Materials Day

“WERKSTOFFE FÜR TRANSPORT UND VERKEHR ”, 18th of May 2001, ETH Zürich, Switzerland

NEW ALUMINIUM ALLOYS AND FUSELAGE STRUCTURES IN AIRCRAFT DESIGN

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Outline

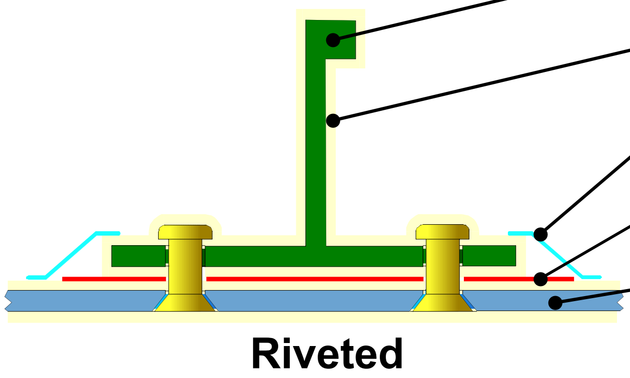
- **New Fuselage Structures:**
  - → **Laser Beam Welding (LBW)**
  - → **Friction Stir Welding (FSW)**
  - → **Extruding**

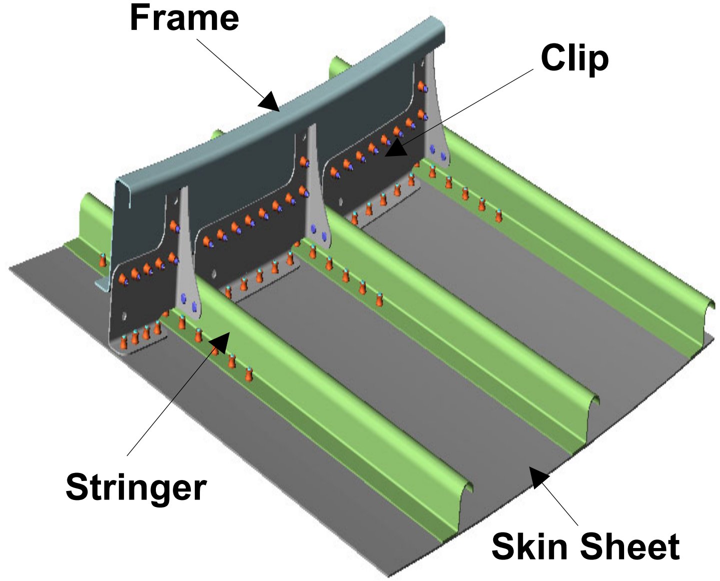
- **New Aluminium Aerospace Alloys:**
  - → **Al-Mg-Si-Cu Alloy (AA6013)**
  - → **Al-Mg-Sc-Alloy**
  - → **Al-Mg-Li-Alloy (1424)**

NEW FUSELAGE STRUCTURES

Today

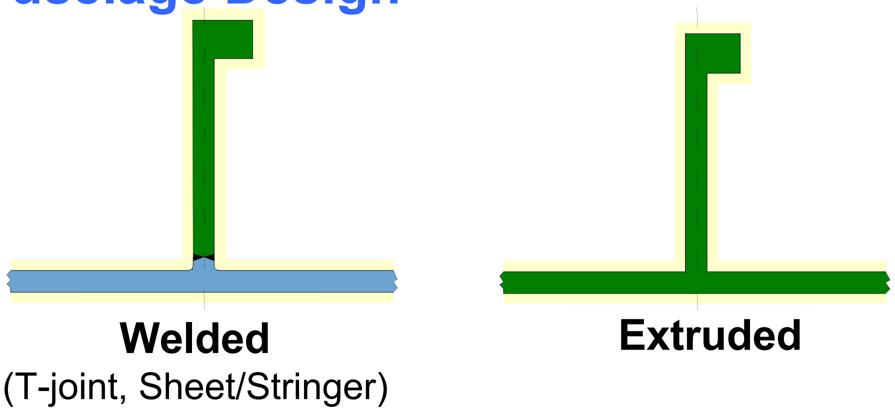
Differential Structures

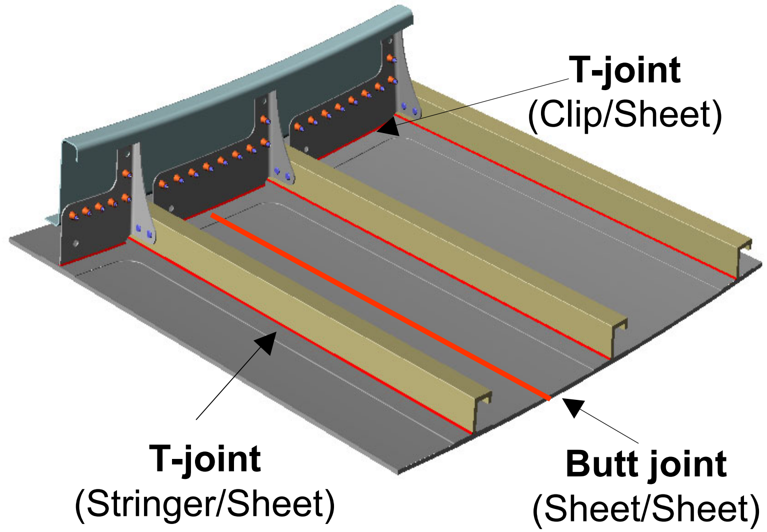




Tomorrow

Integral Fuselage Design





INTEGRAL STRUCTURES - Goals

Cost reduction max. 15 %

- High grade of automation
- Reduced mass of material (joining elements, sealing)
- Saving of manufacturing steps

Weight reduction max. 10 %

- Reduced mass of sealing
- More freedom for design
- Aluminium alloys with lower density

Corrosion-resistance improvement

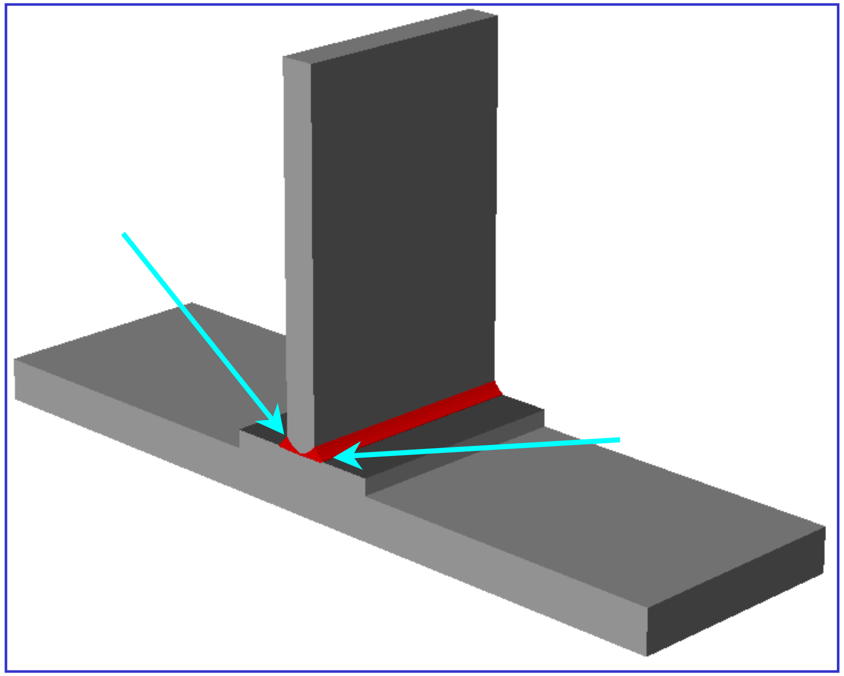
- Free of gaps and crevices
- No rivet holes

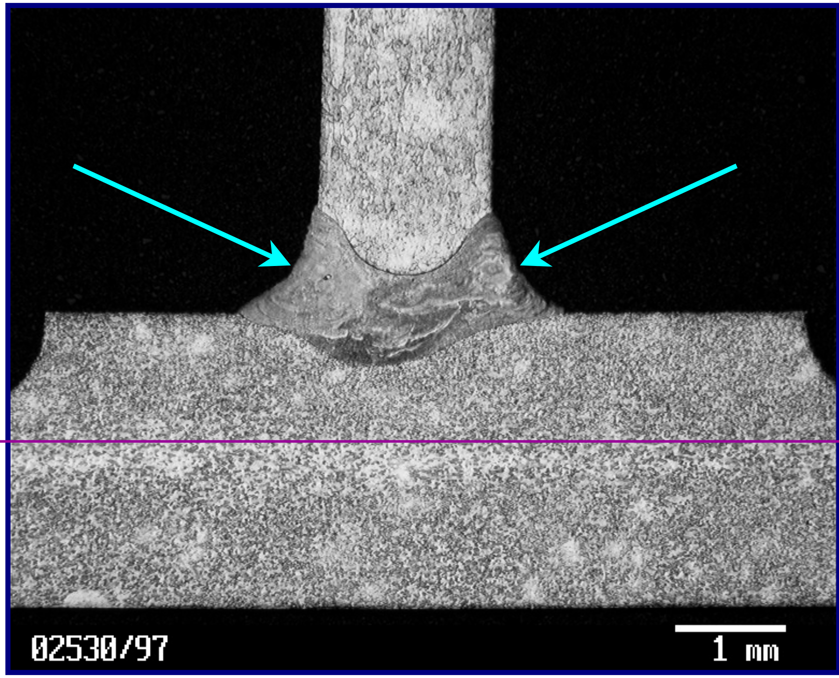
LASER BEAM WELDING (LBW)

Advantages

- Narrow welding seam
- Low energy input per seam length → reduced distortion, reduced heat
- affected zone
- Very high welding speed
-

LASER BEAM WELDING (LBW) – Cross-Section of T-joint





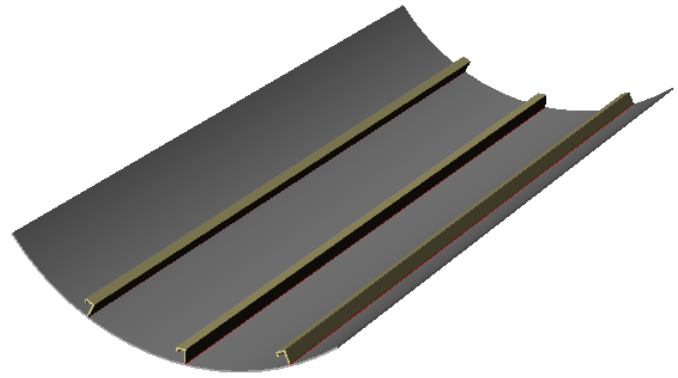
- Extruded stringer
- Chemically milled sheet
- Simultaneous welding from both sides

- Skin itself is not influenced by the laser beam welding process (HAZ)

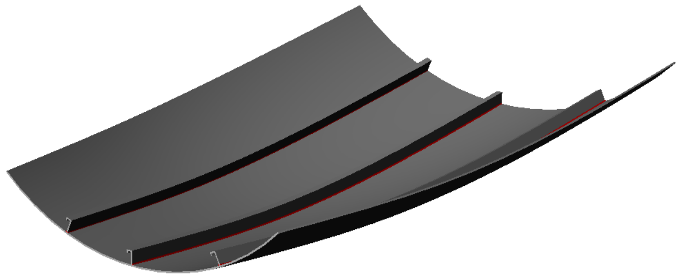
LBW Pilot Equipment

LBW

Nov. 2000
1st A318 spherical panel of series production



Cylindrical panel

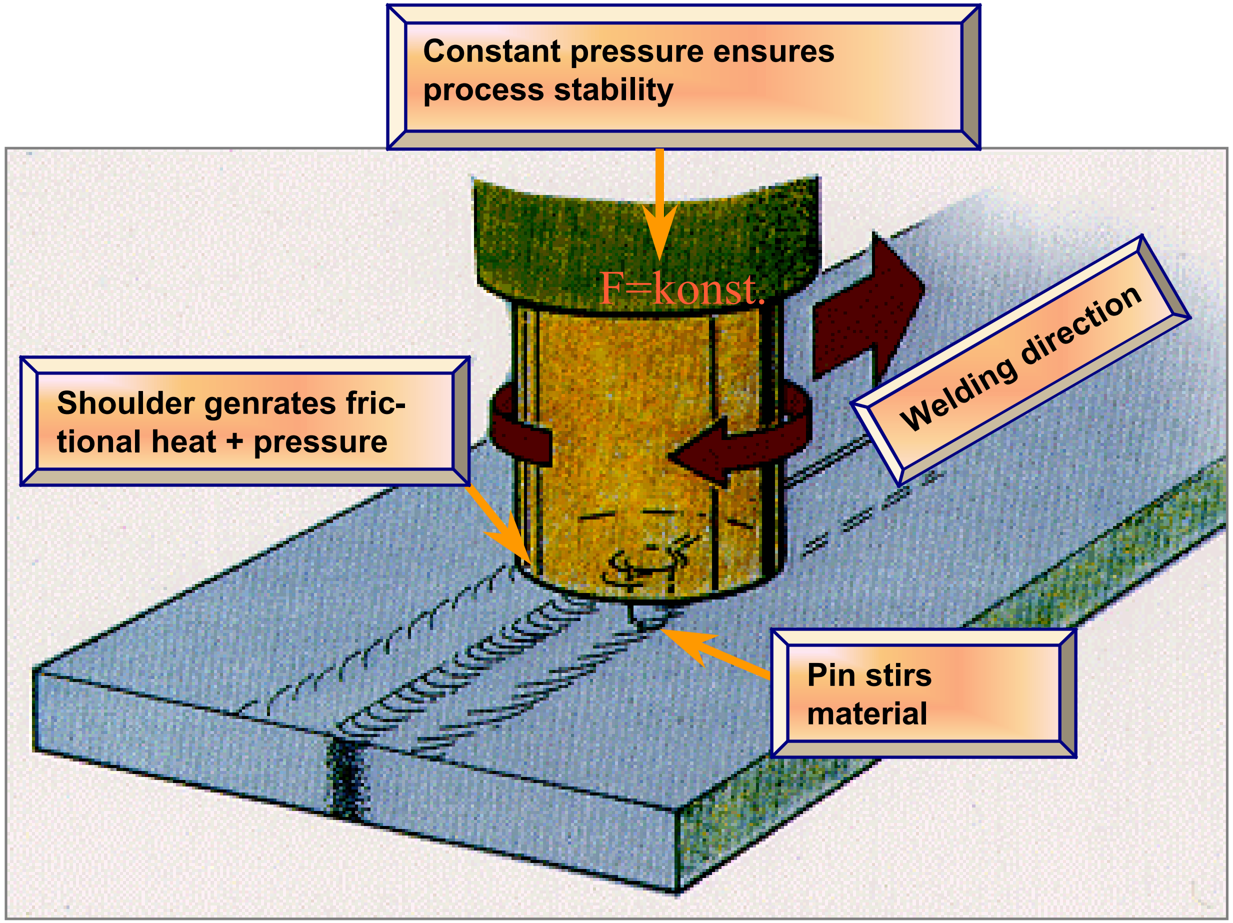


Spherical panel

FRICTION STIR WELDING (FSW) CONCEPT

<u>Solid state joining process:</u>

Material is heated by frictional heat and stirred by the rotating pin into a uniform joint



FSW

Process:

T = 400 – 500 °C, v = 0.2 to 1 m/min
Thickness = 0.5 –50 mm (from both sides up to 100 mm)

Material:

All Al–Alloys weldable, i.e. also the not fusion weldable
Combination of different alloys

Advantages:

No filler metal, no hot cracks, no pores, no shielding gas
Fine recrystallised microstructure, minimum distorsion
High static and dynamic properties (e.g. joint strength 80 –100% of R_m of base material)

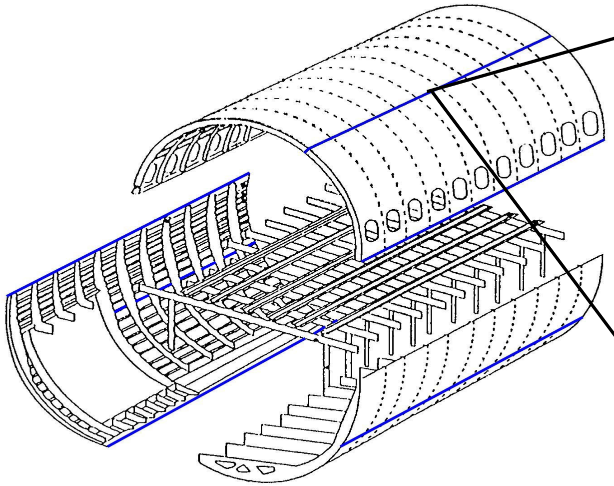
Disadvantages:

Special clamping system necessary
Only for simple joint geometries (especially butt joints)
License required from TWI (The Welding Institute, GB, Patents 1991)

Applications today:

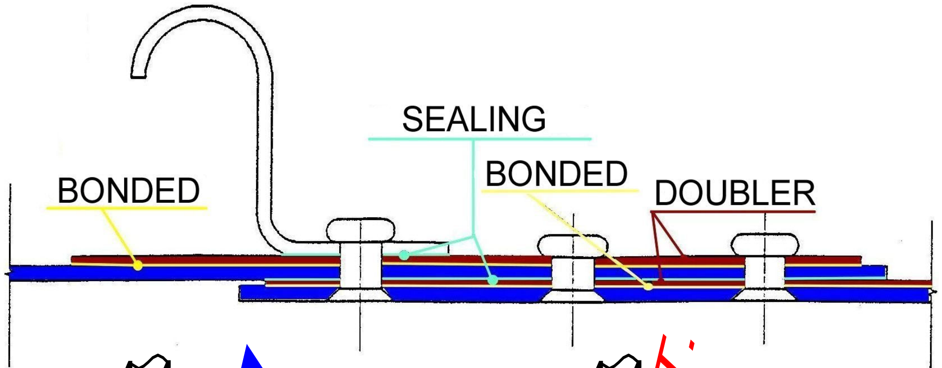
Ship, High Speed Train, Rockets

Longitudinal FSW butt joint



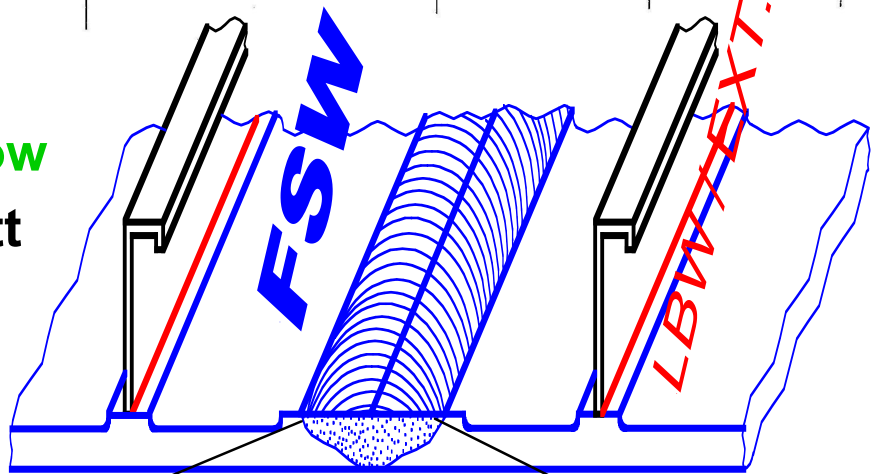
Today

Riveted lap joint

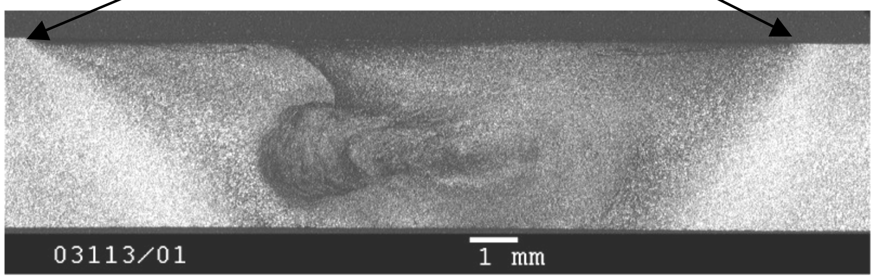


Tomorrow

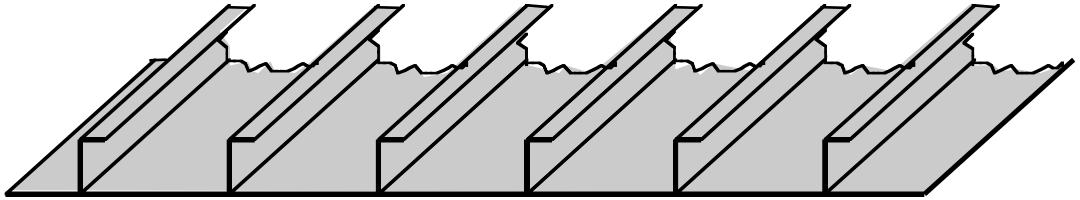
FSW butt joint



Microsection



EXTRUDED PANELS



Goals:

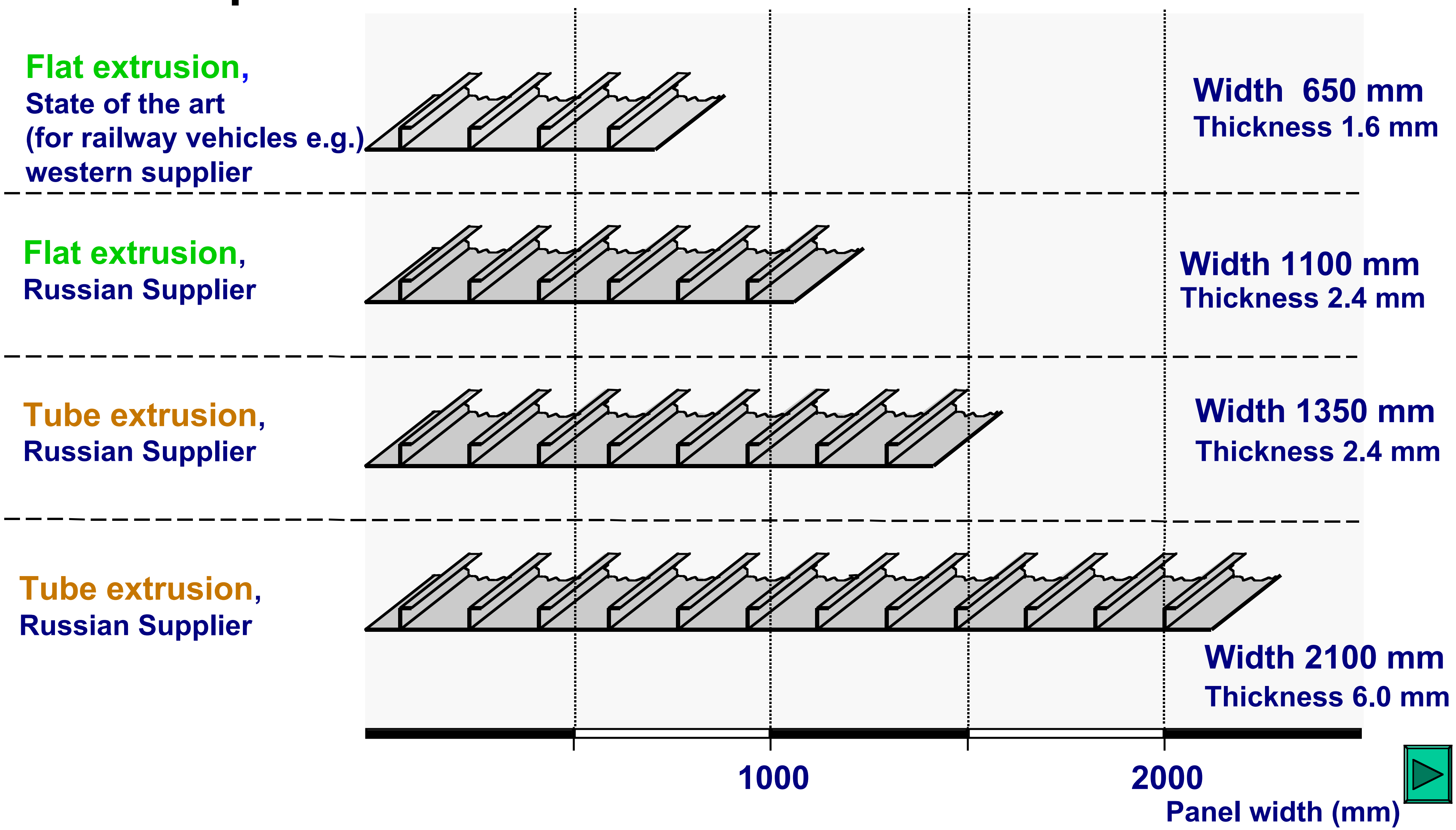
- Maximum panel width (> 1500 mm)
- Thickness 1.6 mm – 6.0 mm
- Tight tolerances
- High surface quality
- Properties like the 2024 standard skin sheet alloy

Material:

- AlMgSiCu (AA 6013)

EXTRUDED PANELS

Maximum panel width

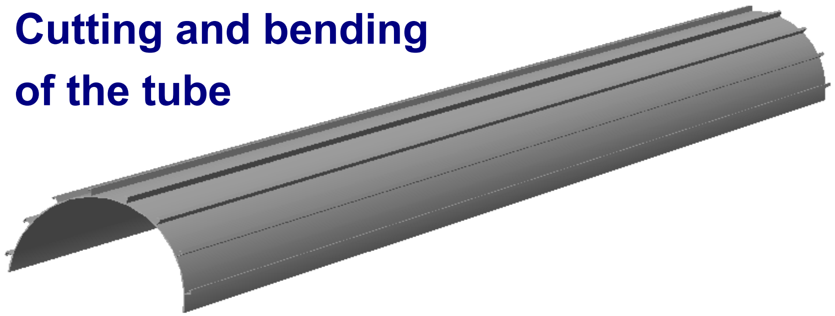


EXTRUDED 6013 PANELS

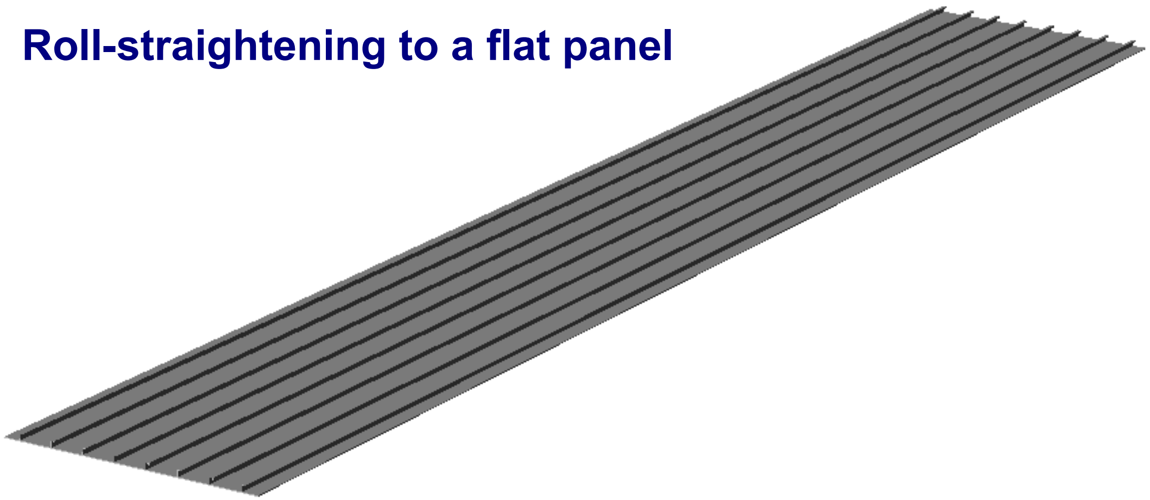
Process for maximising the panel width

Extruding as a tube

Cutting and bending of the tube

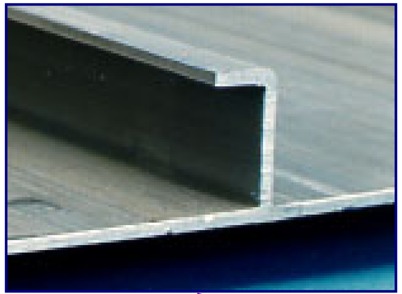


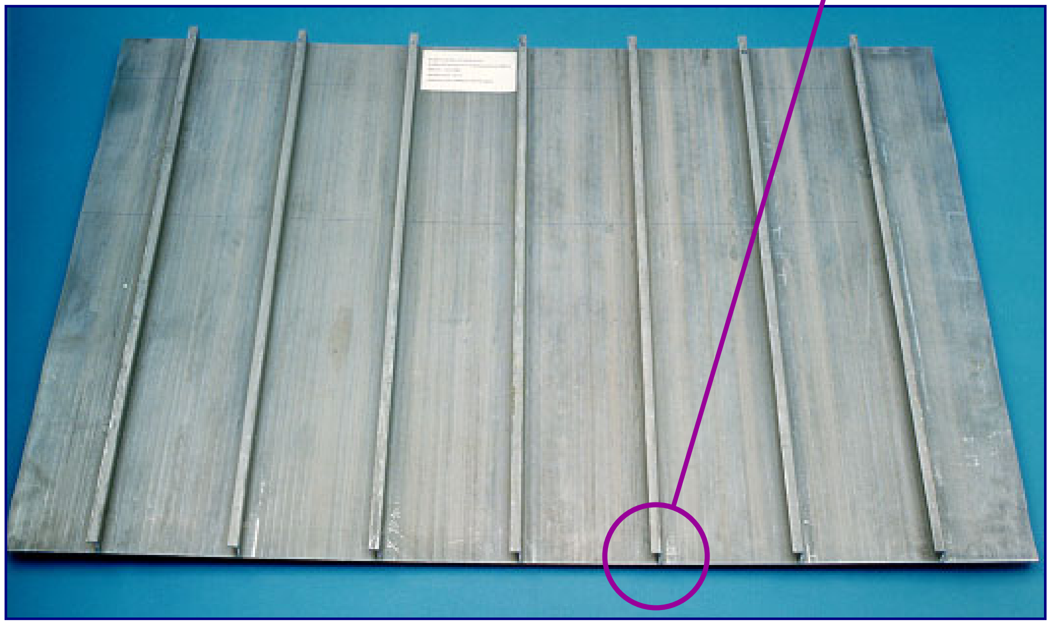
Roll-straightening to a flat panel



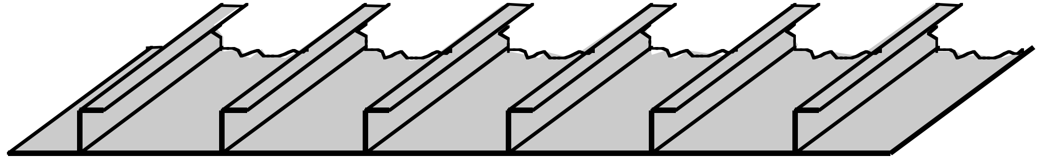
EXTRUDED TUBE

Alloy:	**6013**
Dimensions:	**Ø 300 mm x 1.6 mm** ⇒ 650 mm panel width
Producer:	**VILS (Moscow)**





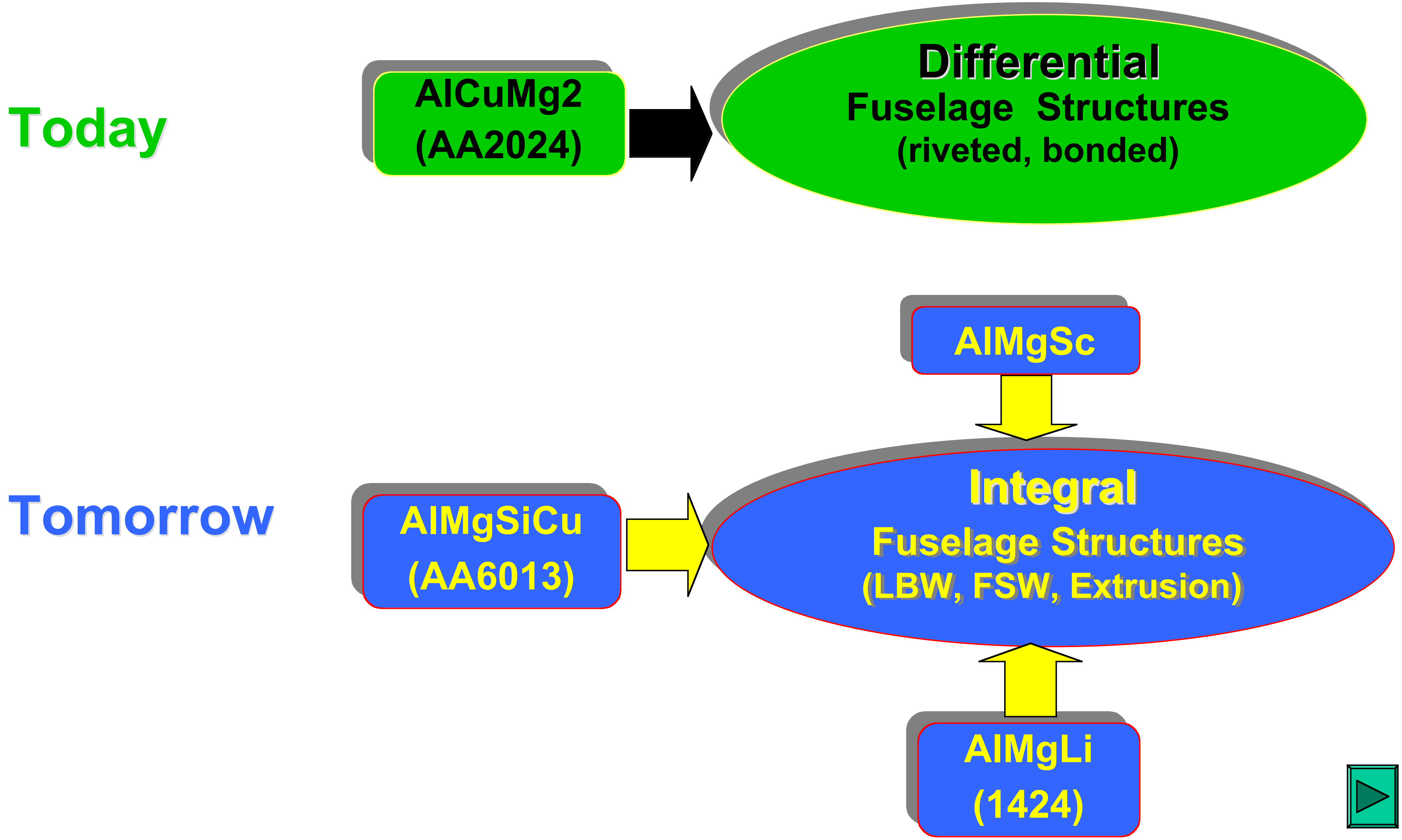
EXTRUDED PANELS



Conclusion

- **Insufficient panel width can be efficiently increased by joining several panels with FSW**
- **Insufficient surface quality**
- **Property requirements are fulfilled**

NEW ALUMINIUM ALLOYS



Chemical Composition of the New Sheet Alloys

Alloy	No.	Si	Cu	Mn	Mg	Li	Sc	Zr	Zn
AlMgSiCu	AA6013	**0.6 1.0**	**0.6 1.1**	0.2 0.8	**0.8 1.2**	-	-	-	-
AlMgSc		0.15	-	0.4 1.0	**4.0 4.5**	-	**0.1 0.3**	0.03 0.2	-
AlMgLi	1424	0.08	-	-	**5,0 5,6**	**1.5 1.75**	0.01 0.06	0.05 0.3	0.4 0.7
AlCuMg2	AA2024	0.5	**3.8 4.9**	0.3 0.9	**1.2 1.8**	-	-	-	-

AlMgSiCu (AA6013 T6) Sheets

- **Age hardening alloy** ⇒ **T6** (artificially peak aged)

♣**Development of LBW Technology**

♣**First civil aircraft application in LBW fuselage panel of A318**

6013 T6 vs 2024 T3

↑ **Weldable**

↑ **Increased Yield Strength** (+25%)

↑ **Reduced Fatigue Crack Growth Rate** (-50% at ΔK=25 MPa√m)

↑ **Higher Toughness** (+23%)

↑ **3% Lower Density**

AlMgSc HX Sheets

- **Work hardening alloy ⇒HX** (strain hardened + partially annealed)

♣**High microstructure stability due to coherent stable Al_3SC-phases causing an additional slight strength increase**

AlMgSc HX vs 2024 T3

↑ **Excellent Corrosion Resistance**

↑ **Excellent Weldability** (No Hot Crack Sensitivity, High Joint Strength)

↑ **Reduced Fatigue Crack Growth Rate** (-20% at $\Delta K=25\ MPa\sqrt{m}$)

↑ **5% Lower Density**

↓ **Reduced Tensile Strength** (-10%)

↓ **More Expensive**

Al-Mg-Sc

Processing Problems

- - Chemical milling → Surface attack
  (pitting → initiates fatigue cracks)

- - Stretch forming → Limited stretching rate
  → Luderlines (optical appearance)

Consequences

- - New chemical bath / Mechanical milling
- - New forming process → Creep forming

AlMgLi (1424 TX) Sheets

- Age + Work hardening alloy ⇒ TX (3 step artificially aged)

♣Development in cooperation with:
- EADS Airbus (Leadership)
- Institute VILS / VIAM (Moscow)
- Co. KUMZ (Russian)
- Co. Corus (Koblenz)

1424 Tx vs 2024 T3

↑ **10% Lower Density**

↑ **Excellent Weldability** (No Hot Crack Sensititvity, High Joint Strength)

↑ **Increased Tensile Strength** (+15%)

↑ **Reduced Fatigue Crack Growth Rate** (-70% at $\Delta K=25\ MPa\sqrt{m}$)

↓ **More Expensive**

Al-Mg-Li

Non-Permissible Critical Properties

- - Insufficient thermal stability > 3000h at 85°C,
- especially drop in fracture toughness
-
- - Accelerated fatigue crack propagation in NaCl,
- especially at low frequencies

Consequences

- - Ongoing investigations with VIAM (Moscow)