Scalmalloy®
A unique high strength and corrosion insensitive AlMgScZr material concept

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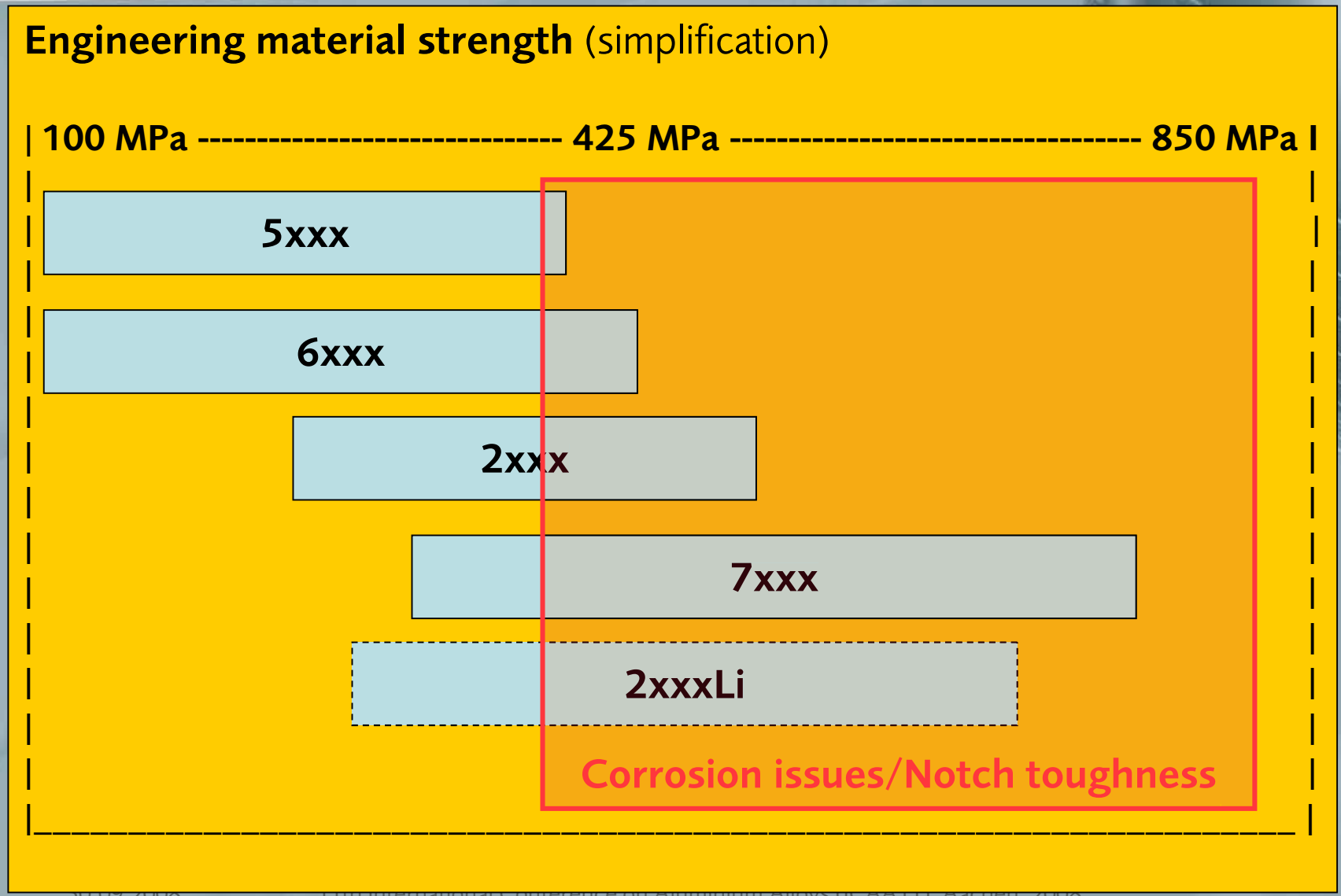
ALU-Menziken, ALERIS, ALCOA, ALUnna, several colleagues & diploma thesis(students), public funded projects (WAFS, WEL-AIR, DATON, ENWERUM, ScaLA)

Technical Driver in Aircraft Engineering

Corrosion ⇔ Durability

Sources:
www.hsc.csu.edu.au
www.cctechnologies.com
hawaiicorrosionlab.org

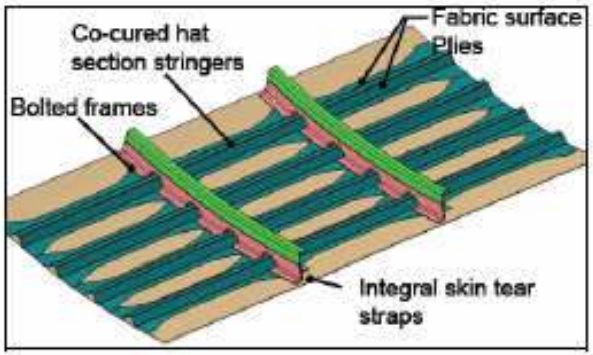
Technical Driver in Aircraft Engineering



Technical Driver in Aircraft Engineering
New Competition

Perception of CFRP:

- **If you have a weight issue ➔ CFRP is the solution**
- **Corrosion ➔ CFRP is the solution**
- **"Old" fashion ➔ CFRP is "hip"**
- **Nano technology ➔ CFRP is "nano" capable……**

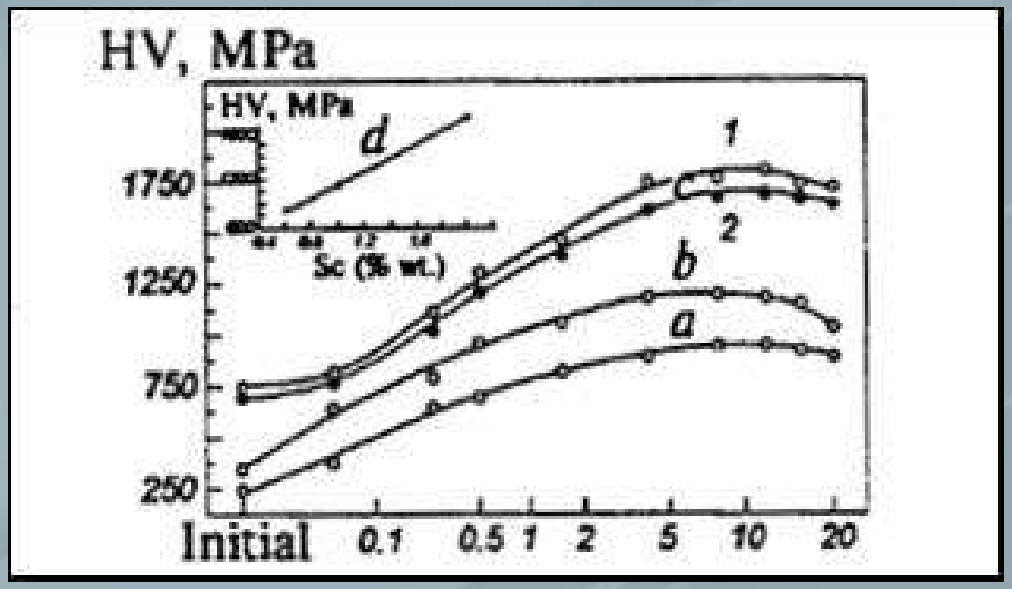



Stringer


Frame


Shear Tie

Higher Strength in AlMgSc-Alloys



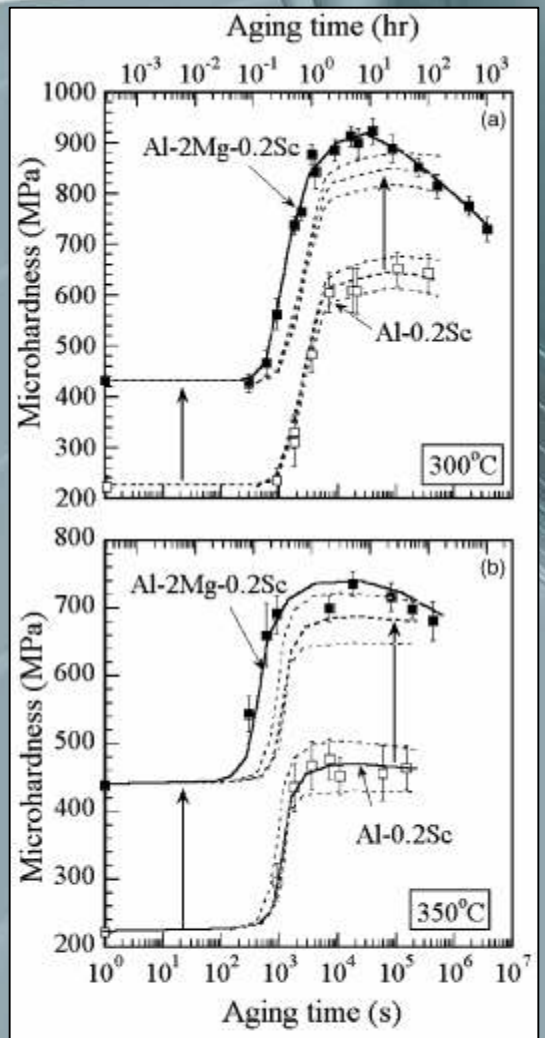


Fig. 4. Vickers microhardness as a function of aging time for Al–0.2 wt% Sc (open squares, from Ref. [2]) and Al–2 wt% Mg–0.2 wt% Sc (solid squares) at (a) 300 °C and (b) 350 °C. The dashed lines correspond to the curves for the Al–0.2 wt% Sc alloy translated upward by 220 MPa.

Higher Strength in AlMgSc-Alloys

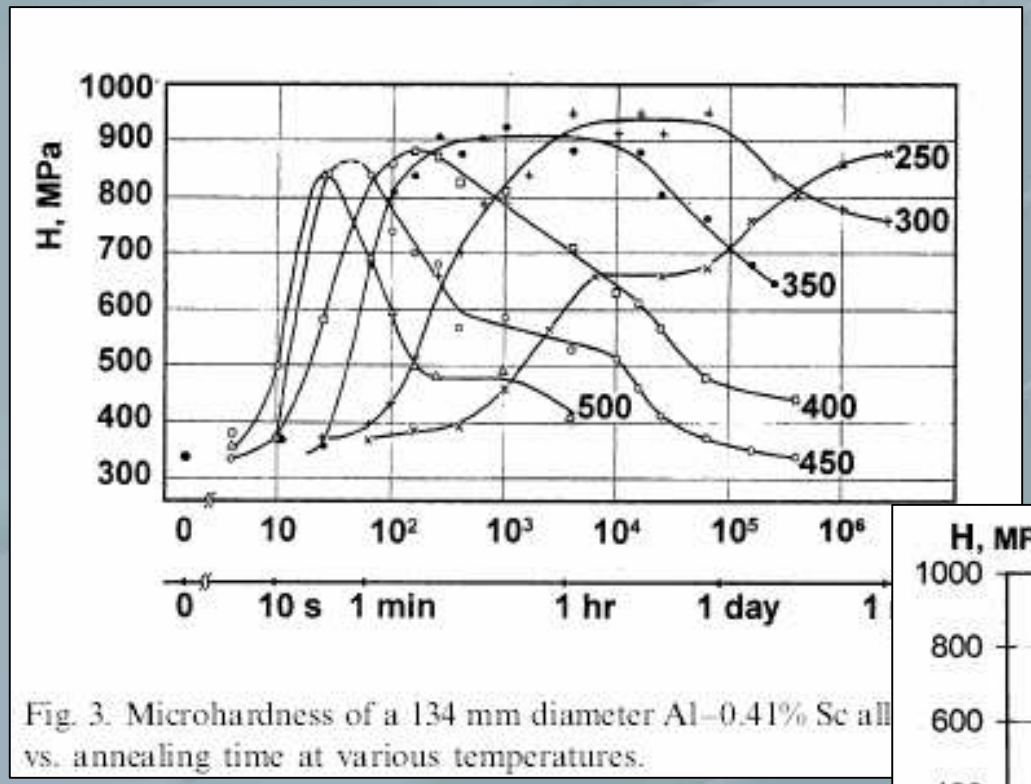


Fig. 3. Microhardness of a 134 mm diameter Al–0.41% Sc all
vs. annealing time at various temperatures.

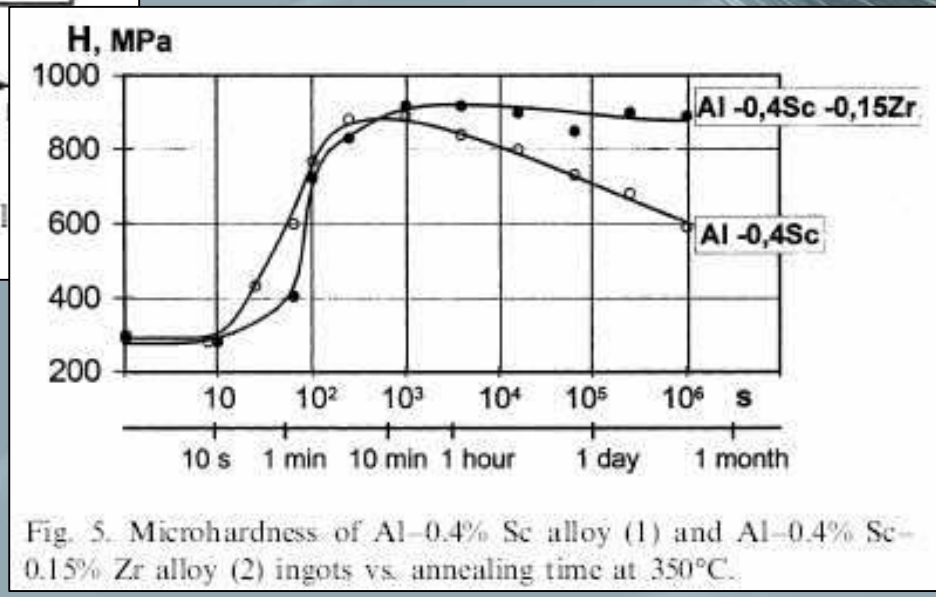
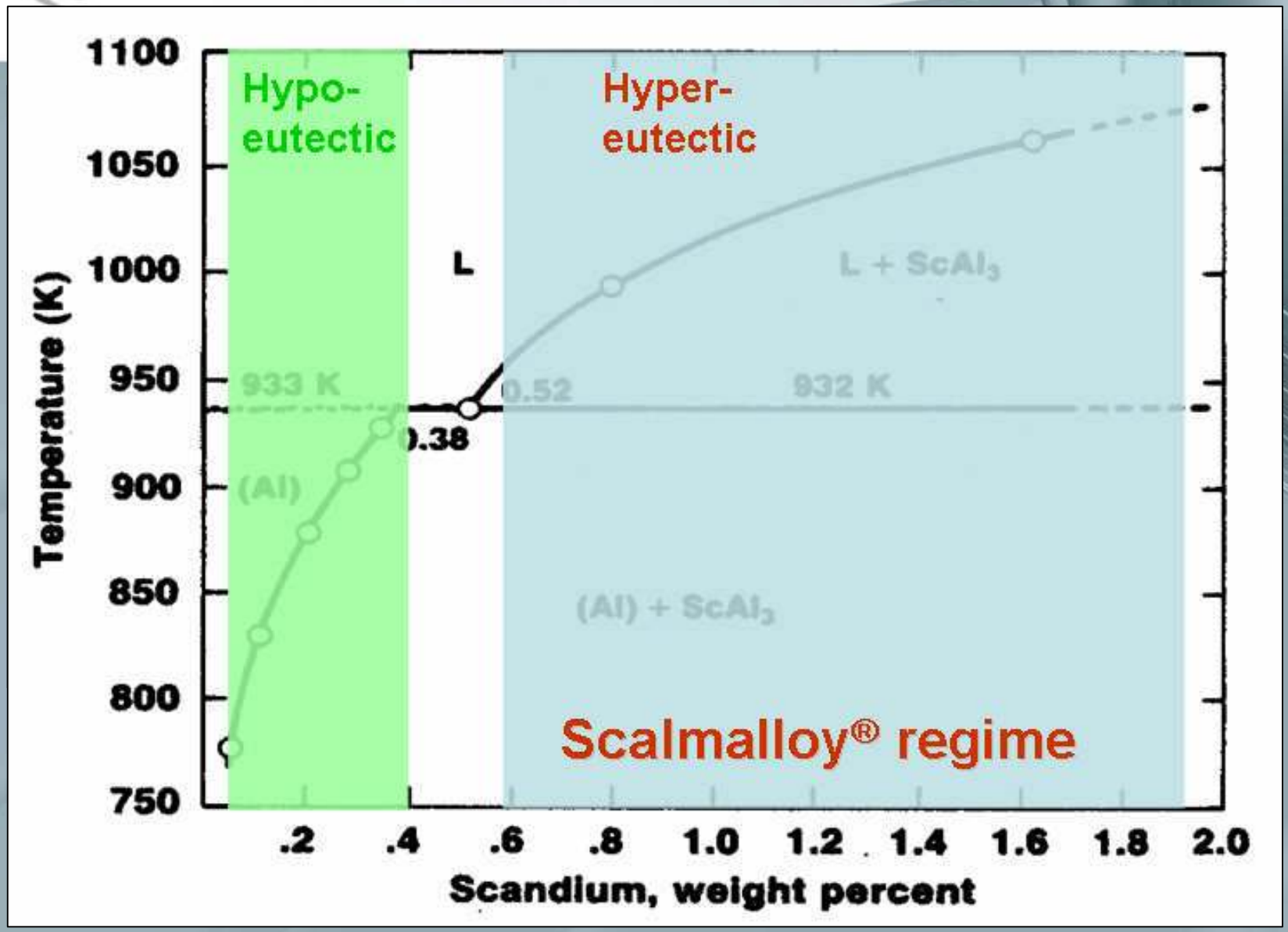


Fig. 5. Microhardness of Al–0.4% Sc alloy (1) and Al–0.4% Sc–0.15% Zr alloy (2) ingots vs. annealing time at 350°C.

Higher Strength in AlMgSc-Alloys



Scalmalloy® - Portfolio

Hypereutectic AlMgScZrMn-Alloys (since 2003)

Mg-content: 1,80 – 4,30% (higher Mg-contents are possible)

Sc-content: 0,70 – 1,40%

Zr-content: 0,22 – 0,55%

Mn-content: 0,30 – 0,70%

➔ Sc / Zr ≈ 2 : 1

➔ Mg-content ≤ 3,30% (in order to maximize corrosion resistance)

➔ In the designation: *ScalmalloyX®* ➔ X relates to the Sc-content

Scalmalloy® ⇔ Rapid solidification

Why melt-sinning ?:

- **Very high solidification rates**
- **Relatively stable process ➔ much higher usable "powder" output**
- **Handling – storage of powder (flakes) / risk of surface contamination**
- **Industrial up-scaling**

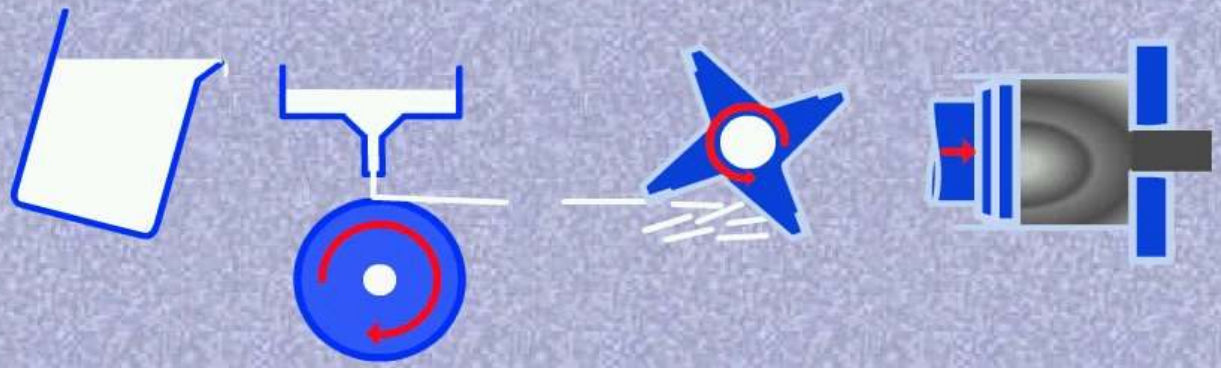
Scalmalloy® ⇔ Rapid solidification

Meltspinning

Rapid Solidification

The meltspinning process

During the meltspinning process, molten aluminium hits a fast rotating wheel and almost instantaneously releases a continuous metal ribbon at room temperature. This ribbon is converted into flakes and finally into an extrusion product, after which a special heat treatment may be applied. The name Rapid Solidification Process stems from the sudden temperature drop that takes place at a rate of more than 1,000,000 °C per second as the aluminium comes in contact with the wheel.



Melting+Alloying | Meltspinning | Chopping | Consolidation

Further processing by e.g. forging, machining and rolling.

Source RSP Technology

Scalmalloy® ⇔ Rapid solidification Video

Source RSP Technology

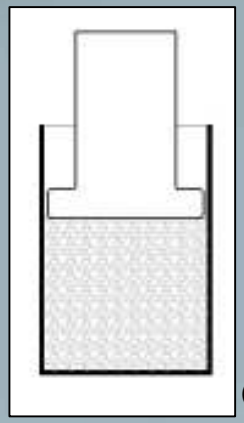
Scalmalloy®
From Melt ➔ Material (Profiles)

Scalmalloy0.7 (AlMg4,3Sc0,7Zr0,3Mn0,5)
Aging response (300°C/8h):
as melt spun 117 HV0.05
Aged: 157 HV0.05

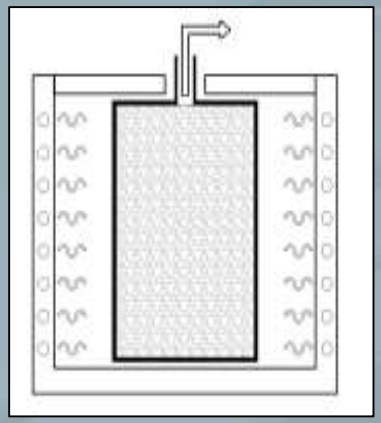
Scalmalloy1.25 (AlMg3,9Sc1,25Zr0,55Mn0,7)
Aging response (300°C/8h):
as melt spun 192 HV0.05
aged: 212 HV0.05

Scalmalloy0.7 – flakes: Oxide layer (ESCA) ≈ 25 nm, consisting of Al_2O_3 and MgO (Spinell) (after about 4 weeks of handling (transport & storage)

Scalmalloy® Manufacturing Chain



CIP



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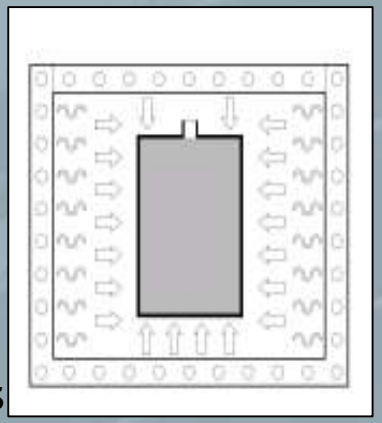
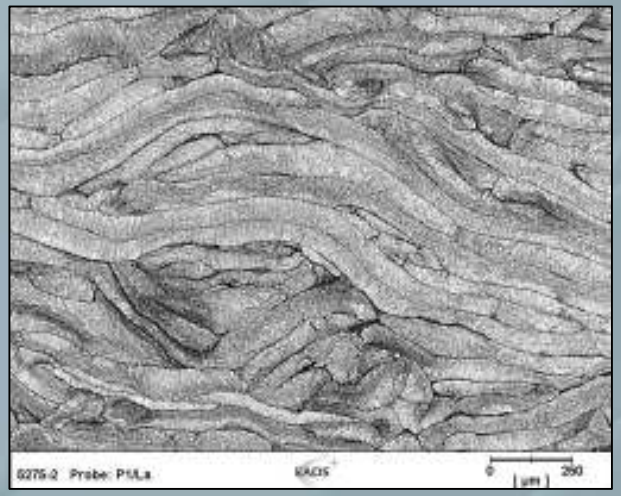
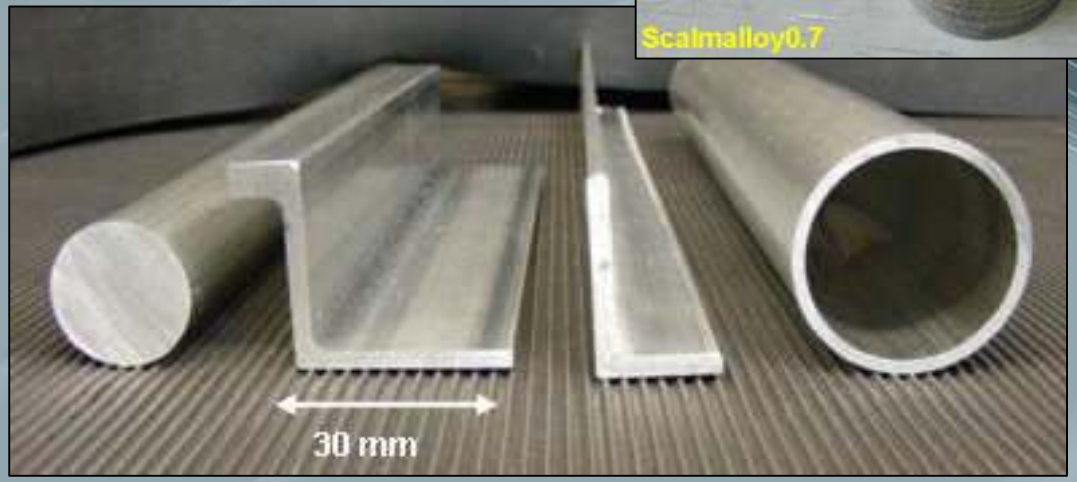


HIP



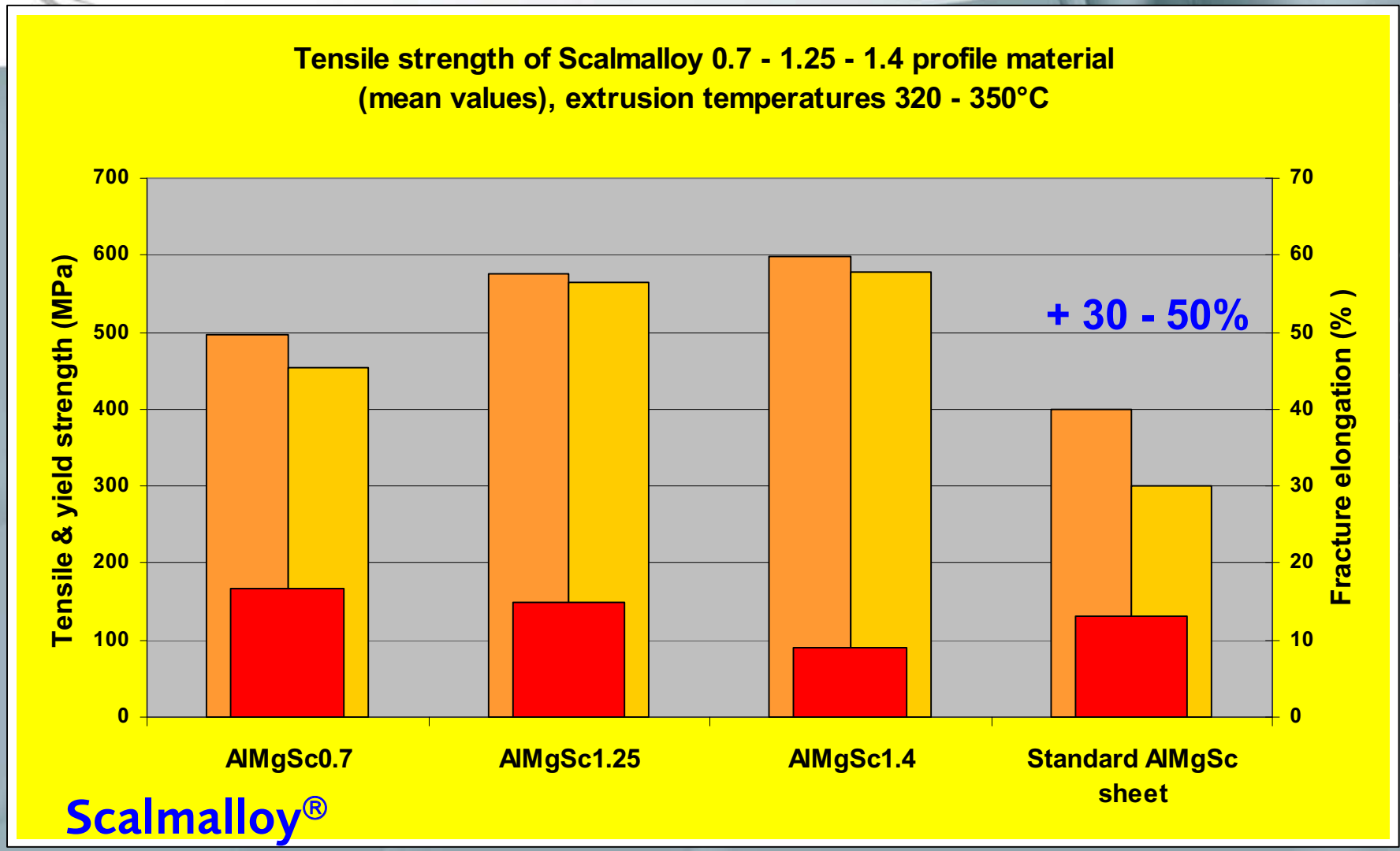


Extrusion ratio tested ≈ 8,0 - 36 : 1 (depending on geometry)

➔ Round bar (several extrusion temperatures 300 - 380°C)

➔ Aerospace profile bar extruded at 360 - 380°C

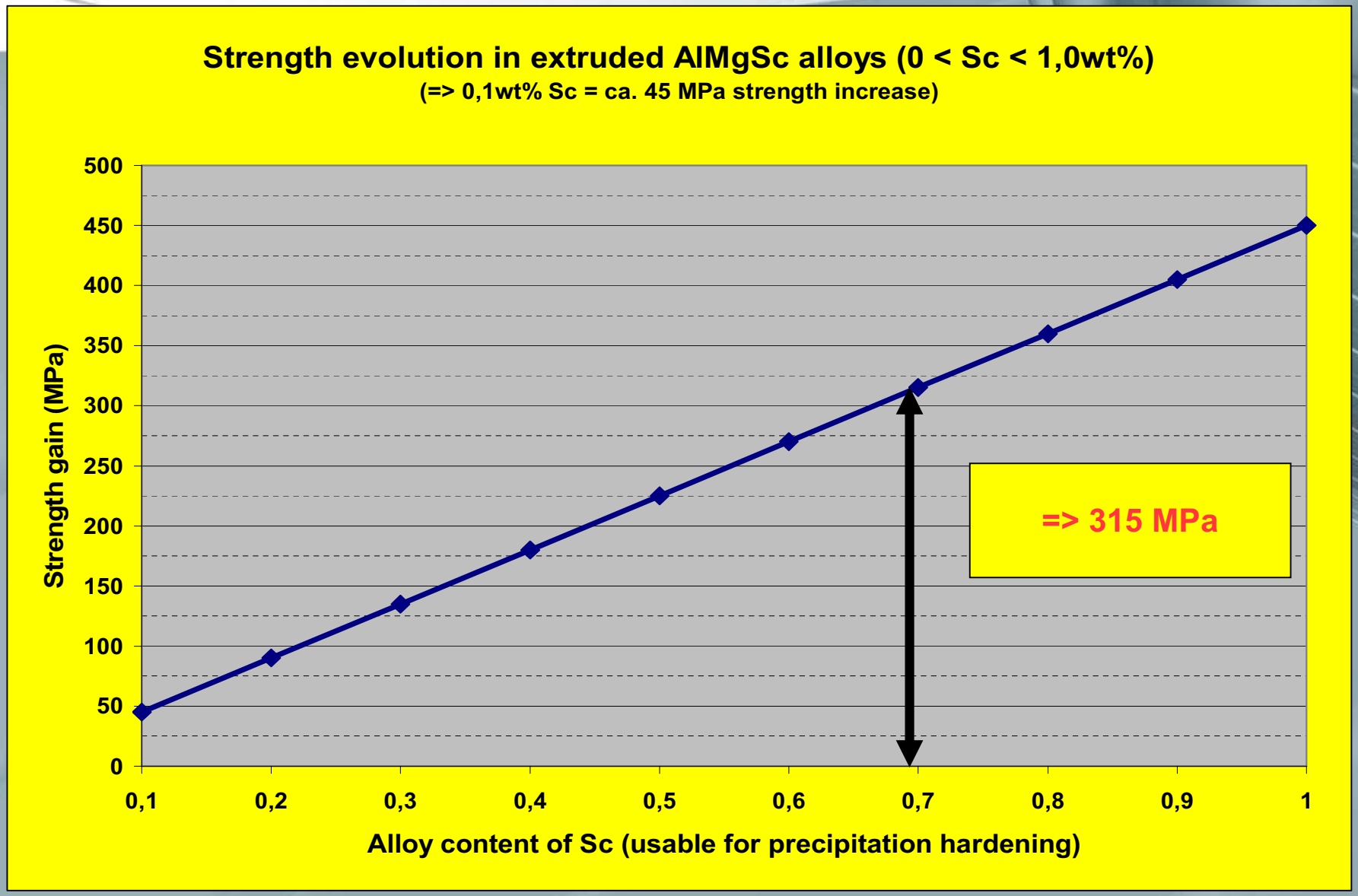
Scalmalloy® Strength Evolution



=> High strength & ductile material with exceptional high notch toughness => low density (ρ ≈ 2,65 g/cm³) => very good tensile length and notched fatigue

Scalmalloy® Yield Strength Estimation

AlMg4,3Sc0,7Zr0,3Mn0,5



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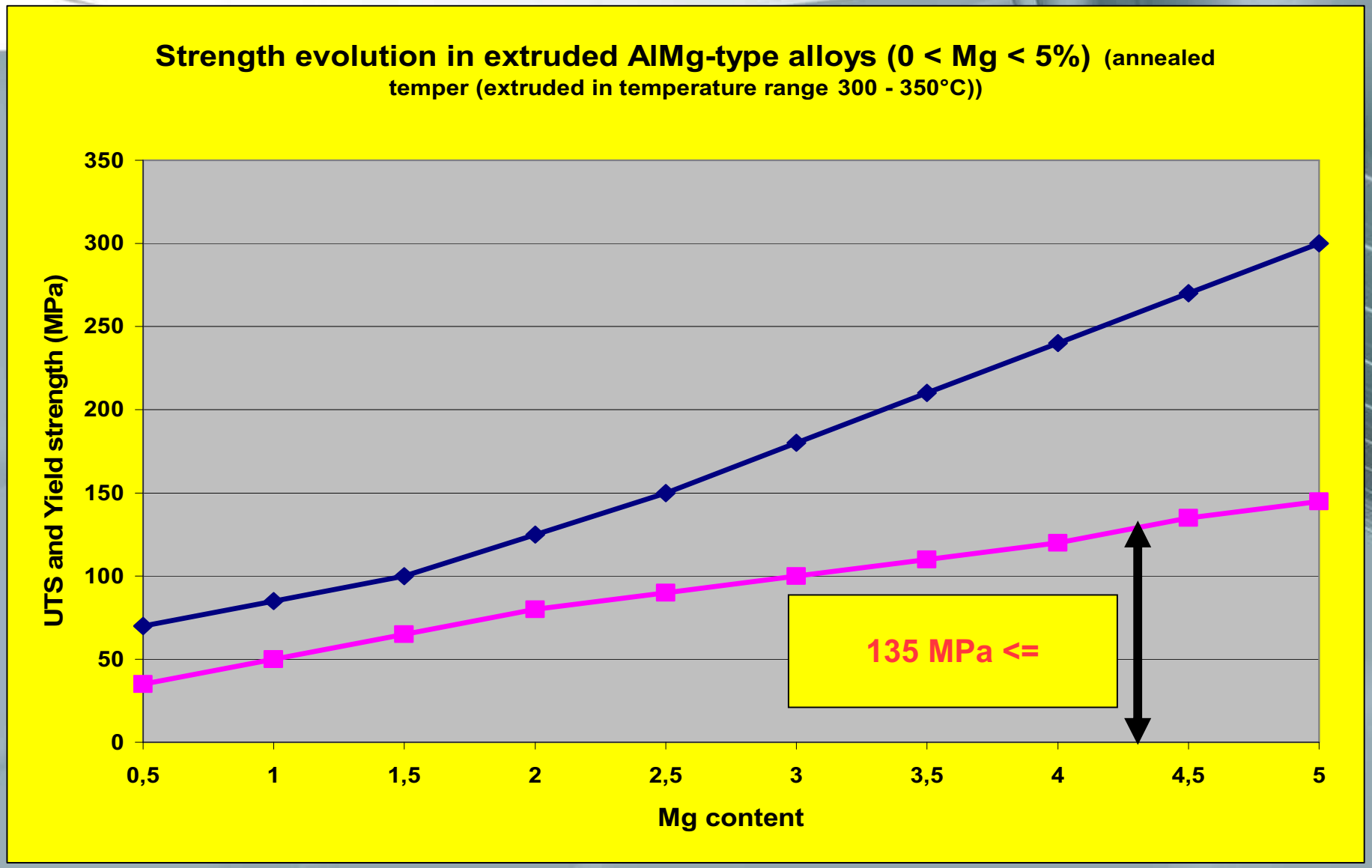

Scalmalloy® Yield Strength Estimation

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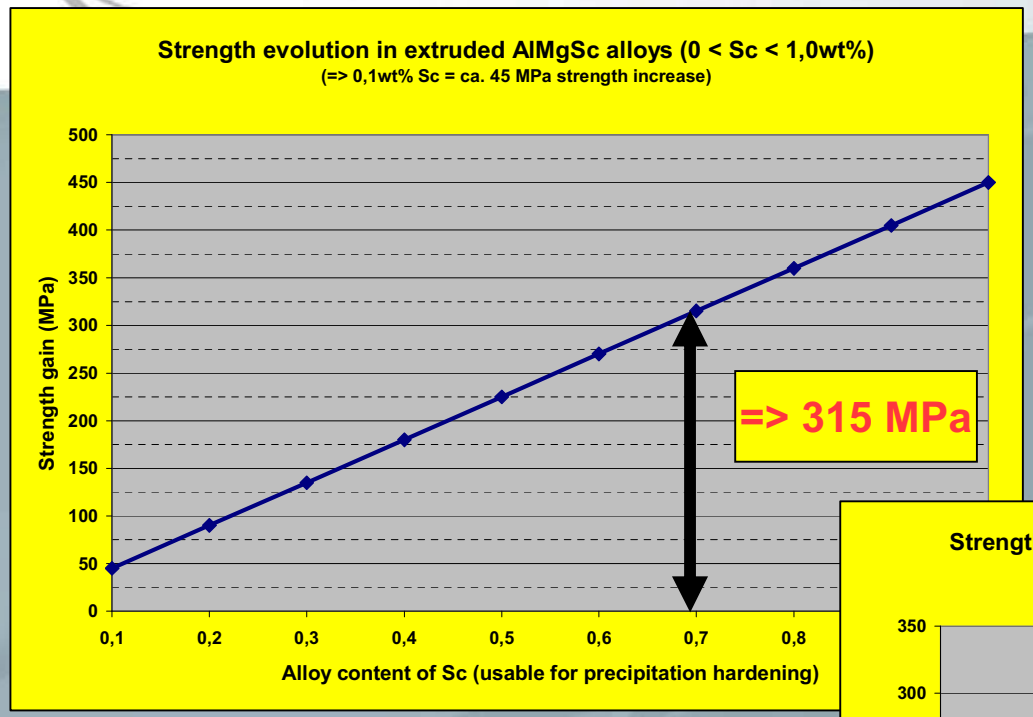
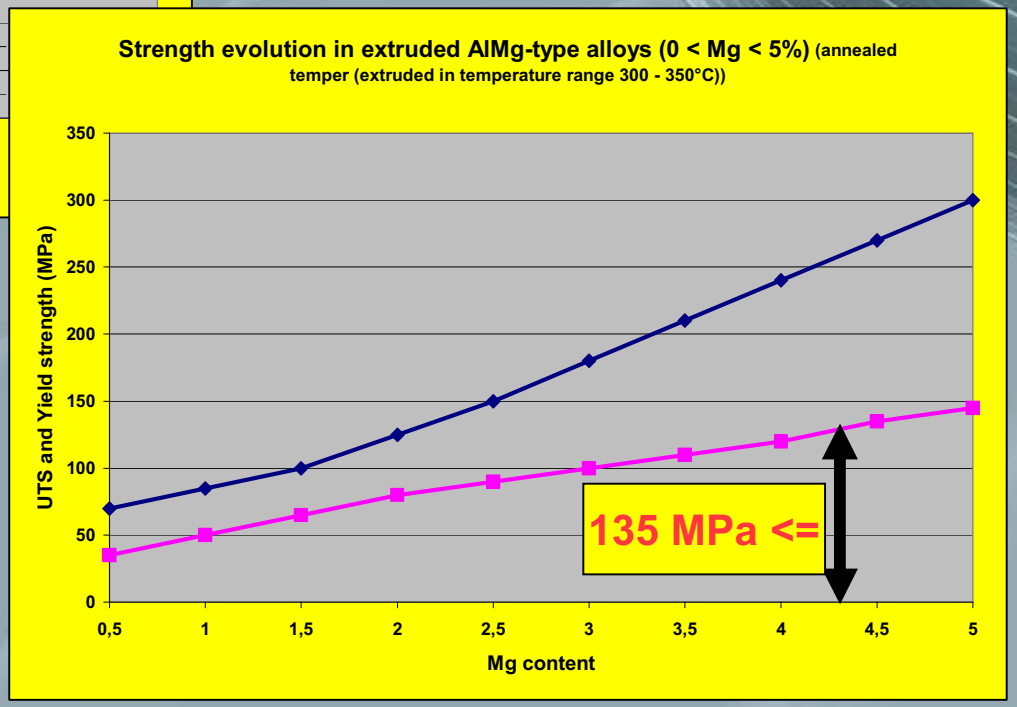




Strength capabilities of AlMg4,3Sc0,7Zr0,3Mn0,5:

UTS ≈ 500 MPa

YS ≈ 450 MPa

A > 15%

Easy UTS approximation via HB

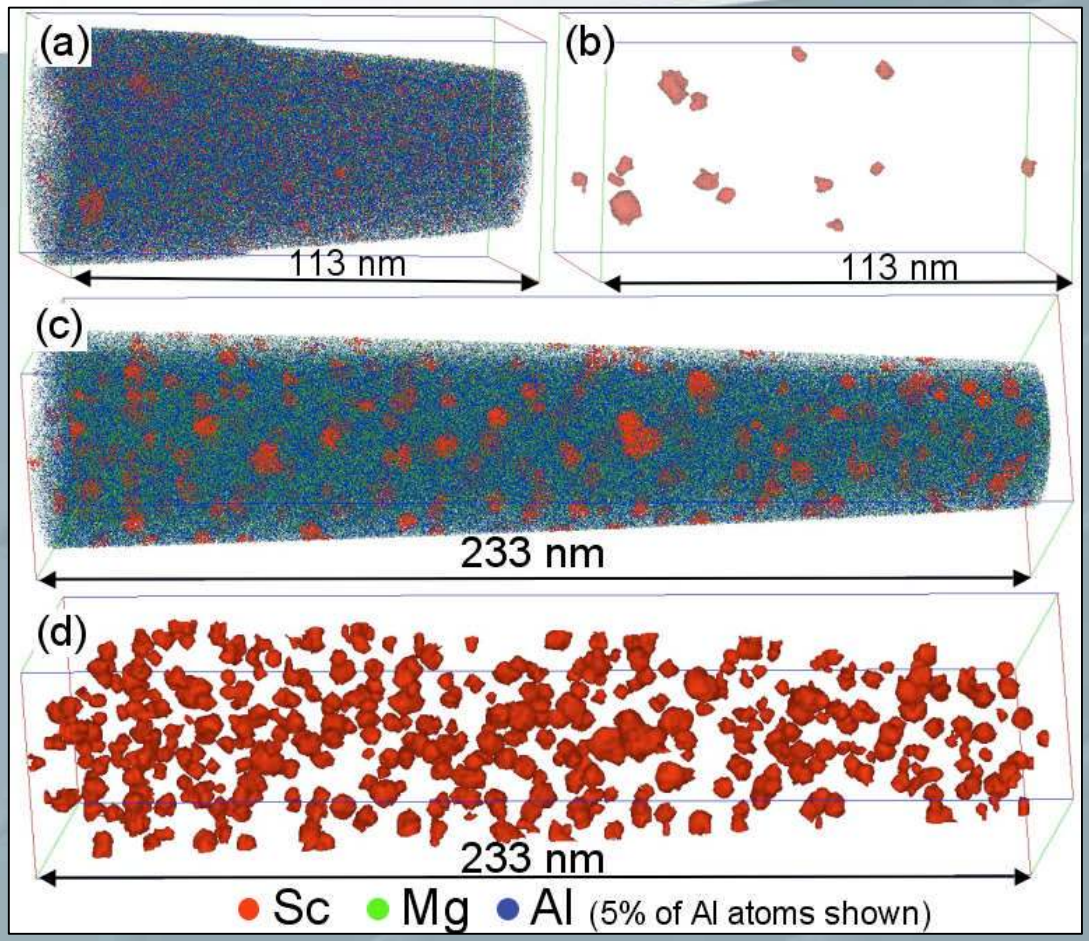
➔ **Factor ≈ 3,5 !**

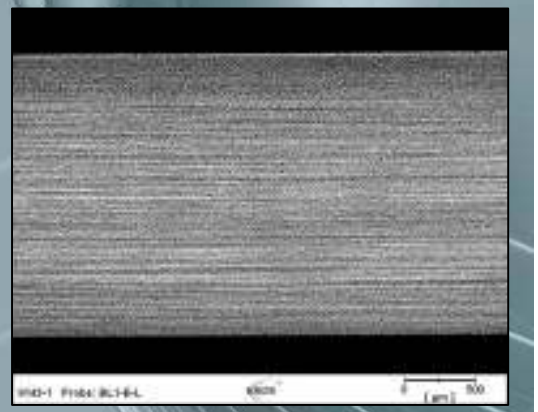
Scalmalloy® physical Strength Evolution

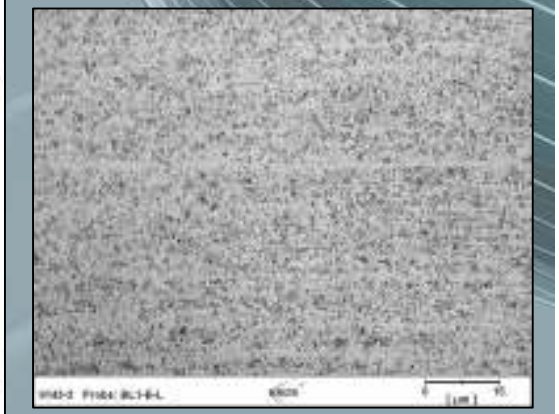
As cast

Aged at 300°C/8 h

Aged at 300°C/8 h





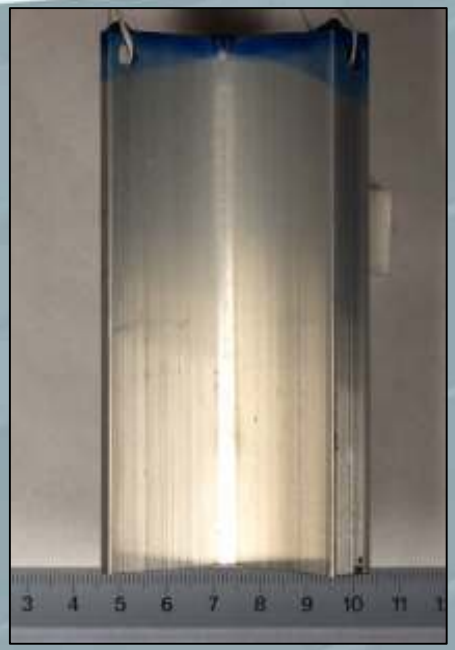


Scalmalloy®

➔ Unique combination of strength & notch toughness by ultra fine ("nano-sized" (2 – 4 nm)) micro structure of coherent Al_3Sc (and $Al_3Sc_xZr_{1-x}$) phases

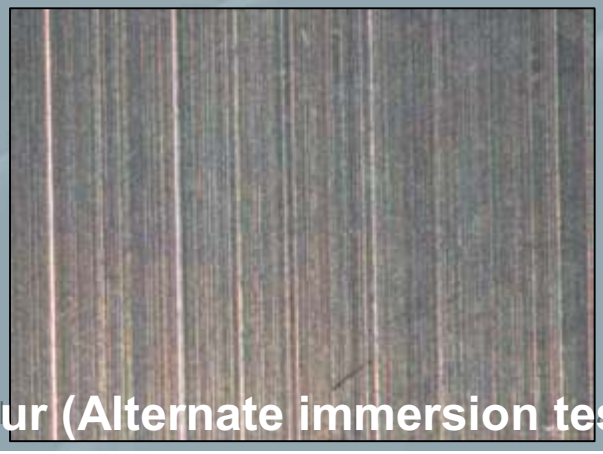
Scalmalloy® Corrosion Behaviour I

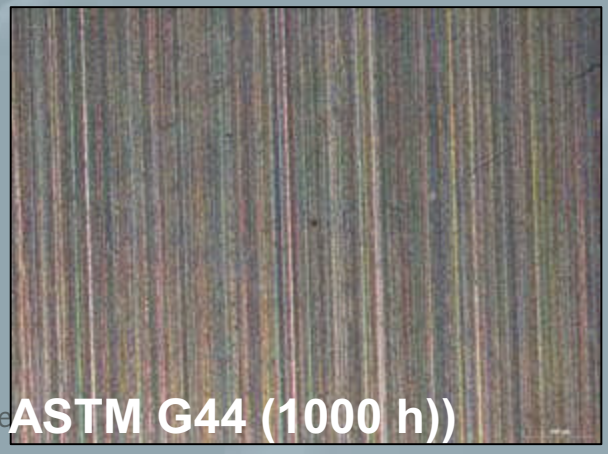
AA7349 T76



Scalmalloy0.7

Scalmalloy1.25



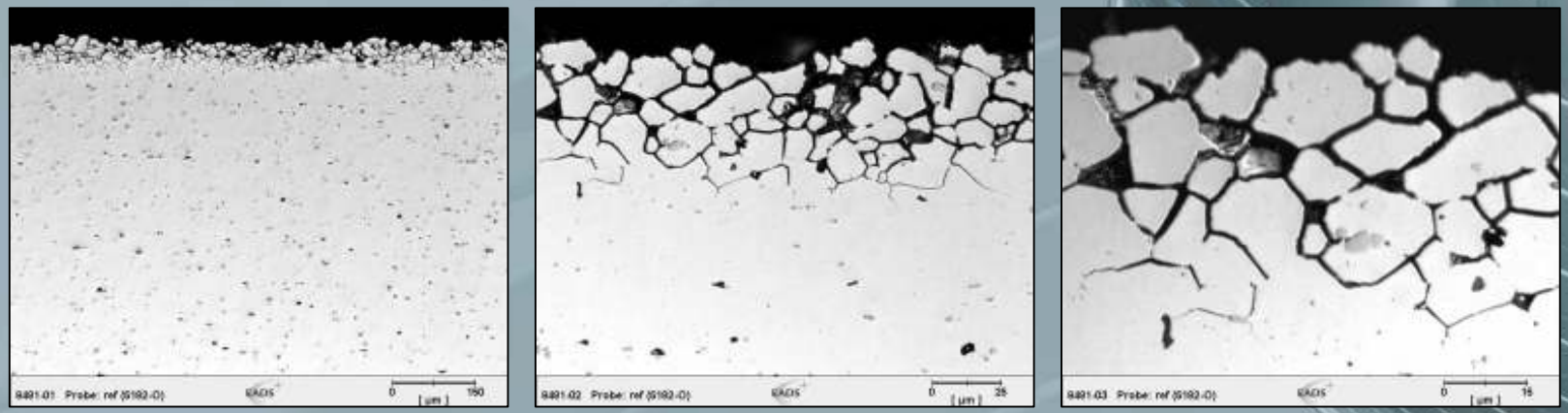


Corrosion behaviour (Alternate immersion test ASTM G44 (1000 h))

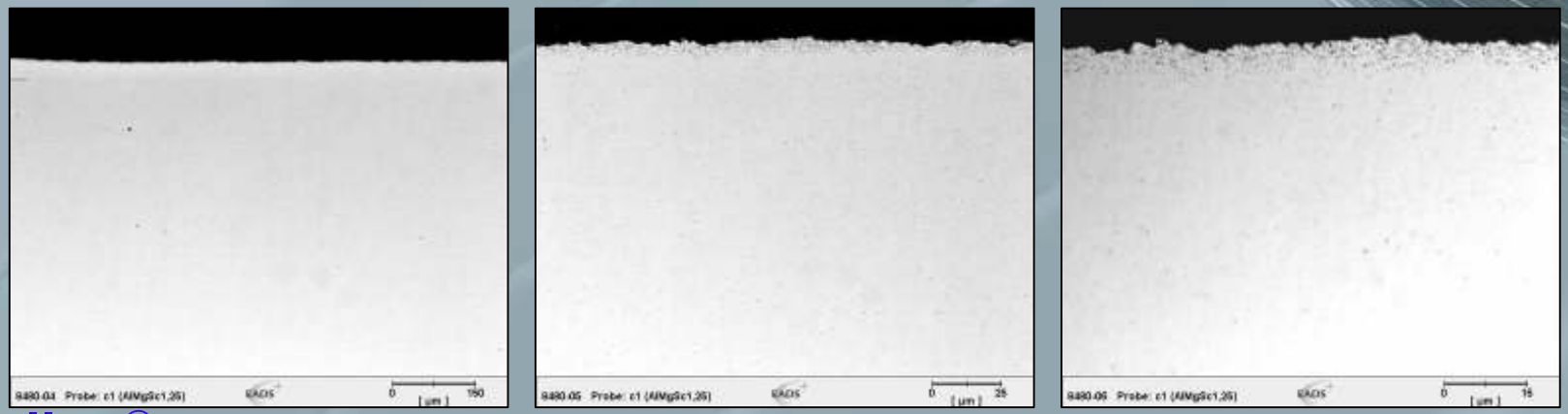
Scalmalloy® Corrosion Behaviour II

(IGC test ASTM G67 (sensitize 150°C/250 h)

AA5182

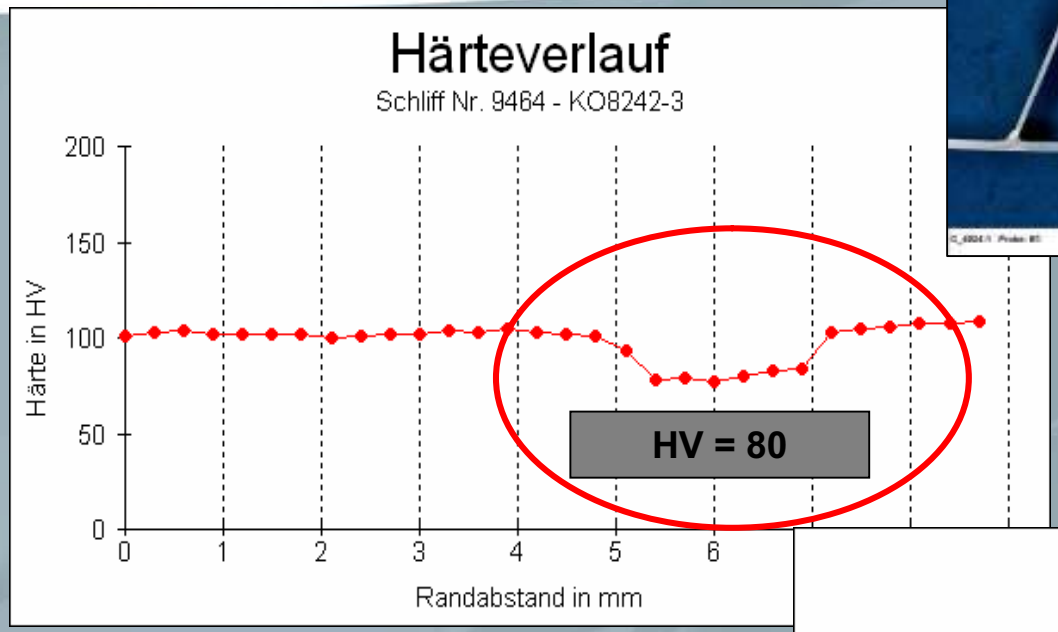


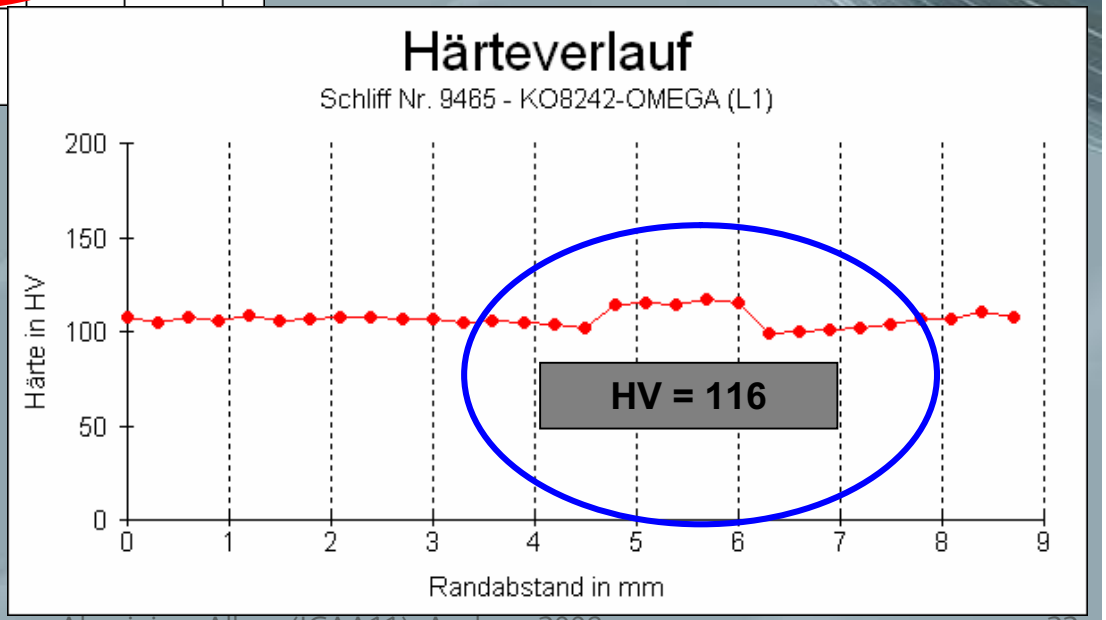
Scalm. 1.25



➔Scalmalloy® with adjusted Mg-content is obviously immune against IGC compared to established 5xxx alloys and allows applications with temporarily exposures between 75 – 250°C

Scalmalloy® Material Processing (i.e. Welding)

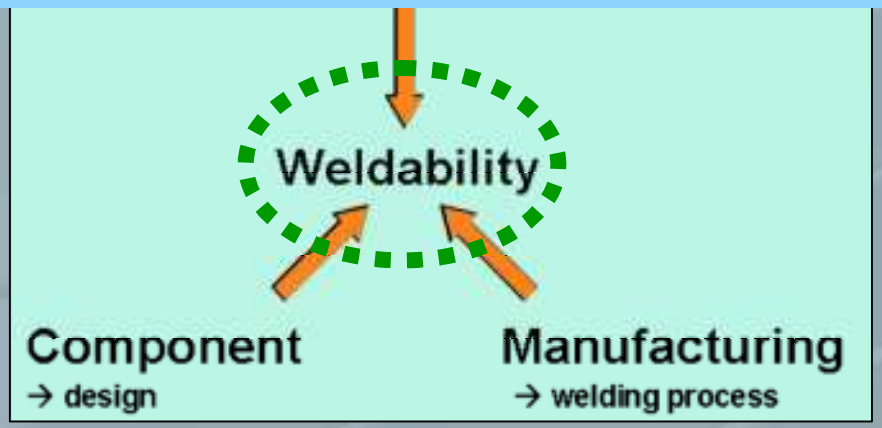




AlMgSc allows converting „under-matched“ weld zone into „over-matched“ weld zone by selected post weld heat treatments at 300 – 325°C (= stress relief and final shaping possibility) !!

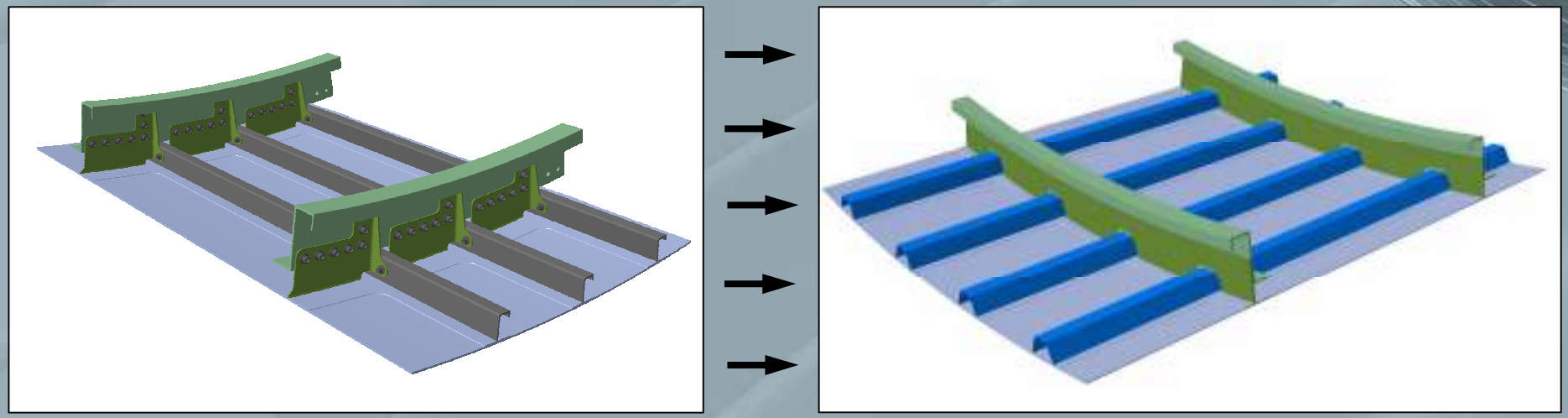
Scalmalloy® New Designs
➔ higher Performance

"Standard-AlMgSc" and Scalmalloy®



Exceptional high corrosion resistance

Special Sc related metallurgy



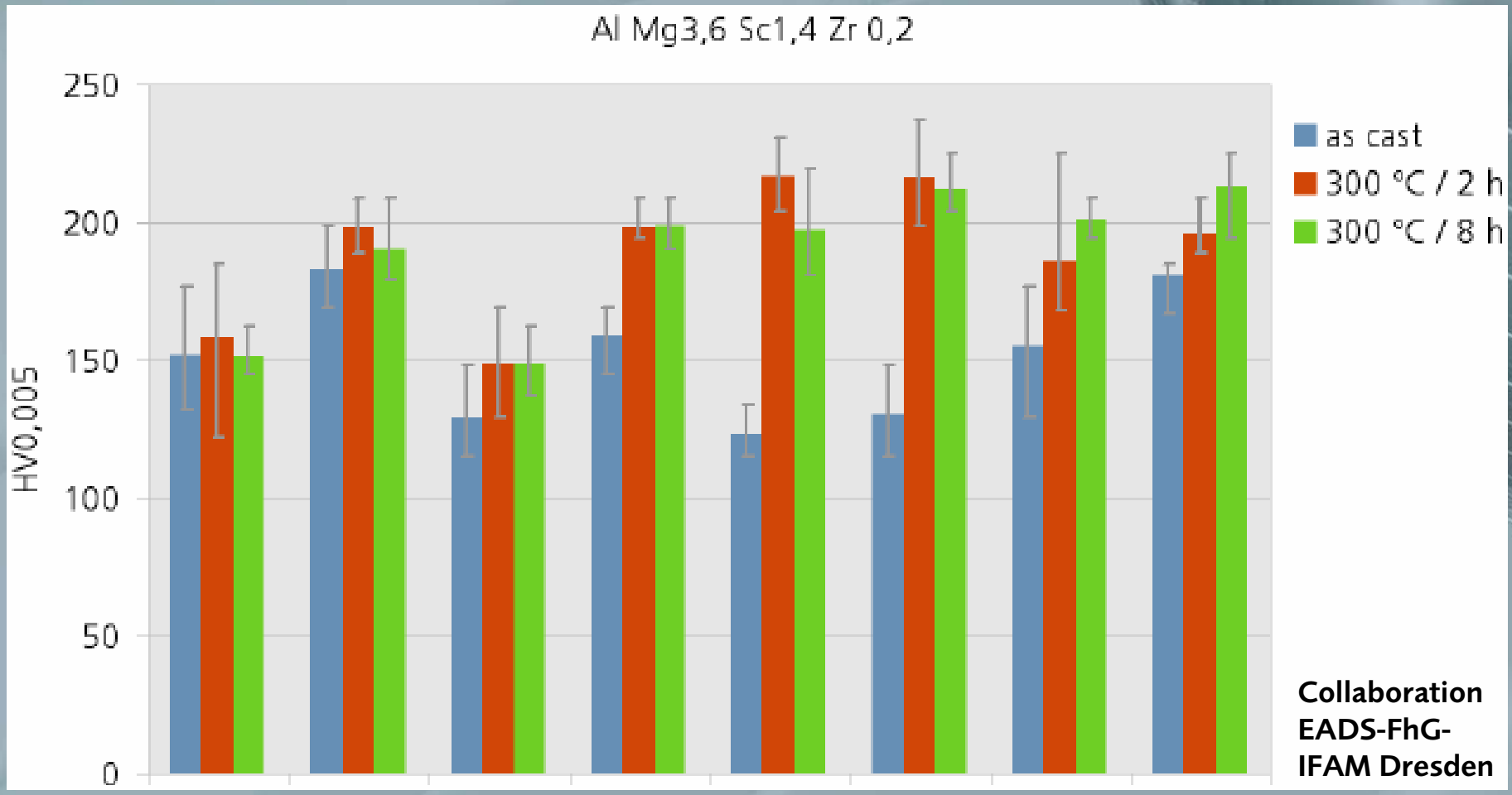
➔New („old") high performance designs with 10-20% weight reduction capacity

Scalmalloy® Challenges ⇔ Limits

Next targets:

1. **Improvements of the melt-spin rapid solidification process & process chain (strength window 450 – 750 MPa)**
2. **Ongoing material assessment (static – dynamic - corrosion)**
3. **Extending the thermal working window limits (375°C ➔ 400 – 425°C) ➔ improved alloying i.e. Zr + Hf (?)**
4. **Clarification of melting anomalies when Sc + Zr amounts exceed 2,5 wt% (“colloid melts”)**
5. **Overcome current extrusion limits (i.e. hydro-static extrusion or allow higher overall extrusion temperatures)**
6. **Evolution of Sc master alloy price (s.a. “red mud deposits”)**

Scalmalloy® Challenges ⇔ Limits
➔ Improved Melt-spin Processing



Improved melt-spin parameter secure better super saturated matrix enabling improved aging response ➔ 700+ MPa appears feasible !!