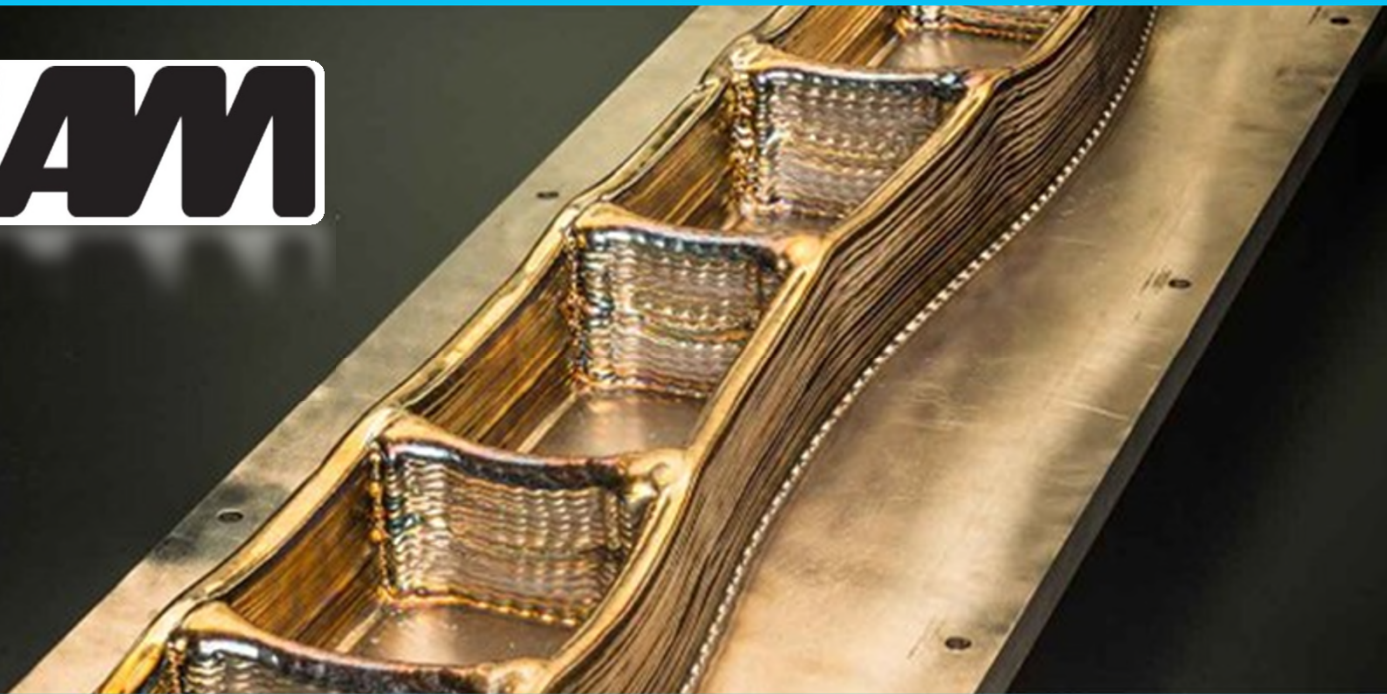


Residual Stress Control in the Additive Manufacture of Large Scale Metal Structures

WAAM



Presented by Stewart Williams

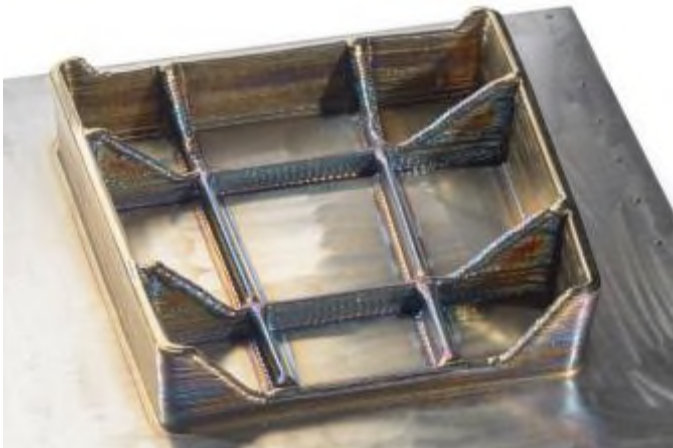
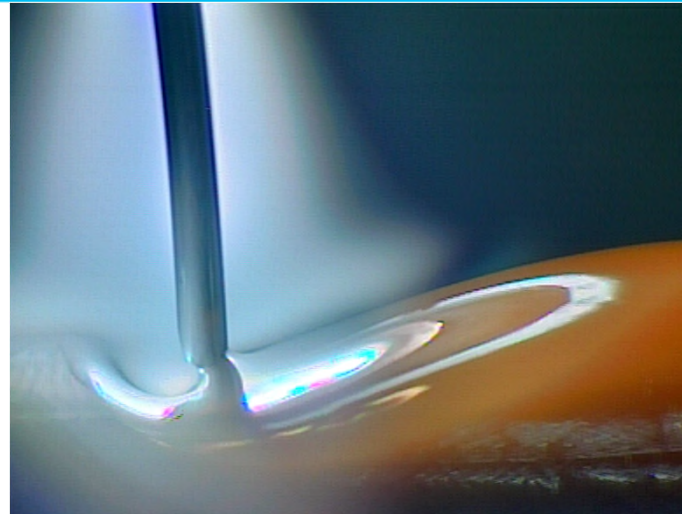
Welding Engineering and Laser Processing Centre

www.cranfield.ac.uk

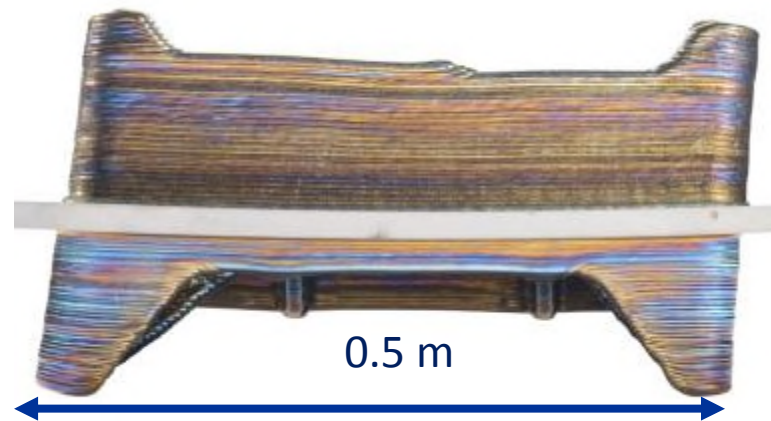
Agenda

1. Wire + Arc Additive Manufacturing **WAAM**
2. Development, Magnitude and Distribution of σ_{res}
3. Measurement of σ_{res}
 - Contour Method
 - Neutron Diffraction
4. Approaches to Control σ_{res} by
 - Top Rolling
 - Pinch Rolling
 - Peening

Wire + Arc Additive Manufacture (WAAM) Process

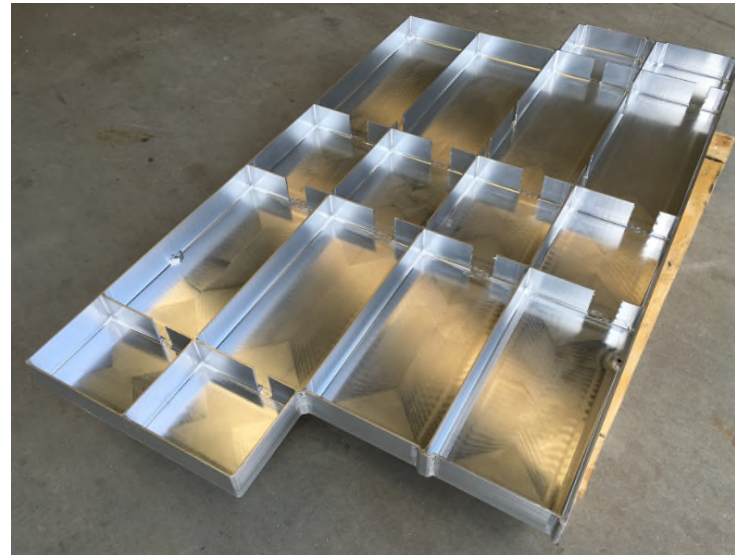


Deposition time 24 hours



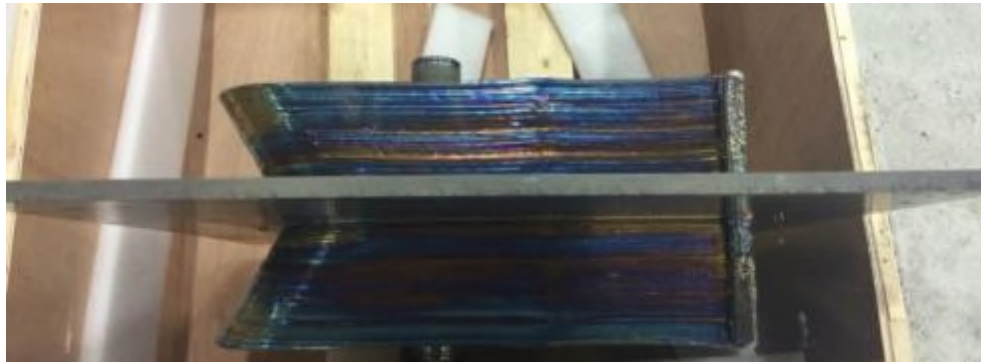
Key WAAM process features

- Business drivers – cost and lead time saving
- Build rates 0.5 - 4 kg/hour – typical 1kg/hr titanium
- Unlimited build volume
- Fully dense materials with excellent mechanical properties
- Minimum feature size 2 mm
- No commercial systems available – yet

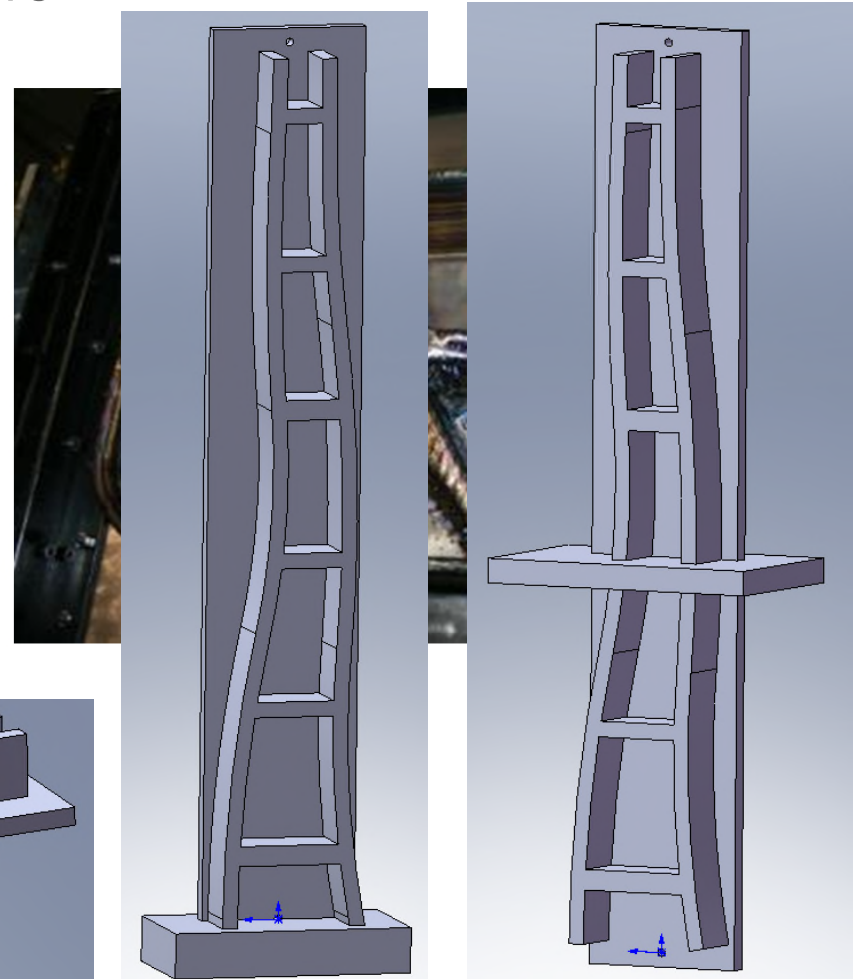
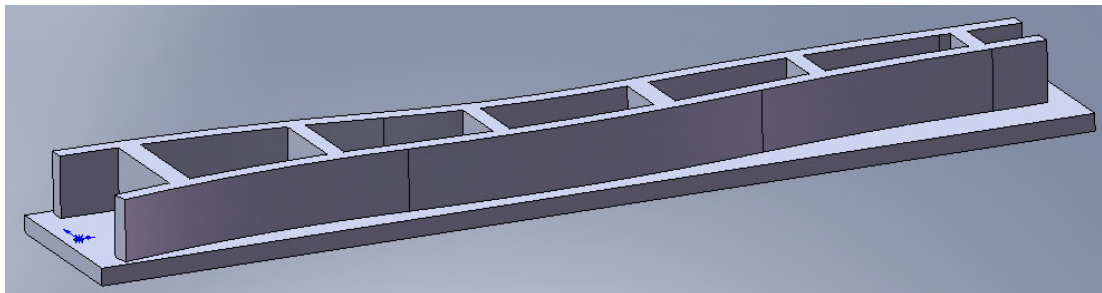


Distortion management – usual approaches

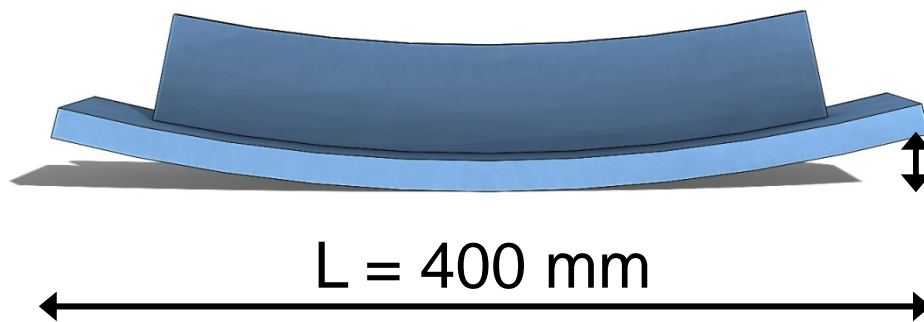
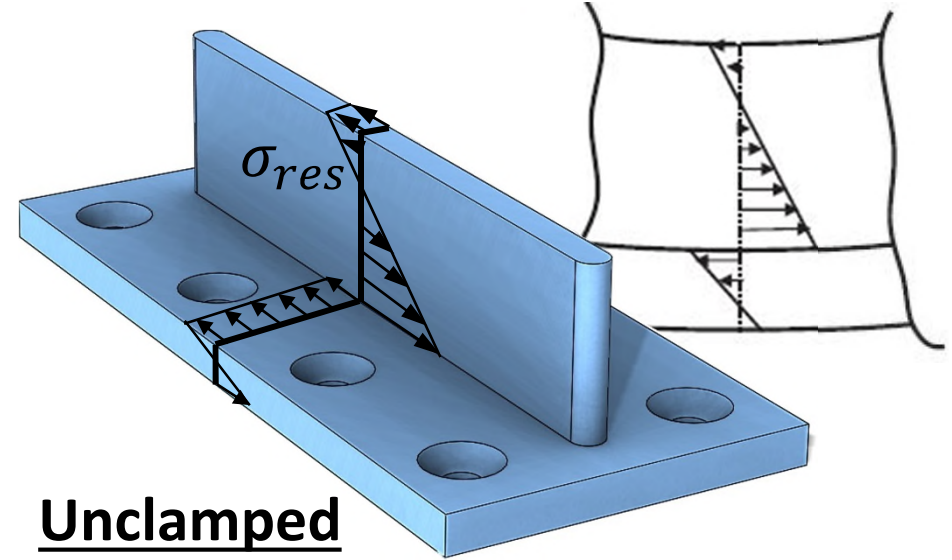
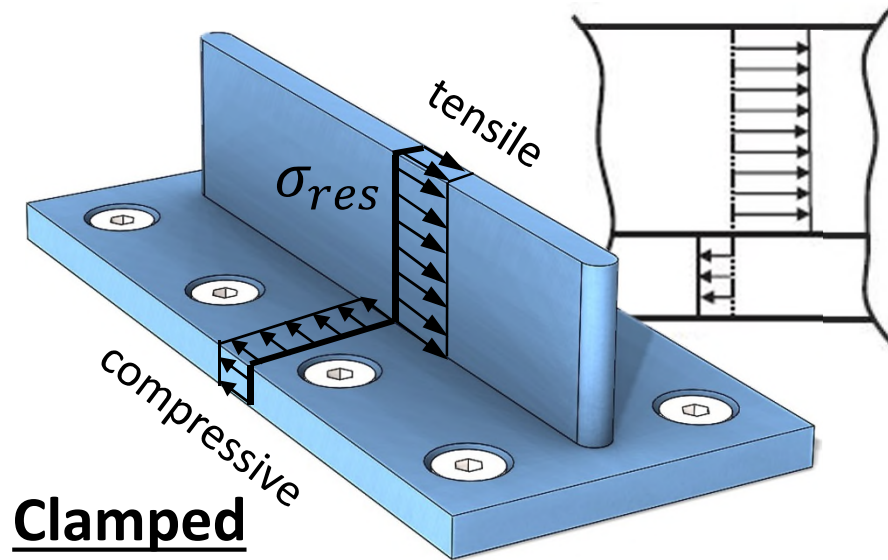
- Back to back part building, stress relieve and split into two by EDM



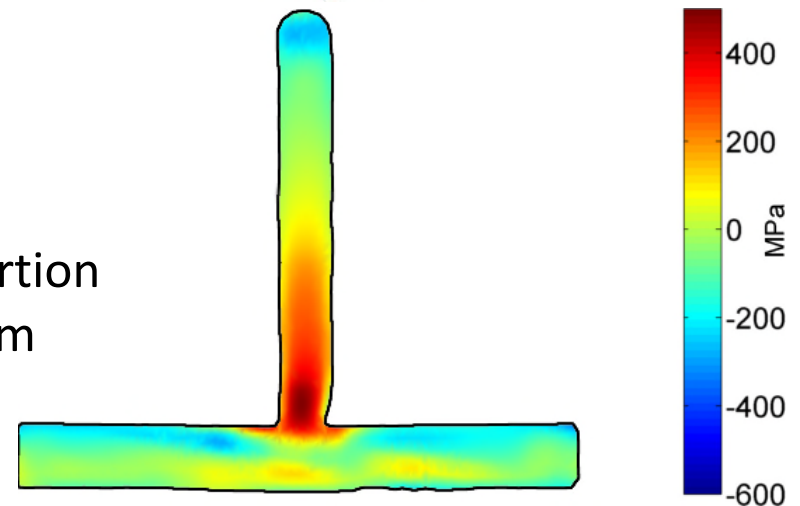
- Build in tool, stress relieve and then remove from the tool
- Build in a different orientation



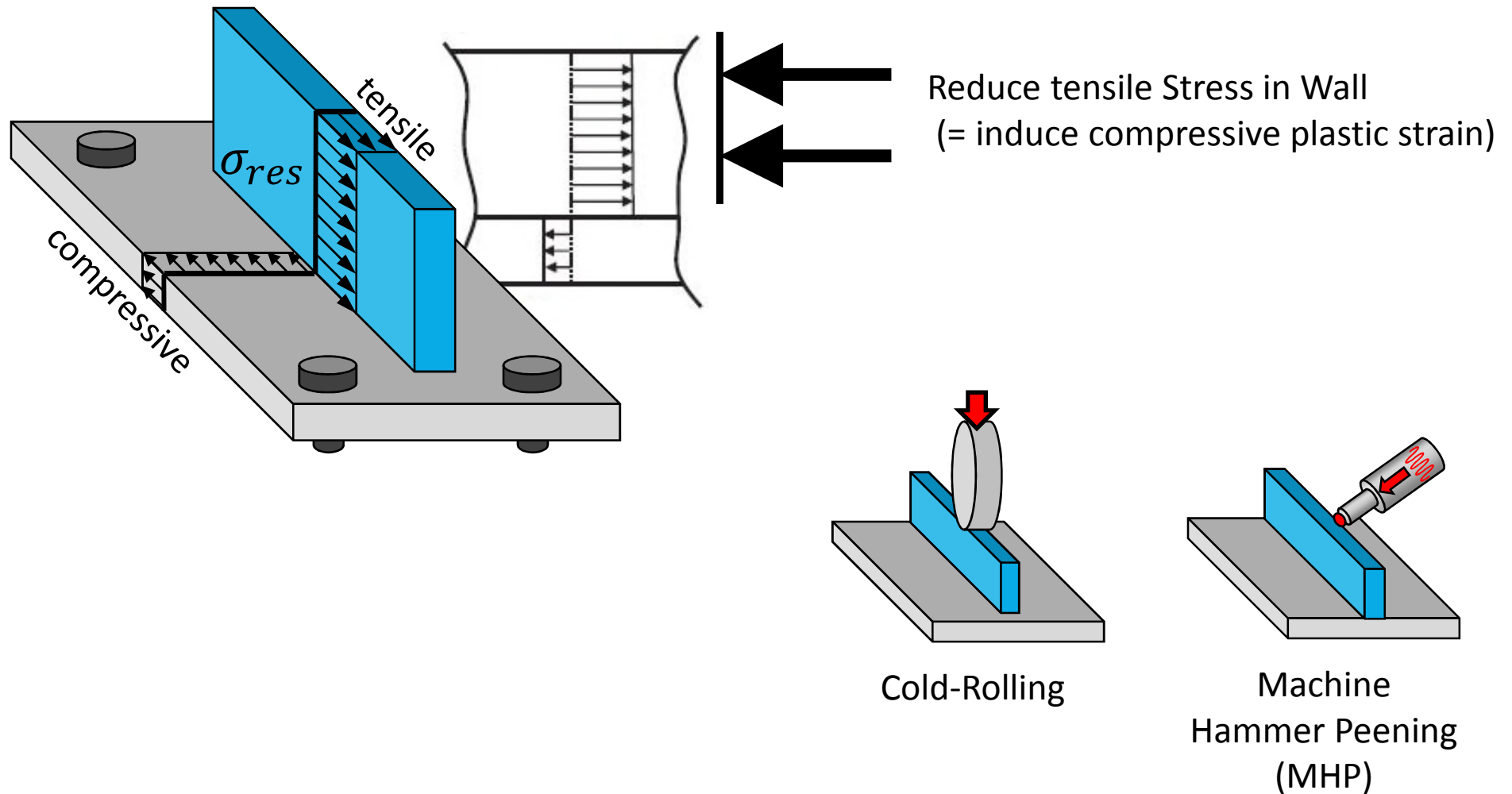
Residual stress and distortion in simple walls



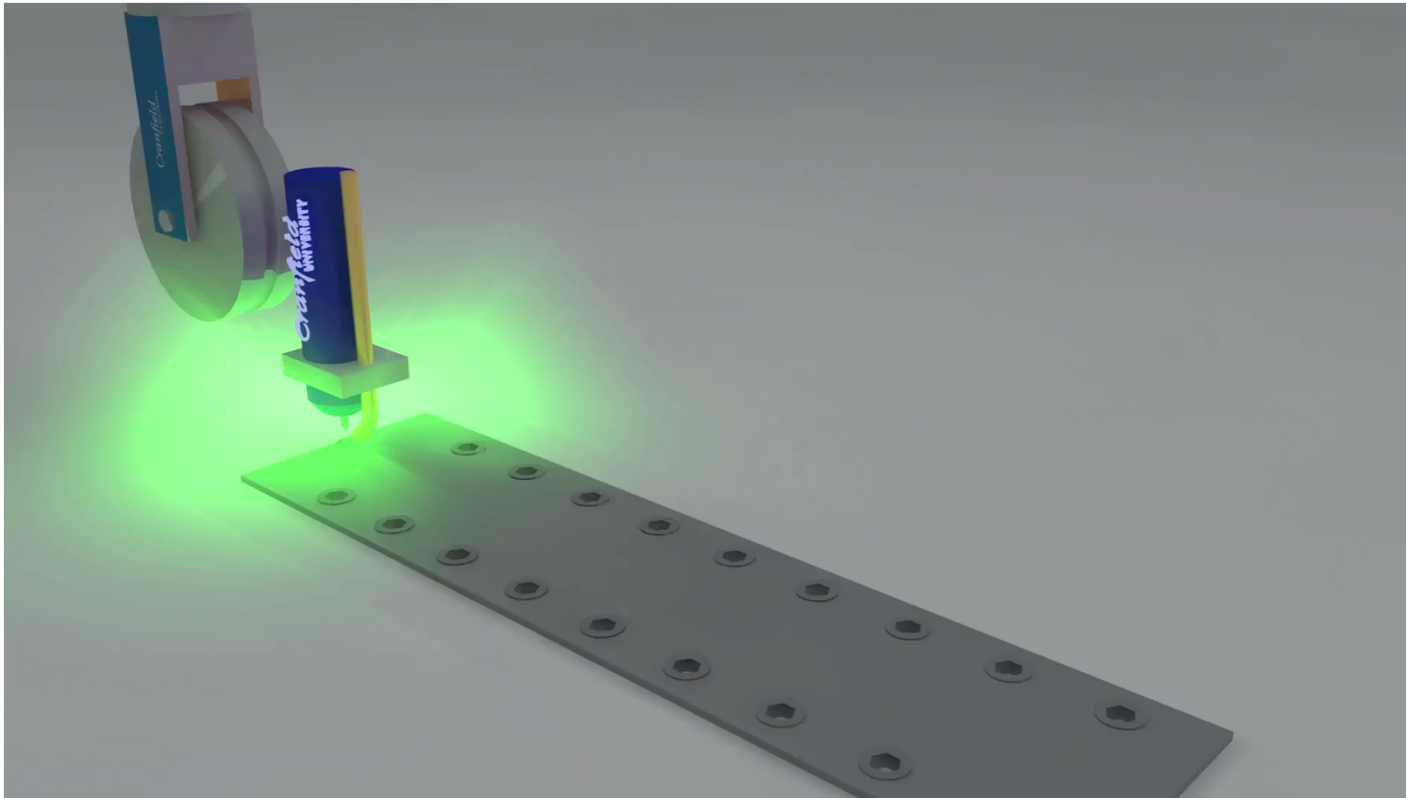
OoP-
Distortion
= 7mm



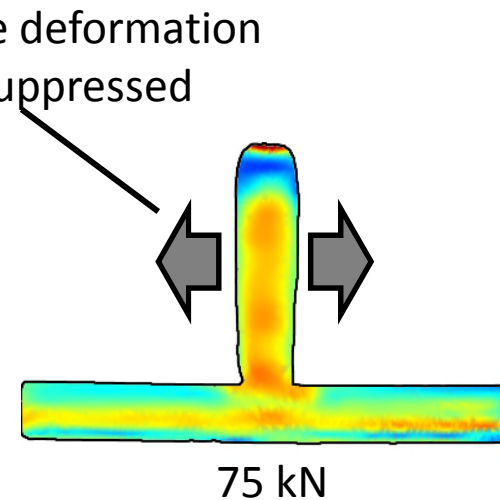
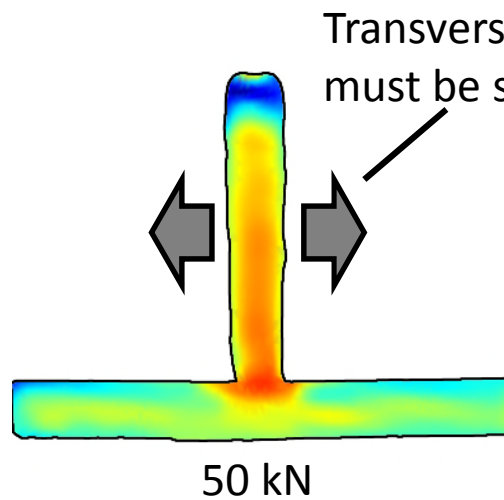
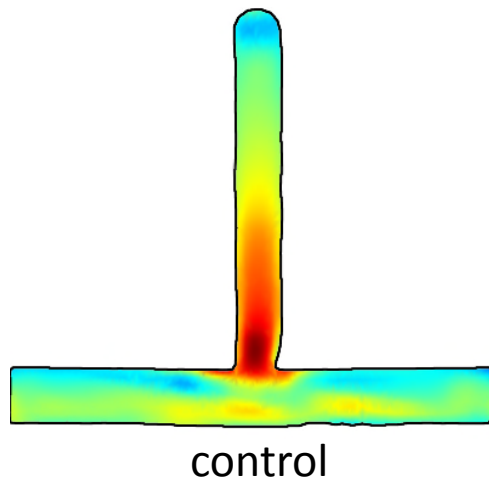
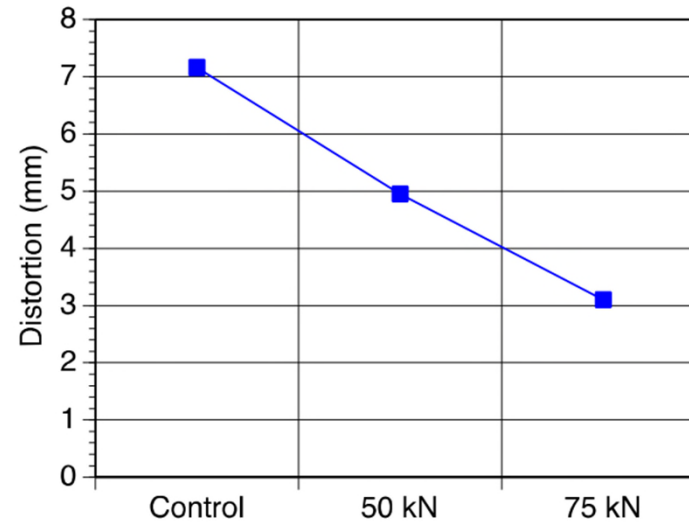
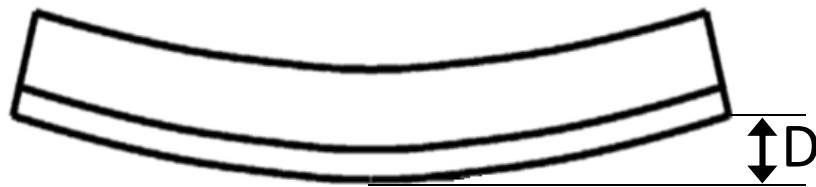
Control Options



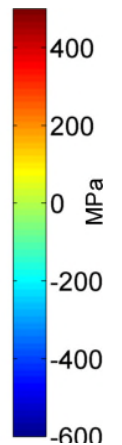
Inter-Pass Cold Rolling



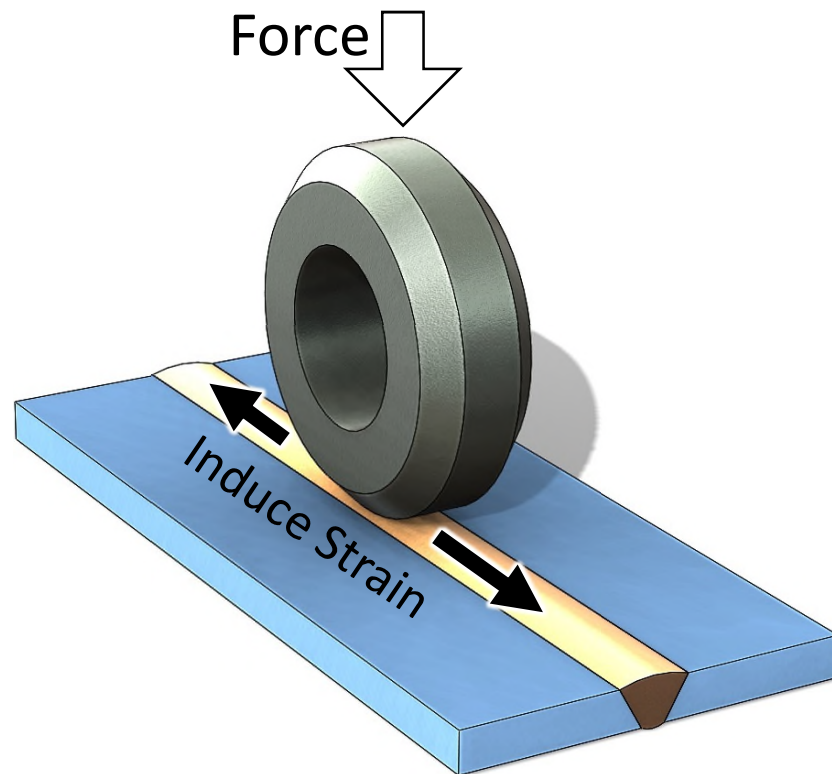
Inter-Pass Rolling



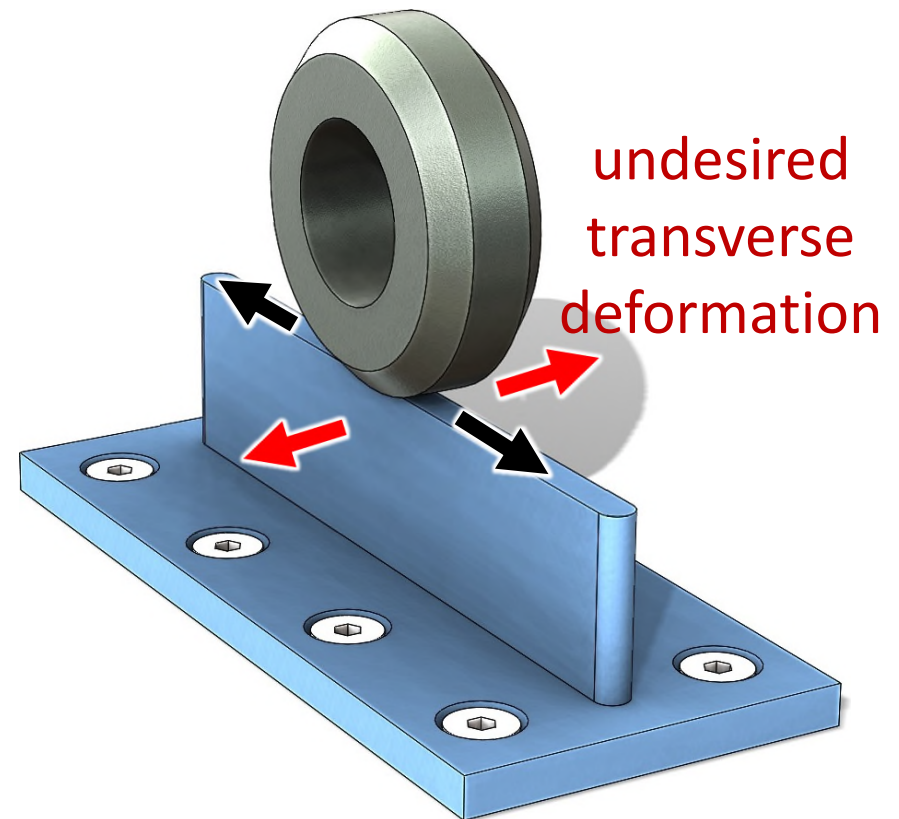
Transverse deformation
must be suppressed



Top Rolling

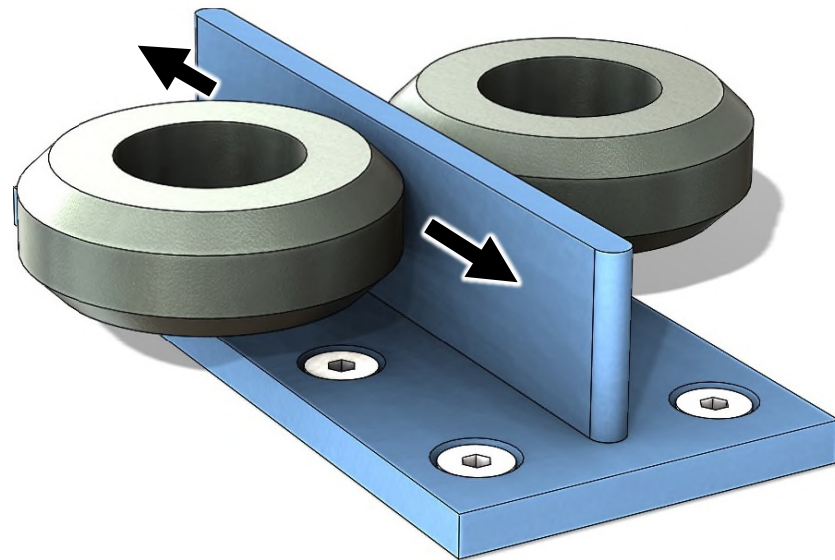


Initial application:
Rolling Butt Welds

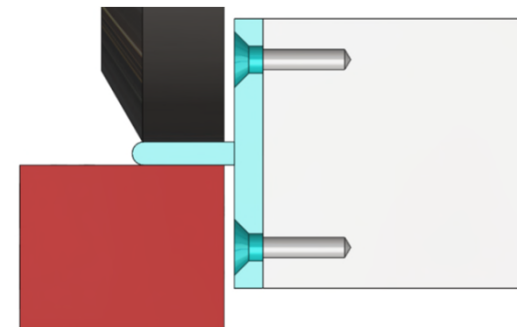
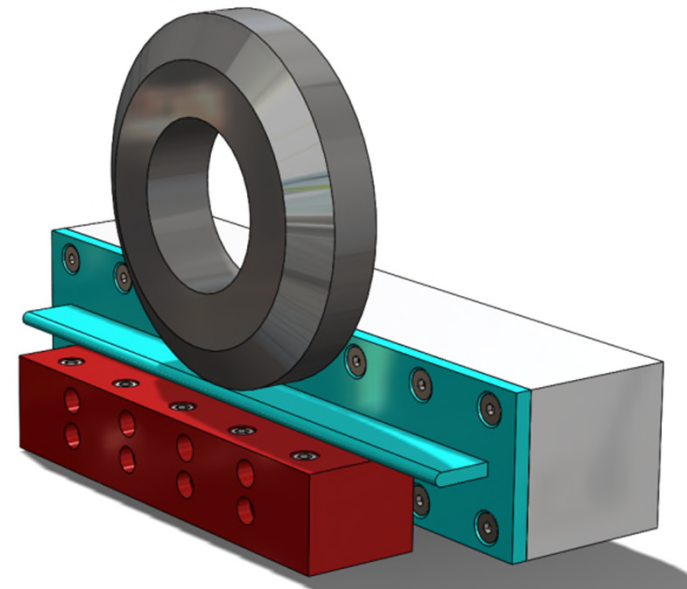


Transfer to:
"Vertical Rolling on WAAM"

Preliminary Study: Side Rolling

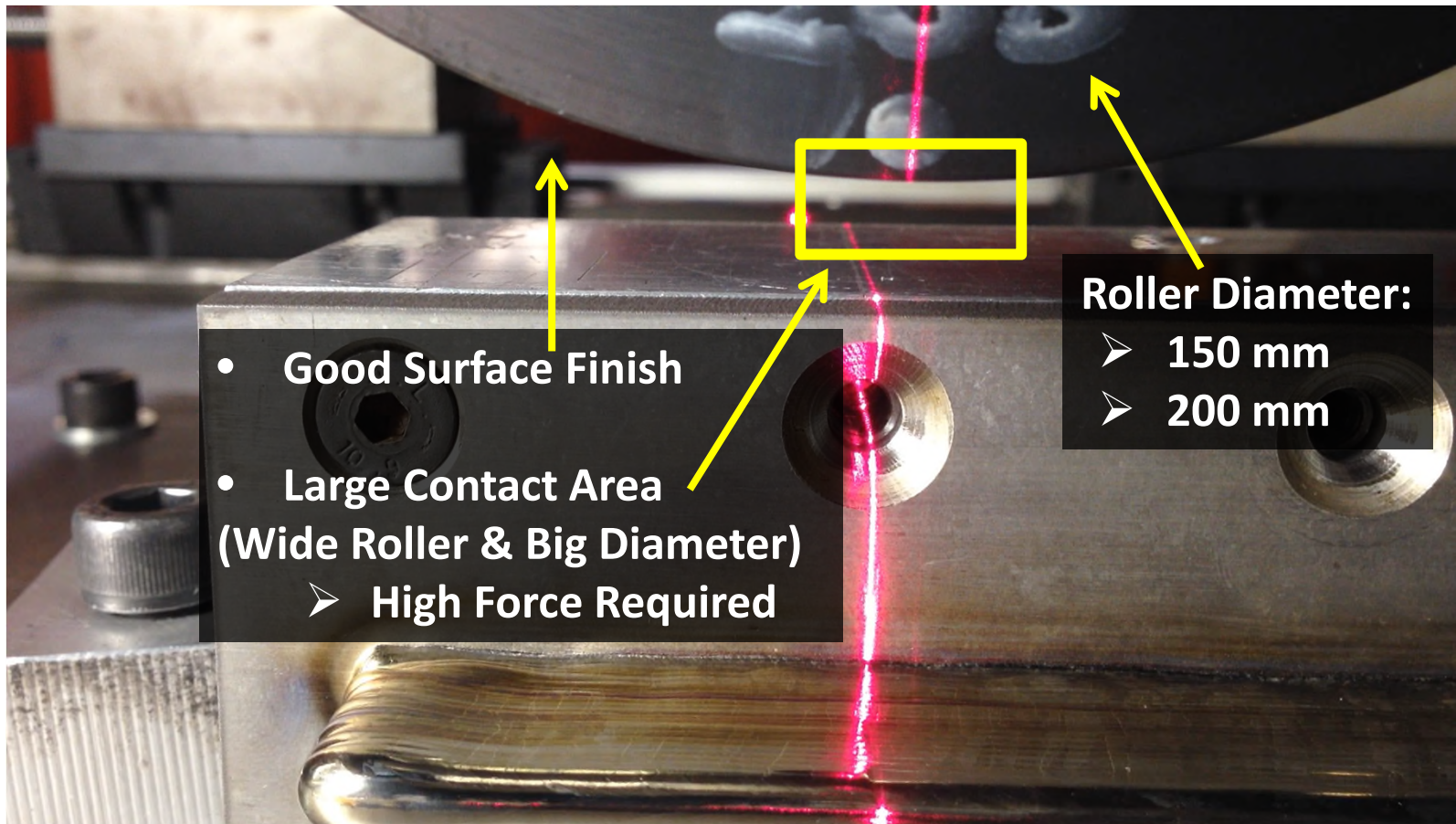


Idea:
"Pinch Rolling"

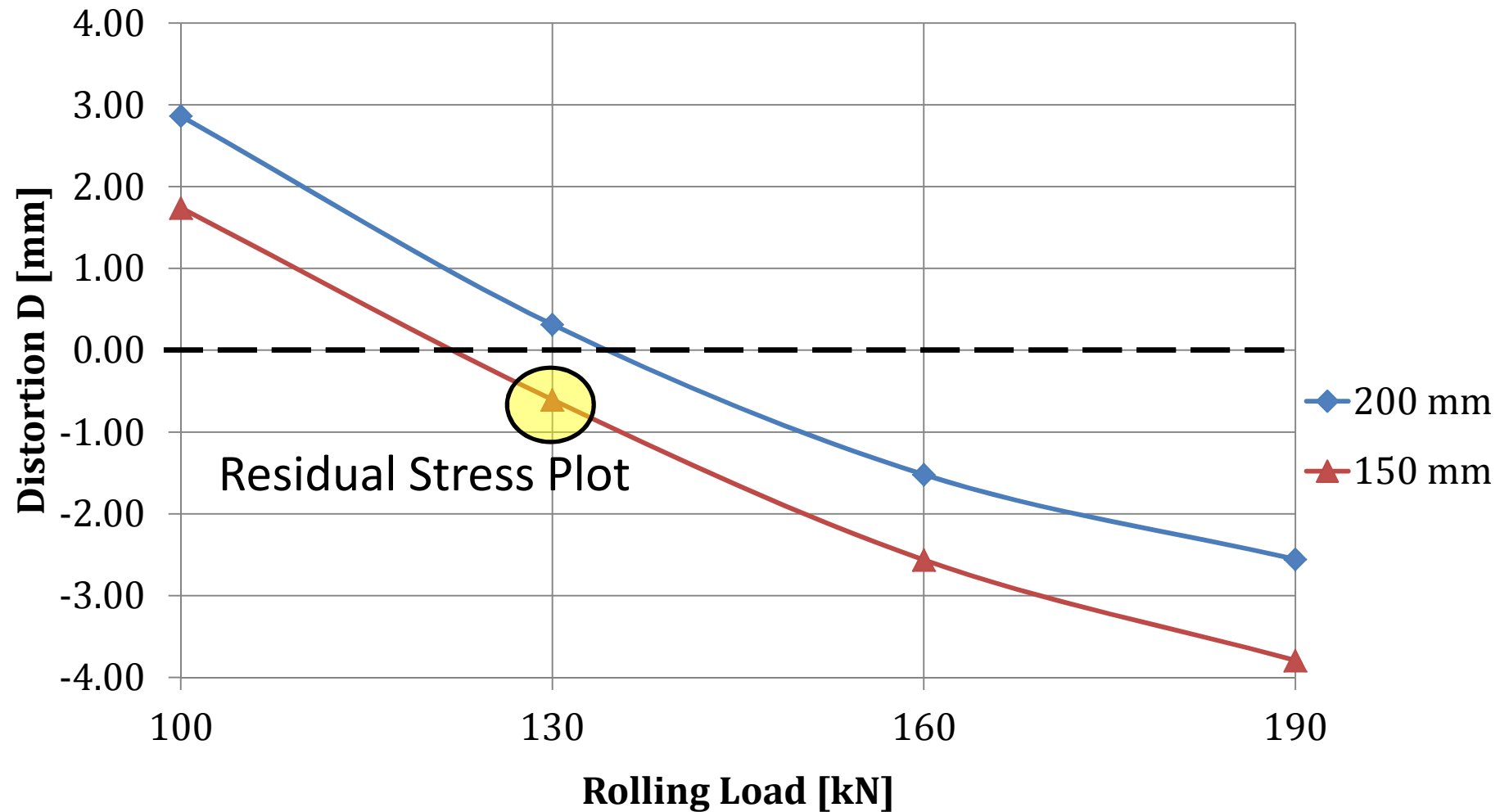


"Side Rolling"

Pinch & Side Rolling

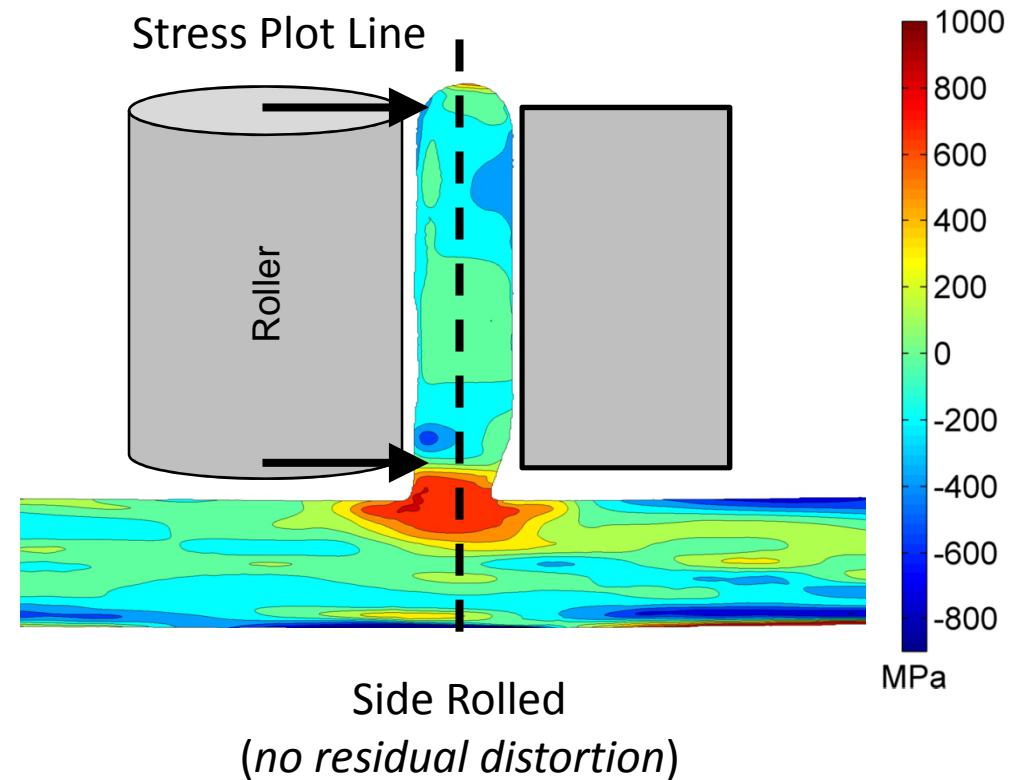
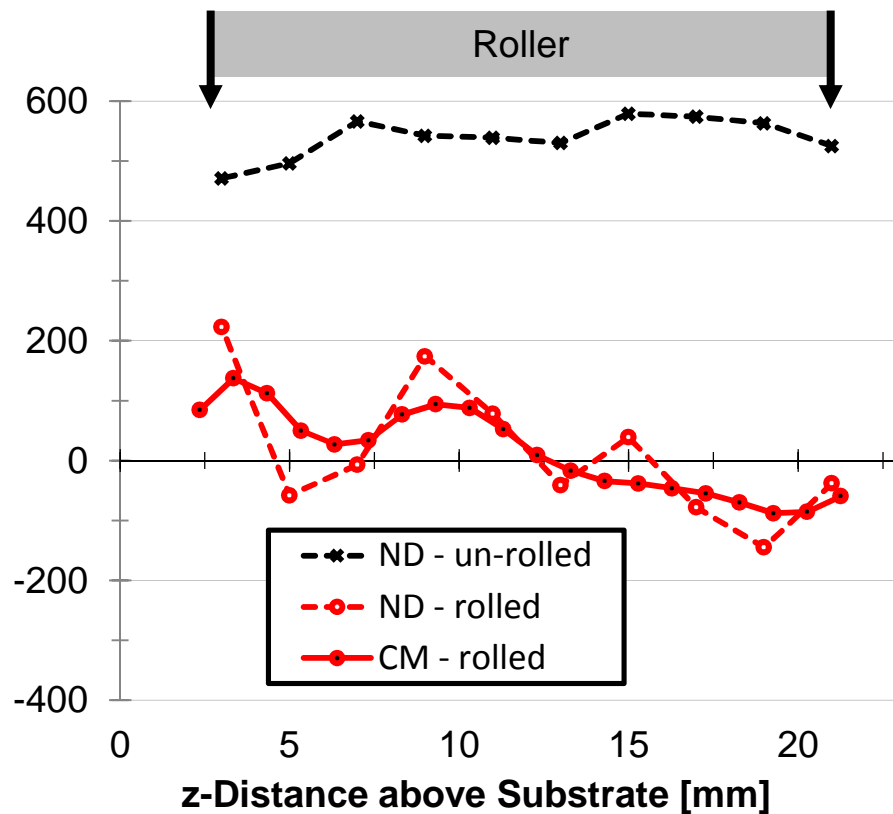


Reduction in Distortion



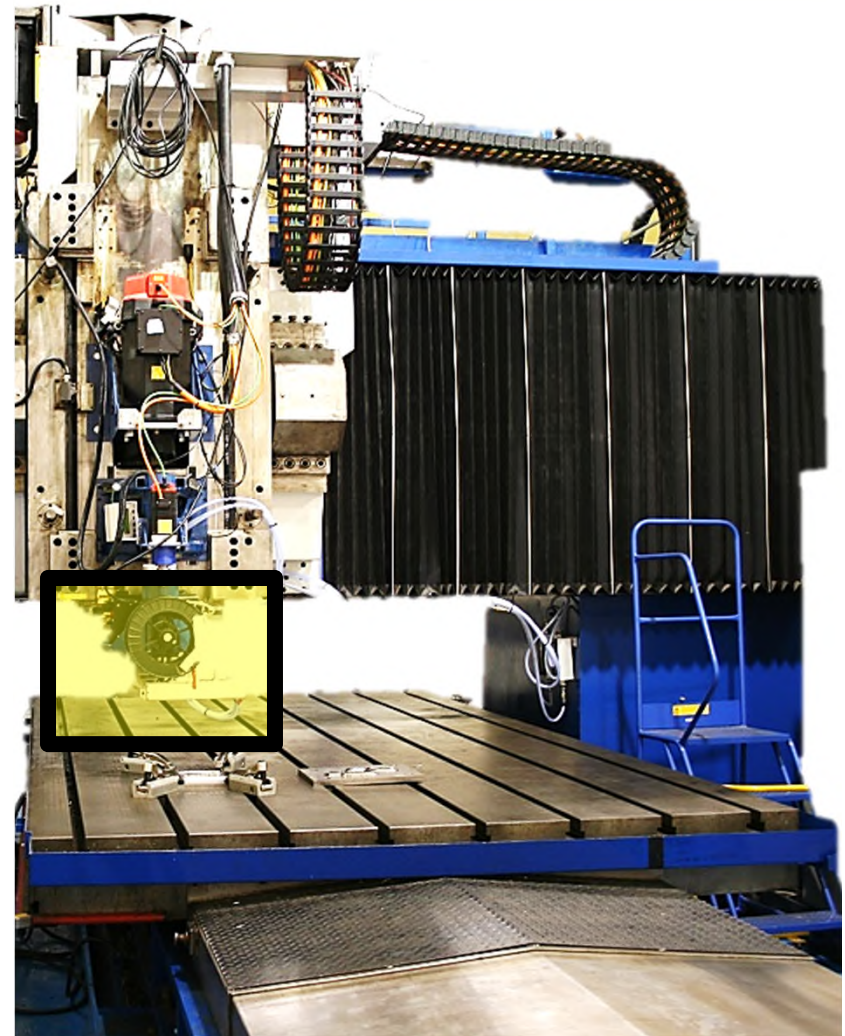
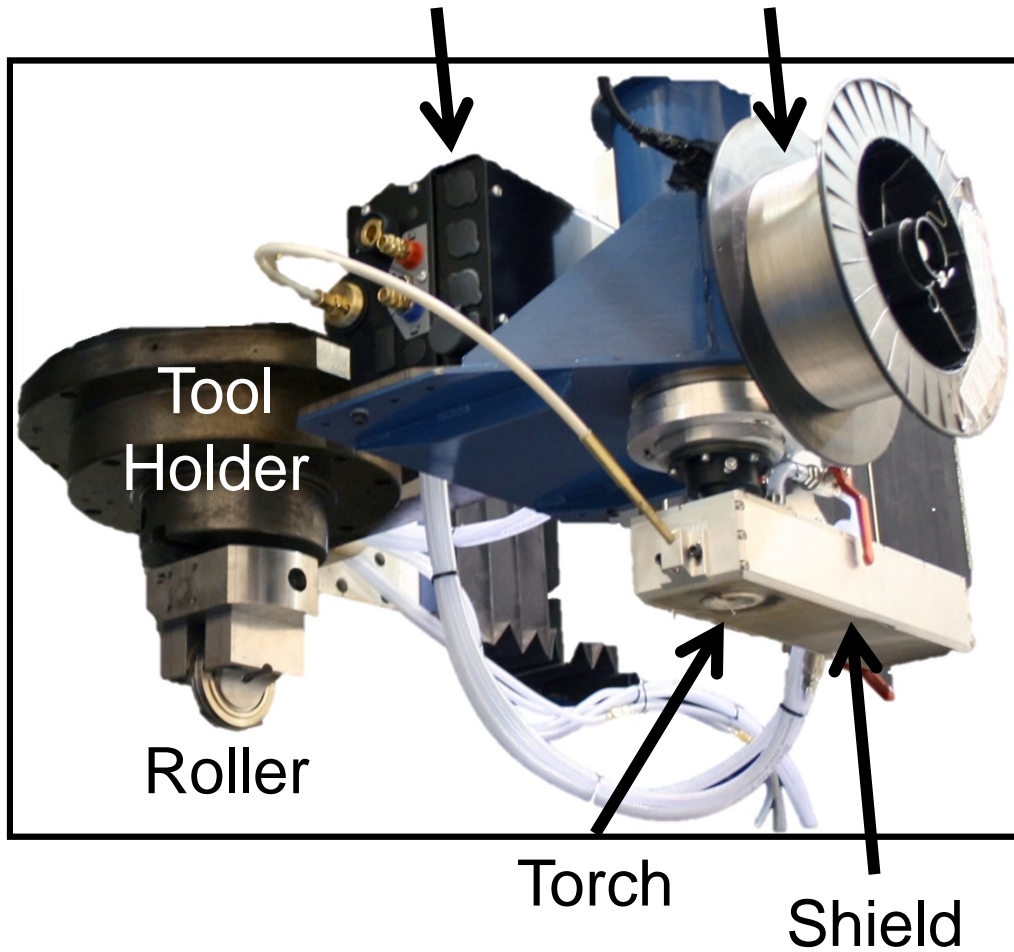
Longitudinal Residual Stress σ_{xx} :

Contour Method (M. Roy - Manchester University)
Neutron Diffraction (J. Hönnige - ENGIN-X (ISIS / UK))

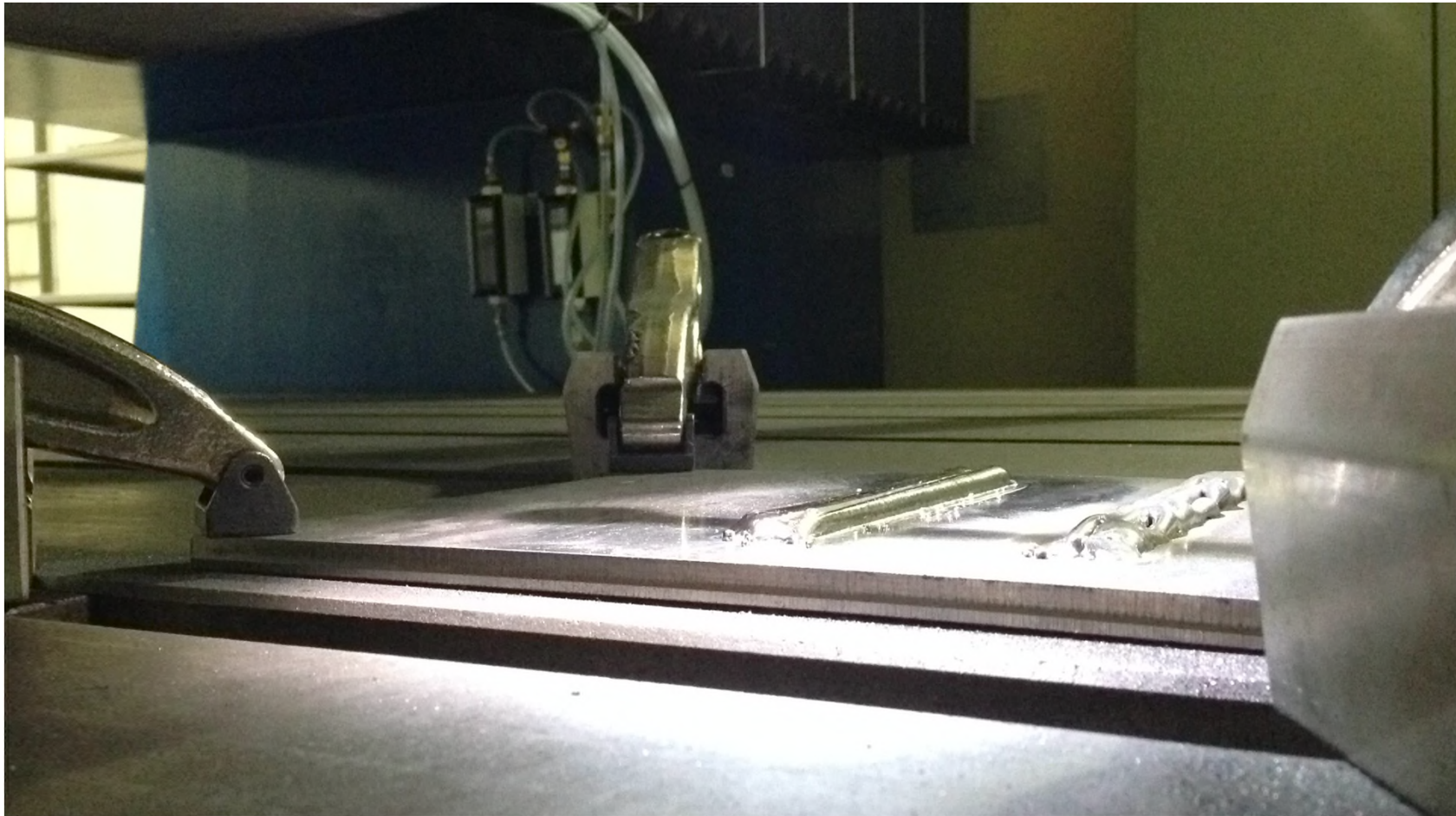


Rolling Assisted WAAM

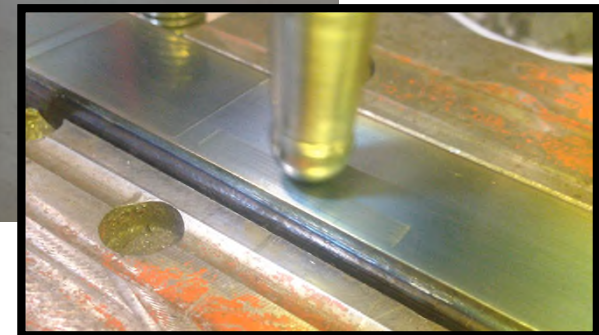
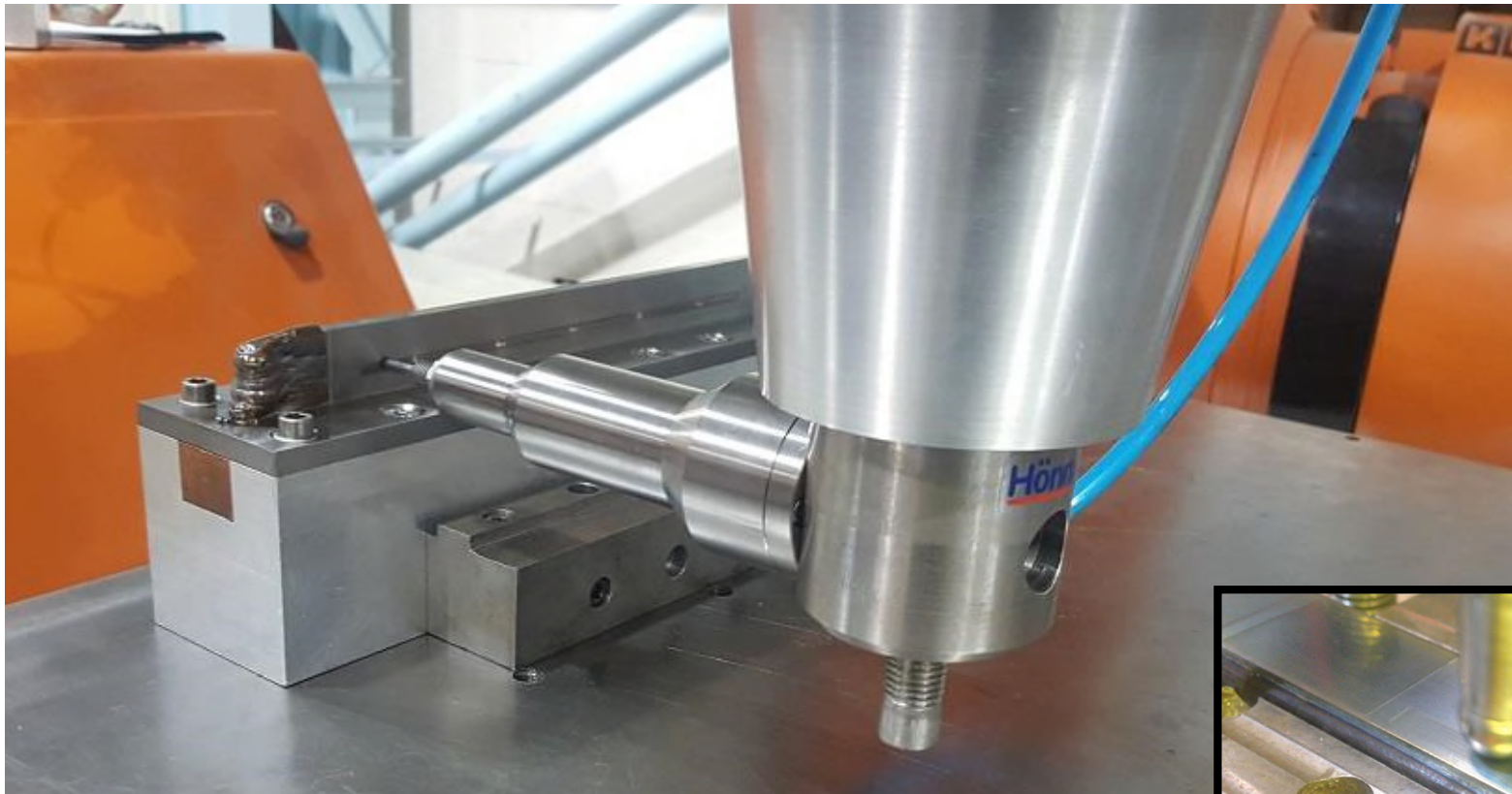
Wire Feeder and Spool



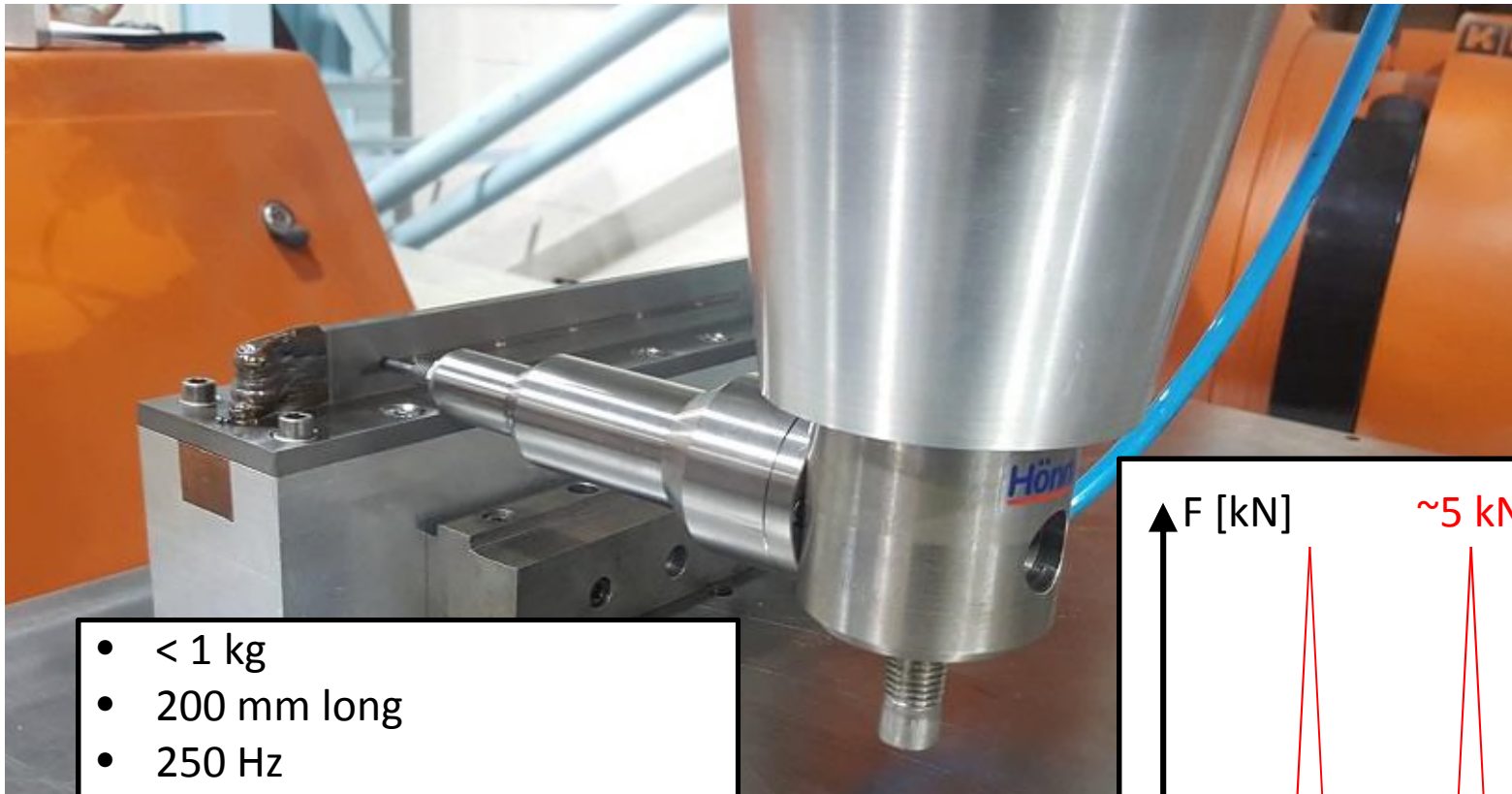
Local shield and 2 D rolling ional



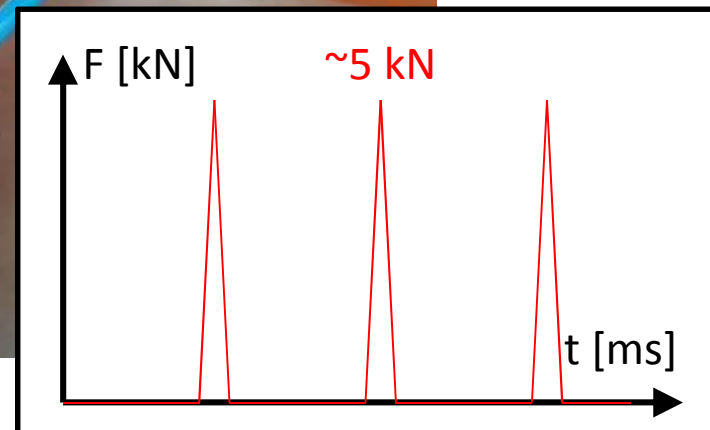
Peening: Pneumatic Prototype



Peening: Pneumatic Prototype German Company Visit March '16

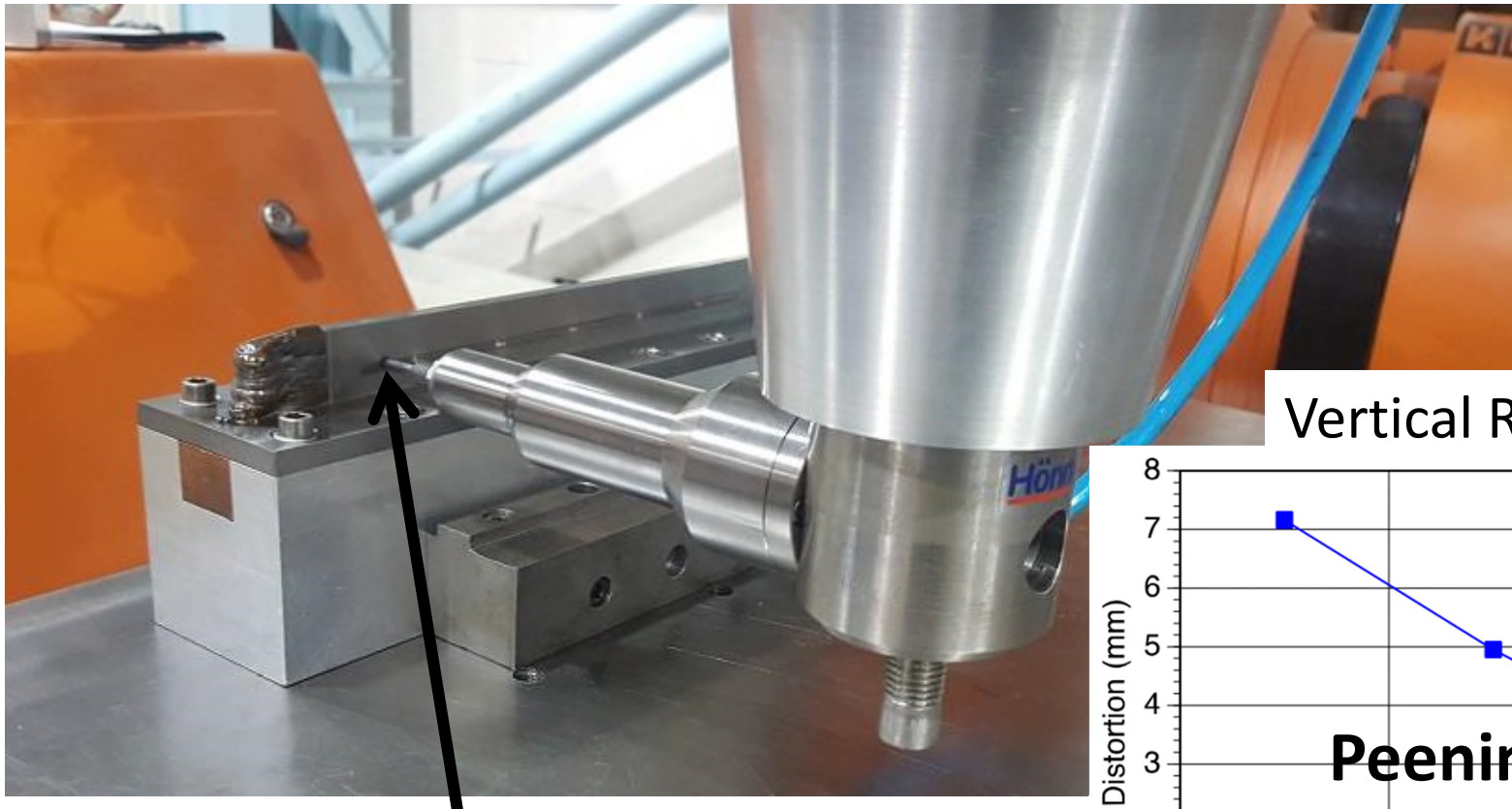


- < 1 kg
- 200 mm long
- 250 Hz
- 6 bar supply pressure
- 1 mm workpiece distance
- 78 dB



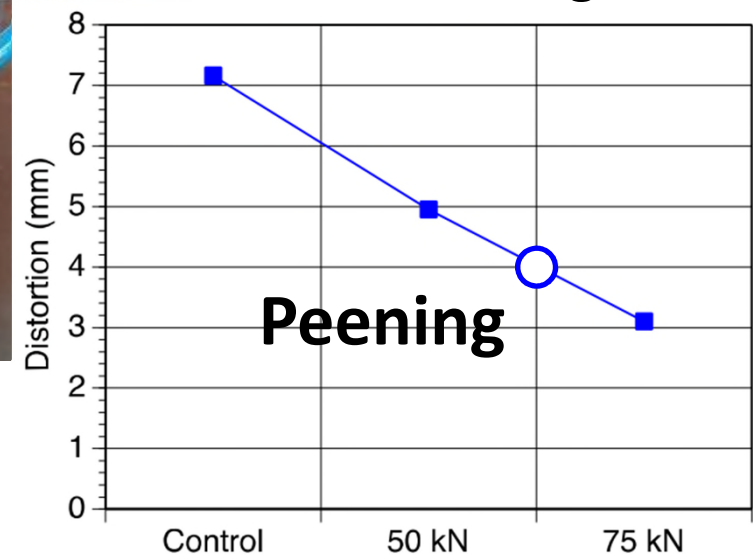
Force on manipulator is insignificant !!

Peening Results: Peening vs. Vertical Rolling

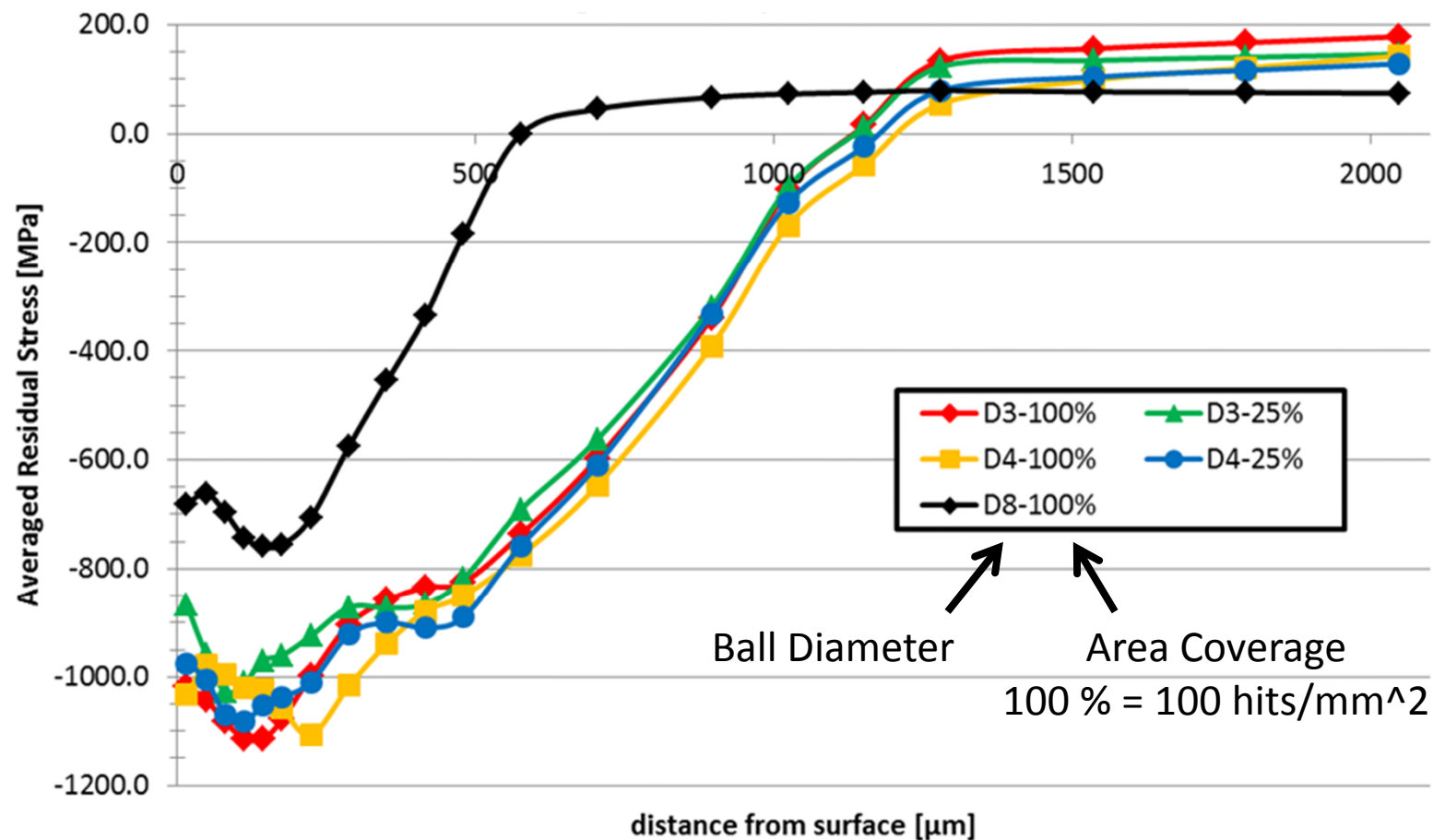


Both Side Surfaces were
machined + peened

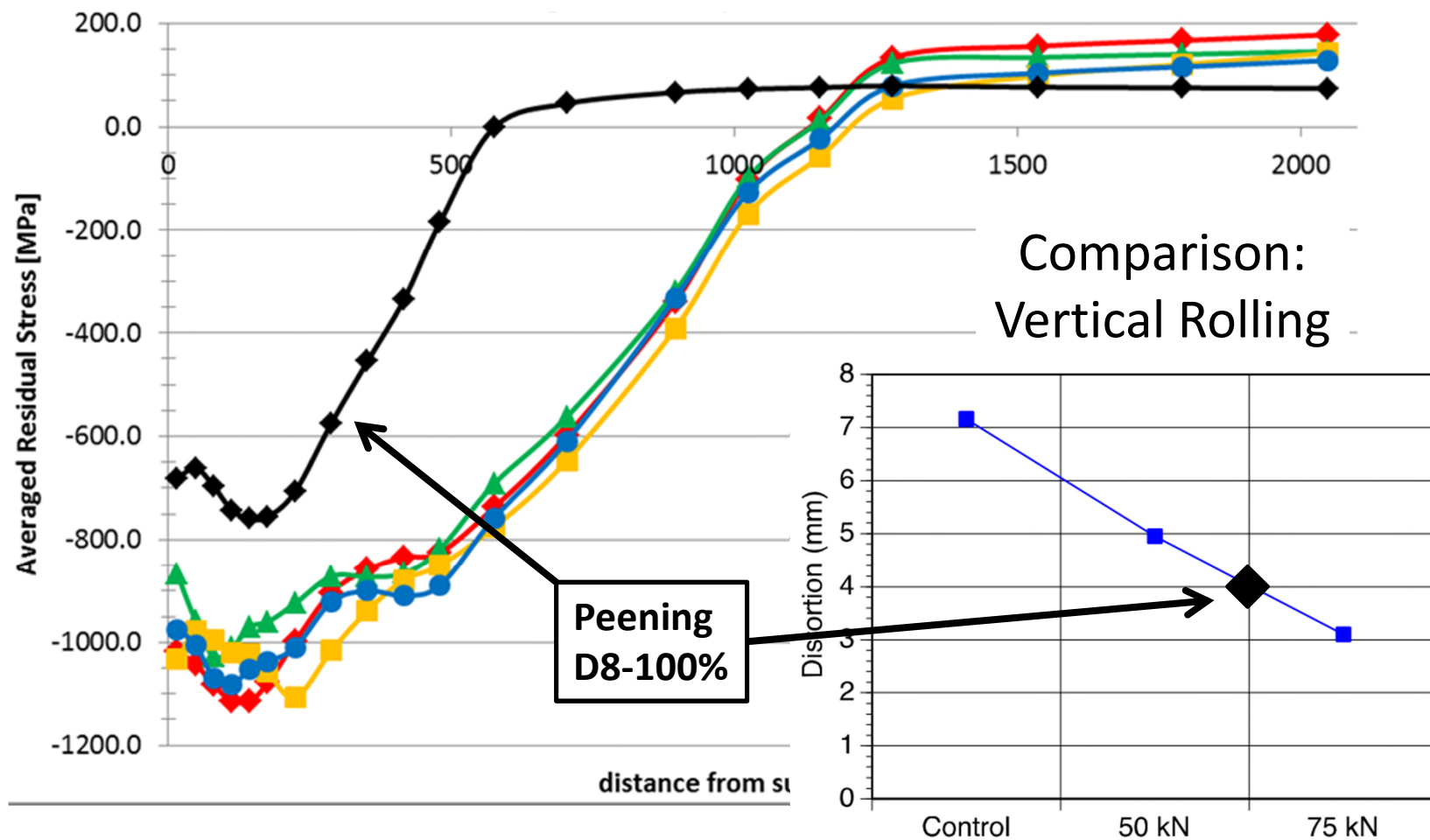
Vertical Rolling



Peening Results: Residual Stress by Hole Drilling



Peening Results: Residual Stress by Hole Drilling

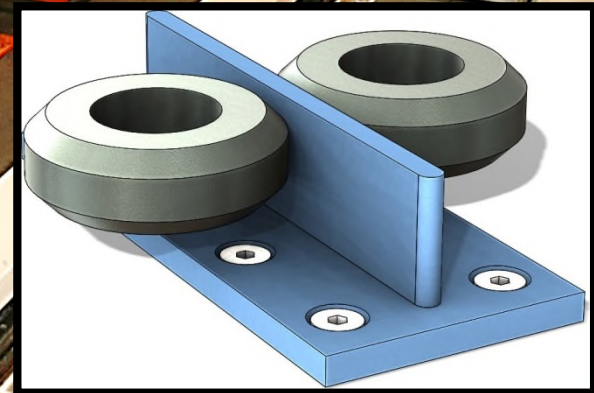
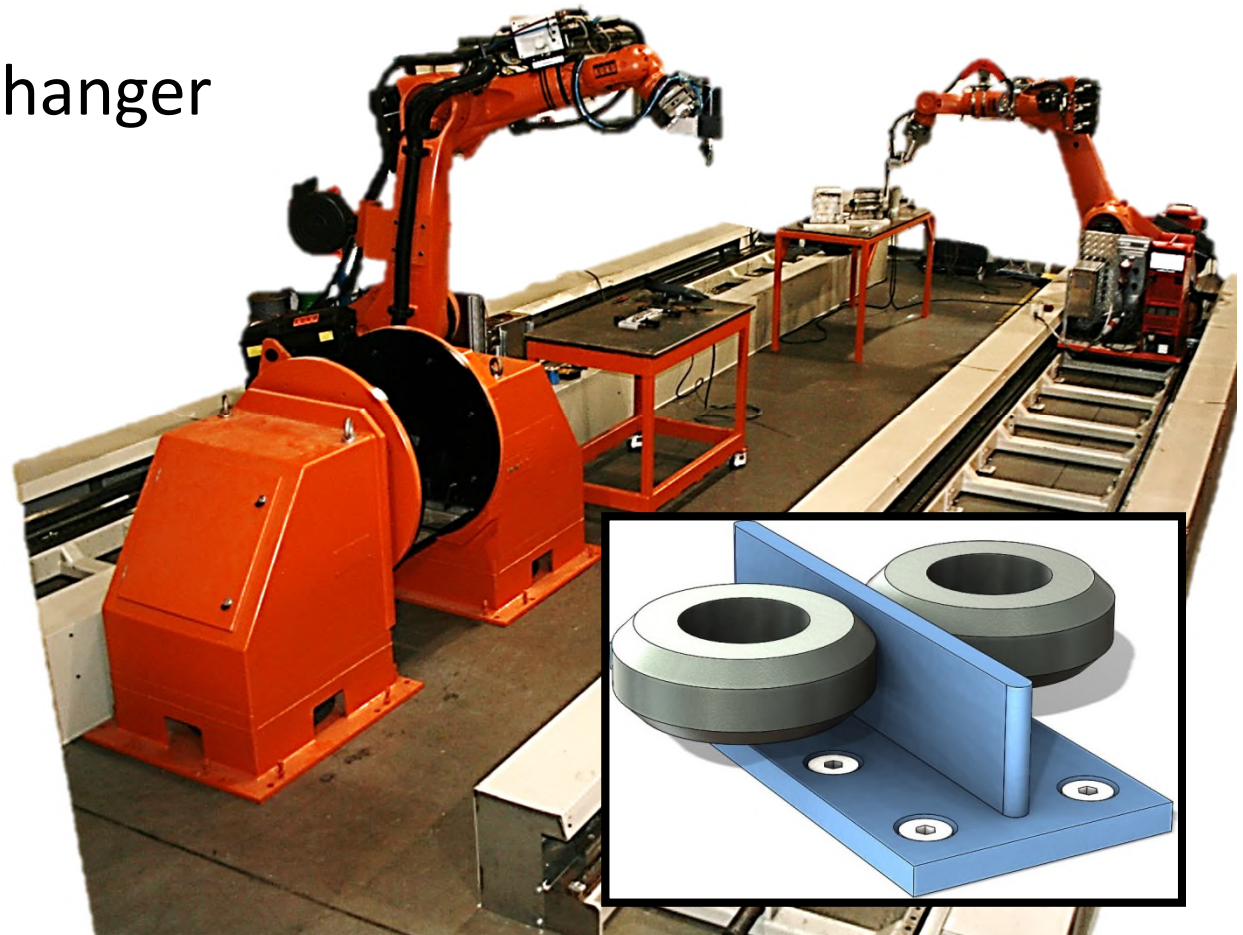


System: Open Robot Cell

Twin Robot System on Rails

Customizable Tool Changer

- Welding Torch
- Machining
- Pinch Roller
- Peening Tool



Acknowledgements

- Cranfield team
 - **Jan Hönnige**
 - Paul Colegrove
 - Supriyo Ganguly
 - Jialuo Ding
 - Filomeno Martina
 - Anthony Mcandrew
- Manchester University
 - **Mathew Roy**

Summary

- Rolling
 - Top surface rolling is very effective for microstructure control and useful for residual stresses
 - Side or pinch rolling is the other way round
- Peening
 - Effective for treating for residual stress in areas not accessible by rolling
 - New peening tools are suitable for robotic application



THANK YOU FOR YOUR
ATTENTION 😊



Website – waammat.com

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