PhD Torbjörn Ilar, tilar@ltu.se
Profession – Manufacturing System design (Modeling, Production Philosophies and Joining Processes)

Interreg Nord

Combined Laser CMT -effects on productivity and tolerances

- Brief introduction to the laser group at LTU
- Introduction to HSI
- Humping control – productivity
- Tolerances and quality
- Final remarks / comments

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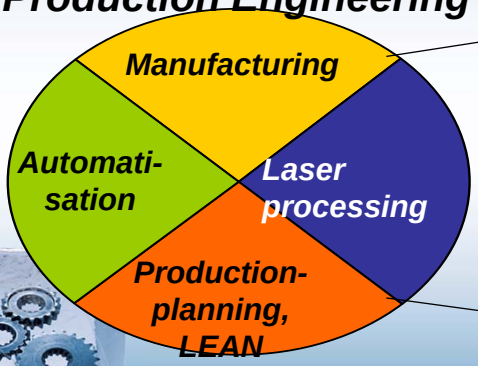
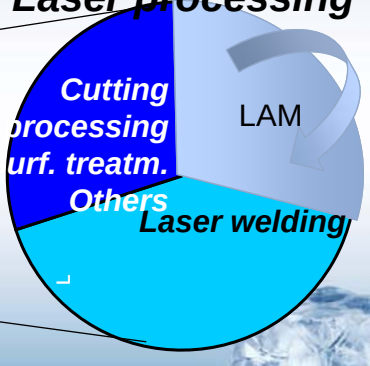
INTRODUCTION
LTU / CHAIR OF MANUFACTURING

Teaching:
Production Engineering

Research:
Laser processing





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INTRODUCTION
LTU / CHAIR OF MANUFACTURING

Implementation: People, Human factors

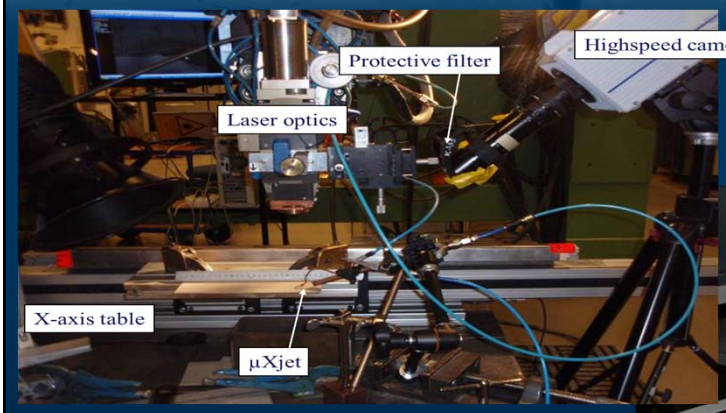
Factory layout, Logistics, Economy

Laser systems, Sensors, Automation

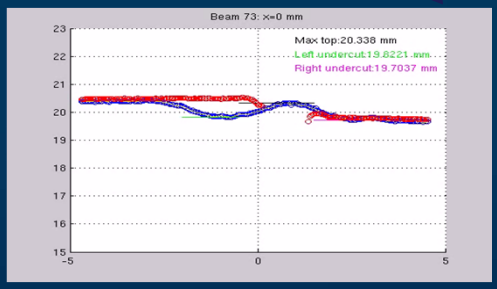
Laser process: Thermodynamics, Fluid flow, Quantum physics, Optics, Materials science

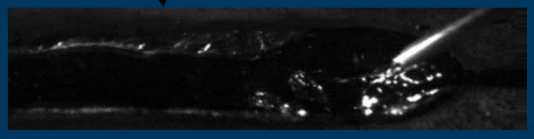
Product properties: Material, Mechanics

HIGH SPEED IMAGING



CHAIN: EDGE GEO - WELD POOL [illegible] GEO





- Tracking of the causes of the (scanned) weld surface quality
  - via the process melt flow (High speed imaging)
  - and via the joint edges (scanning)

INCREASING GAP WIDTH W_G

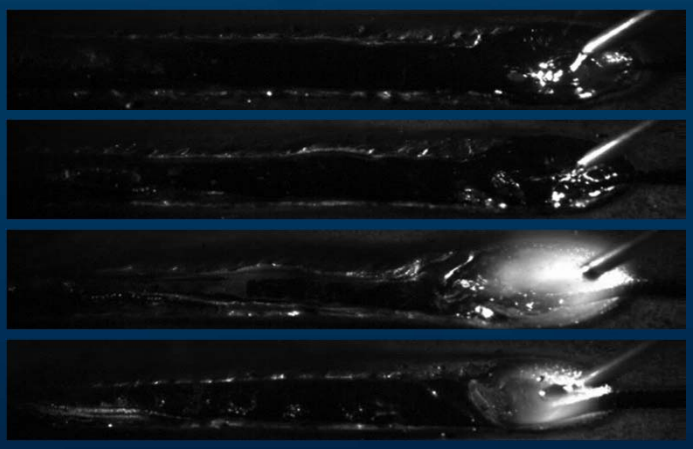
Gap width

0

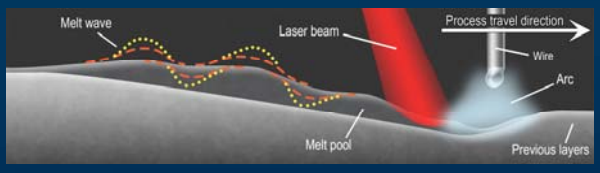
0.5 mm

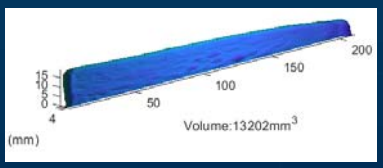
0.8 mm

1.2 mm



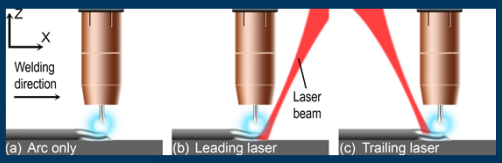
LTU CMT DEPOSITION RESEARCH RESULTS

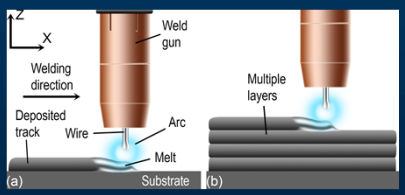


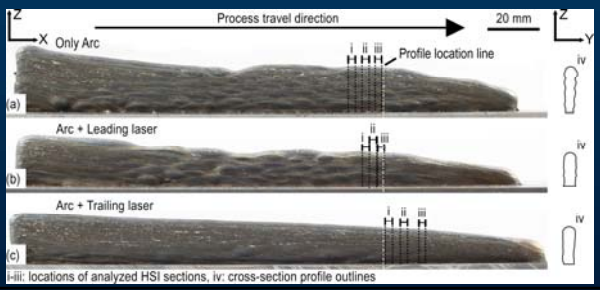


CMT AND CMT+LASER STRUCTURES

- CMT and CMT+laser hybrid multi-layer structures have been generated and analysed using e.g. X-ray, 3D-scanning, and EDX



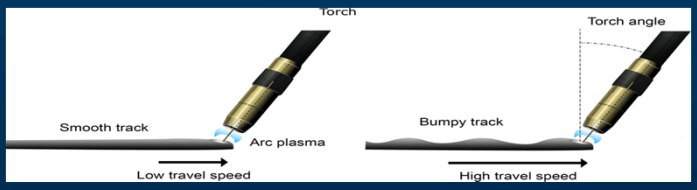


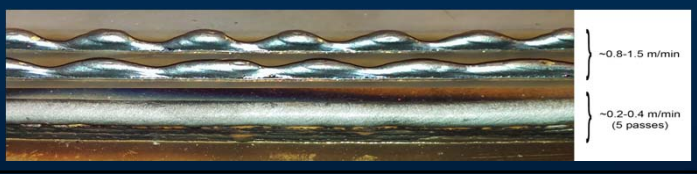


Lulea TU research plans:

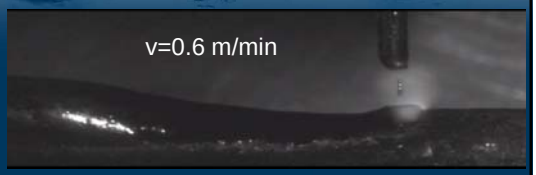
General: Investigate the limitations for CMT for net shape applications and improve it in terms of productivity and property.

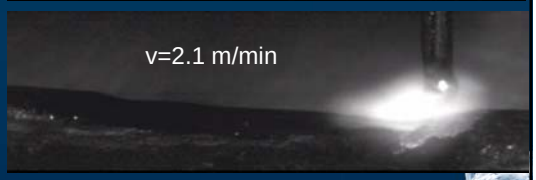
Control humping behaviour; improve accuracy (adaptive energy input); business case – combined laser/CMT cladding/net shaping

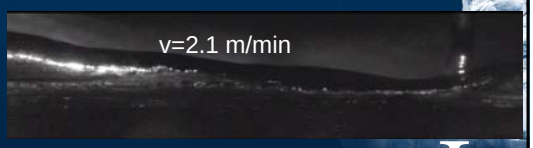




High Speed Video of the CMT Humping phenomena – net shaping:



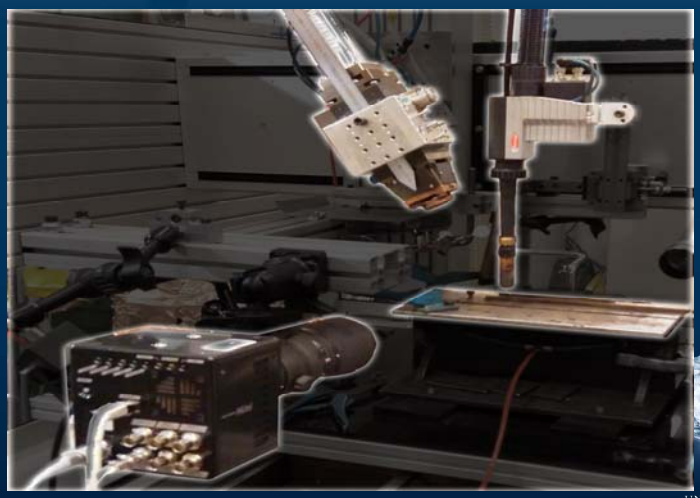




J. Näsström (LTU)

EXPERIMENTAL SETUP

- Wire: 316 LSI
- Lens 200mm
- Focal shift +50mm



J. Näsström (LTU)

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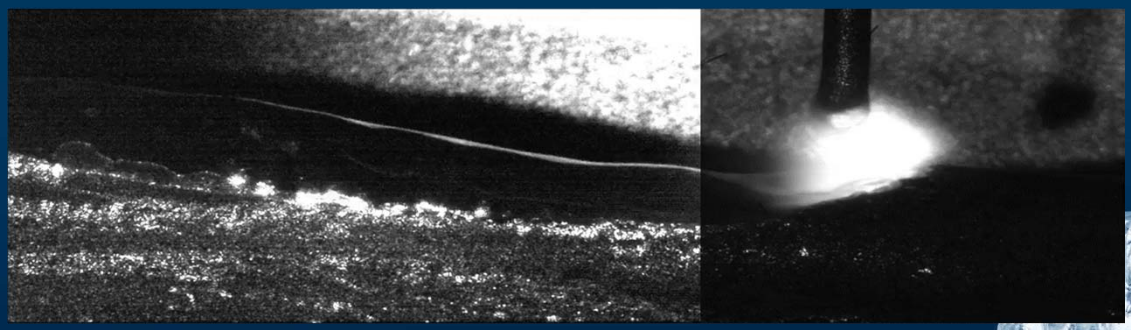
HIGH SPEED IMAGING

Only CMT

V_t: 16,565 mm/s



J. Näsström (LTU)

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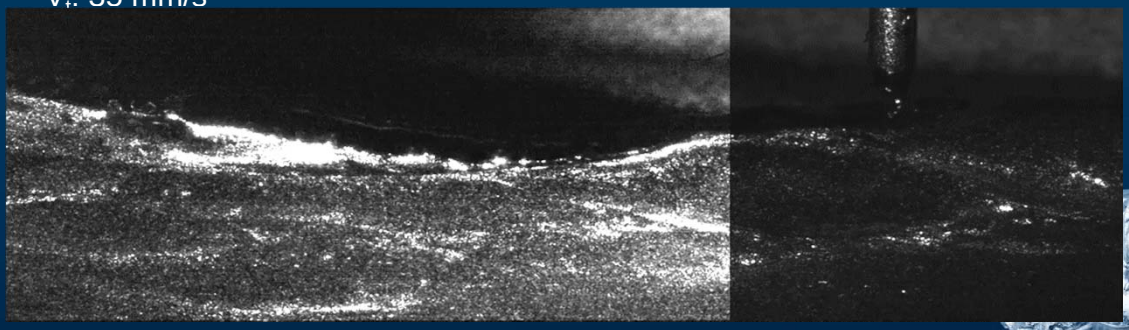
HIGH SPEED IMAGING

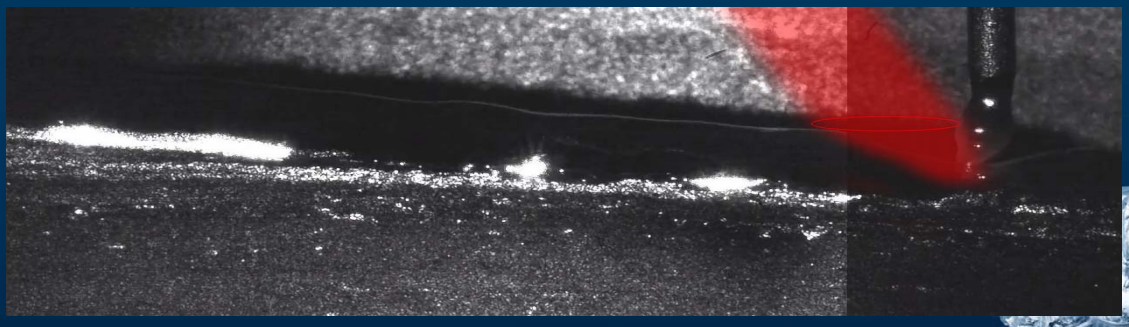
- Only CMT
  V_t: 35 mm/s



J. Näsström (LTU)

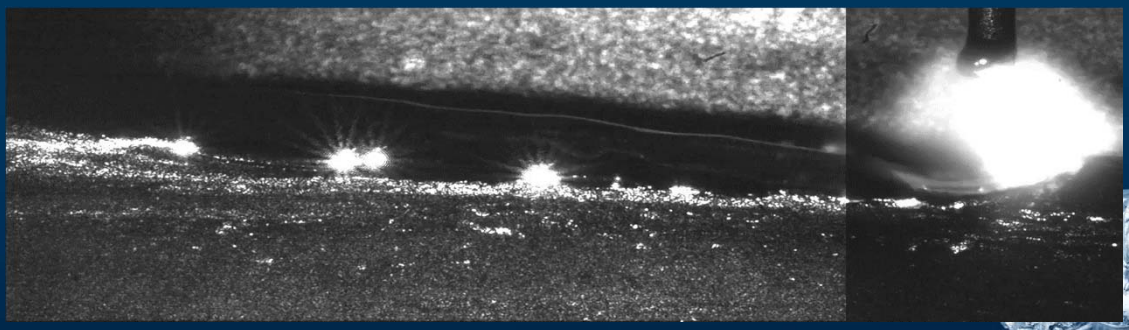
HIGH SPEED IMAGING

- CMT + Laser
  V_t: 35 mm/s



J. Näsström (LTU)

HIGH SPEED IMAGING



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CMT RESULTS - PRODUCTIVITY

- Only CMT
  16,565 mm/s
- Only CMT
  35 mm/s
- CMT +
  Laser
  35 mm/s

Laser benefits: Increased speed, adaptive energy input (better tolerances)

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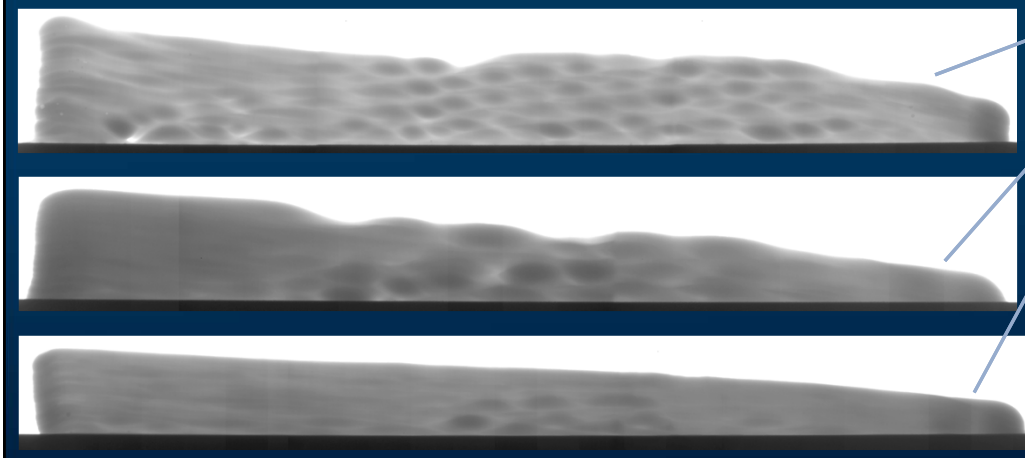
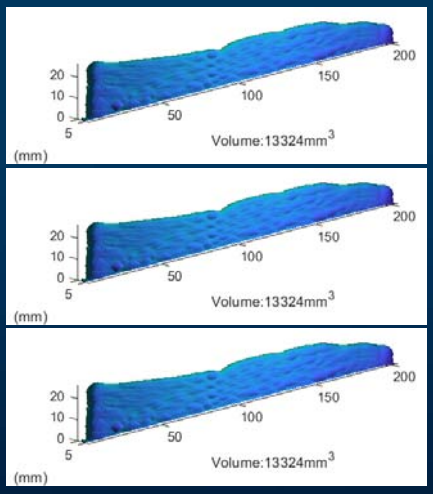
QUALITY - COMPOSITE X-RAY IMAGES

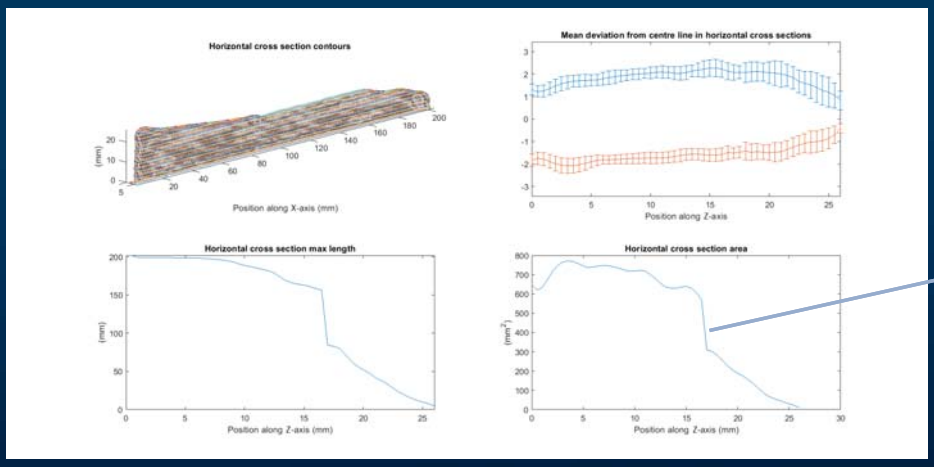


3D SCANNING – TOLERANCES/OUTPUT

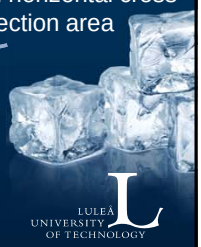
- The produced samples were 3D scanned to evaluate geometrical aspects



3D SCANNING ANALYSIS, ONLY CMT



Note that the way of analysis would remove/disregard top surface "humps", which explains the sudden decrease in horizontal cross section area



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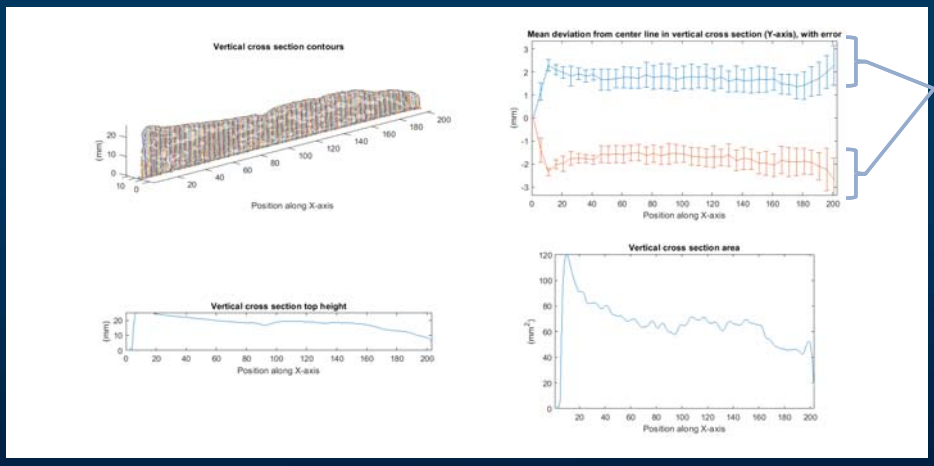
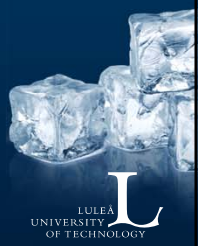
3D SCANNING ANALYSIS, ONLY CMT



High fluctuations in the surface topology



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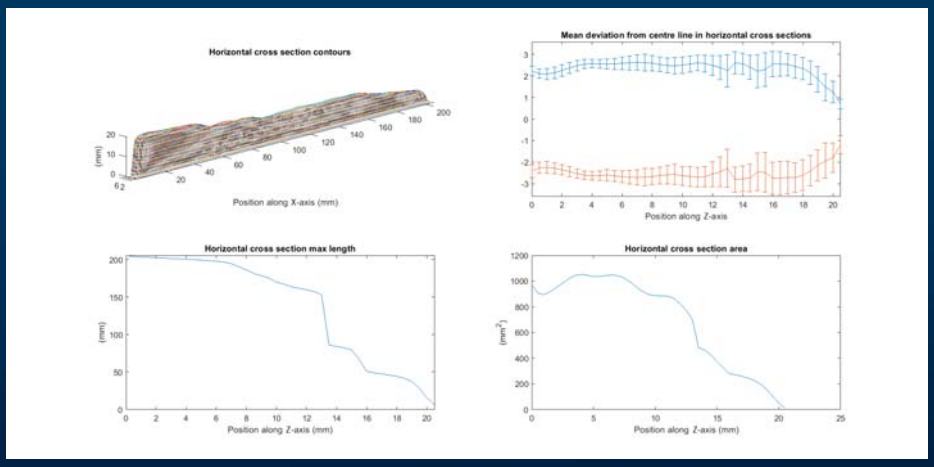
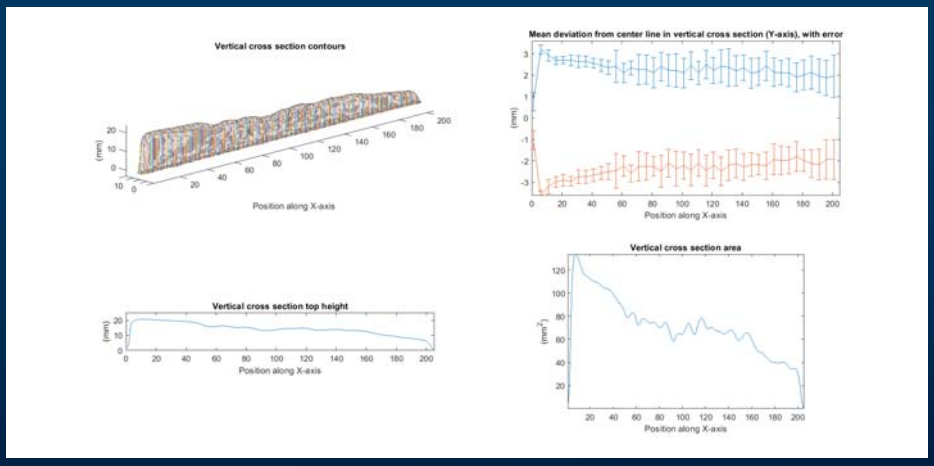
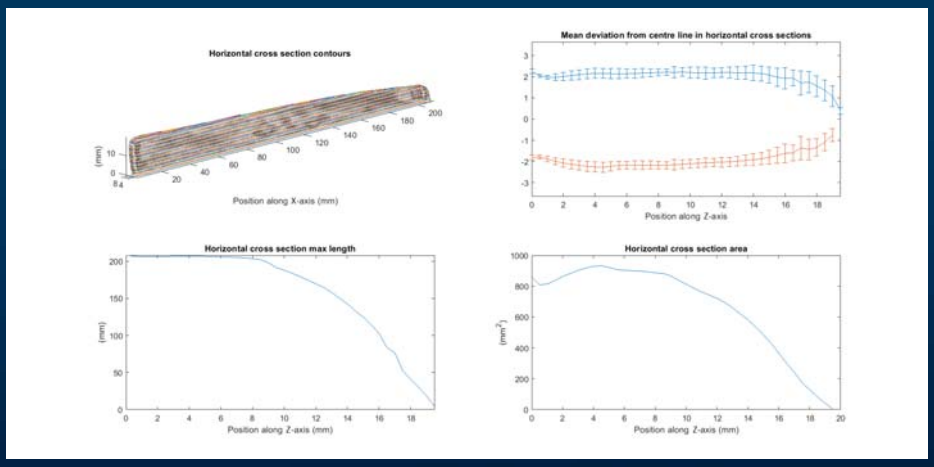
3D SCANNING ANALYSIS, CMT+LEADING LASER



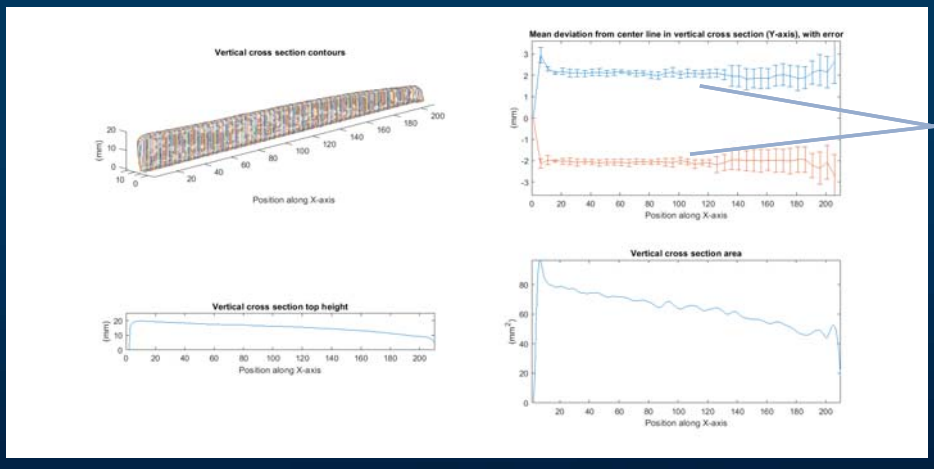
3D SCANNING ANALYSIS, CMT+LEADING LASER



3D SCANNING ANALYSIS, CMT+TRAILING LASER



3D SCANNING ANALYSIS, CMT+TRAILING LASER



Smaller fluctuations in the surface topology closer to the substrate

VOLUMETRIC ANALYSIS

- Scanned geometry , nominal cuboid (calculated from wire feed rate, travel speed and layer raising height) and the largest volume cuboid inside the scanned parts were compared to determine how much of the generated structures may be used if all surface unevenness were to be machined off
- Note that the difference between the scanned and nominal volumes is likely due to the self-adjusting nature of the CMT process, where the wire is repeatedly fed downwards towards the underlying metal until the molten wire tip touches it and the short-circuit phase is initiated; upon which the wire is retracted for a certain period of time and then fed downwards again

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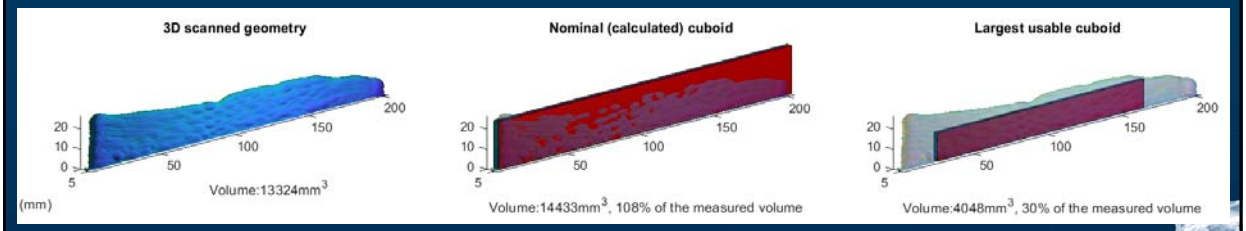
VOLUMETRIC ANALYSIS, ONLY CMT



- The nominal volume was 8% larger than the scanned one
- The largest machinable cuboid (parallel with the substrate) would be 30% of the deposited volume

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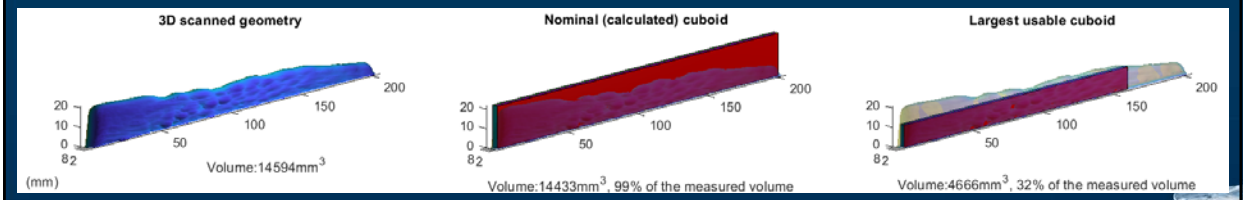
VOLUMETRIC ANALYSIS, CMT+LEADING LASER



- The nominal volume was 1% smaller than the scanned one, again likely* due to the self-regulating behaviour of the CMT process
- The largest machinable cuboid would be 32% of the deposited volume, and 35% of the one made using only CMT

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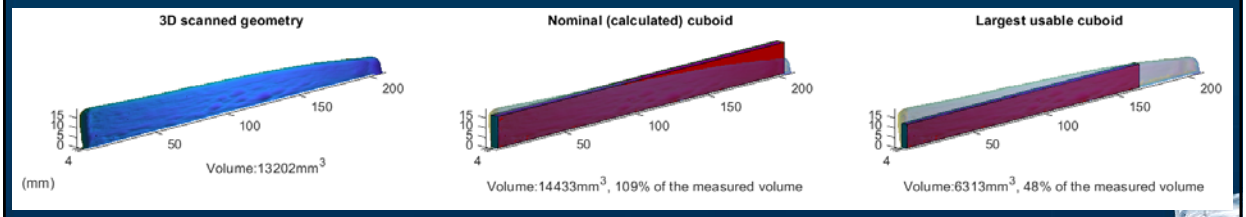
VOLUMETRIC ANALYSIS, CMT+TRAILING LASER



- The nominal volume was 8% larger than the scanned one
- The largest machinable cuboid would be 48% of the deposited volume, meaning an improvement of 60% compared to using only CMT

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PUBLICATIONS

- Paper regarding the different geometries generated using CMT and CMT + Laser hybrid deposition called "**Laser enhancement of wire arc additive manufacturing**" is currently being written, and will be submitted to and presented at the ICALEO conference as a peer-reviewed paper, which then will be published in the "Journal of Laser Applications"

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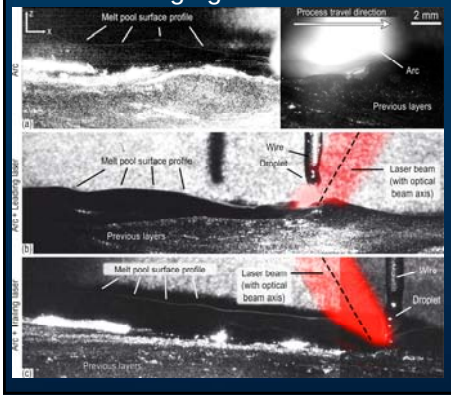
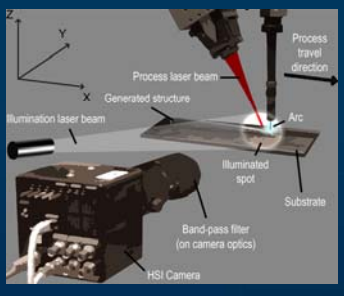
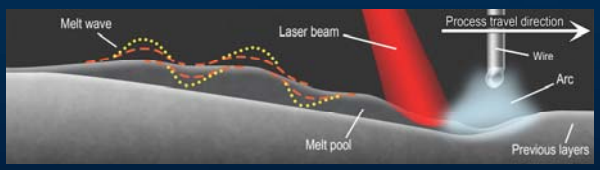
MEASURING MELT POOL FLUCTUATION IN CMT AND CMT+LASER AM USING HSI (1)

- Melt pool fluctuations in CMT and CMT+Laser hybrid deposition has been studied using High Speed Imaging



- Below and right: Illustration of setup and process
- Left: HSI pictures with illustrated laser beam





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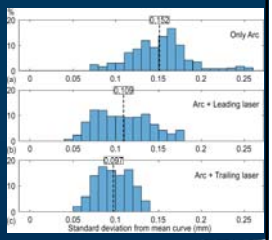
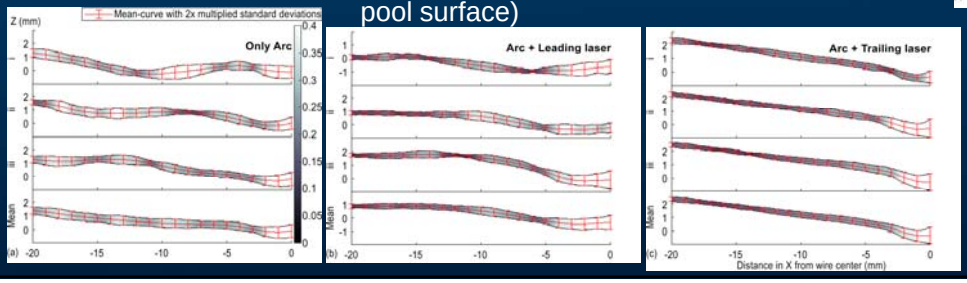
MEASURING MELT POOL FLUCTUATION IN CMT AND CMT+LASER AM USING HSI (2)

- The melt pool surface was traced from HSI, and plotted with mean curve+standard deviaton (Below; patch curves, with thicker/wider lines where the surface standard deviation/waviness was larger)
- Results show that melt pool waviness/fluctuations can be decreased by up to 35% (Right; Relative frequency histogram of standard deviations (with mean value) from the average melt pool surface)





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PUBLICATIONS

- Paper regarding the method of quantifying features studied using HSI and the decrease of melt pool surface fluctuations called "**Measuring the effects of a laser beam on melt pool fluctuation in arc additive manufacturing**" has been submitted to the "Rapid Prototyping Journal", and is currently under review

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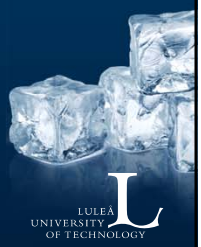
CONCLUSIONS

- The deposition speed was about 50% higher for the combined laser CMT (trailing) compare to the CMT
- The output (useful volumetrics) was about 60% higher for the combine
- A procedure for monitoring and quality control was demonstrated



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Contact: Torbjörn Ilar, ilar@ltu.se, +46920491679