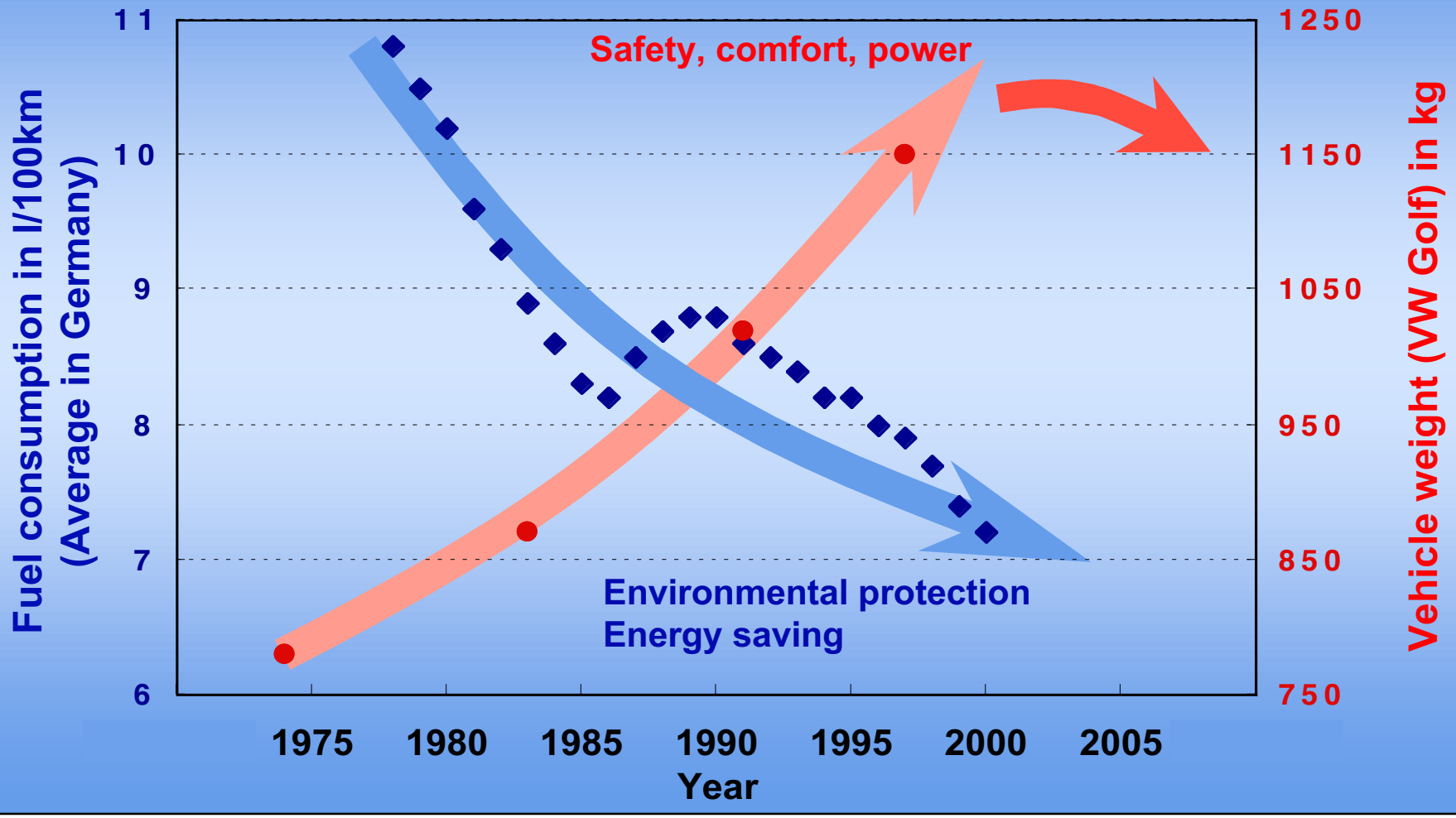
Paint bake response of aluminium car body sheet alloy

Definition: Paint bake response (PBR) = Increase in yield strength (or hardness) caused by paint baking

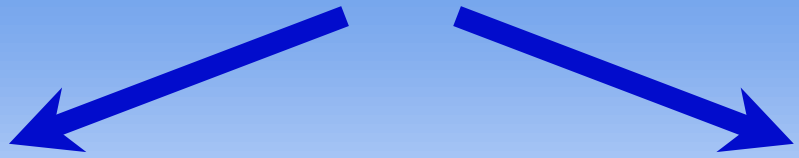
Contents:

- Why aluminium body sheets
- Aging of AlMgSi alloys
- The challenge
- The solution
- Summary and outlook

Conflict of aims



Aluminium for car body applications



All-aluminium body:

- Extrusions
- Castings
- Sheets

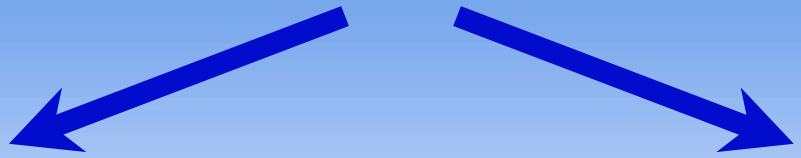
Weight saving of about 30-40% compared to steel body

Steel body structure with aluminium parts:

- Sheets (engine hood, boot lid, doors, fenders)

Preferred sheet alloy in Europe: AA6016 (1.2%Si, 0.4% Mg)

Requirements for body sheets



Before forming:

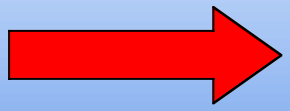
- good formability:

Yield strength: $R_{p0.2}$ < 130 MPa
Elongation: A > 24%

In service:

- high dent resistance:

Yield strength: $R_{p0.2}$ > 200 MPa
Elongation: A > 12%



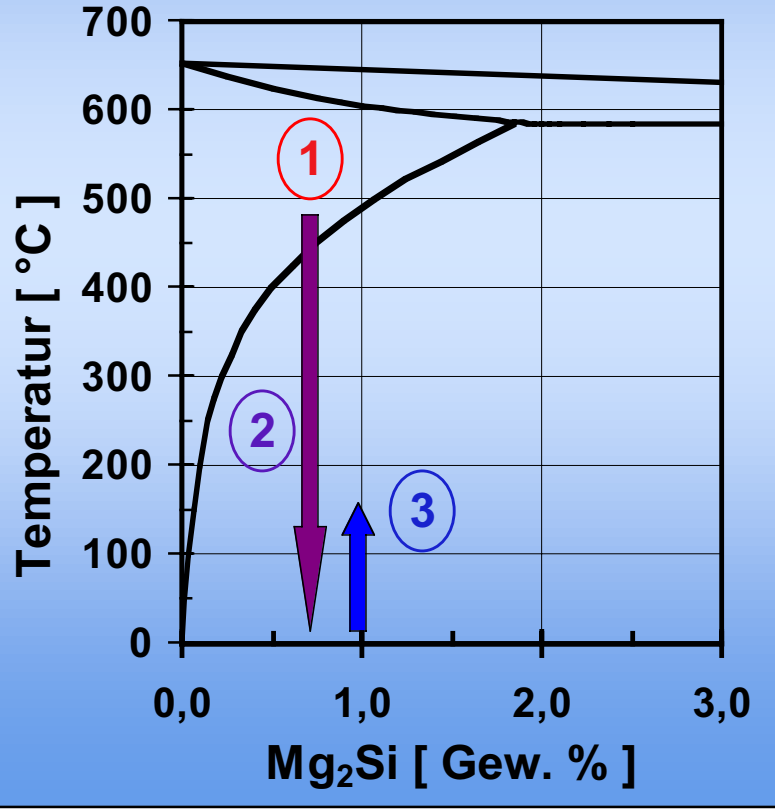
Artificial aging treatment necessary

i.e. forming in T4 condition
aging ⇒ T6 condition in service

Age-hardening of AlMgSi alloys

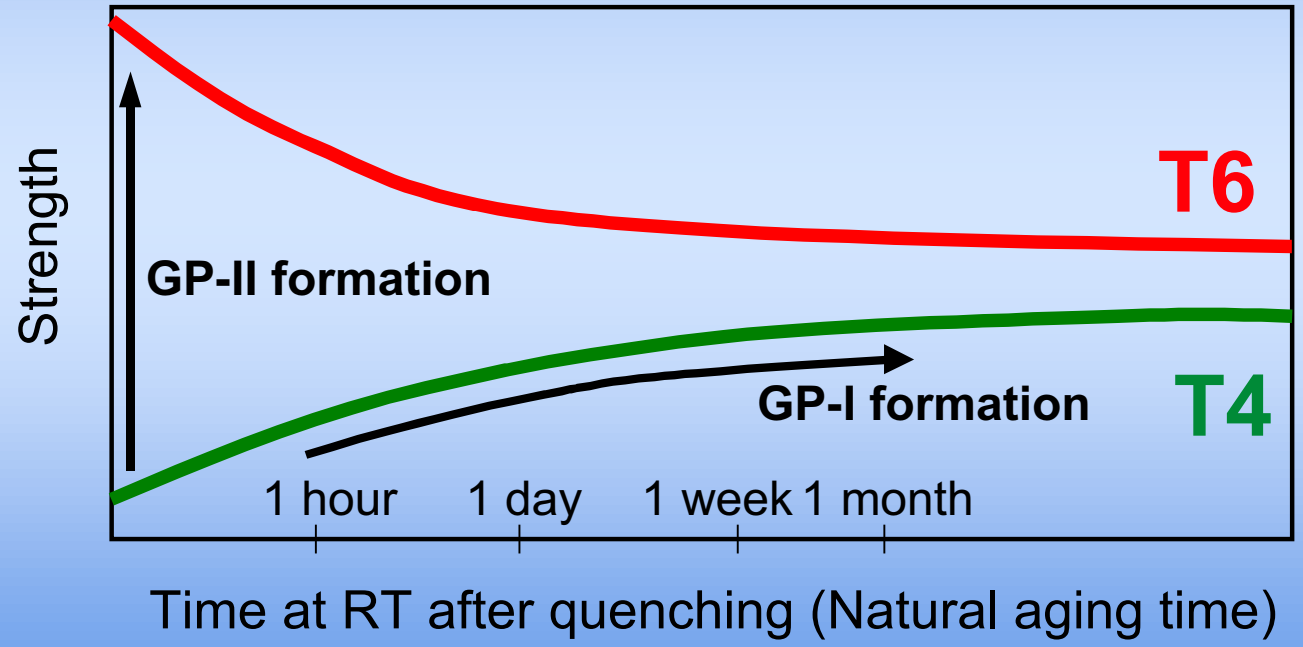
Basic requirement: Decrease in solid solubility of the alloying elements with decreasing temperature

- Dissolve the alloying elements within the single-phase region
- Quenching to obtain a super-saturated solid solution (SSSS)
- Controlled decomposition of the SSSS to form finely dispersed precipitates
  RT: natural aging, T4
  elevated T: artificial aging, T6



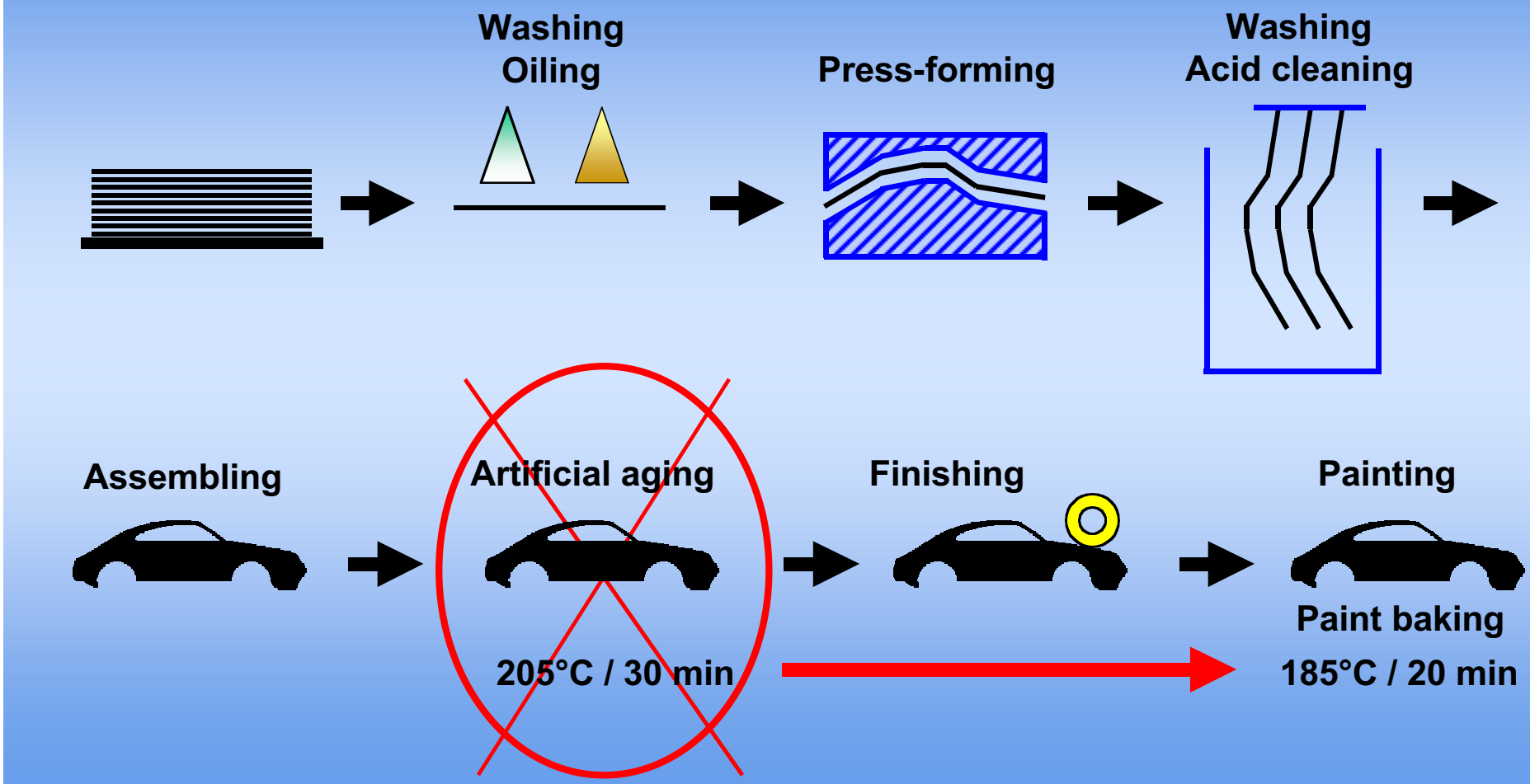
Age-hardening of AlMgSi alloys

- **Precipitation sequence: supersaturated solid solution → Cluster and/or Guinier-Preston I (GP-I) zones → GP-II zones (β“ needles) → β‘ rods → β plates (Mg_2Si)**

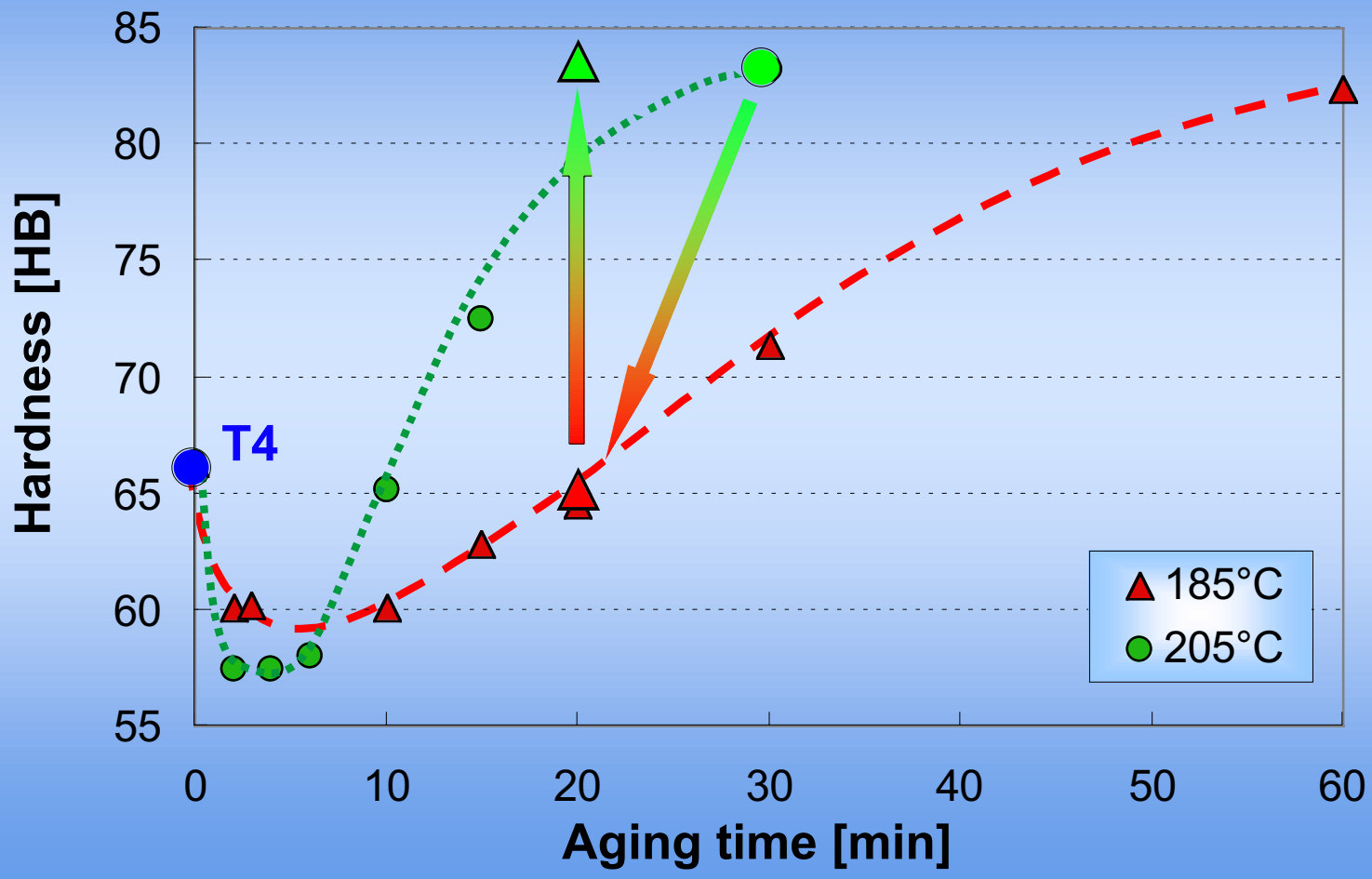


Aging is most effective if carried out immediately after quenching!

Production scheme of an aluminium body



The challenge: 185°C/20min instead of 205°C/30min



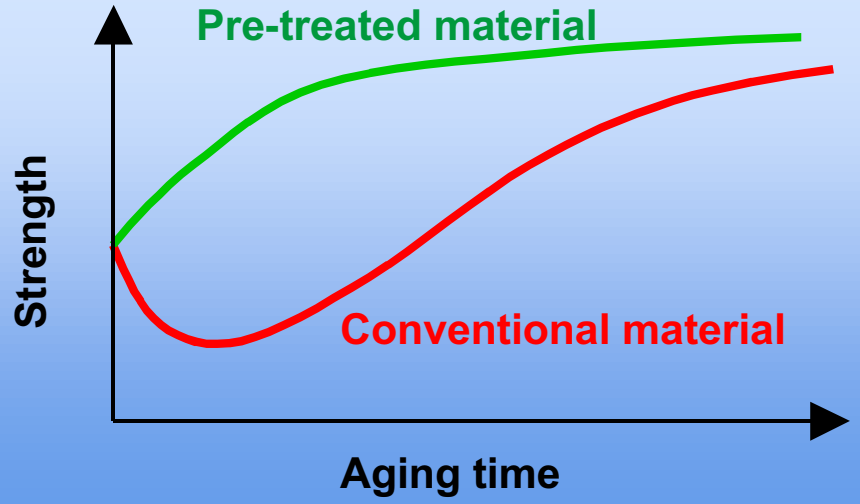
Methods to increase the PBR

Two known methods to reduce the detrimental effect of a RT delay, i.e. to increase the PBR:

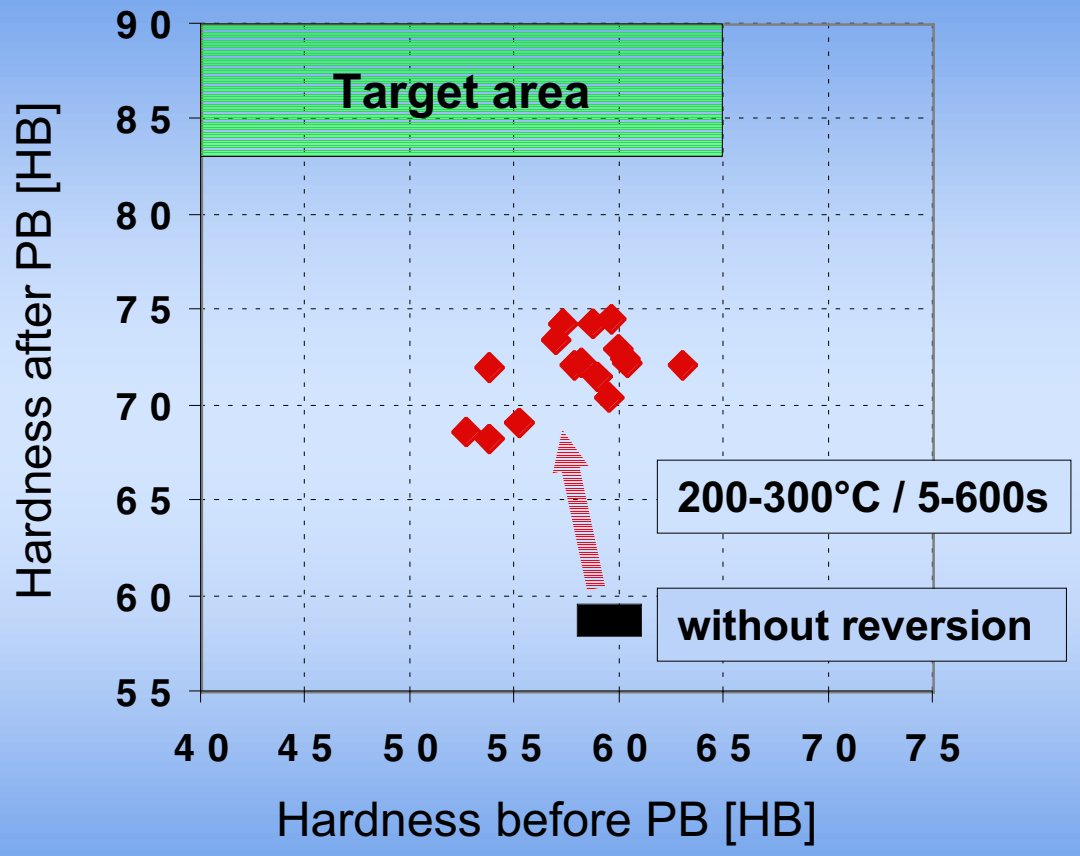
- **Pre-aging treatment shortly after quenching**
- **Reversion treatment in T4 condition**

➡ **avoid / reverse GP-I formation and provide GP-II nuclei**

➡ **change in the aging behaviour**



Reversion treatments



Solution treatment

↓

Quenching

↓

Storage at RT
> 7 d

↓

Reversion treatment

↓

Storage at RT
> 7 d

↓

Artificial aging
185°C / 20 min

reversion is not as efficient as required

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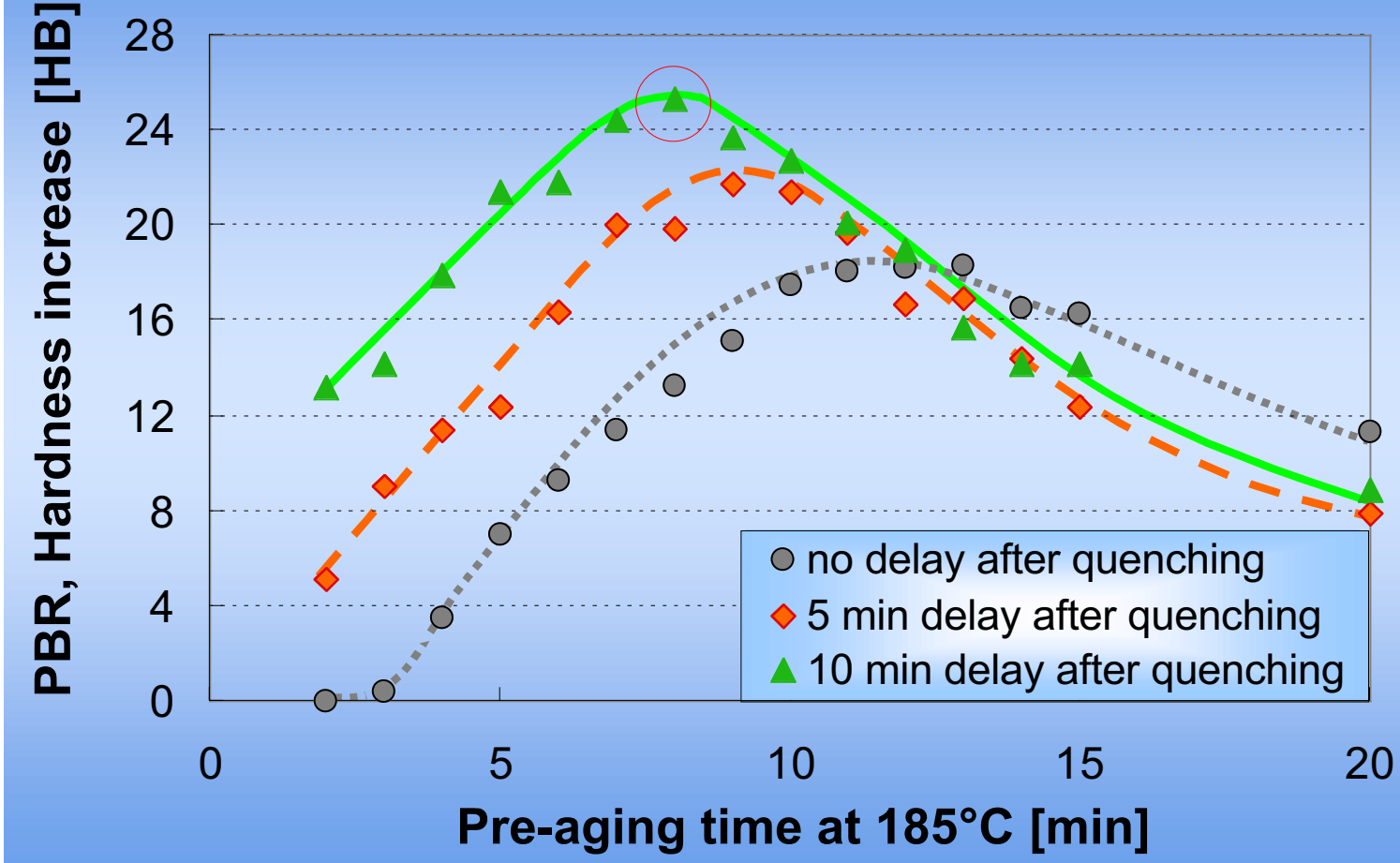
Pre-aging treatments 1 (PA1)



Solution treatment

↓

Quenching

↓

Pre-aging treatment

↓

Storage at RT > 7 d

↓

Artificial aging 185°C / 20 min

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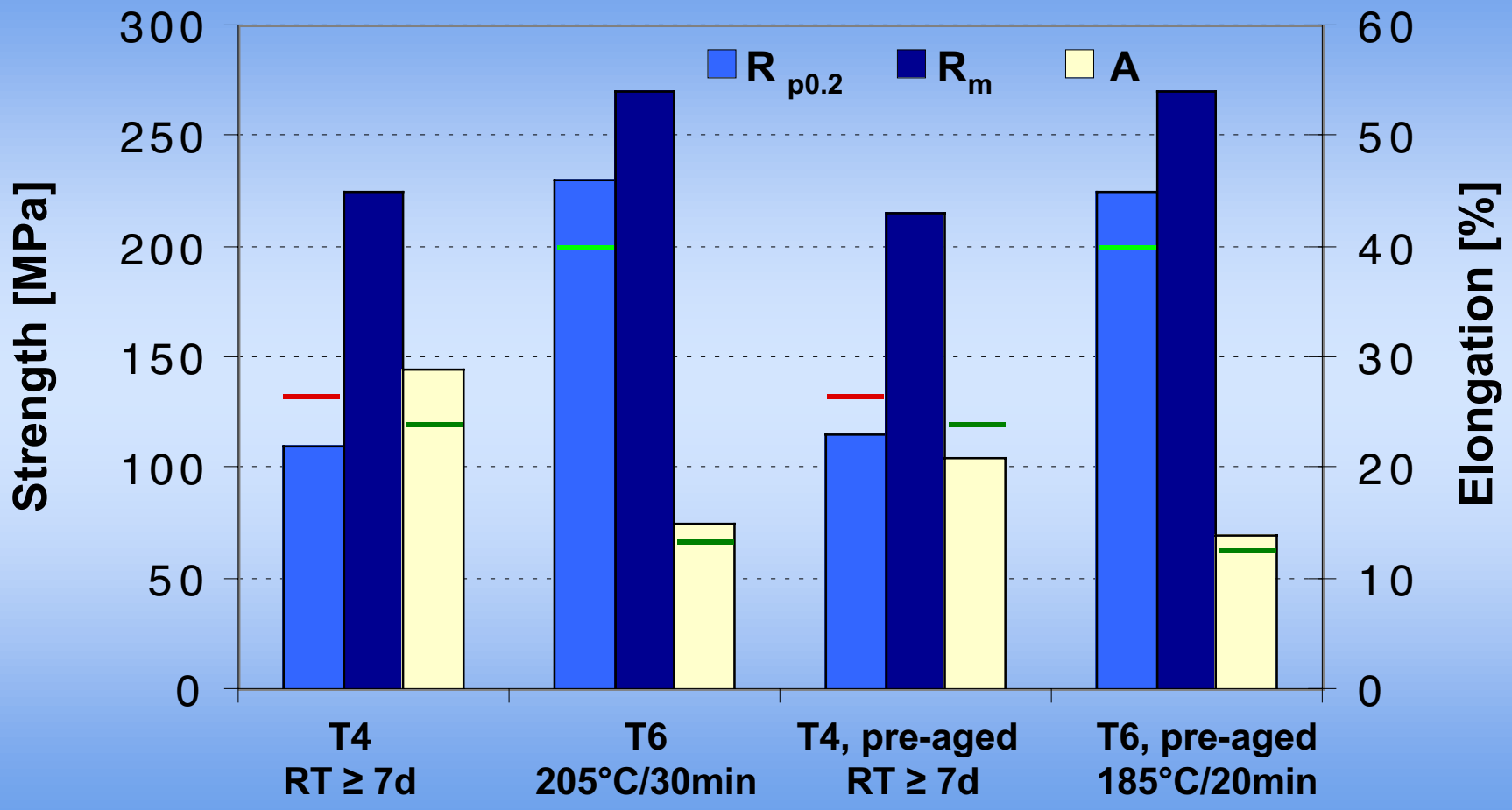
Mechanical properties, PA1



Pre-aging treatment: 10min RT + 8min 185°C

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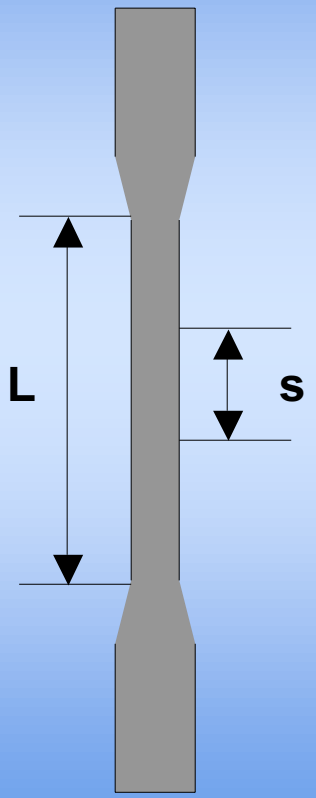
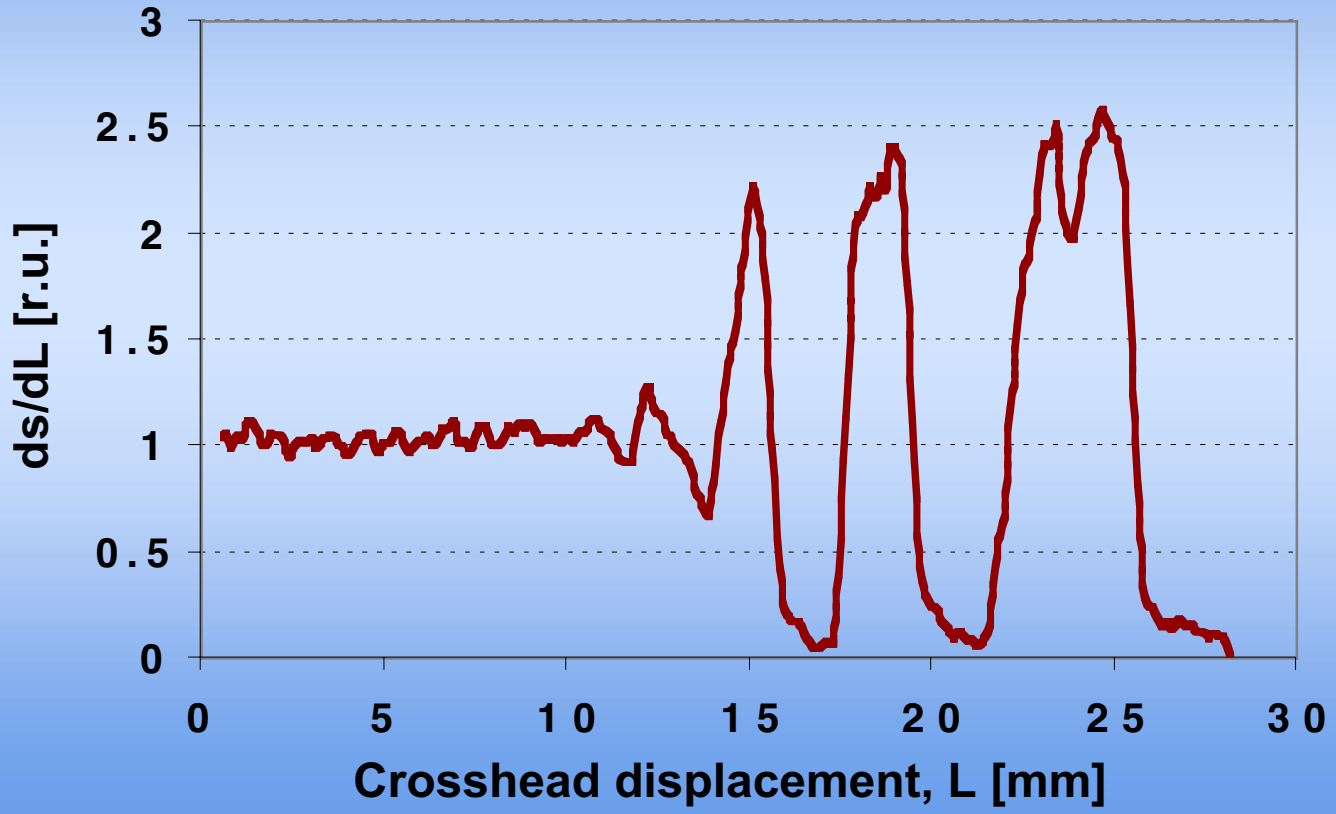
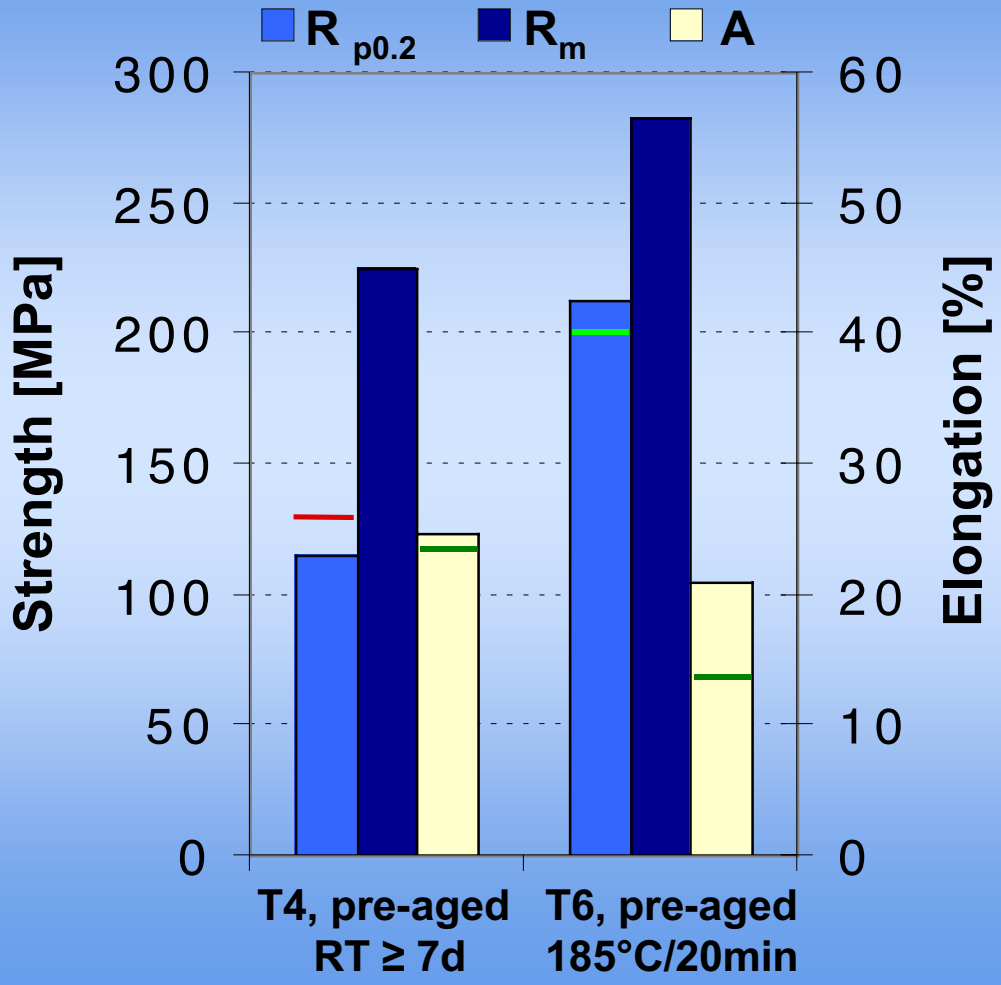
Non-uniform deformation, PA1

T4-Q condition = pre-aging + 7 days RT-storage





Pre-aging treatment 2 (PA2), Mechanical properties



Solution treatment

↓

Quenching

↓

Pre-aging
100°C / 8h

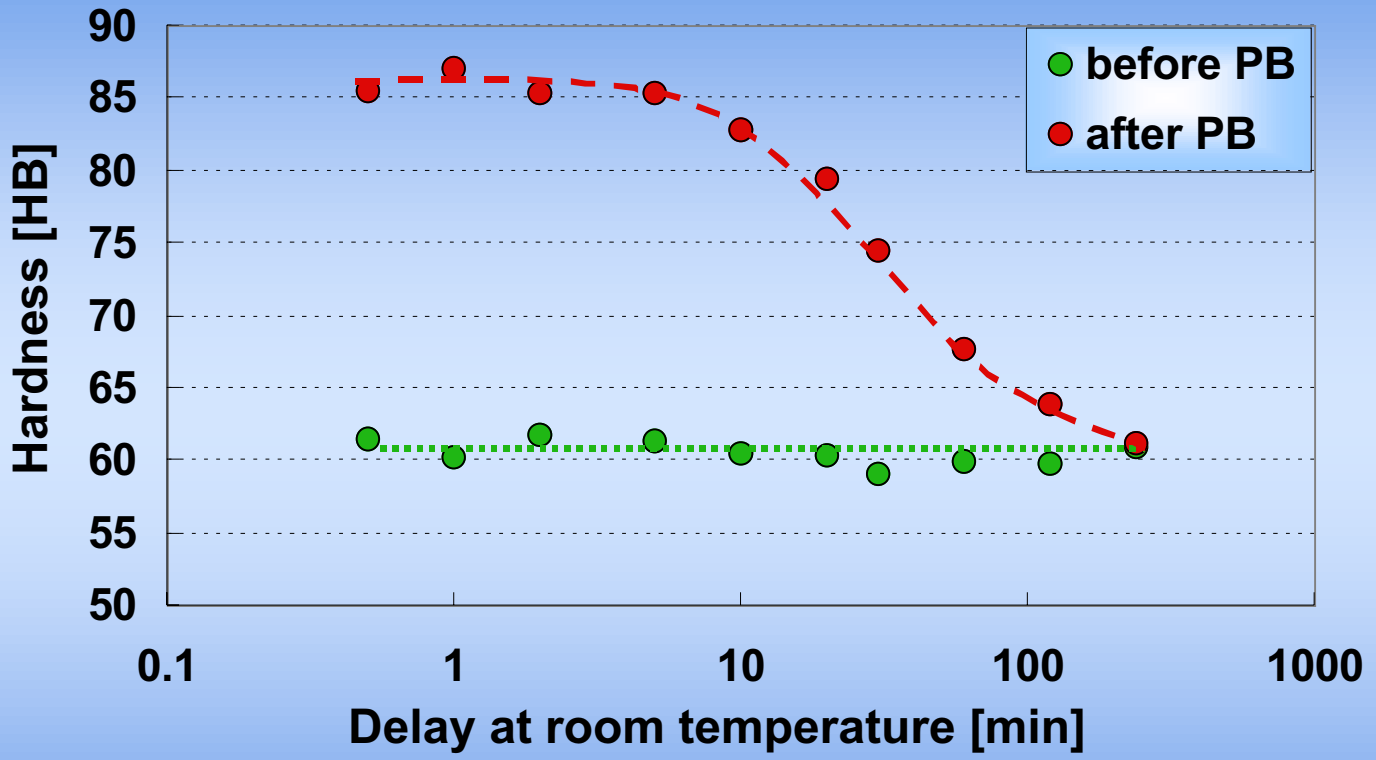
↓

Storage at RT
> 7 d

↓

Artificial aging
185°C / 20 min

Effectiveness of PA2



Solution treatment

↓

Quenching

Delay ↓

Pre-aging
100°C / 8h

↓

Storage at RT
> 7 d

↓

Artificial aging
185°C / 20 min

→ **method 2 is very sensitive to a delay after quenching**

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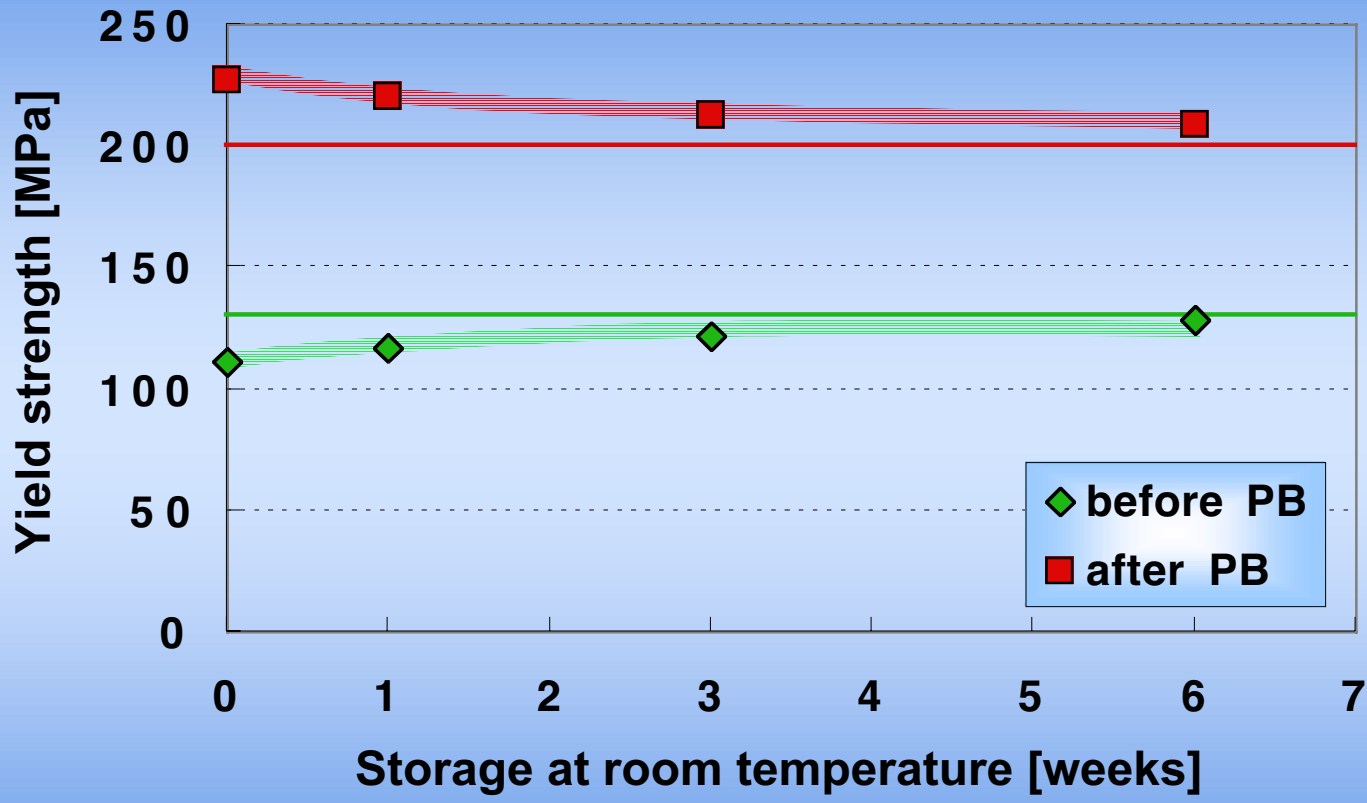
Combination of PA1 and PA2



Solution treatment
↓
Quenching
↓
Pre-aging 1
↓
Delay at RT < 20h
↓
Pre-aging 2
↓
Storage at RT
↓
Artificial aging
185°C / 20 min

Elongation in T4-Q condition: 23-25%, no non-uniform deformation

Summary and outlook

- AA6016 shows no PBR in normal T4-condition while pre-aged material shows a high PBR of 80-110 MPa

- Best pre-aging parameters are:
  RT-80°C / 3-10min + 160-190°C / 3-10min, continous furnace treatment
  80-120°C / 5-12h, batchwise treatment
  (Patented in 2001)

→ **Artificial aging treatment of car bodies can be avoided** → **saves time, money and energy!**

- Elongation in T4-Q is still slightly lower than in T4
  ⇒ further investigations to improve formability