

 **BORALCAN**TM
ALLOYING ALUMINIUM AND HIGH PERFORMANCE

Pierre Marchand, product director, speciality product
Meeting NEI-NRC
March 14th 2013

Agenda

- Dubuc works: location and overview
- MMC fabrication process at Rio Tinto Alcan
- *Boralcan* product characteristics

Dubuc works localization



Dubuc works is located Saguenay, Quebec, Canada



RTA in Saguenay region has hydroelectric power capacity, over 1 million tons of alumina and aluminum smelting capacity, a research center and support to a local university research program in aluminium

Overview of Dubuc works

24 years in 2013



- Horizontal Casting machine
 - Busbar & foundry alloys
- Vertical Casting machine
 - Low Density alloys
 - MMC
 - Duralcan
 - Boralcan
- ISO 9001 - 14001 - 18001 Certified



Duralcan[®], Aluminium MMC

Metal matrix composites: Al alloy with Al_2O_3 or SiC addition



DURALCAN[®] AL MMC Billet

Duralcan[®] is a family of ceramic reinforced aluminum alloys which offers significant improvement in **wear resistance** and **stiffness** when compared to unreinforced aluminum and provide weight savings of $\approx 50\%$ over cast iron and steel in selected applications.



Duralcan[®], Aluminium MMC

Development by Knorr Bremse AG Germany:

“Brake rotors for German high speed train ICE-2 made from a particulate reinforced Aluminium alloy (AlSi7Mg+SiC particulates, supplied by Duralcan)”.

37% weight saving with Duralcan over cast iron brakes



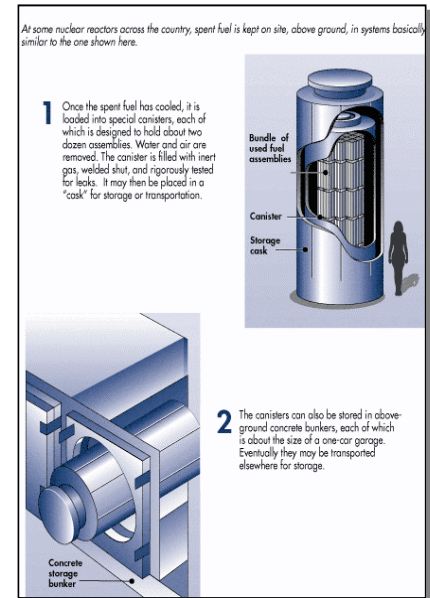
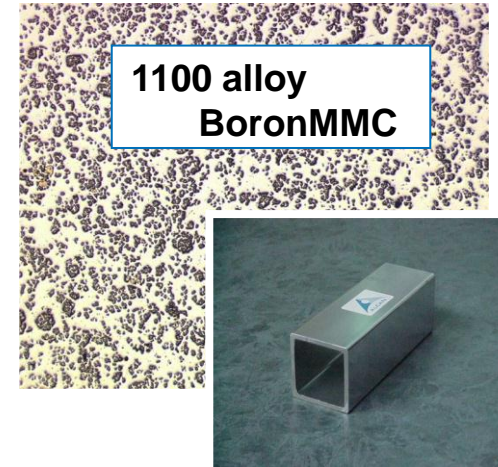


First development in 2001

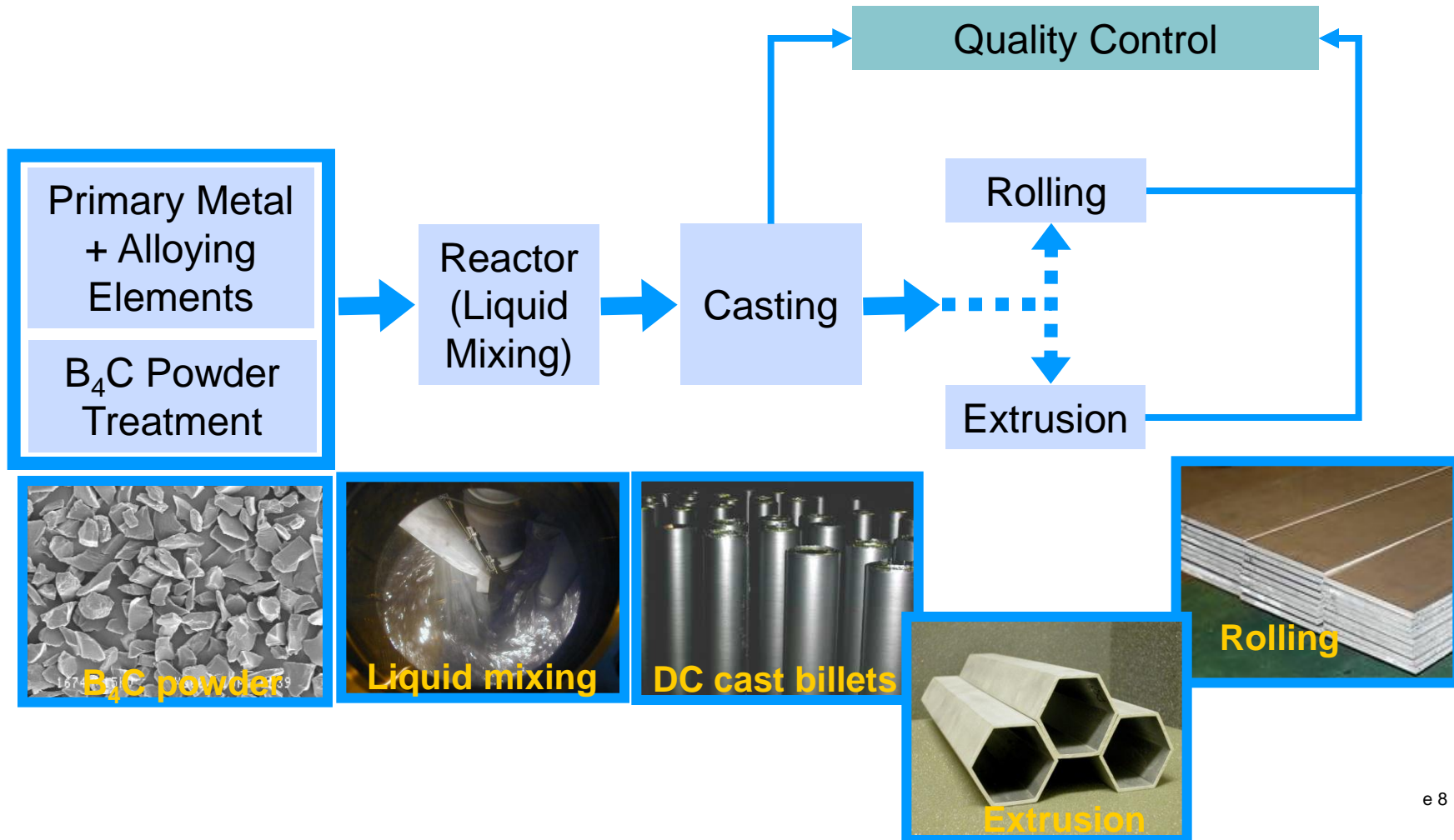
Boralcan™ is based on 10 years of Duralcan® industrial experience

Boralcan™ is a MMC: aluminum alloy with nuclear grade B4C addition. W1100N.xxB, W6351N.xxB

- Spent Fuel Dry Storage Basket : rolled strip or extruded shapes
- Spent Fuel Wet pool Rack shielding : rolled strip.



Boralcan™ : production process route



Duralcan[®] & Boralcan[™] production process route

SiC, Al₂O₃ or B₄C powder is injected and mixed into liquid Al alloy

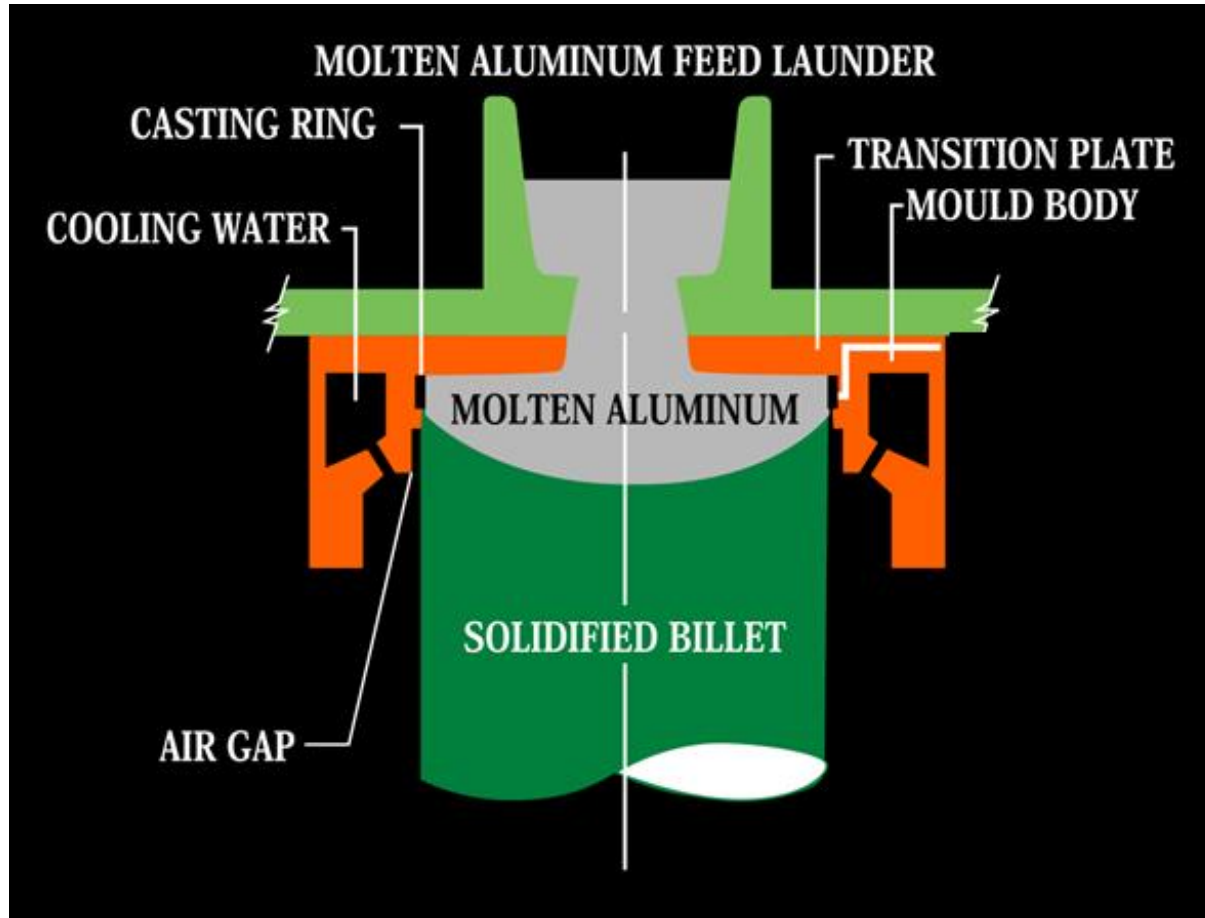


Main features:

- Powder added in liquid aluminium alloy
- Ceramic particle is wetted to aluminium
- Batching elaboration process maintain uniform particle distribution in liquid Al matrix
- Casting is taking place similarly to other Al casting process
- Efficient process for large scale production

Boralcantm : production process route

DC Casting with hot top technique



Ingot format

Square billet:

- 6 x 6 inch

Round billet:

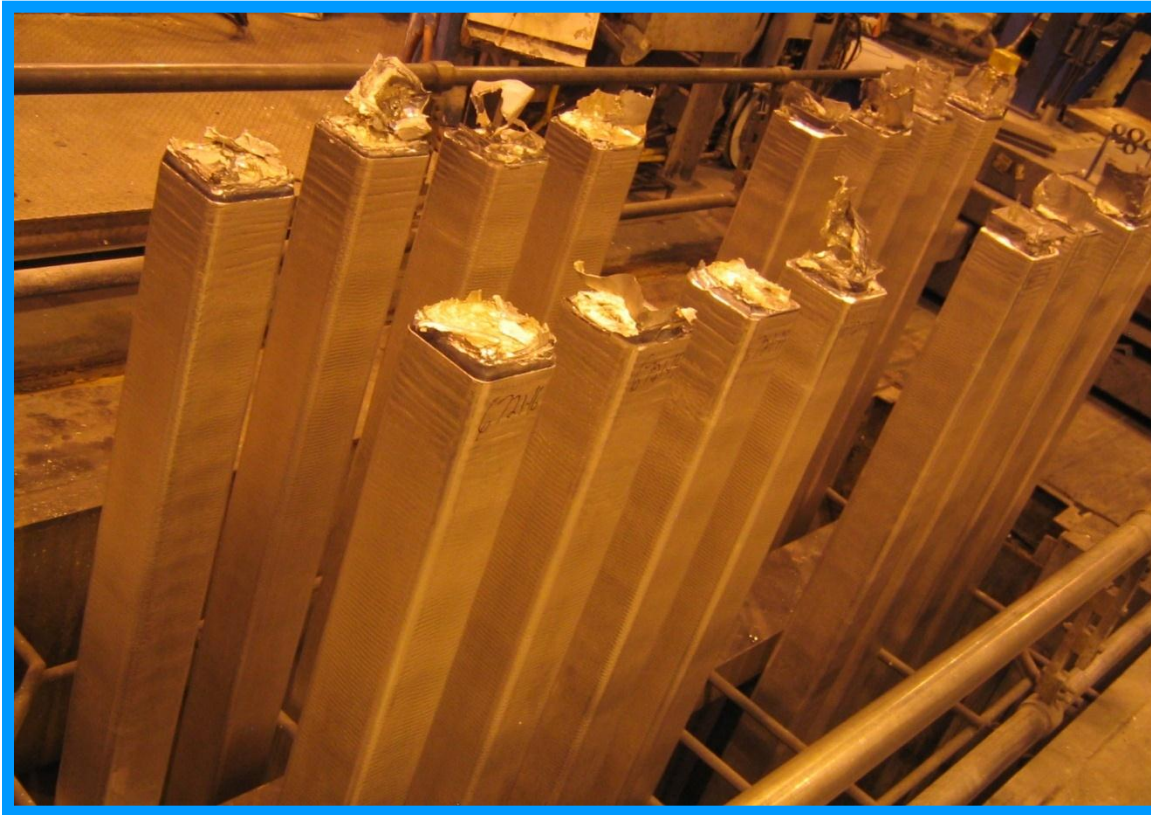
- 7 in
- 9 in
- 11½ in
- 17 in

Length

Up to 200 in

Boralcantm : production process route

Typical production, end of a cast



Quality control & certification :

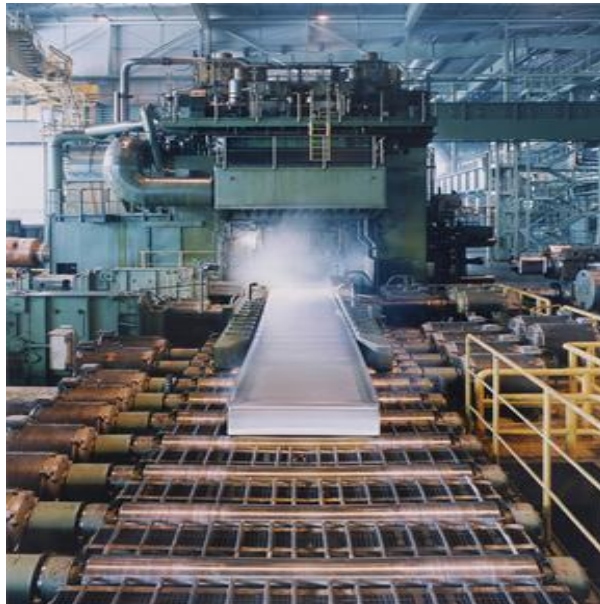
A- Chemical analysis :

OES samples taken during the cast (Beginning/middle/end)

B- Metallographic analysis :

Boralcan™ : production process route

Via our partners, conversion to finished product by rolling or extrusion



Boralcan™ history and challenges

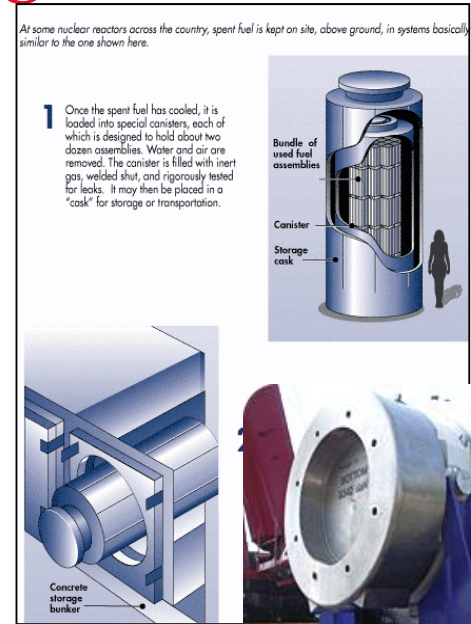
4.5 to 28.5% v/v B₄C production

- Current product range for US & EU customers
 - 4.5 to xx% B₄C for extruded products
 - 16 to 28.5% B₄C for rolled products

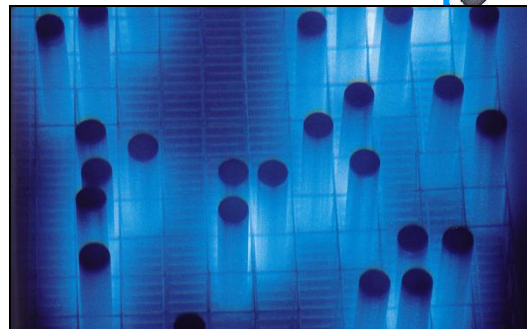
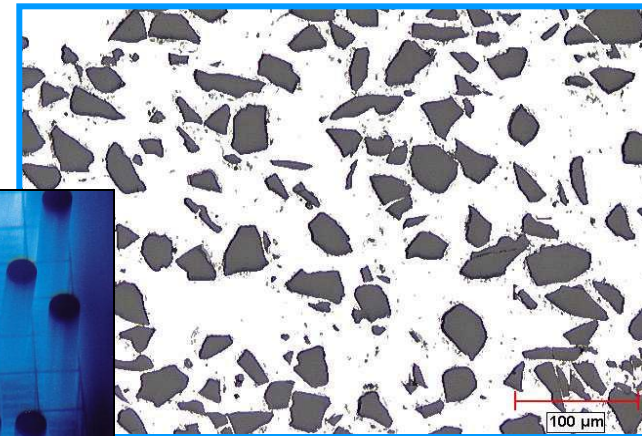
Challenges for 2013 +

Pursue development on:

- Increase max B₄C content
- Increase recycling

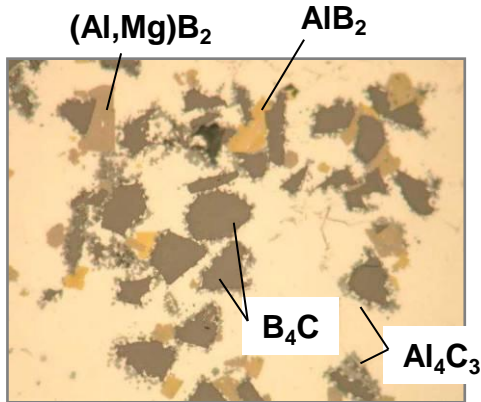


Nuclear Waste Dry Storage

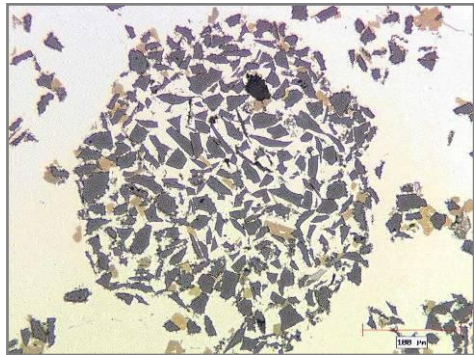


Boralcantm : R&D innovation

Before improvement

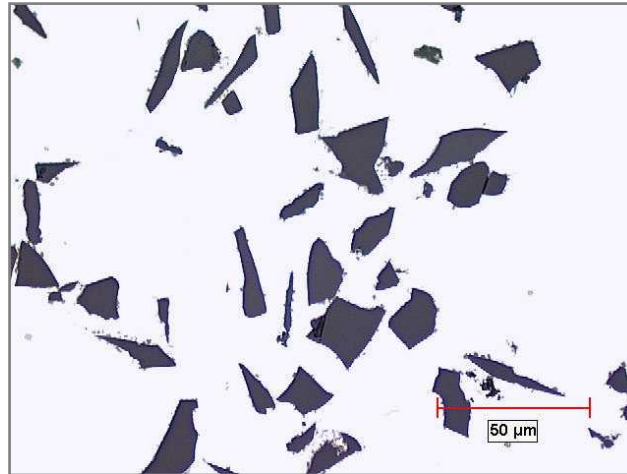


Producing many secondary phases



Forming large clusters

After improvement



- Ti addition makes the B_4C particles more stable in liquid Al matrix
- It increases the castability and maintain the dispersion of the particles
- B_4C particle is wetted by liquid Al, cohesion with Al is maintained in solid state, Young modulus increased by up to 50%,

Boralcan[™] as rolled sheet

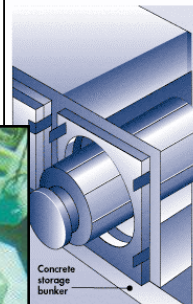
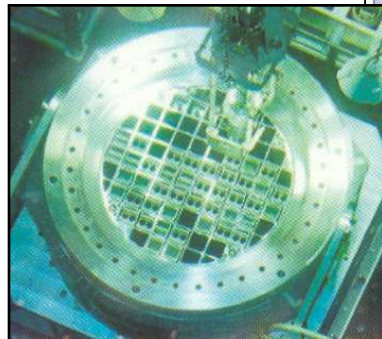
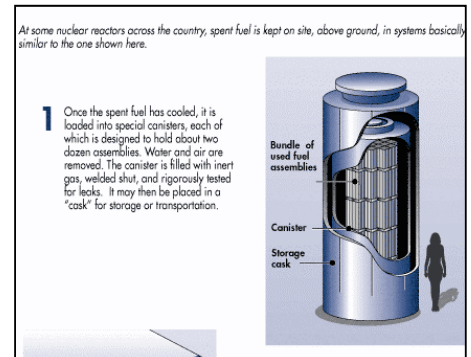
Rolled sheet: 16 - 28,5% v/v B4C in AA1100 aluminum matrix has been successfully cast with full size industrial scale equipment since 2006

The product has since been successfully rolled in thicknesses to

- 6 mm, ¼ inch
- 3 mm, ⅛ inch
- 2 mm, 0.080 inch

Key product characteristics:

- B₁₀ areal density
- Heat conductivity
- Sheet dimensions



Boralcan™ : extruded shape form

Extruded shape: 4.5 to xx% v/v B₄C in AA 6351 alloy matrix has been successfully cast and extruded in solid shape since 2008

The product has since been successfully extruded into
flat bars: 7 - 25mm x 130 - 180mm
hexagonal tube: app 200mm across

Key product characteristics:

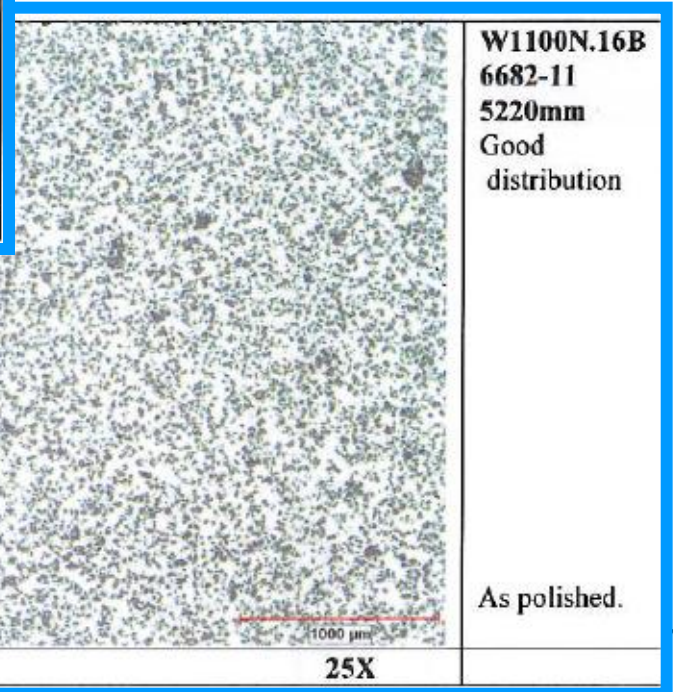
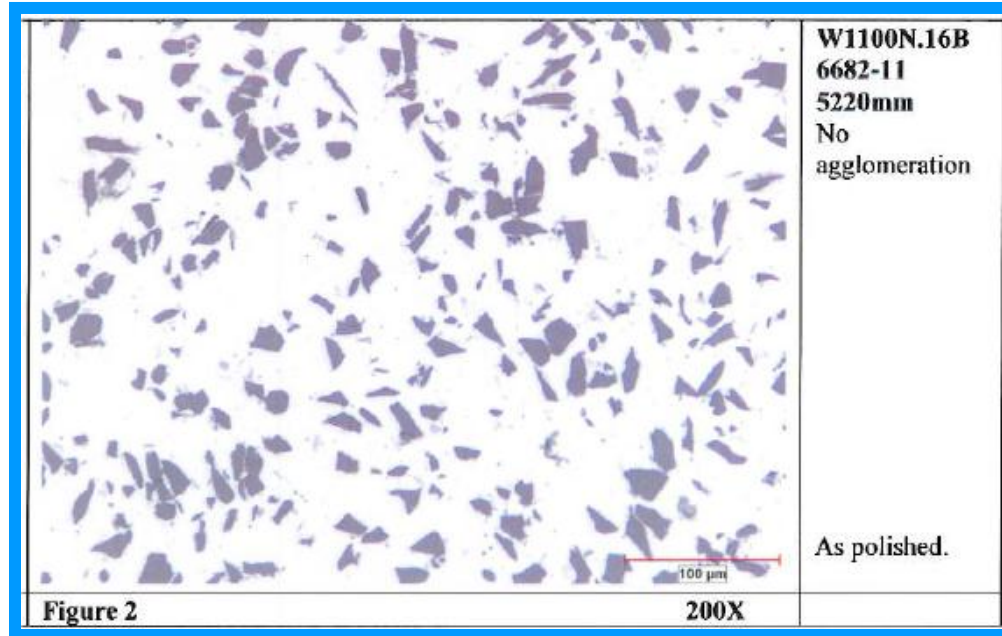
- B₁₀ areal density
- Heat conductivity
- Profile dimensions
- Mechanical characteristics



basket made of Al-B₄C extruded plates for neutron shielding

Boralcantm : production process route

AA1100-16% B4C as cast slice



Boralcan[™] : product characteristics

Large lot: good uniformity of B₄C distribution

Stiffer: Young Modulus, 1.5 X more than std alloys (105 vs 69 GPa)

Bendable: high elongation but lower than regular alloys

Weldable: with friction stir welding

Dryable: 100% dense

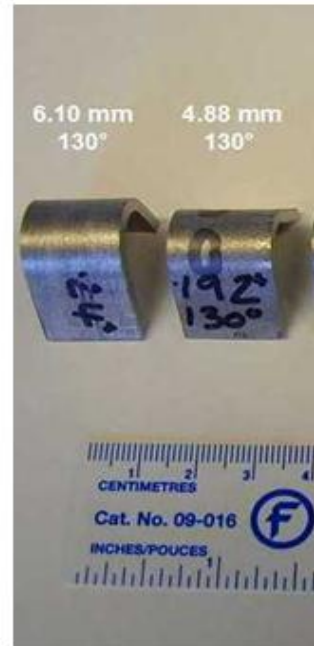
Corrosion resistance: very good, similar to AA 1200

Bendable

Temper condition: complete annealed (o temper)

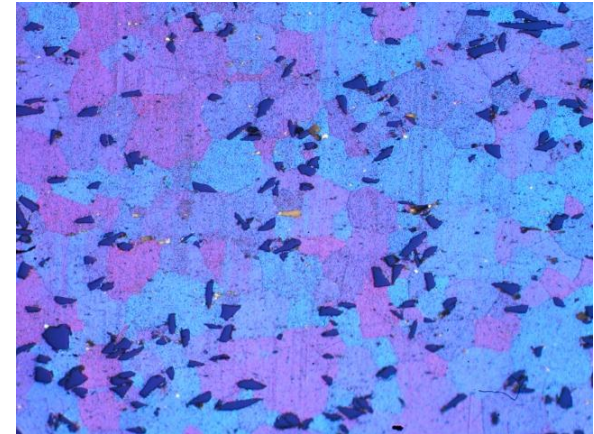
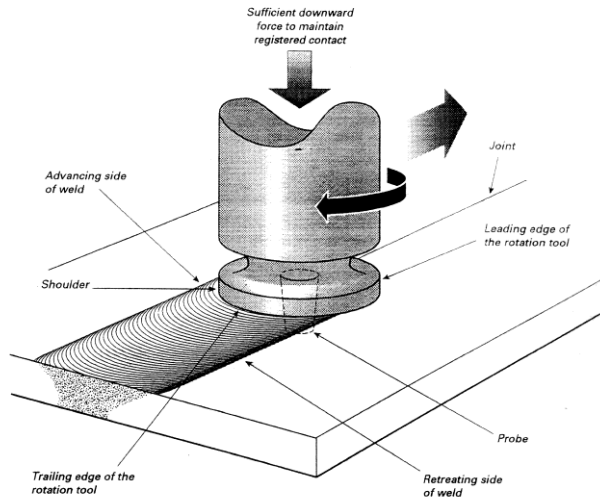
Bending abilities impacted by

- B₄C content,
- Thickness,
- Radius,

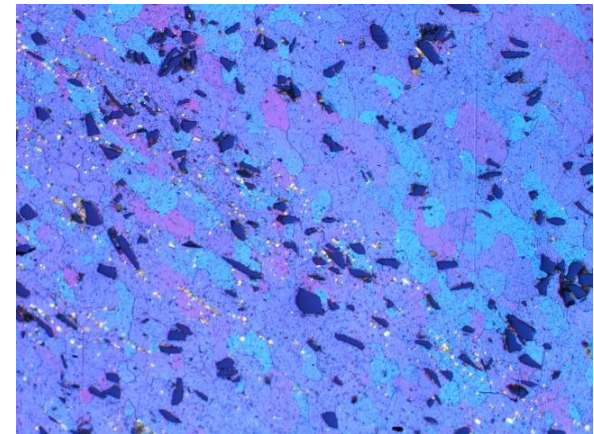


Weldable

- Friction stir welding



AA6063-6%B4C before welding

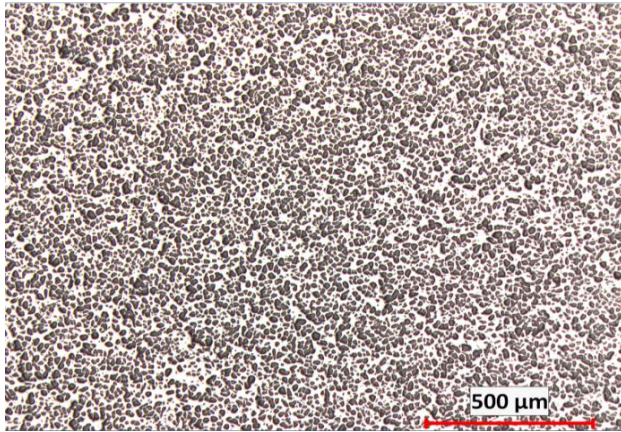


AA6063-6%B4C after welding

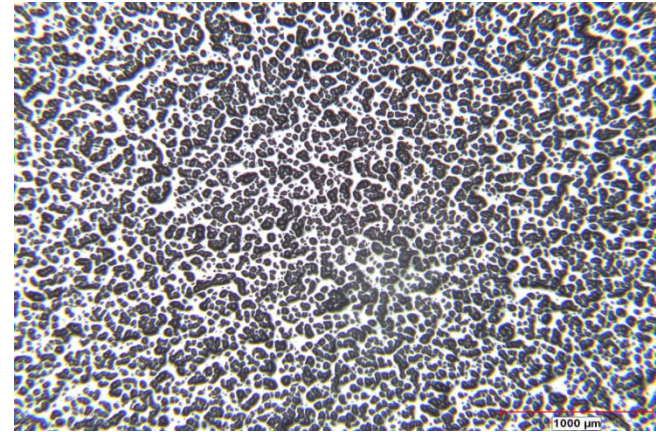
Dense material, easy to dry

W1100.23B

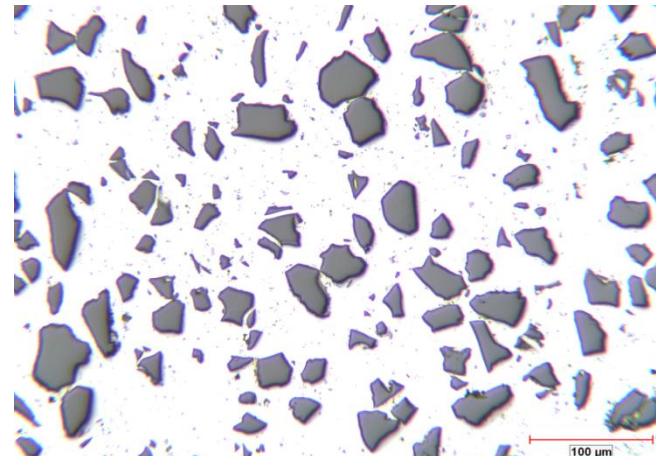
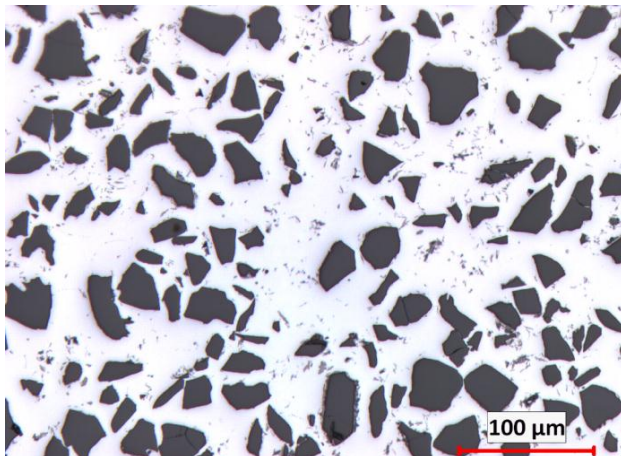
as cast



rolled



25X



200x

0.06 % porosity typical

Corrosion resistance

Accelerated corrosion test (2009)

- BWR and PWR pool environment
- In contact with 304L, Inconel 718, Zircaloy
- 16 and 25% B₄C (v/v), bent sheet
- Up to 8000 hrs at 195°F, equivalent to 17 years at 80°F

Main conclusions:

- Typical corrosion rate: -0.01-0.04 mills/year
- Identical corrosion rate for Boralcan 16 and 25% B₄C
- No differences between BWR and PWR environment
- No difference when exposed to galvanic conditions
- No local corrosion observed, no lost of carbides
- No differences of corrosion near the bent

Conclusion



- **Boralcan** : Al MMC with B4C having a unique process manufacturing in the industry
- **Boralcan** follows process route similar to large scale Al industry
- **Boralcan** can support fabrication processes such as bending, cutting
- **Boralcan** has been shows good corrosion resistance for application in spent fuel pool, BWR and PWR