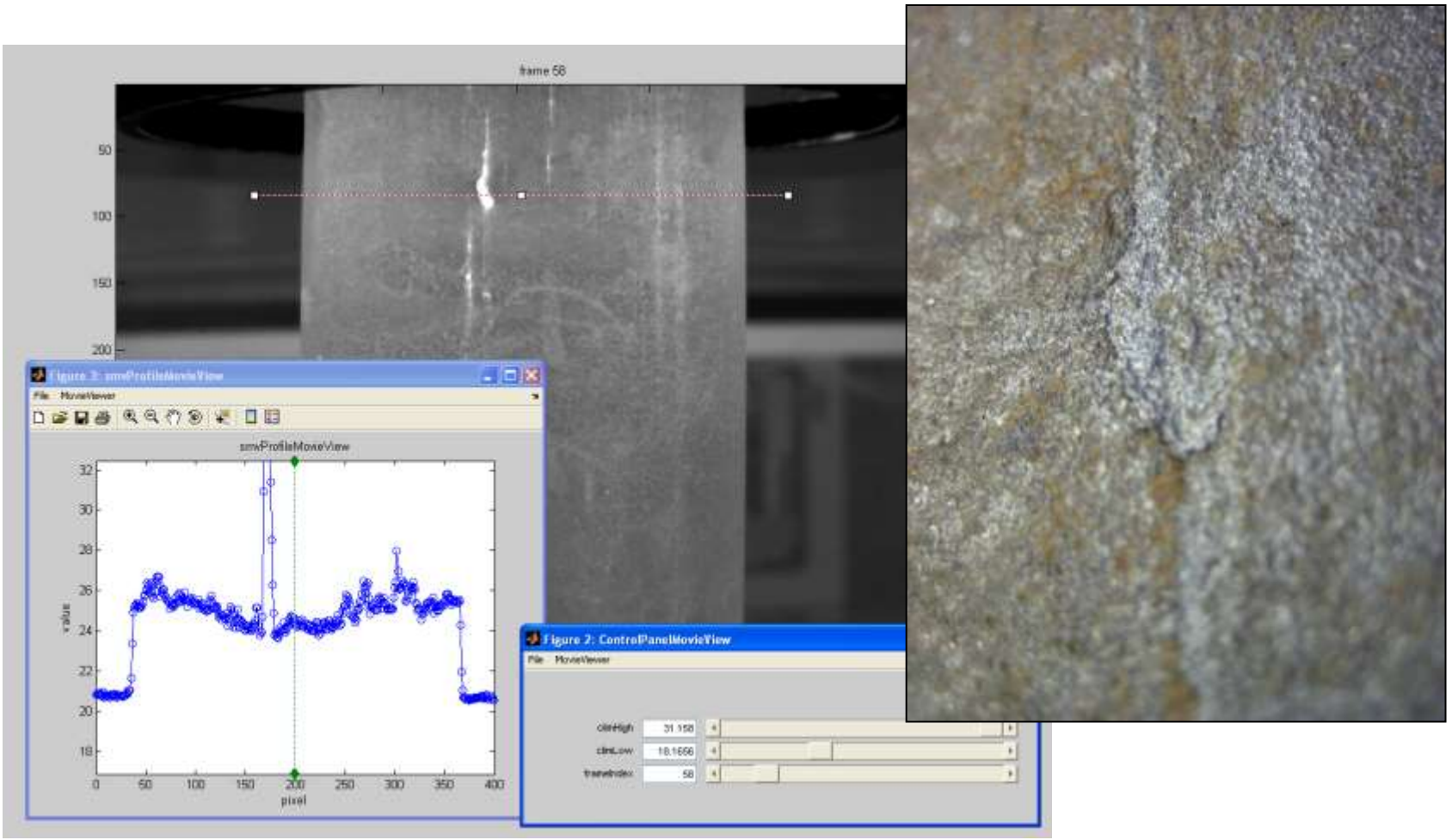

# STEP 4: IMAGE PROCESSING

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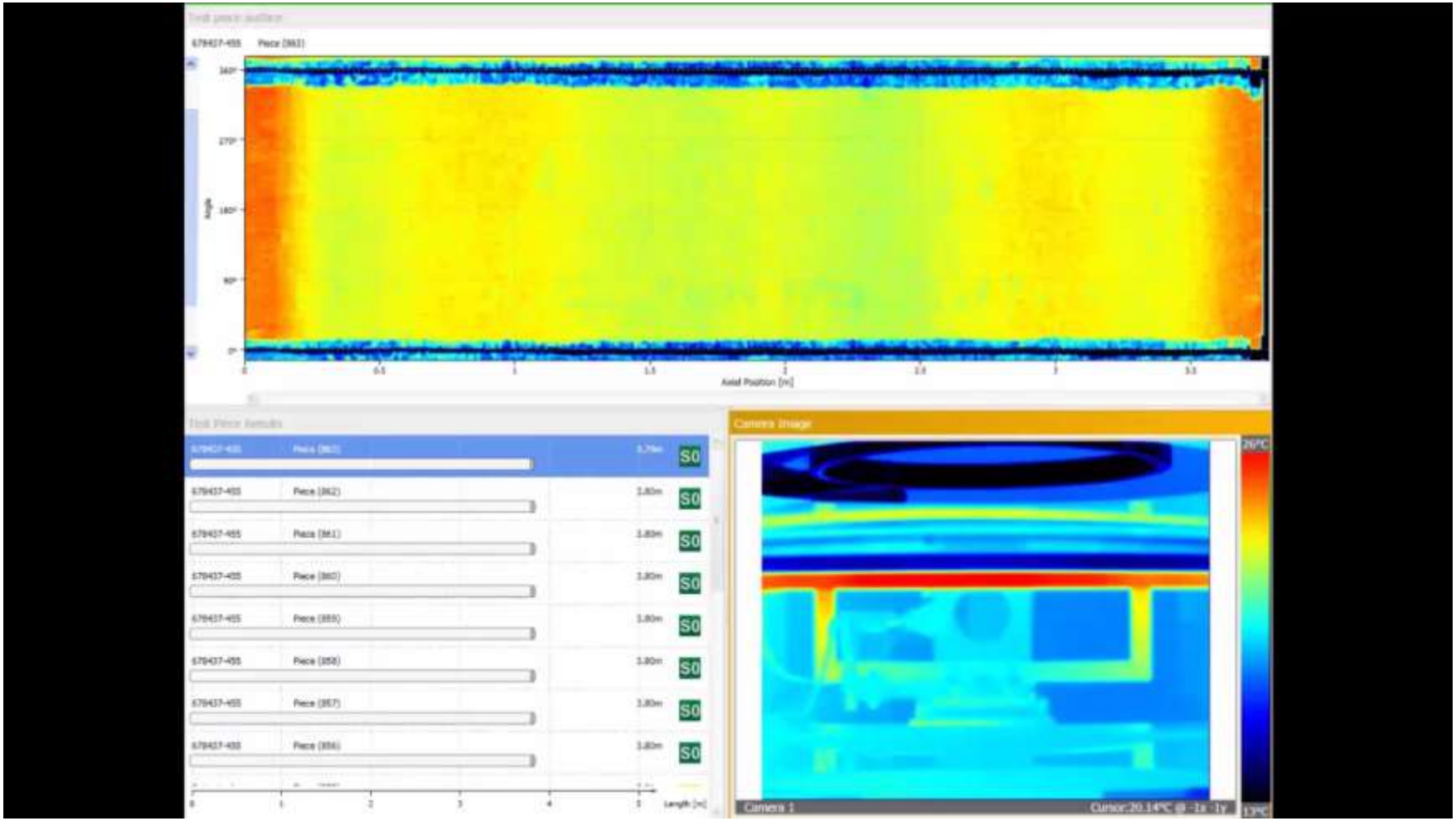

# HEAT DISSIPATION IN CRACK

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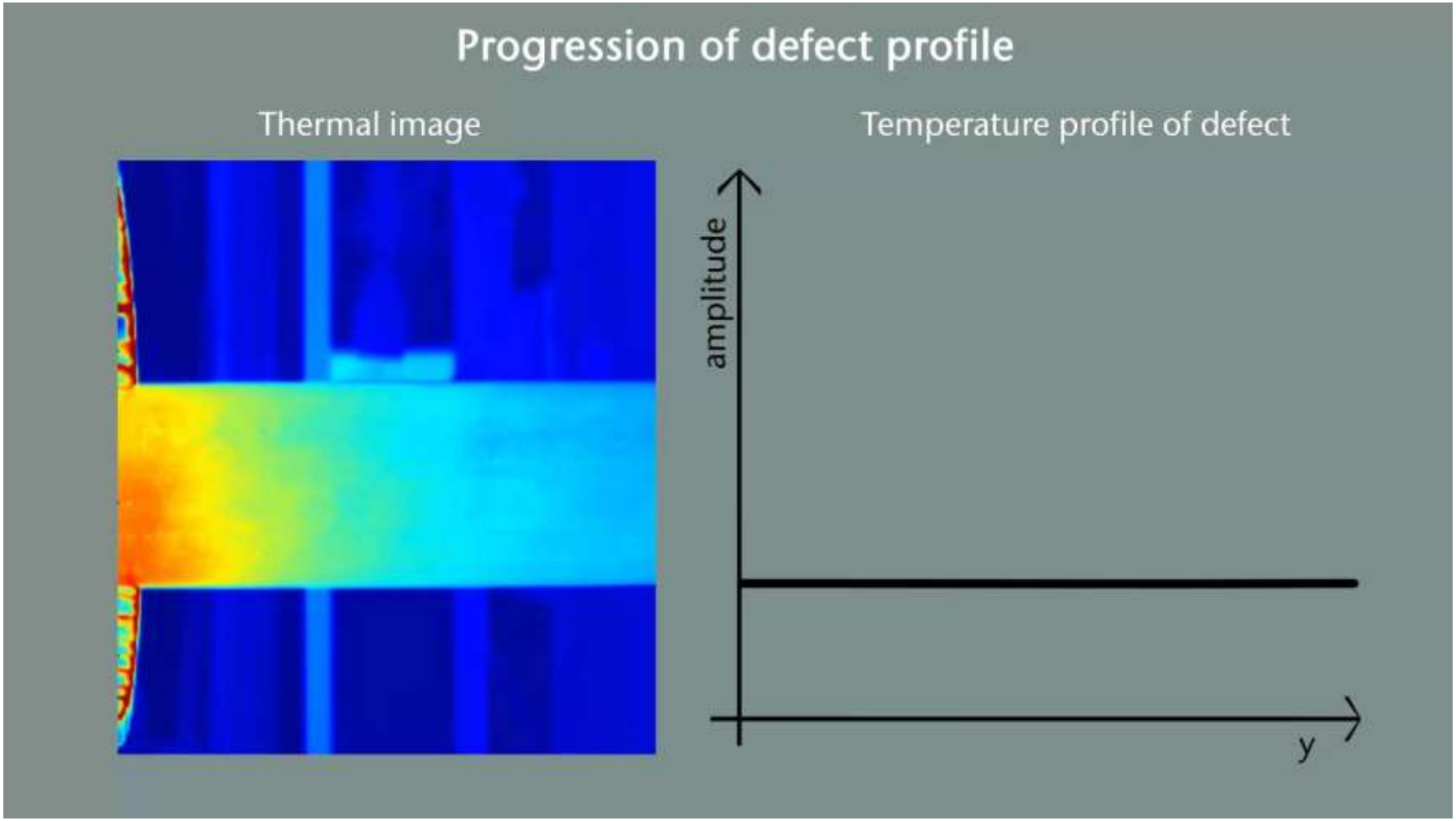

# NEW CONCEPT:
# HEAT FLUX THERMOGRAPHY

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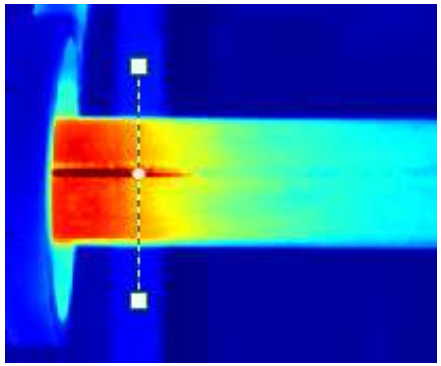

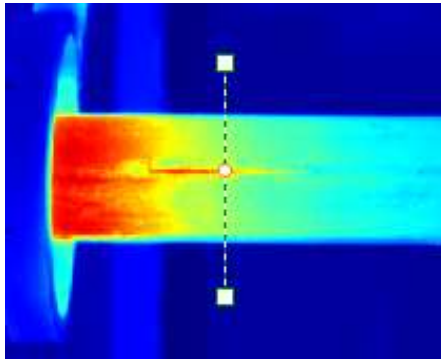

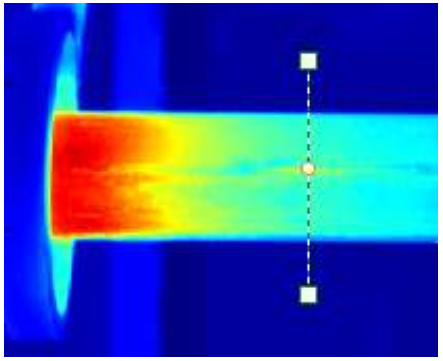

- Up to 30 shots of every single position in the ‚Field of View' !
- 100 frames/s, 640x512px, MWIR
- Resolution 1/2 mm x 1/2 mm

# TIME-DEPENDENCY OF DEFECT PROFILE

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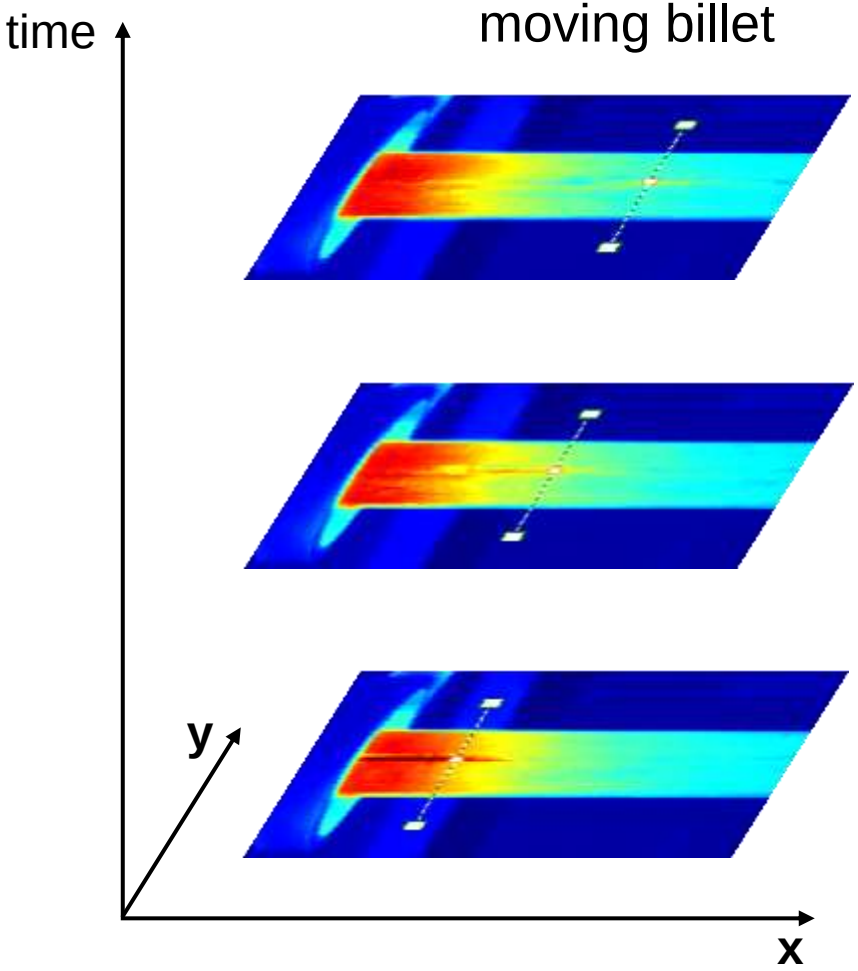
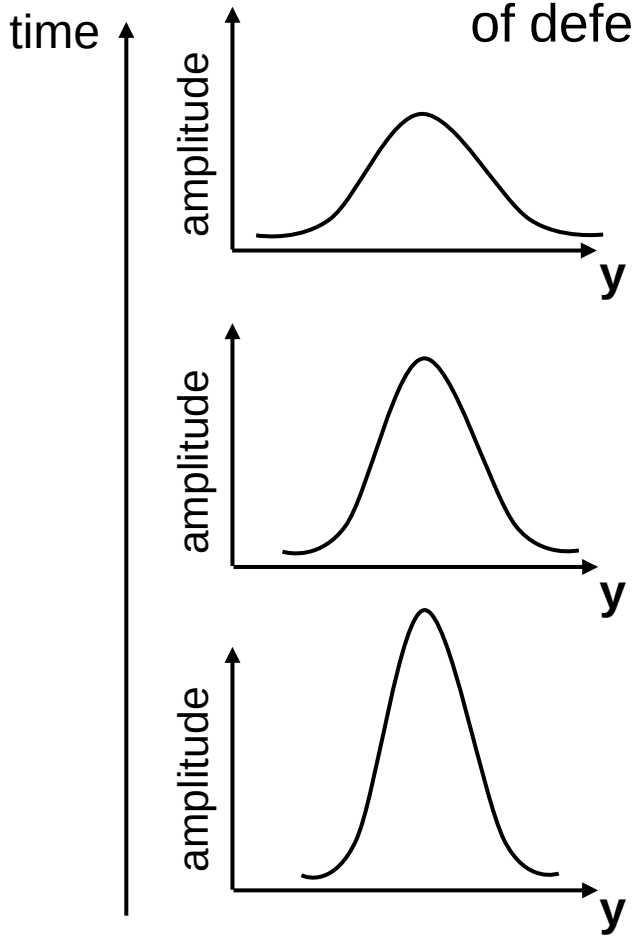
Image sequence of moving billet




Temperature profile of defect



# TIME-DEPENDENCY OF DEFECT PROFILE PARAMETERS

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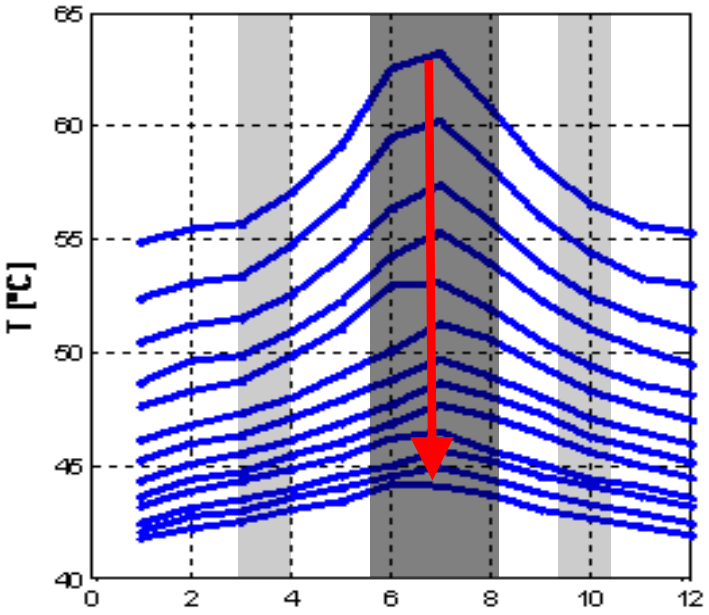
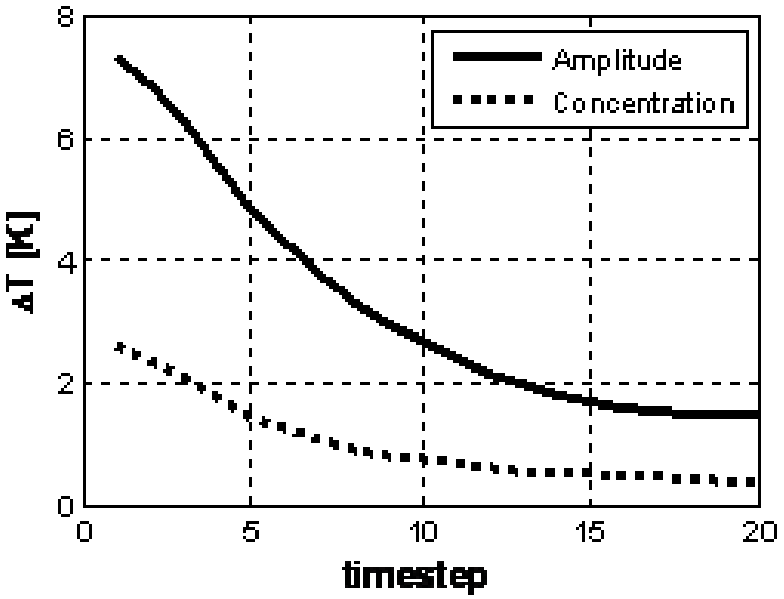



Defect profile
at different times




Time dependency

- defect amplitude
- heat concentration

# BEHAVIOUR OF NOISE (CASE 1)

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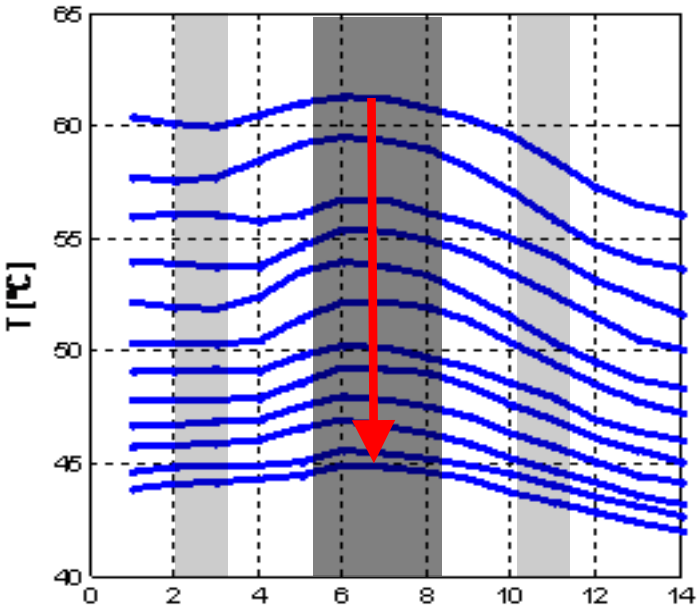


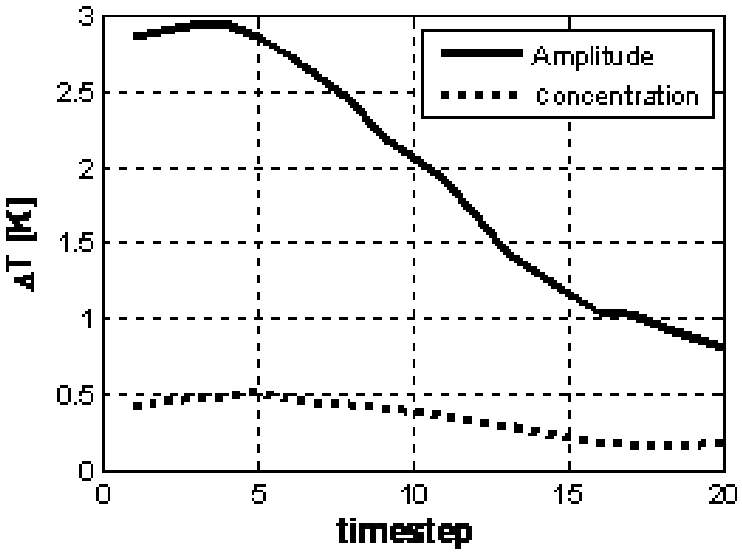


Broad amplitude,
therefore small concentration
and concentration change rate

# BEHAVIOUR OF NOISE (CASE 2)

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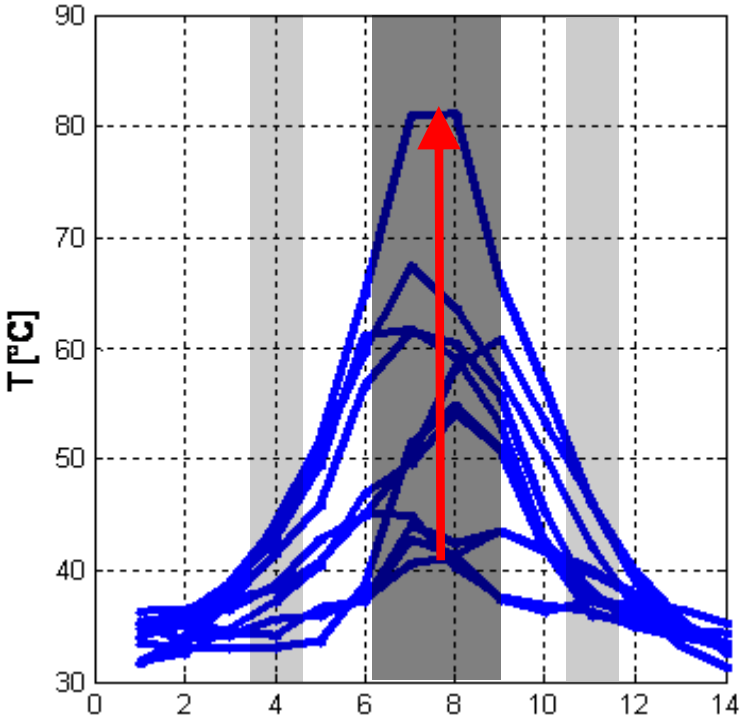


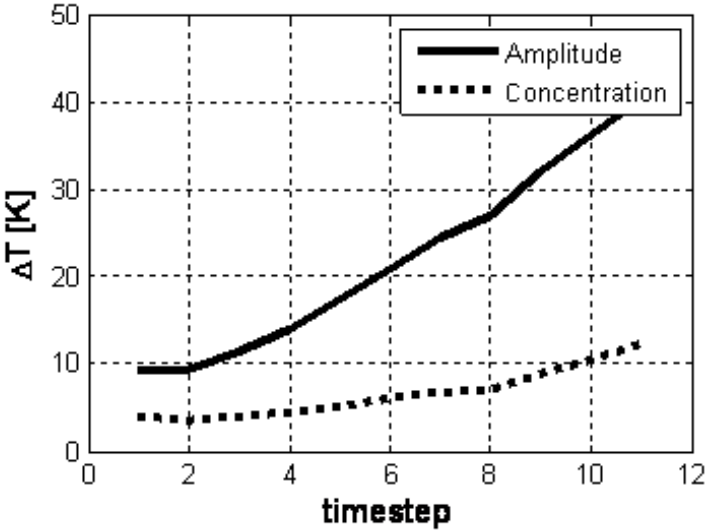


Increase of signal amplitude,
also increase of concentration

# CRITERIA FOR DEFECT RATING

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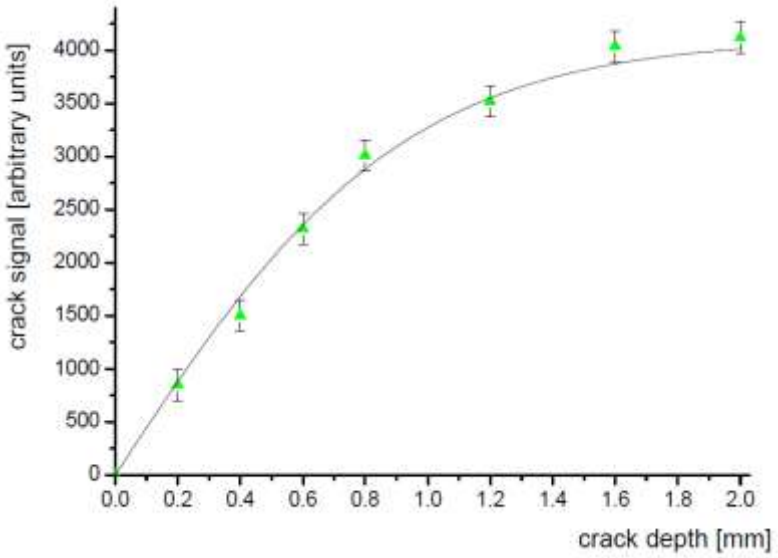
- Amplitude ΔT of defect signal → main criterion that defines the depth of the defect




- Cooling rate of defect signal in longitudinal direction
- Change rate of heat concentration in defect
- Shape of the ‘crack’ signal

# CONCLUSION

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Thermography

- Contactless
- Max. inspection speed: 1.5m/s
- Complete inspection of test piece with minimum untested end

Usage of Focal plane array (FPA)

- Detection of very short defects → Minimum defect length: 10mm

Heat Flux Thermography

- Excellent suppression of false indications → minimum repair costs
- Improvement if signal-to-noise ration → minimum defect depth: 0.3mm

# FURTHER CAPABILITIES

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- Full documentation of request, piece and defect results as a well as all testing conditions and parameters
- Automatic marking and sorting
- Level 2 integration

# IMPRESSIONS IN FINISHING LINE

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# DEFECTOVISION® IR

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