Centre for Joining & Structures

ongoing activities related to FSW

Outline

1. **XPRES**
2. Hybrid joints in metal-composite structures
3. SignaStir
4. StiRoFlex
(new proposal in collaboration with HV)

XPRES

Initiative for excellence in production research

Strategic priorities in the Swedish research and innovation bill (2009–2012)

REGERINGSKANSLIET
Government Offices of Sweden

TECHNOLOGY

- Nanoscience and nanotechnology
- e-Science
- Materials science
- Production engineering
- IT and mobile communications
- Transport research
- Aviation
- Space research

MEDICINE

- Molecular bioscience
- Stem cells
- Diabetes
- Neuroscience
- Epidemiology
- Cancer
- Psychiatry
- Health care research

CLIMATE

- Energy
- Sustainable use of natural resources
- Impact on natural resources
- Climate models
- Marine environment research

XPRES

Initiative for excellence in production research

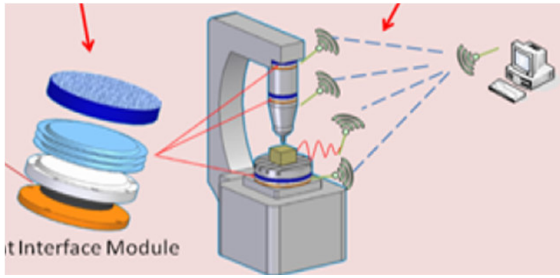
- Research:
  - KTH Production engineering
  - KTH Lightweight structures
  - KTH Machine design
  - KTH Materials science and engineering
  - KTH Industrial economics and management
  - Mälardalen University
  - Swerea IVF
  - Swerea KIMAB
- Core industrial partners:
- Affiliated industrial partners:

Vision for industrial production in Sweden 2027

•Complex and multimaterial products

•Resource preserving production and after market processes

•Responsive production for small series and *mass customization*

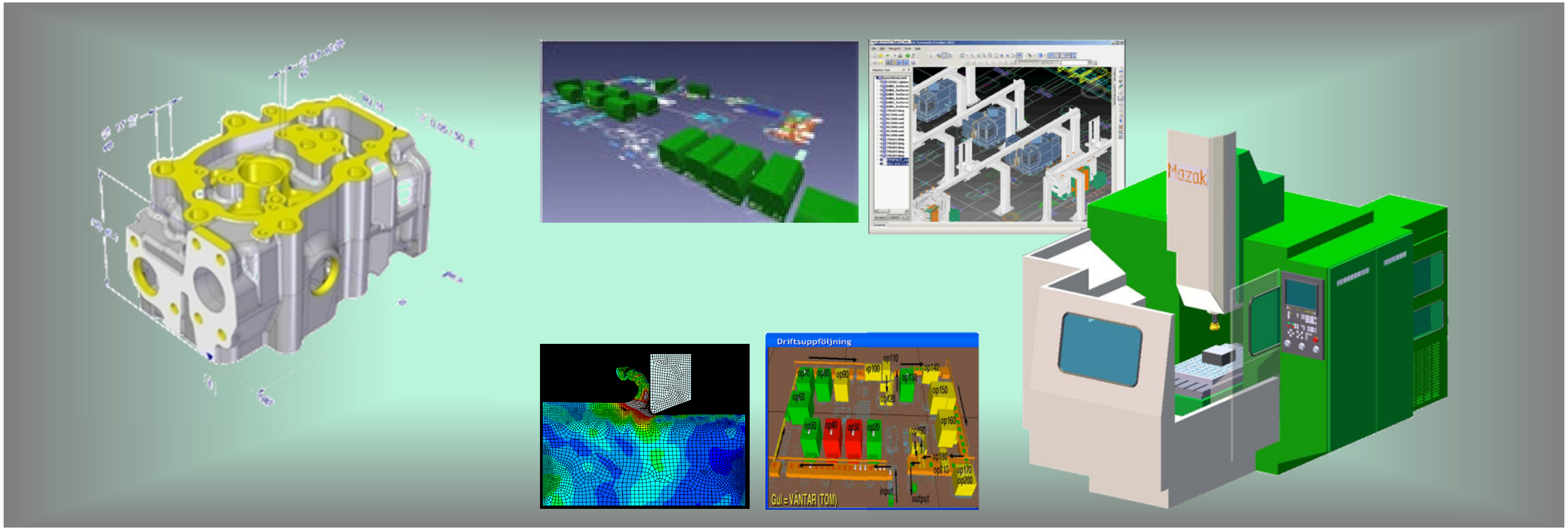


- XPRES vision: adaptive and sustainable manufacturing of future products

XPRES model vision

2010	2025
Empirical models	Physical models
Single processes	Process chains
Single materials	Material integration
Limited production preparation	Frequent production preparation
Limited verification	Verification for use in production

XPRES digital and verification lab

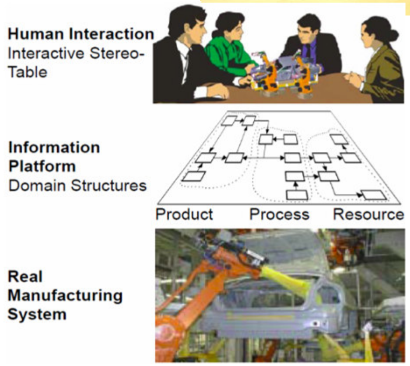


International graduate school

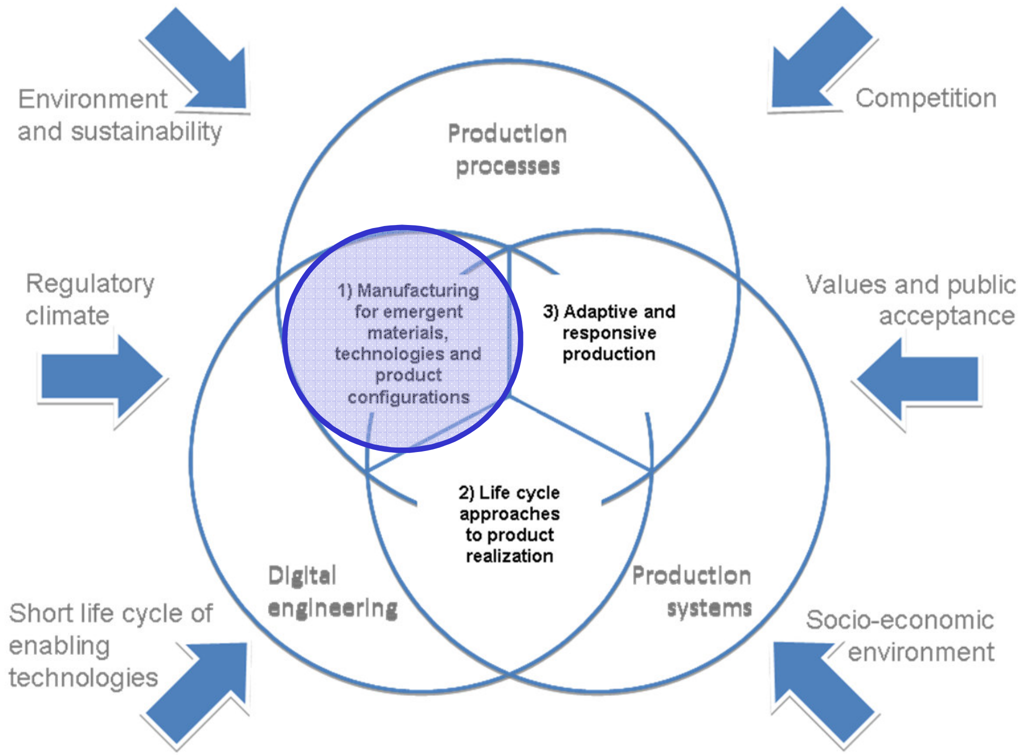
Junior academy

Industrial academy

- research projects
  within XPRES focus areas



Focus area 1
Manufacturing for emergent materials and technologies



- CO_2 + emissions
- Sustainability
- Safety
- Consumer value
- Resource efficiency

- Composites
- Ultra high strength steels
- Powder metallurgy
- Light metals

- **Light weight design**
- **High temperature and pressure engines**
- **Hybrid powertrains**

Products	Heavy vehicle cabin Train body Bus body				
Drivers	Reduced CO_2 emissions Reduced life cycle cost				
New materials	Aluminum	Composite materials	Magnesium	Mixed materials	UHSS
Manufacturing processes	Bending Hydroform Joining	Hot press forming Vacuum infusion Automation	Joining	FSW Mechanical joining Adhesive bonding	Roll forming Bending Local forming Joining
Modeling issues	Large deformations Damage	Large deformations Temperature	Large deformations Temperature Damage	Adhesion damage	Elasticity Large deformations Cyclic deformation Damage

Friction Stir Welding for Hybrid Joining of Al to Polymers

by Wallop Ratanathavorn

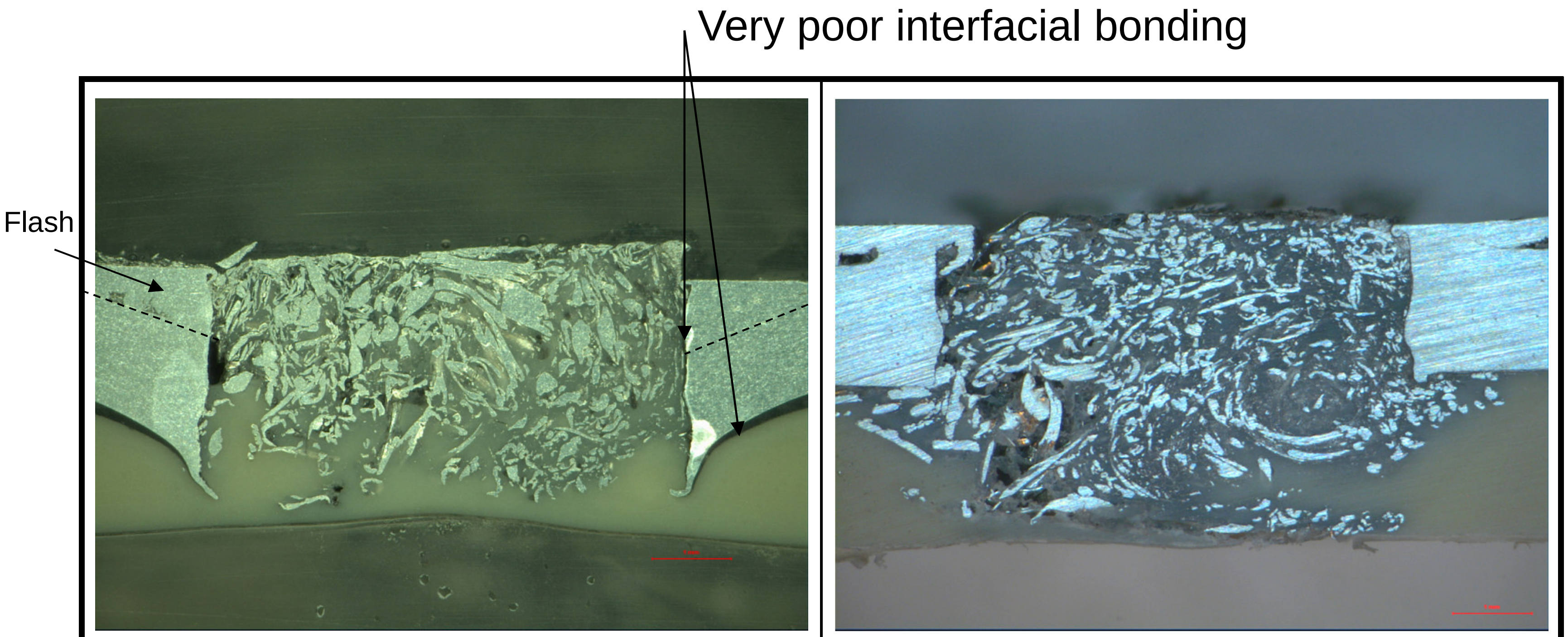
XPRES
Initiative for excellence in production research

swerea | KIMAB

- Polymers and polymer composites:
  PP, PA, PET
  PET/PET and PA/glass fibre
- Aluminium alloys:
  AA5XXX and AA6XXX
- Overlap joints

FSW trials at ESAB in Laxå

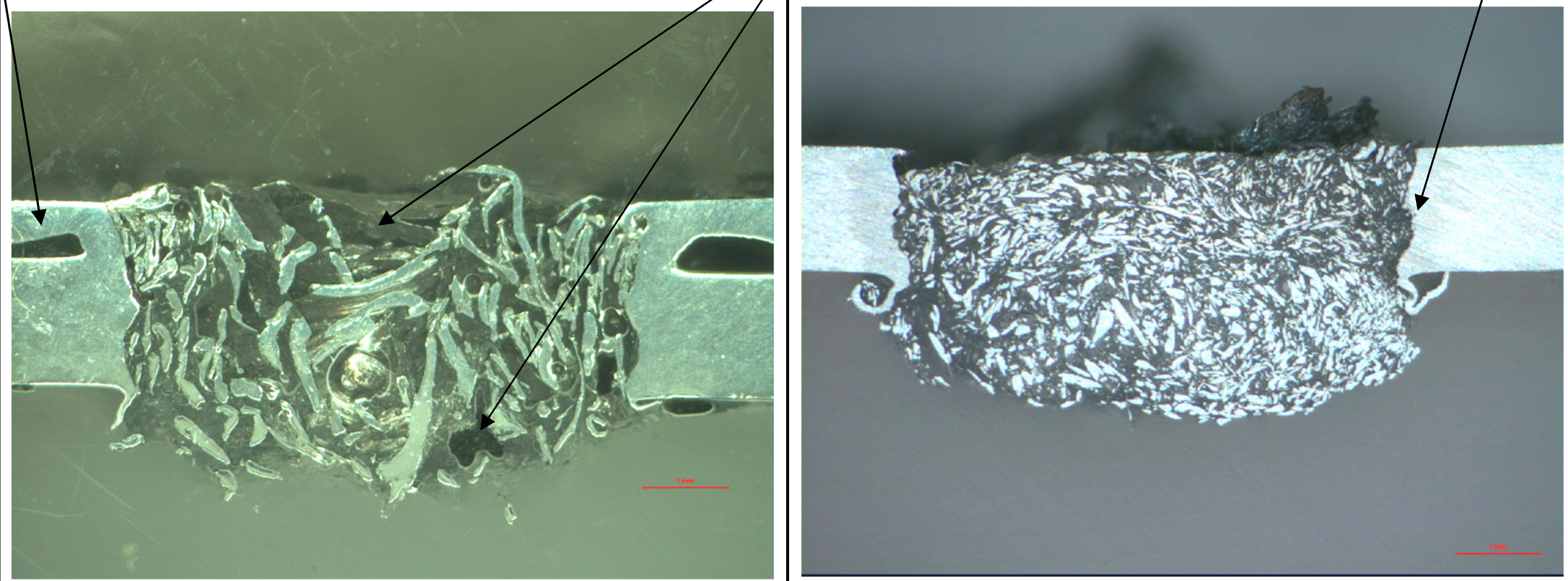
AA5754-Polypropylene (PP)



First trial (10 cm/min, 2°)	Second trial (5 cm/min, 0.5°)

Significantly improvement on upper plate deflection, better interfacial bonding between Al-joint, small void still exists

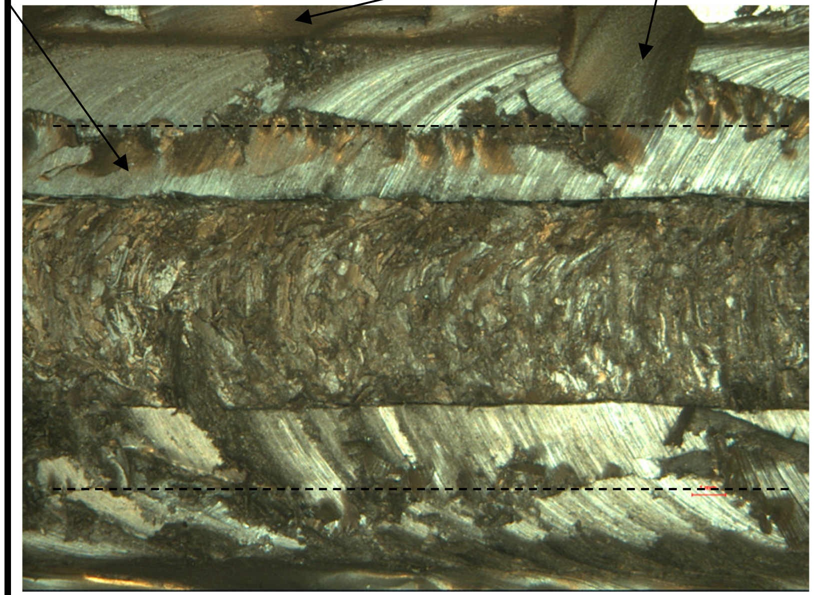
AA5754-Polyamide-12 (PA-12)

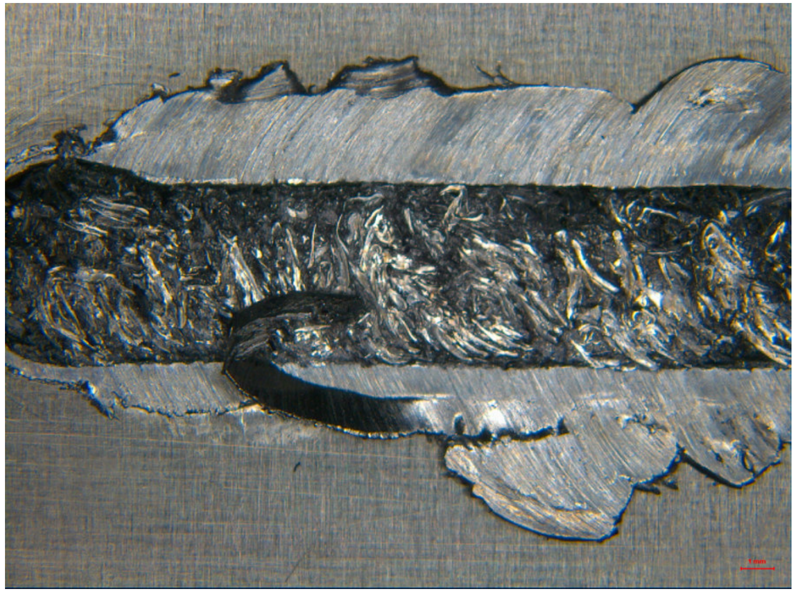


First trial (1800, 20, 2°)	Second trial (1200, 3, 0.5°)

Significant improvement on pore formation, no visible pores can be seen in the 2nd trial samples

AA5754-Polypropylene (PP)



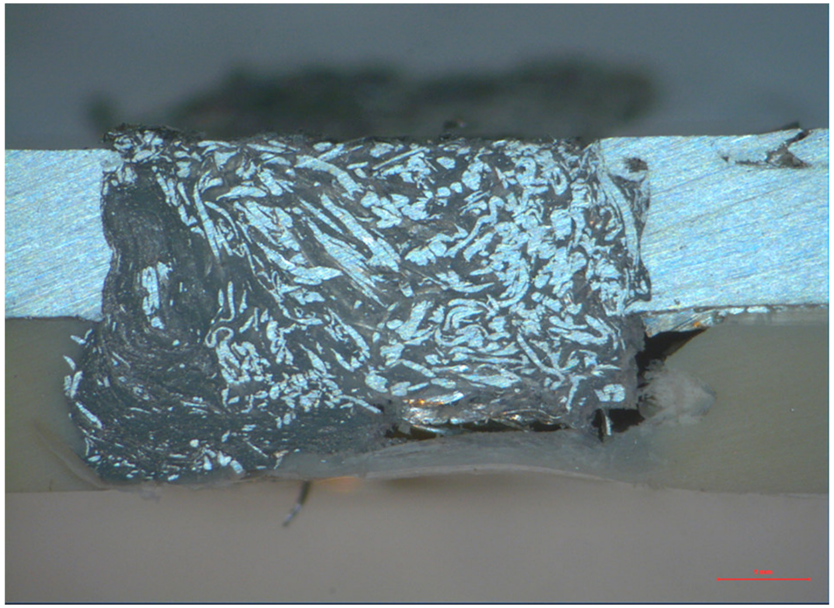
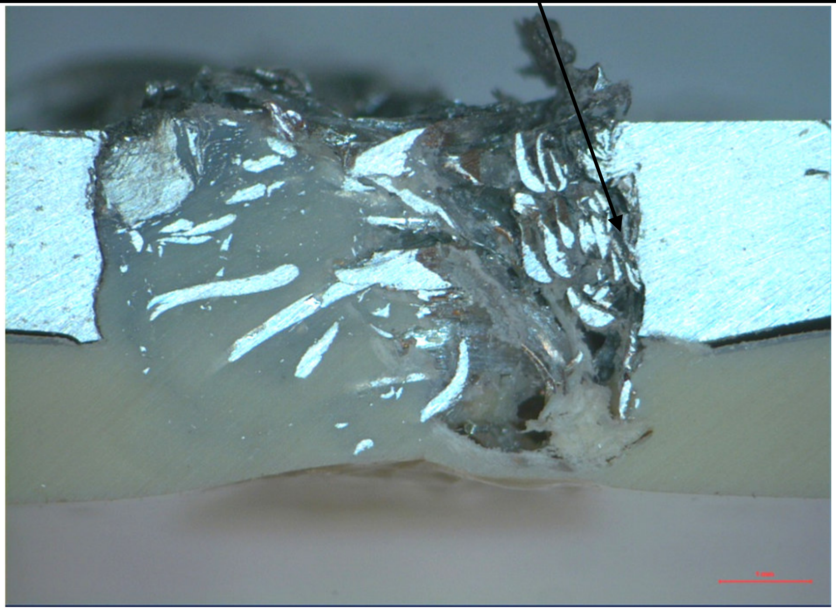


First trial (10 cm/min, 2°)	Second trial (5 cm/min, 0.5°)

Significant improvement on flash formation

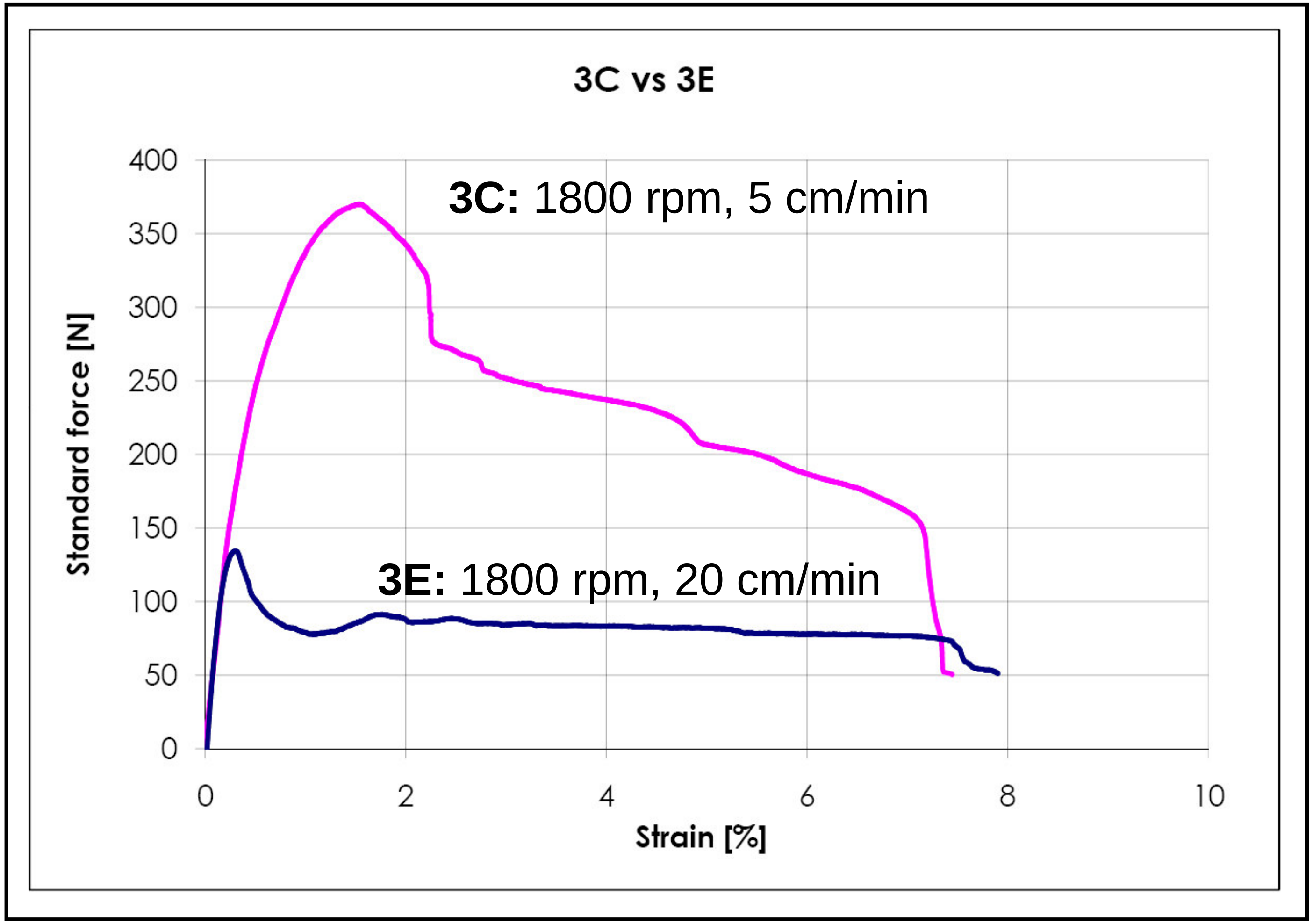
Effect of Welding Speed

Poor materials filling

	
1800 rpm, 5 cm/min (3C)	1800 rpm, 20 cm/min (3E)

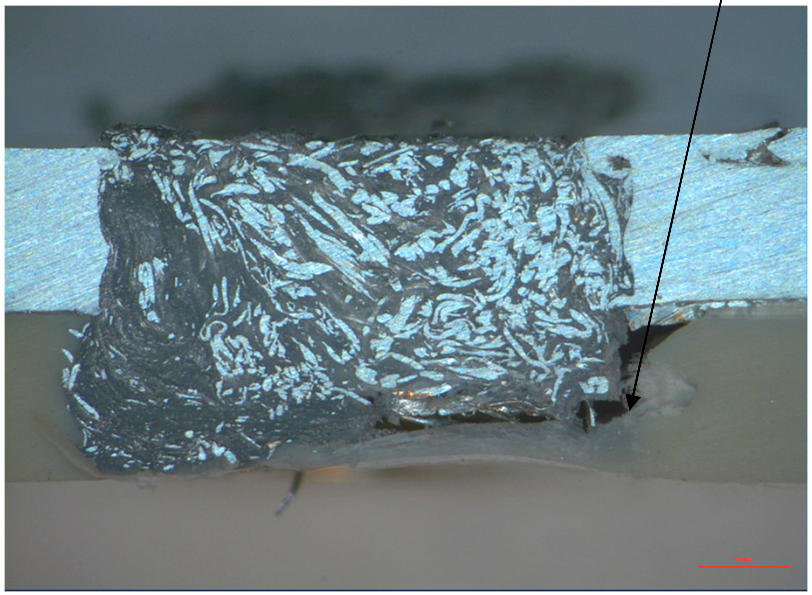
High welding speed (low heat input) gives coarse Al chip in the joints, lowering welding speed enhances materials mixing and reduces Al chip size

Effect of Welding Speed (Tensile Load)

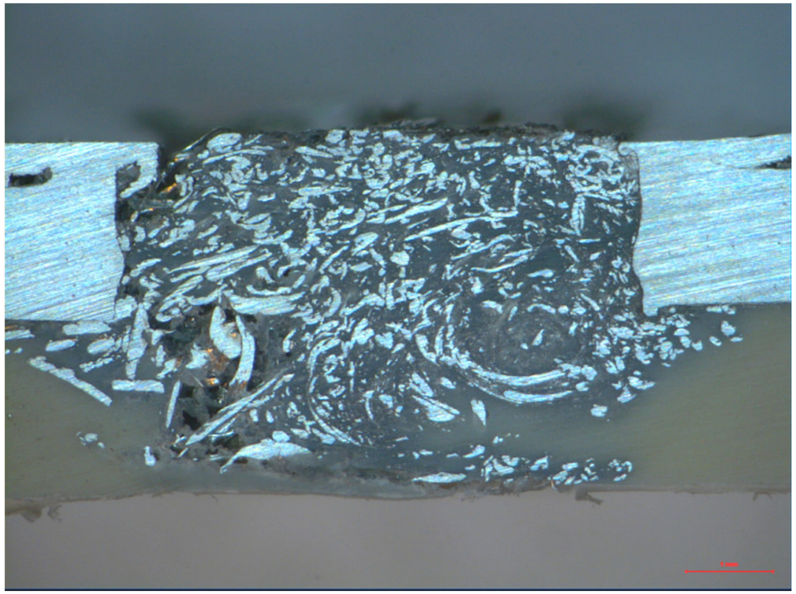


Effect of Rotation Direction

Lack of materials due to highly upward flow



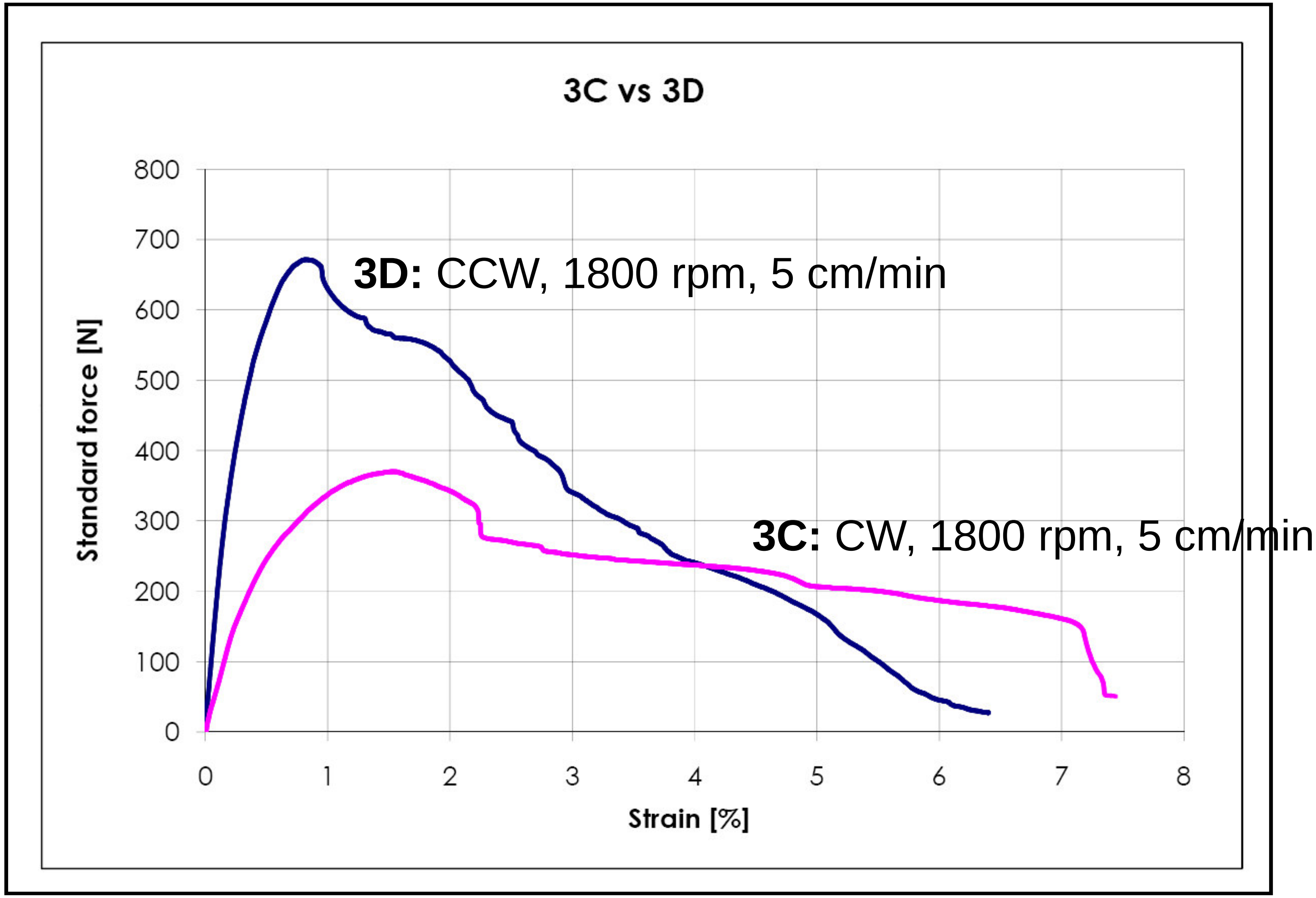
Clockwise (3C)



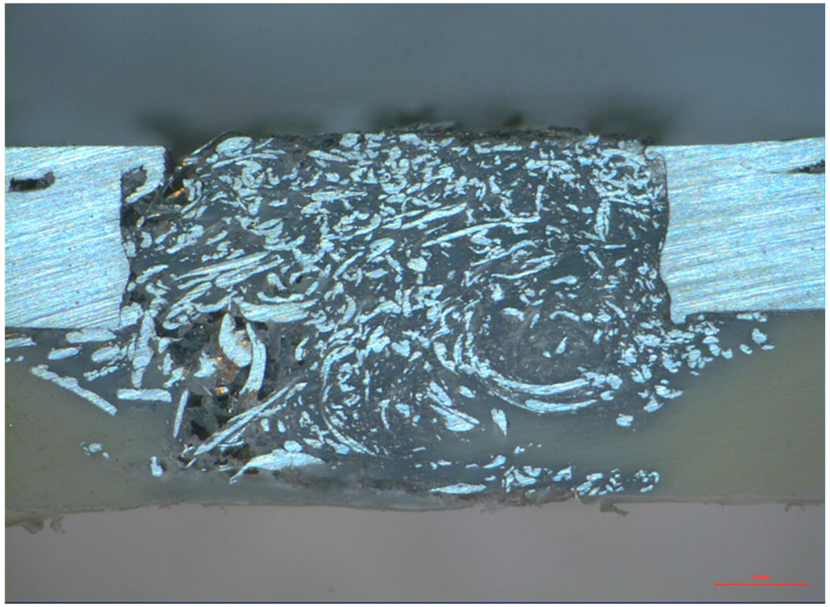
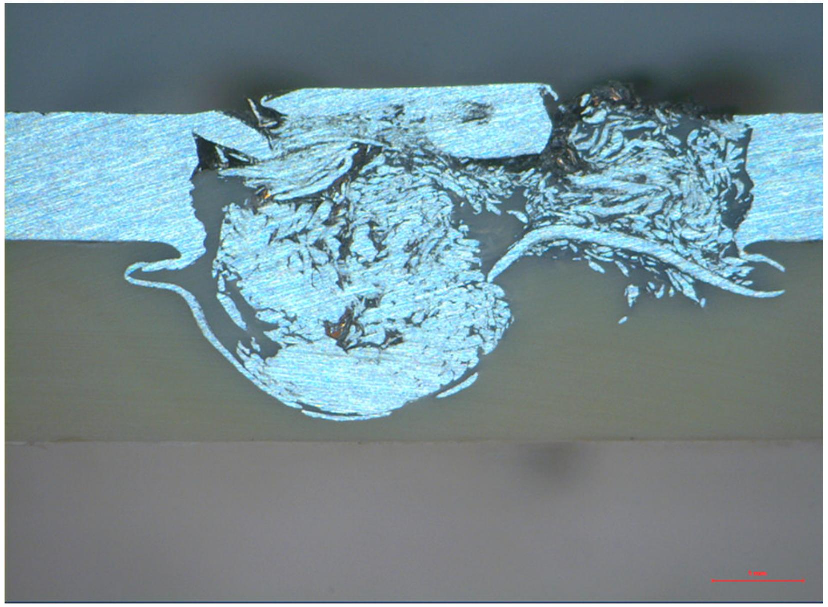
Counter-clockwise (3D)

High level of materials upward flow (CW) causes large voids at the lower part of polymers (Tensile load: 360 N – 671 N)

Effect of Rotation Direction (Tensile Load)

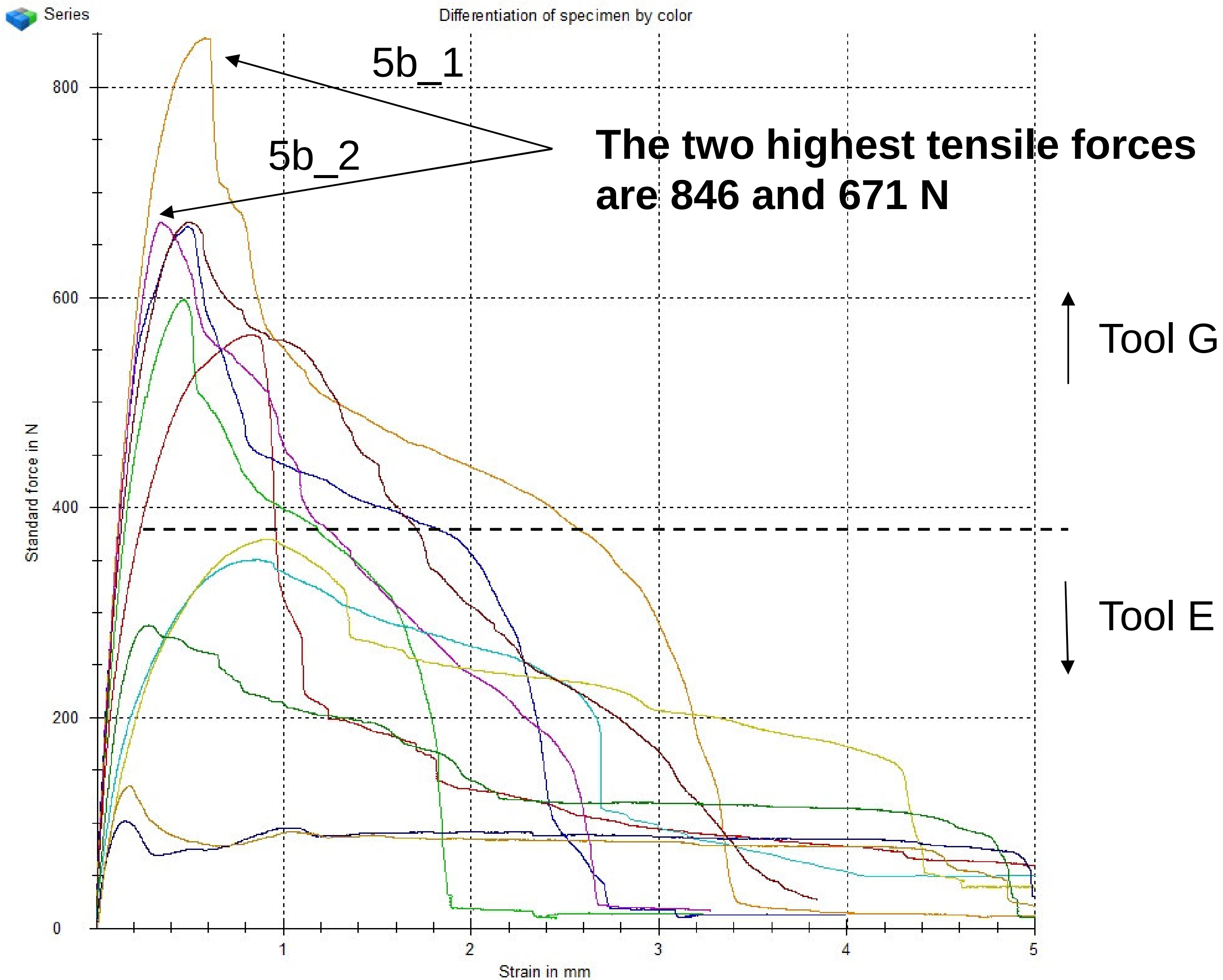


Effect of Tool Geometries

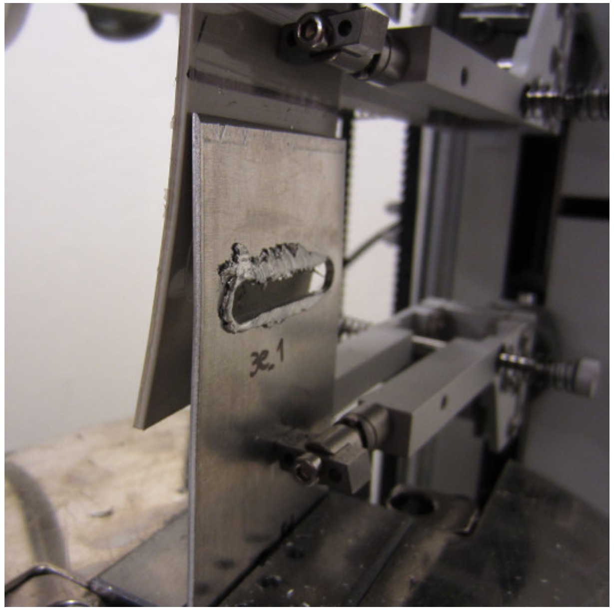
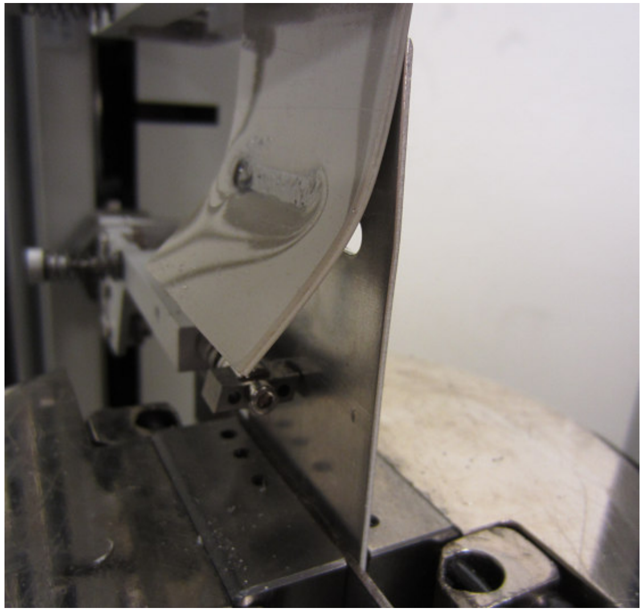
	
Specimen 3D (Tool E) – 671 N	Specimen 5B (Tool G) – 846 N

Scroll groove (G) gives the large fragment of Al chip in the joint comparing with concave tool (E) which gives fine and uniform Al chip in the joint.

Tensile Test Results

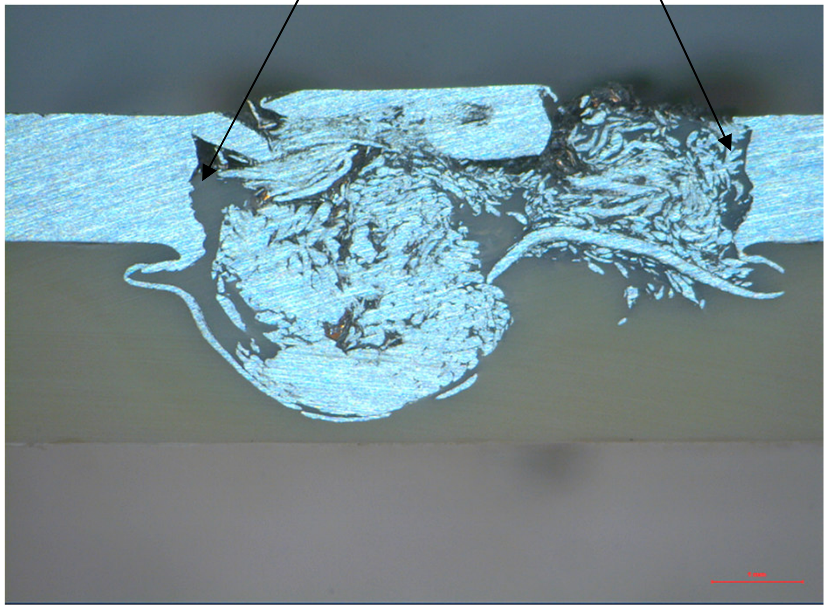
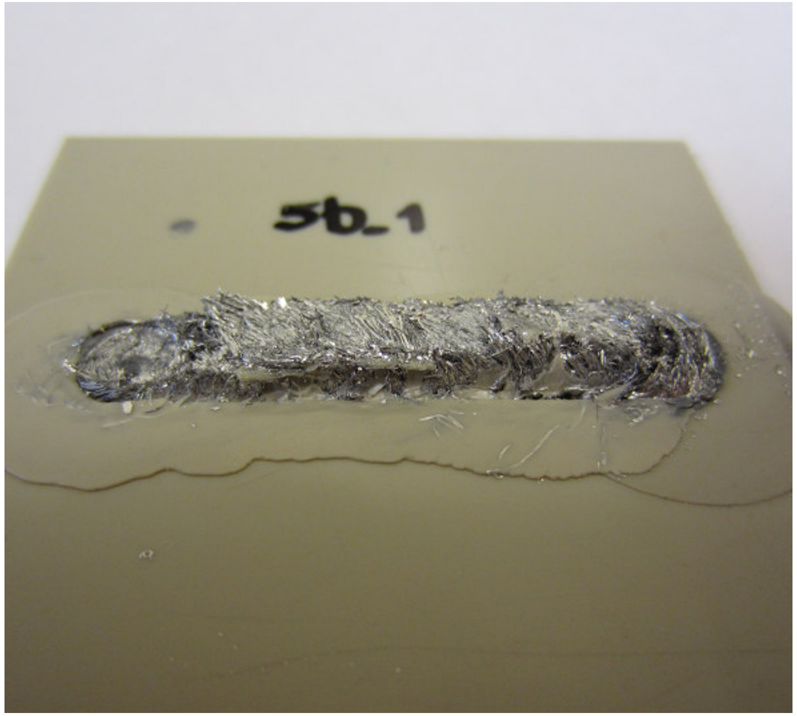


Fracture of specimen

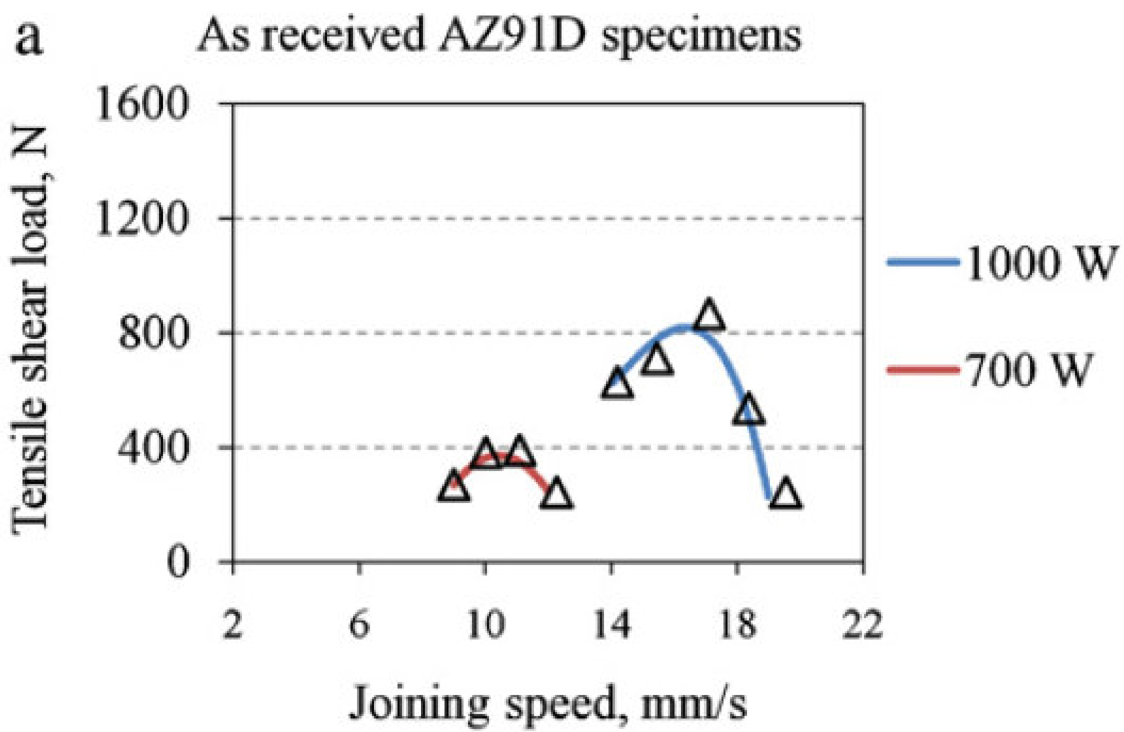
	
Front view	Rear view

Fracture of specimen (5B)

Interface bonding

	
Cross section	Specimen fracture (5B_1)

Comparison with the results from literatures



- The specimen dimension are **70 mm x 32 mm x 2 mm**
- The highest tensile force is **900 N**
- The specimens failed by interface fracture

Summary

- Lap joints between Aluminium and polymers can be joined by FSW.
- Maximum tensile load for lap shear tensile specimens is 846N which is in the same level as adhesive bonded or laser welded joints.
- Process parameters and tool geometry can be further optimized.
- Strong joints have been achieved when the polymer is unmixed at the joint interface acting as adhesive bonding.

Outline

1. XPRES
2. Hybrid joints in metal-composite structures
3. SignaStir
4. StiRoFlex
   (new proposal in collaboration with HV)

SignaStir project
Objectives in Brief

- Demonstrate and characterise the capabilities of non-contact inspection of FSW in aluminium alloys

- To specify, design and assemble prototype inspection hardware and software capable of inspecting FSW welds in real time.

SignaStir Partnership

Research Providers → **System Developers** → **End Users**

Research Providers

TWI (RTD)
Project management and FSW technology

KIM (RTD)
LUS technology

ISPL (RTD)
Scientific testing and evaluation services

System Developers

HBSE (SME) with interest in FSW equipment development

Rubitech (SME)
New FSW user and producer of innovative engineering products.

Inspecta (SME) Inspection system developer and user

BCT (SME)
Developer of measurement, adaptive processing and interfacing systems

↓

Dissemination

End Users

SAPA (LE)
Aluminium extrusion supplier and major user of FSW

↓

Trials and Demonstrations

- **Laser ultrasonics**

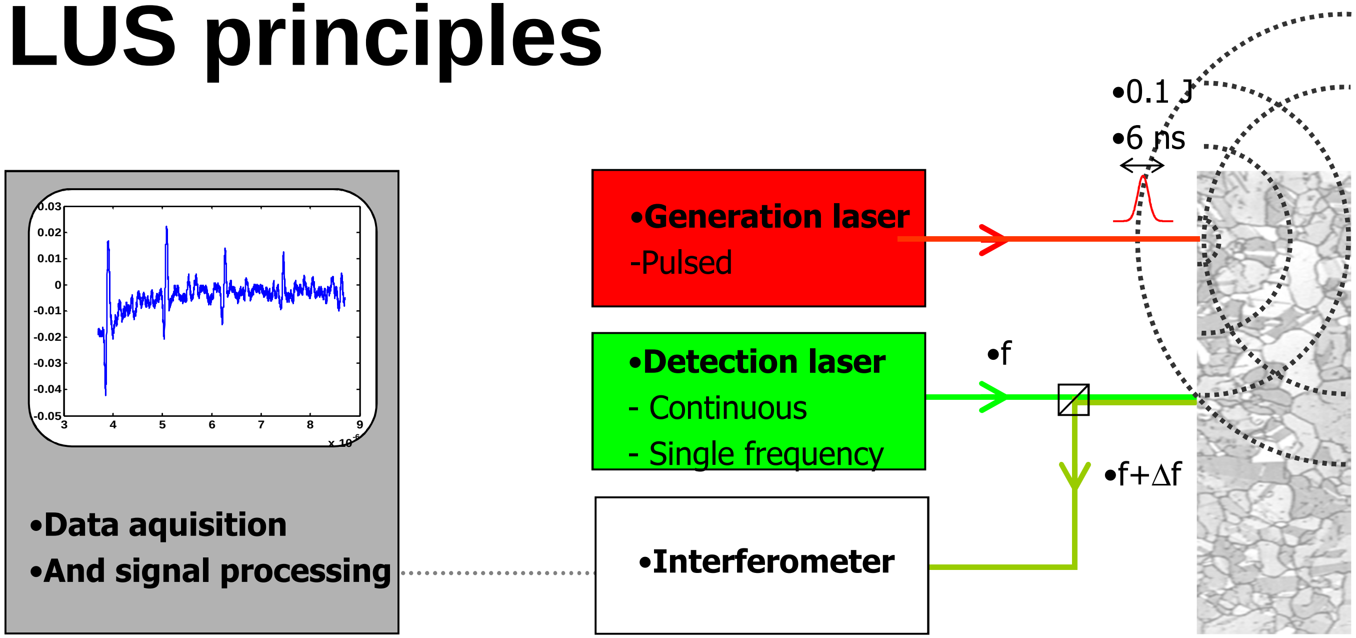
Same information as from conventional ultrasound

BUT

Non-contact	⇨	**High temperatures** **Fast moving samples**

ONLINE QUALITY CONTROLL IN PROCESS INDUSTRY

LUS principles



Generation

A laser pulse impinges on the sample surface
to create an elastic wave that propagates through the material

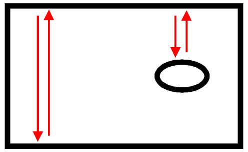
Detection

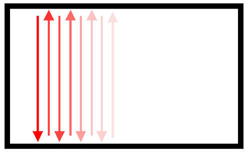
The vibrating surface changes the frequency of the detection laser
The frequency shift is detected by an interferometer

Ultrasonics

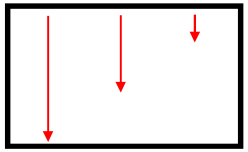
Measurable quantities

Reflection from interfaces *(Change in refractive index)*	**Attenuation** *(Scattering, Absorption)*	**Speed** *(Elasticity)*





Frequency dependent

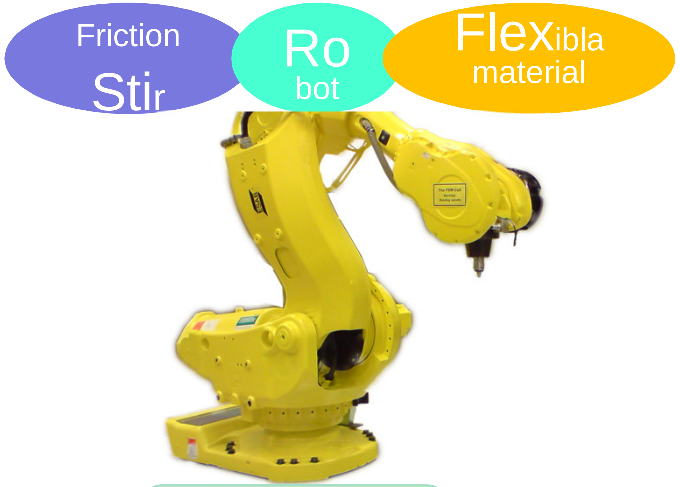


Conclusions (project ongoing)

- ❖ LUS signals show relation to defect occurrence
- ❖ Online trials have shown that the technology can handle process vibrations, speed and temperature
- ❖ System setup and signal processing must be adapted for the intended application

- ❖ The LUS technology has potential for detection of defects in FSW welds

Project proposal StiRoFlex



ESAB Robot FSW

The aim is to develop new innovative and flexible solutions for manufacturing.

The project is intended to develop Friction Stir Welding (FSW) into a commonly known and used technology in Swedish automotive industry.