

# The EU Framework 7 FlexiFab Project

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Materials Joining and Engineering Technologies

A faint, stylized graphic of a globe is positioned in the bottom right corner of the slide. It shows the outlines of continents and latitude/longitude lines.

- EU FP7 – Flexible fabrication of lightweight aluminium structures
  - Develop Robotic FSW heads, tools & weld procedures for:
    - Stationary shoulder
    - Floating bobbin
    - Corner
  - Develop closed loop control system for seam tracking
  - Develop quality monitoring and data logging system



- Stationary Shoulder FSW
  - General introduction
  - Benefits & Limitations
  - Robotic
- FlexiFab robot system at TWI
  - EU FP7 FlexiFab project
  - General results from
    - Thin section SSFSW
    - 3D SSFSW
    - Corner FSW
    - Seam tracking
- Conclusions and further improvements to SSFSW

- Stationary Shoulder Friction Stir Welding

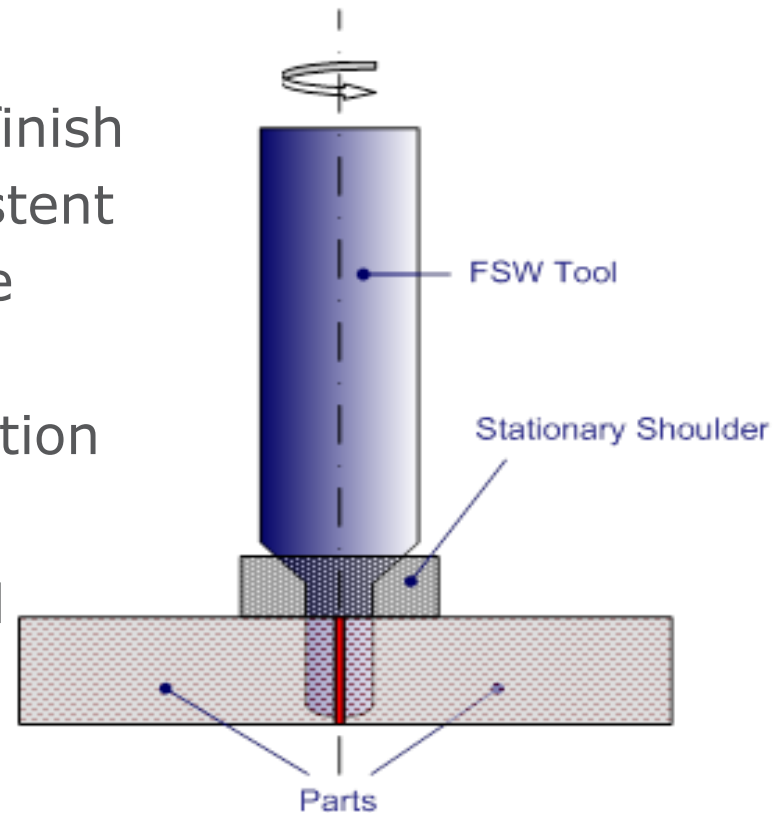
- Rotating probe
  - Static shoulder

- Process benefits

- Excellent component surface finish
  - Limited undercut, more consistent
    - Directly related to tilt angle
  - No flash
  - Lower heat input, lower distortion

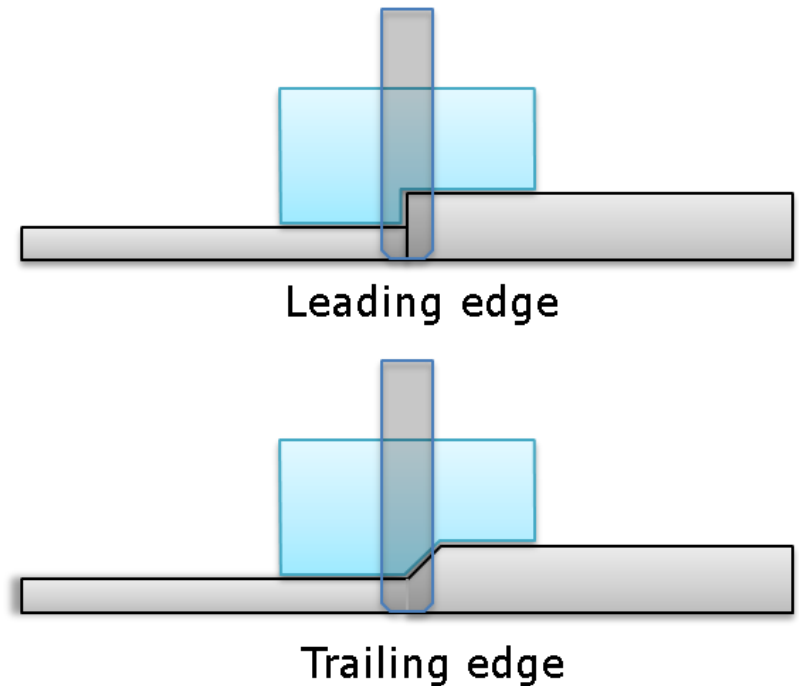
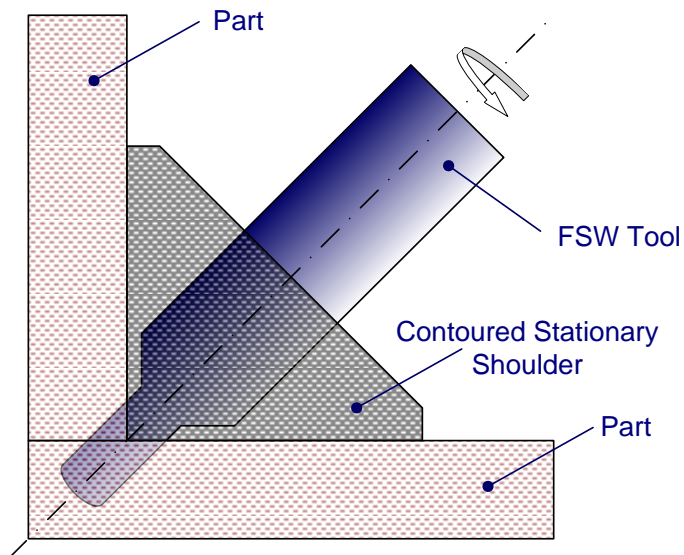
- Limitations

- Lower heat input, lower speed
  - Gaps & thickness variations
  - Probe wear



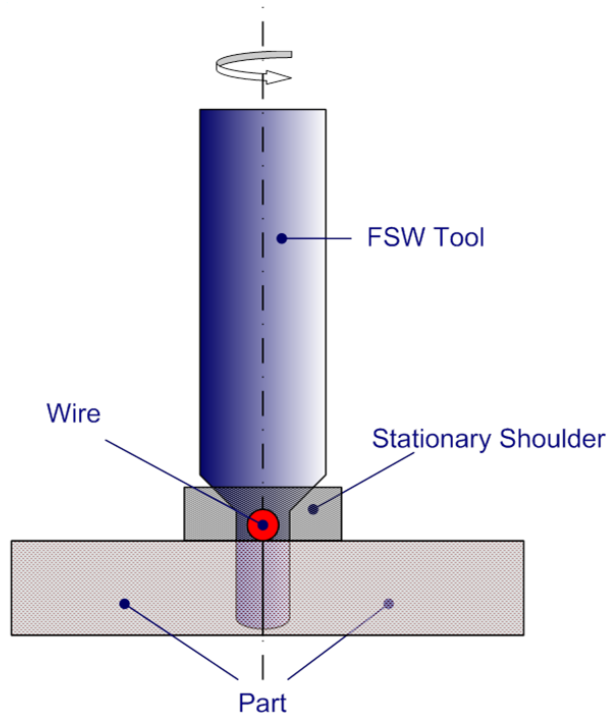
# Benefits - New weld geometries

- Process variants of SSFSW
  - Corner welding (T-joints)
  - Tailor welded blanks (dissimilar thickness)

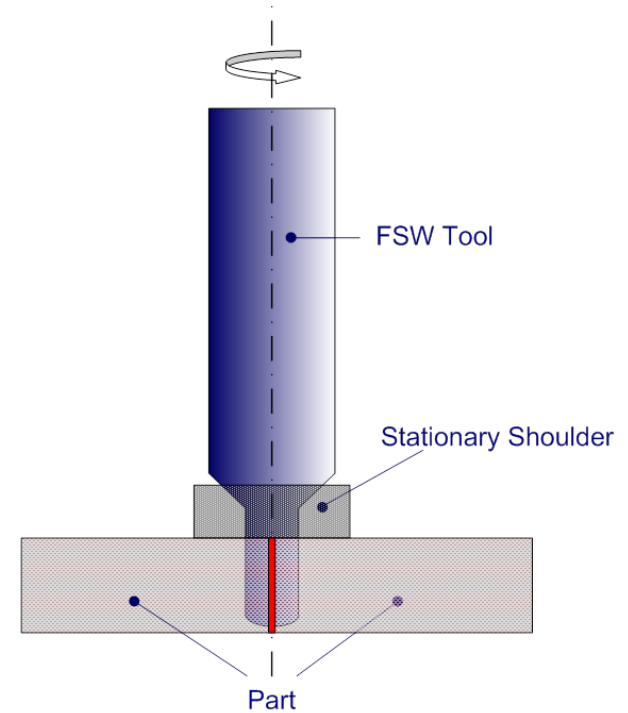


# Benefits - New weld geometries

- Process variants of SSFSW
  - AdStir – Wire feeding into SSFSW tool



**Into the weld view**



**Away from the weld view**

# Benefits – Robotic SSFSW

- Benefits when implemented on robots
  - Shoulder acts as a stabiliser and damper
    - No “meltdown”
    - Reduced vibrations
  - Reduced spindle torque
    - Majority of torque produced by shoulder in conv. FSW
    - more compact FSW head
  - Reduced heat input
    - beneficial for complex (3D) joints



Conventional FSW

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# FlexiFab robot system



# FlexiFab robot system

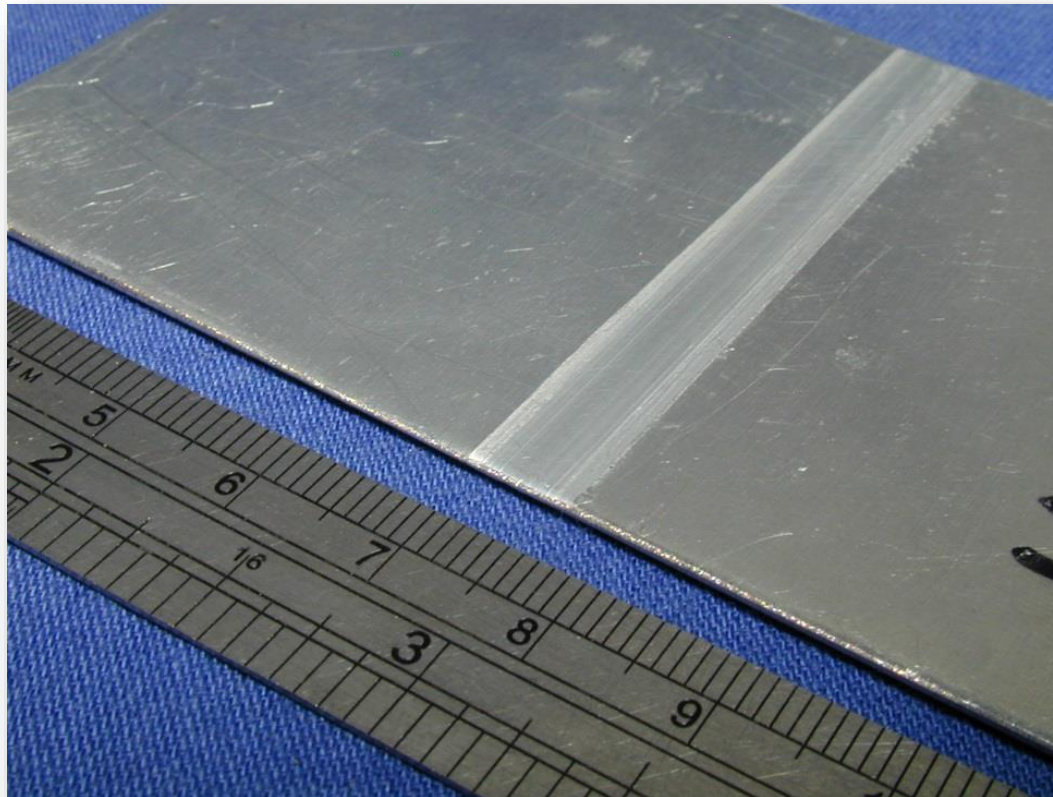
- ABB IRB7600 robot + turntable (7 DOF)
- 6-axis force control (JR3 sensor)
- FSW process head
  - 3300 rpm
  - 70 Nm
  - Retractable pin
  - Water cooling
- Up to 10kN axial force
  - SSFSW [0.3 to 5 mm]
  - Corner FSW [0.5 to 3 mm]
  - Bobbin FSW [3 to 5 mm]
- Laser seam tracking



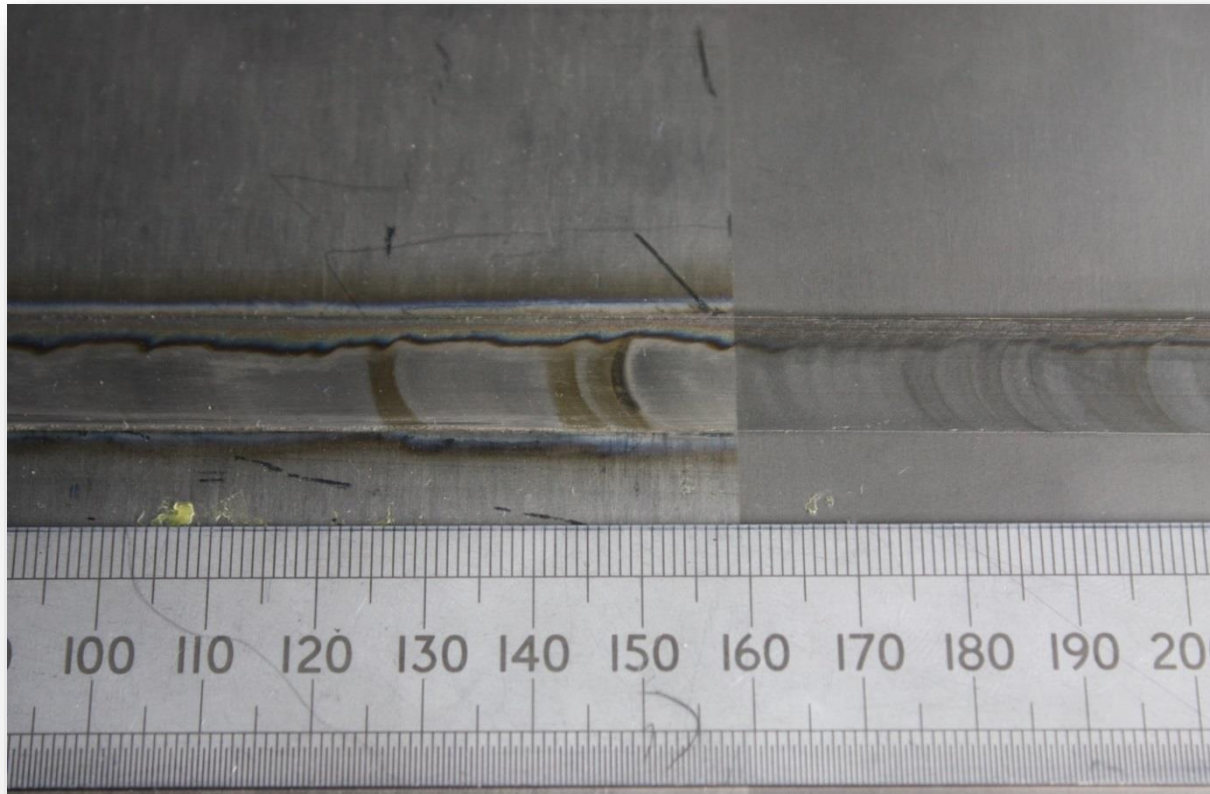
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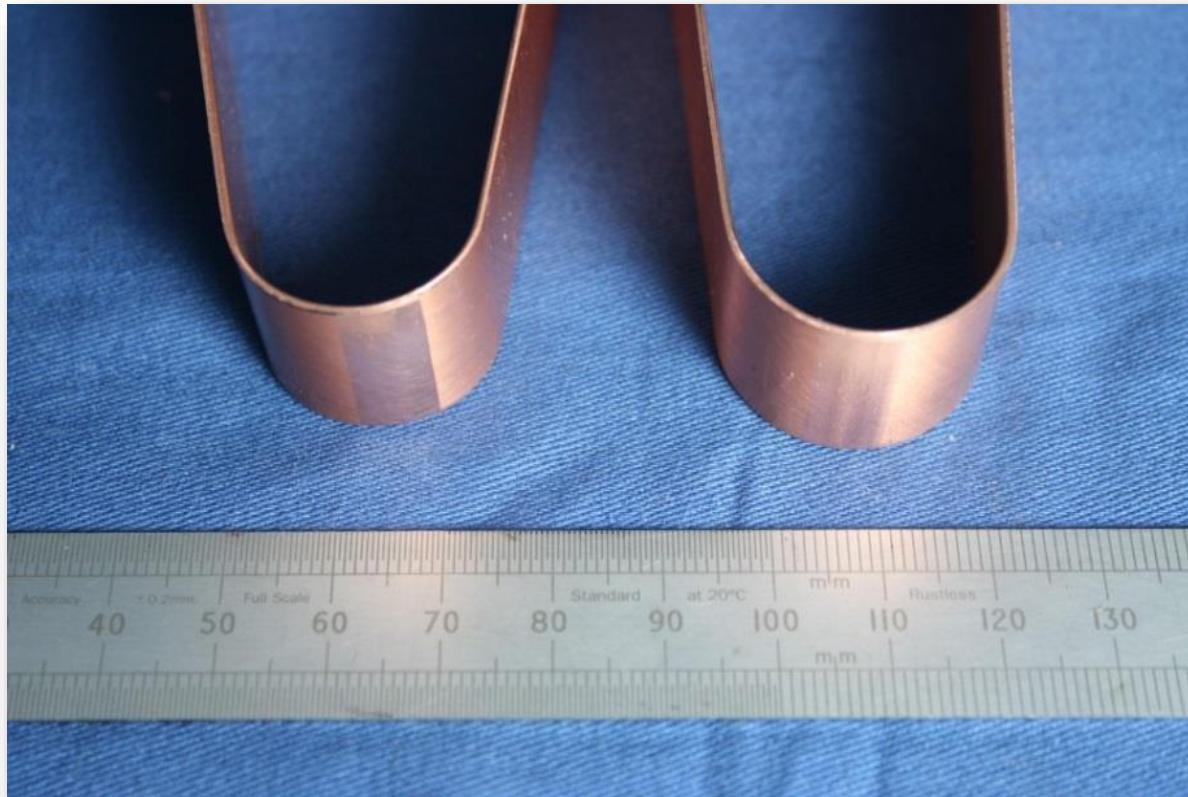
- Thin section SSFSW: AA6082-T6 – 0.5mm



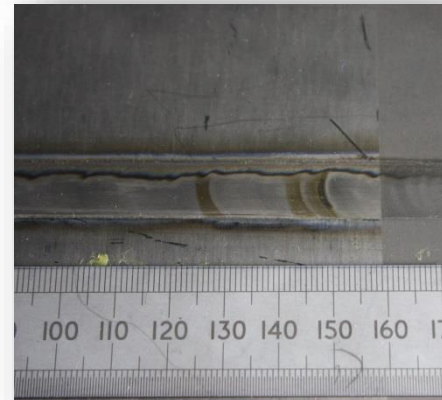
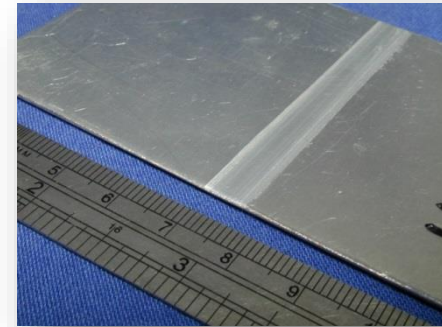
- Thin section 1mm SSFSW: Ti 6-4



- Thin section SSFSW: Cu – 0.5mm



- Thin section – The advantages
  - Better results on lower thickness than conventional FSW
  - Related to
    - Affinity of shoulder material to workpiece material
    - Future work
      - Low friction tools or coatings

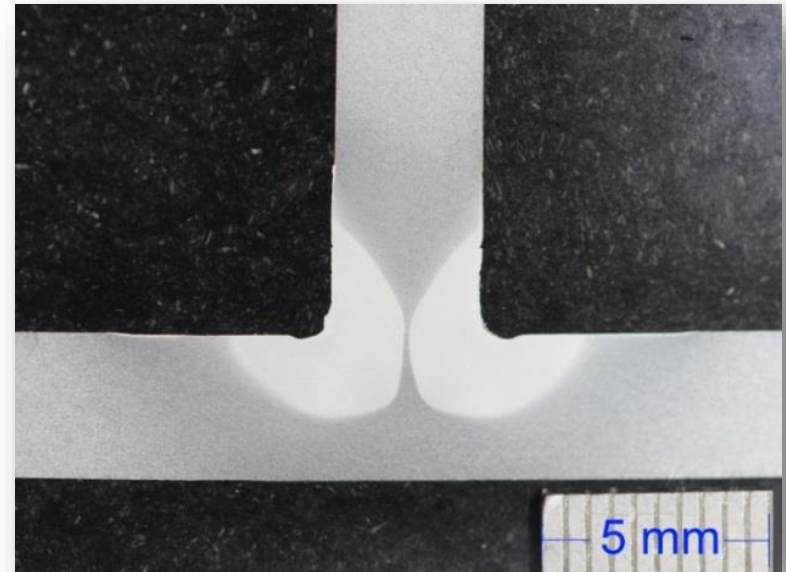
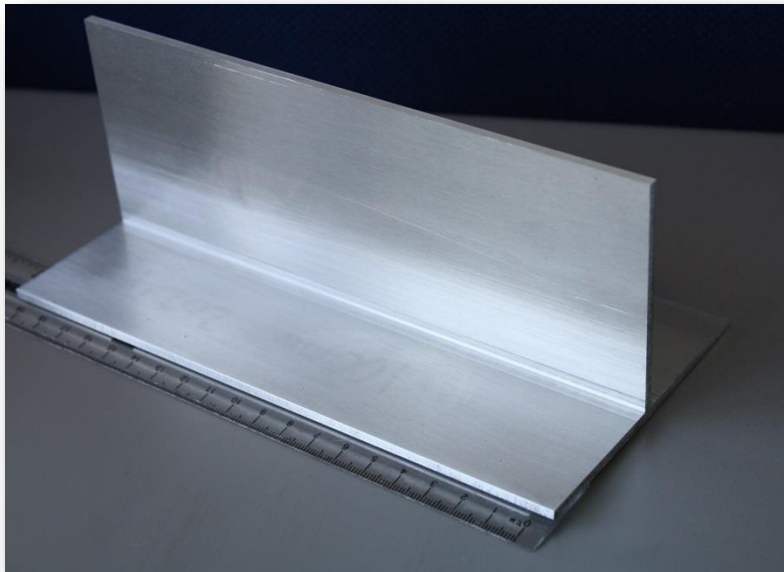




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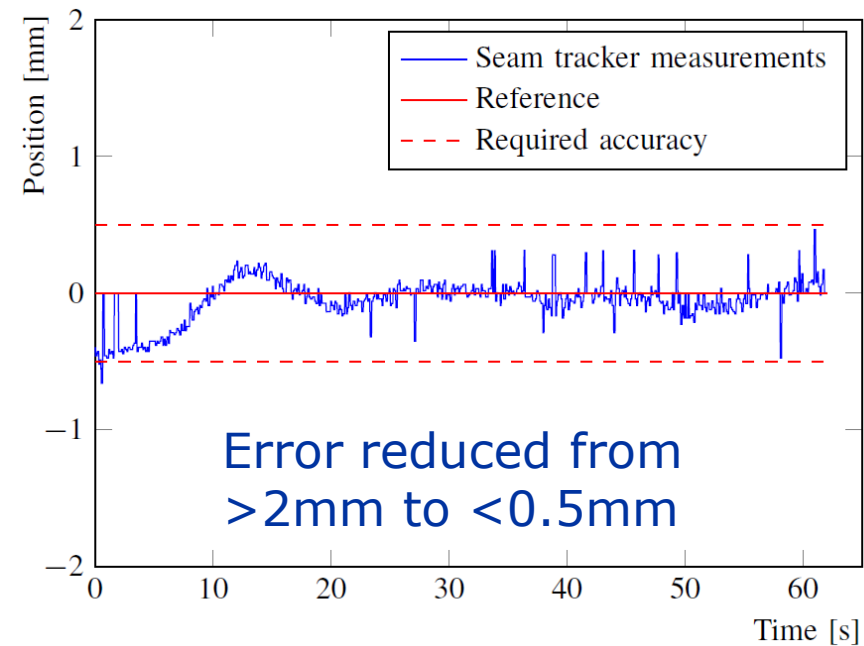
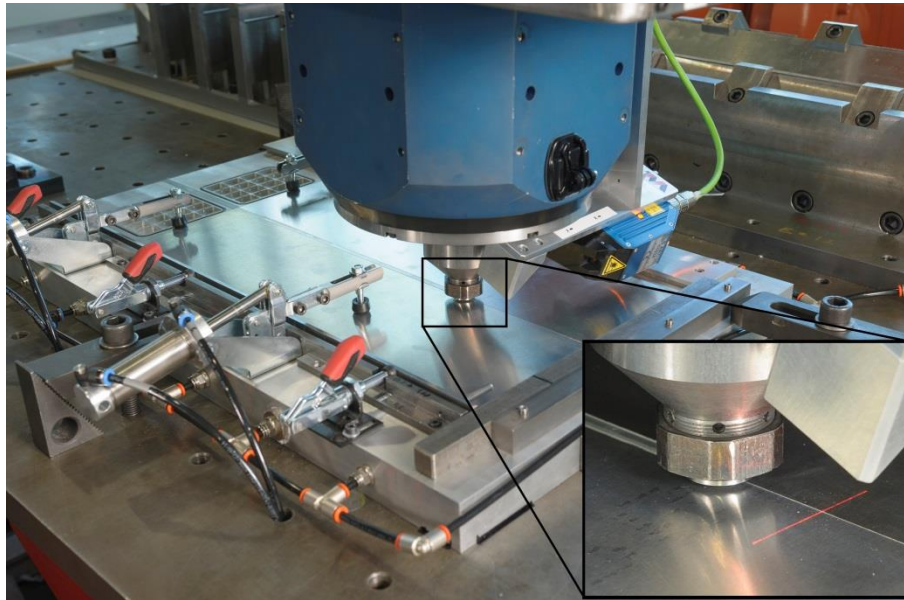
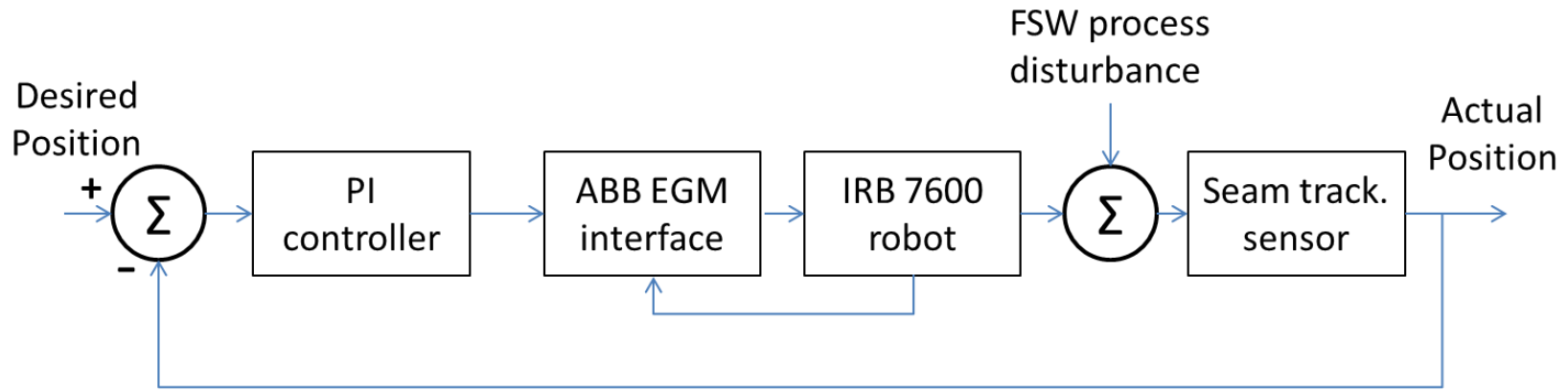
- T-joint of 3mm AA2024-T3
  - ▣ Void-free joints with  $\sim 0.1\text{mm}$  undercut



- ▣ Low welding speed to overcome x-force (3kN)
- ▣ 3-axis simultaneous force control ( $y$ ,  $z$ ,  $M_z$ )
- ▣ Future work: Combined with AdStir to produce fillet

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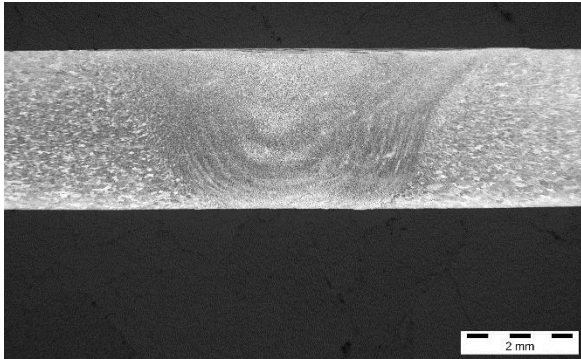
# FlexiFab system - seam tracking



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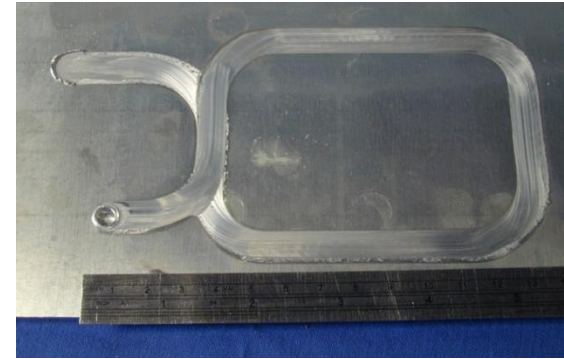
# Robotic SSFSW - Overview



1D butt joint  
1mm – 3mm



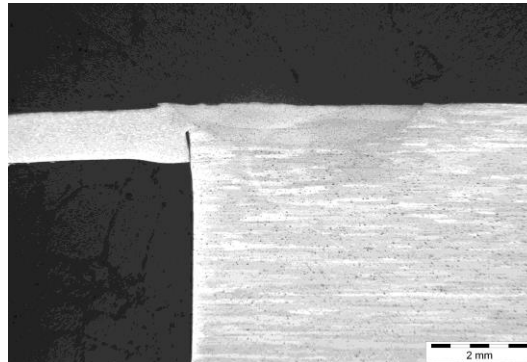
1D lap joint  
2+2mm



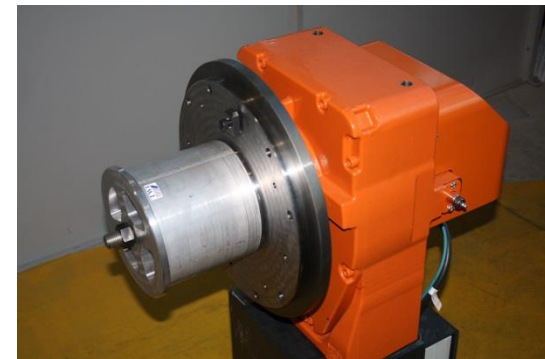
2D lap joint  
2+0.5mm



3D butt joint  
2mm



2D lid-in-box  
1mm – 3mm lid

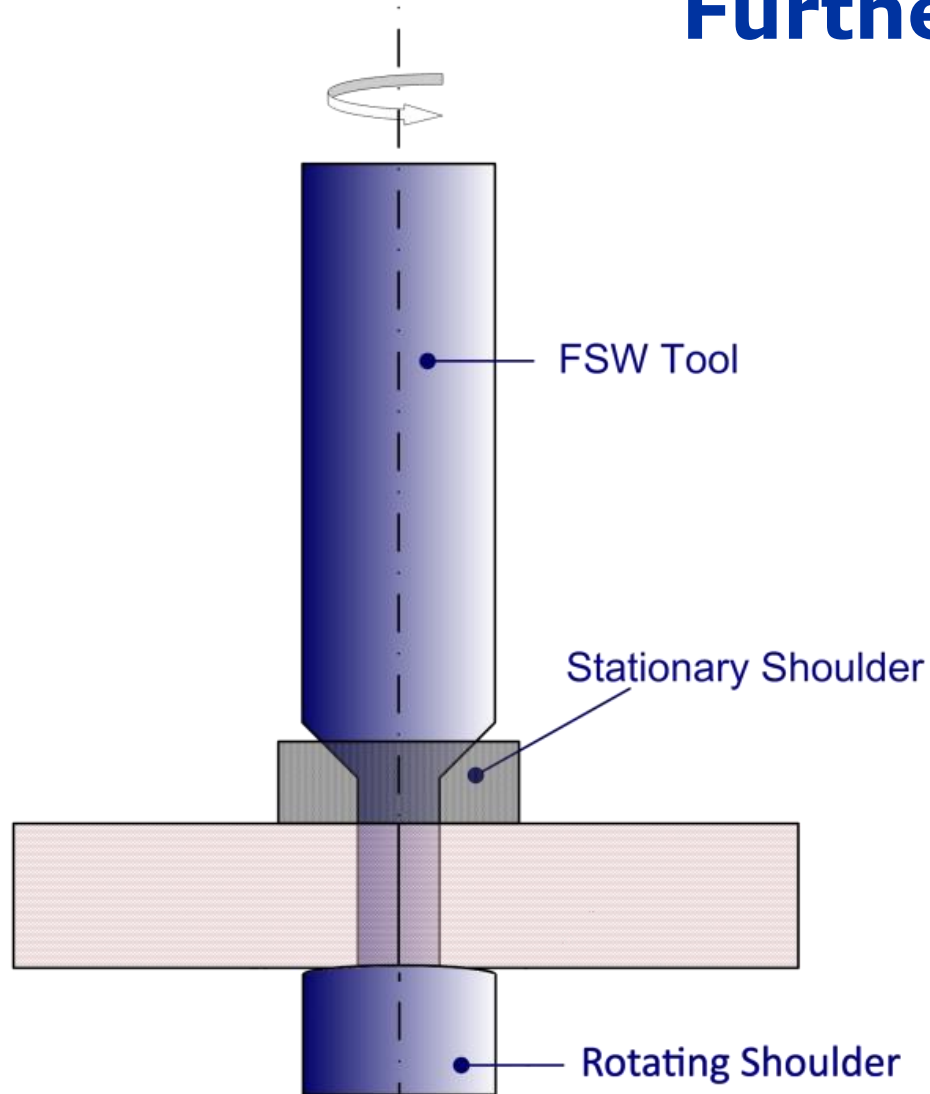


Circumferential  
3mm

- In addition to the general SSFSW benefits, robotic SSFSW is:
  - Generally a more stable process than conventional FSW
  - Less sensitive to plunge parameter variations
  - Easier to weld thin section materials
    - 0.5mm demonstrated for different alloys
    - Further reduction through low friction shoulders
  - Allows new geometries (TWB, Corner)

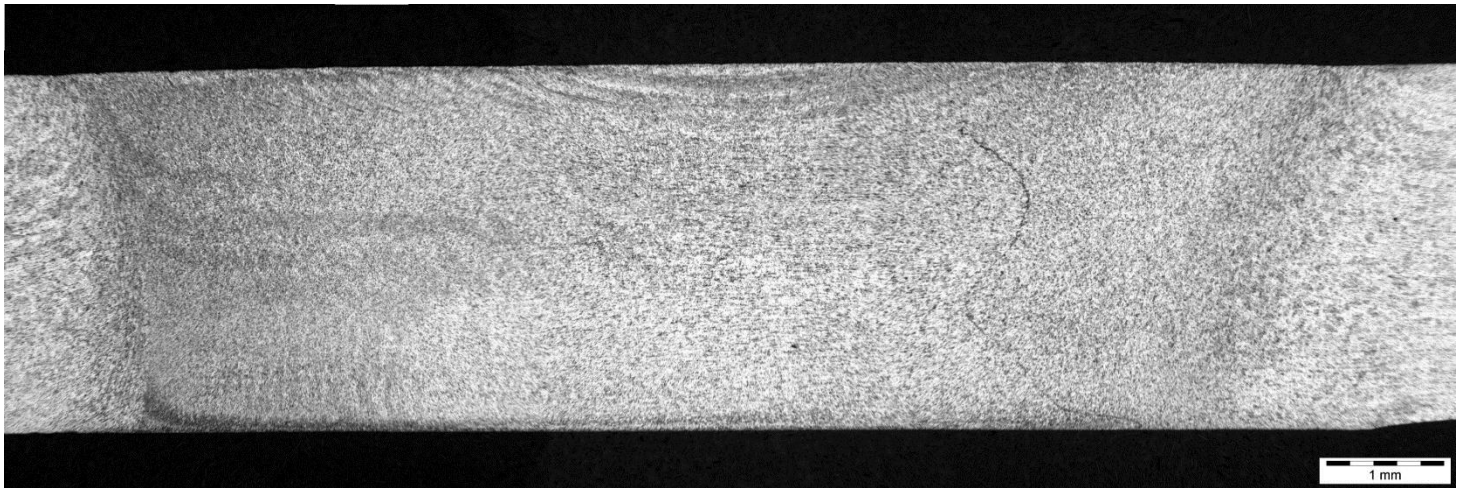
- More challenging than conventional FSW for:
  - Large material tolerances
    - Gaps in between the abutted plates
    - Variations in sheet thickness
    - AdStir to fill gaps
  - 3D joints (due to sensitivity to orientation)
    - Offline path programming
  - High welding speeds
    - Mainly due to system limitations
  - Long welds (tool life)
    - Tool materials and coatings
    - Tool cooling
  - Retractable pin (no flow/heat once pin is retracted)

# Robotic SSFSW Further developments





# Robotic SSFSW Further developments



SSFBSW in AA6082-T6 at 5mm/s

# Future robotic concepts

## ■ Potential Platforms



Industrial robot

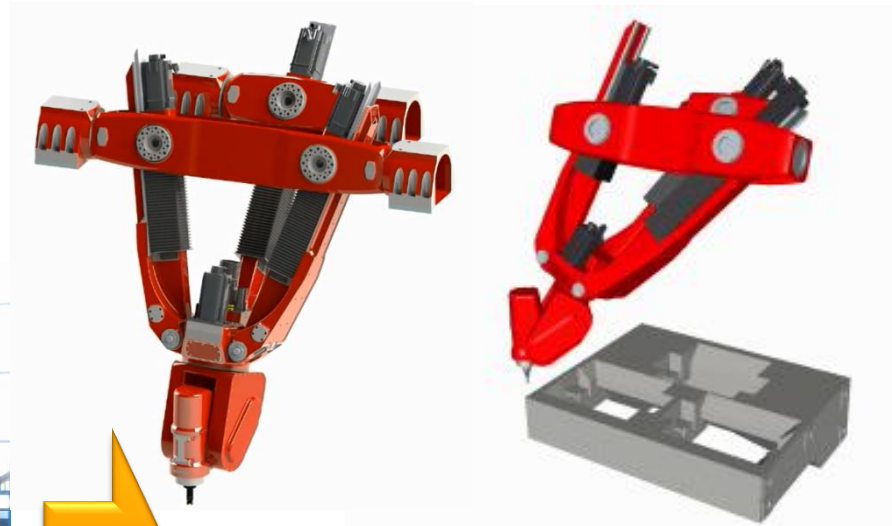
Flexible, low cost,  
reconfigurable,

Inaccurate, low force



Gantry machine

High force, stiff,  
inflexible, expensive



Exechon PKM



Gantry-Tau robot prototype (Lund University)



# Future robotic concepts



**PKM Advantages:**  
Speed, Work space, Stiffness

- Potential Applications
  - Aerospace
    - FSW of fuselage
    - Drilling of wing spars
  - Railway carriage
    - Welding of extruded panels
  - Automotive cylinder block
    - FSW of cooling channels
    - Drilling and machining
  - Electronics
    - Heat exchangers
    - Sealing of computers



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