NIOBIUM IN ADVANCED MATERIALS

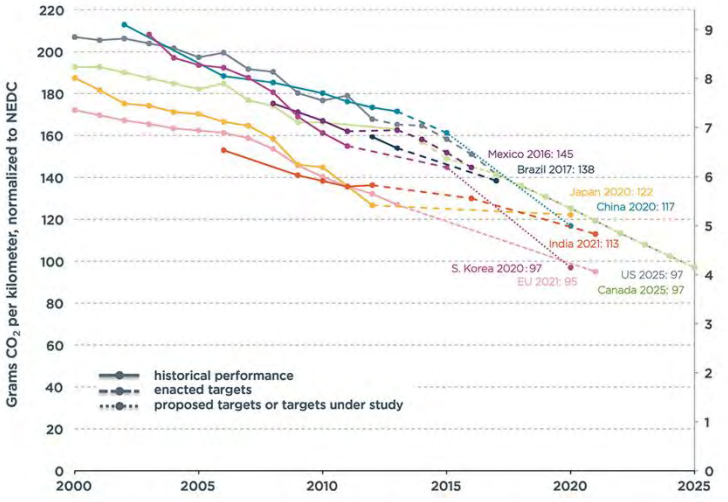
CBMM
Niobium Nb

1.

WHY NEW STRUCTURAL MATERIALS FOR AUTOMOTIVE APPLICATIONS?

AUTOMOTIVE DESIGN REQUIREMENTS

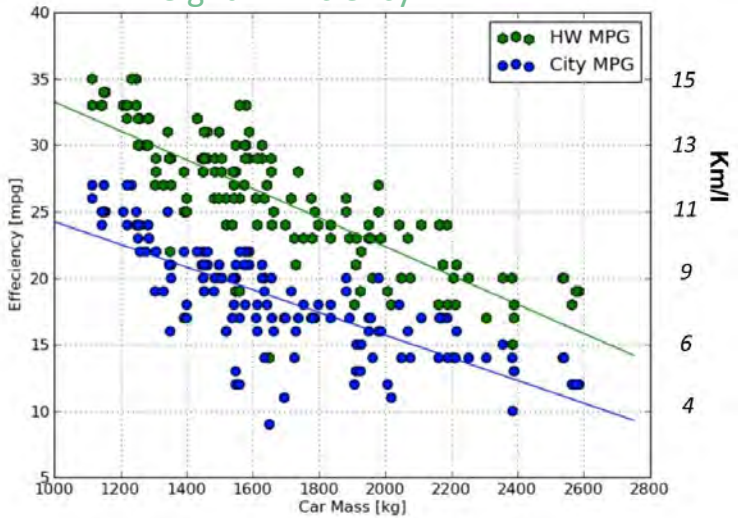
Global fuel efficiency regulations



Source: Published on Aug 25, 2014. 6/4/2014 - International Workshop on Technology and Policy Solutions: GFEI / ICCT China

Combustion Engine:

BIW Weight x Efficiency



RHETT ALLAIN SCIENCE, FUEL ECONOMY VERSUS MASS (https://www.wired.com/2012/08/fuel-economy-vs-mass/)

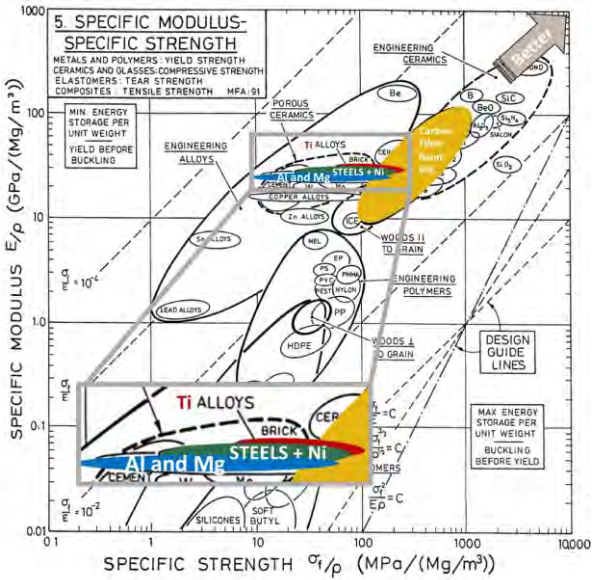
ELECTRIC CARS

In addition to the other advantages:

- Light Body to compensate for
- the additional battery weight
- Also Important:
- Cost and Packaging purposes / easy to engineer geometrically to accommodate battery volume.

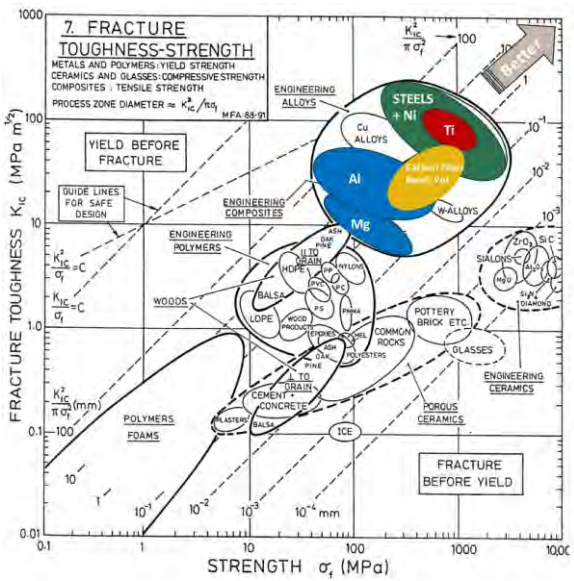
LIGHTWEIGHT & SAFETY

Lightweighting: Strength with Lowest Mass



NOTE: Low strength and low density may lead to good specific strength but large volume (thick sections)

Safety: Toughness



Ashby plot, available at *https://www.lehigh.edu/~intribos/Resources*

CONCLUSION

- Including cost considerations steel is the best performer and Aluminum is second. They are most extensively used as structural materials
- Other materials: used in spot applications.
- Multimaterials concept: challenge for assembly and corrosion, which has been solved in several cases

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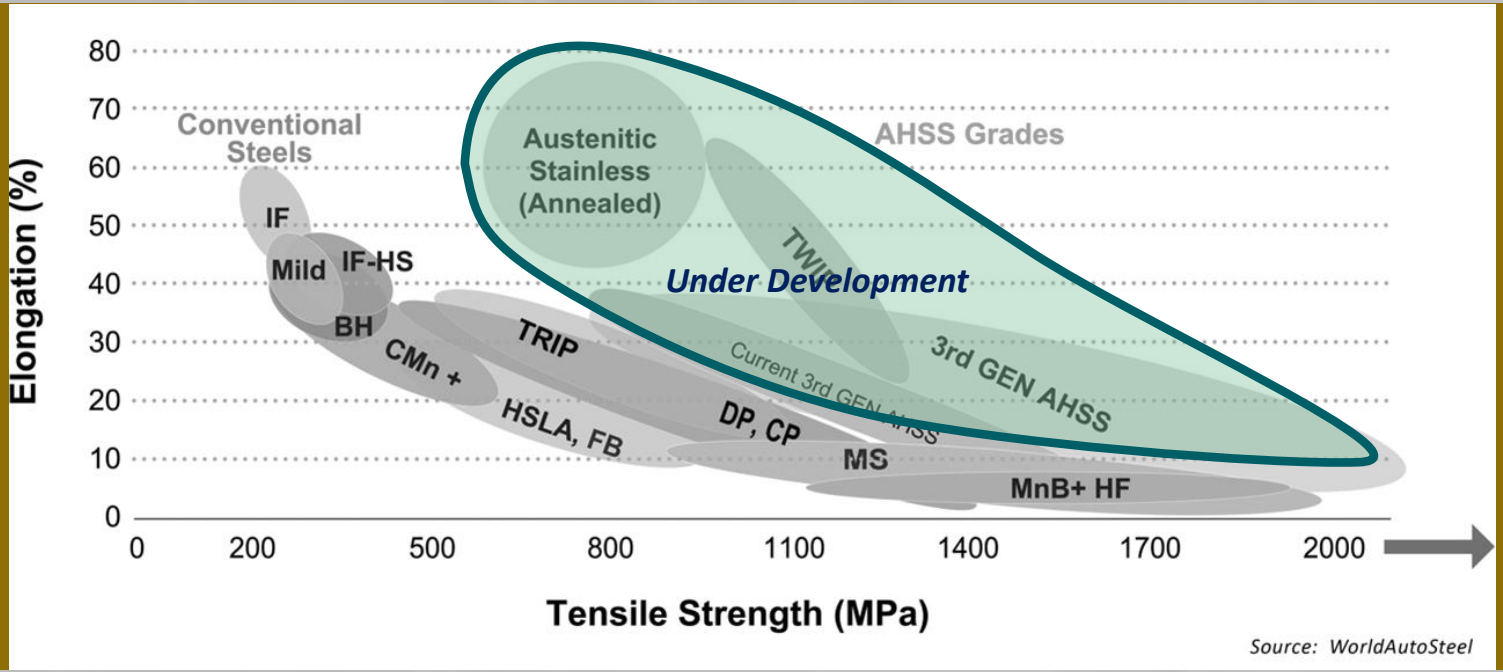
2.
NIOBIUM IN STEELS

STRENGTH AND DUCTILITY: INVERSE RELATION



Option:

Grain refinement increases strength without loss of ductility

Niobium: key effect in refining the grain of steels

NIOBIUM IN STEELS FOR AUTOMOTIVE INDUSTRY

Niobium

- ✓ Makes a lightweight design of vehicles a reality
- ✓ Increases steel strength and toughness
- ✓ Allows car body structures to be lighter
- ✓ Improves crash safety.

300 grams of niobium in the steel of a mid-size car

Reduces its weight by 200 kilograms

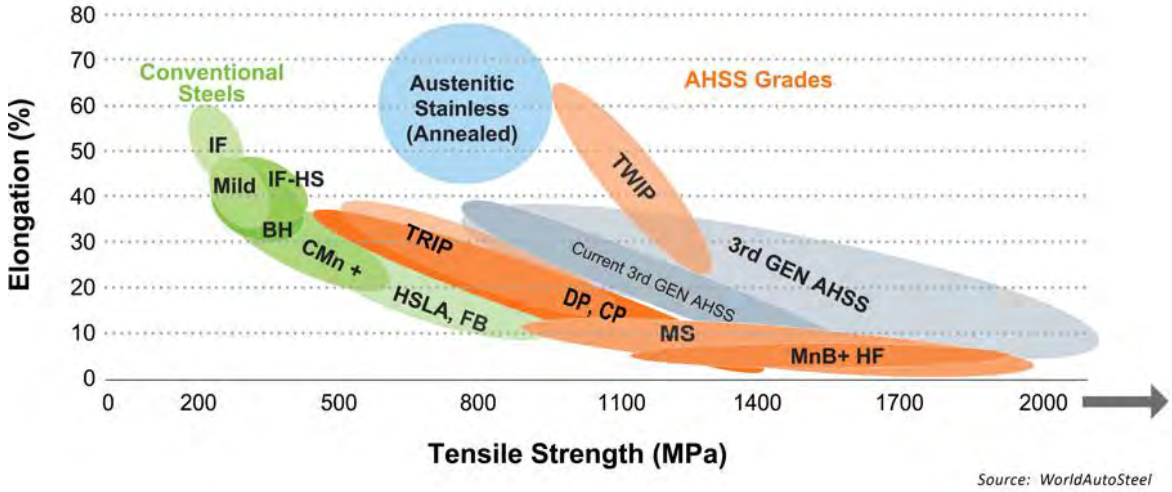
Results in fuel economy of one liter per 200 kilometers driven, and much lower emissions (increase efficiency in 0.6 to 1.5 km/l)

MANUFACTURING ABILITY

- Trip: complex manufacturing process
- DP: difficult local formability (forming defects)
- Martensitic (PHS): instability in process (furnace and limited ductility)
- Twip and Austenitic: high alloy content and cost challenges
- 3rd Generation: in development

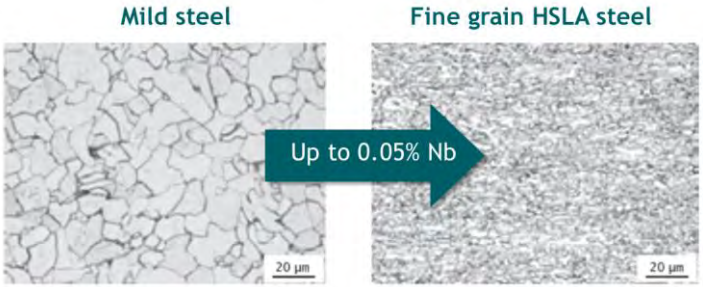
SUMMARY:

Niobium increases strength and toughness simultaneously, enabling high strength steels with good formability or process reliability

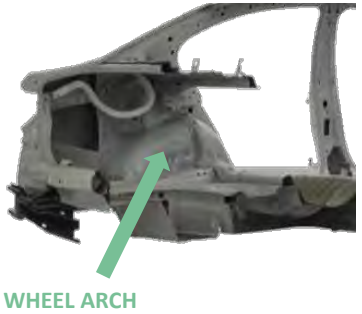


EXAMPLE 1:
HIGH STRENGTH LOW ALLOY STEELS (HSLA)

Compared to mild steels, the alloy balance of HSLA steels is based on the reduction of carbon content to improve toughness and weldability.



	STRENGTH	TOUGHNESS	FORMABILITY	WELDABILITY
Carbon content	++	--	--	--
Solid solution hardening	+	- (+)	-	- (+)
Cold forming (Dislocation hardening)	+	-	--	Neutral
Precipitation hardening	+	-	-	-
Grain refinement	+	++	+	+

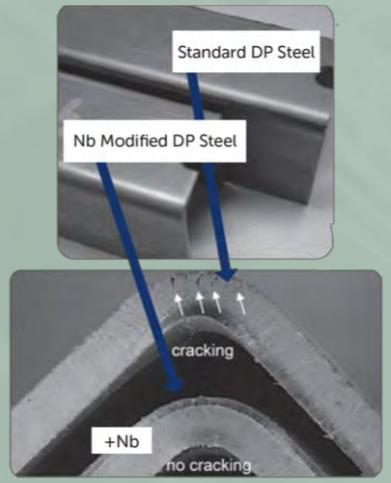


Typical composition:
0.05-0.09%C, 0.02-0.05%Nb, others: Mn, Si, Ti, V

Strength and ductility range (reference figures):
YS: 260 MPa-550 MPa
Elongation (ef): 16%-28%

EXAMPLE 2:
DUAL PHASE STEELS

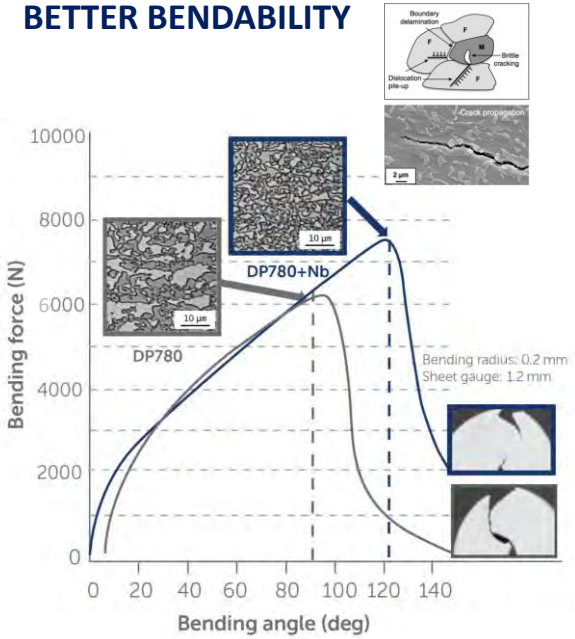
REDUCTION OF CRACKS



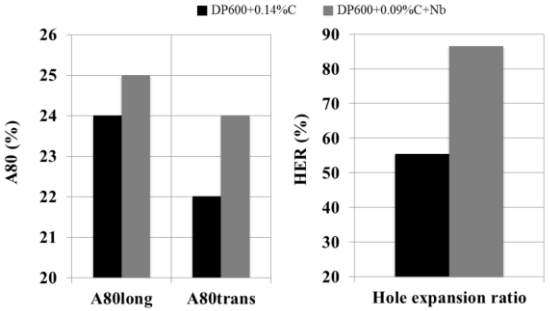
Bendability test demonstrating that the niobium modified DP steel can be submitted to tighter angles before fracture. The images show results after bending to more than 90 degrees, with cracks in the conventional steel but not in the niobium modified steel.

Source: H. Mohrbacher. Intl. Symp. on New Developments in Advanced High-Strength Sheet Steels, AIST, 2013, p. 319-329

BETTER BENDABILITY



GRAIN REFINING + LOWER C:
MUCH HIGHER HE



Typical composition:
0.07-0.20%C, 0.01-0.03%Nb, others: Mn, Si, Cr, Mo

Strength and ductility range (reference figures):
YS: 450 MPa-1,100 MPa Elongation (ef): 5%-25 %

A Pillar DP980

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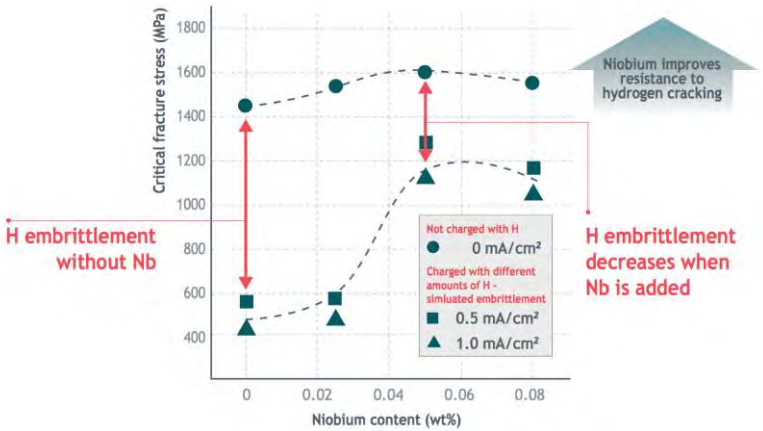
EXAMPLE 3:
PRESS HARDENED STEELS

IMPROVED BENDABILITY

RESISTANCE TO H-EMBRITTLEMENT



Niobium controls grain growth during heating to press-hardening, leading to better bendability. In addition, Nb nano carbides decrease the mobility of H, reflecting in better resistance to hydrogen embrittlement

Door reinforcement (1 mm)

B Pillar (1.85MM)

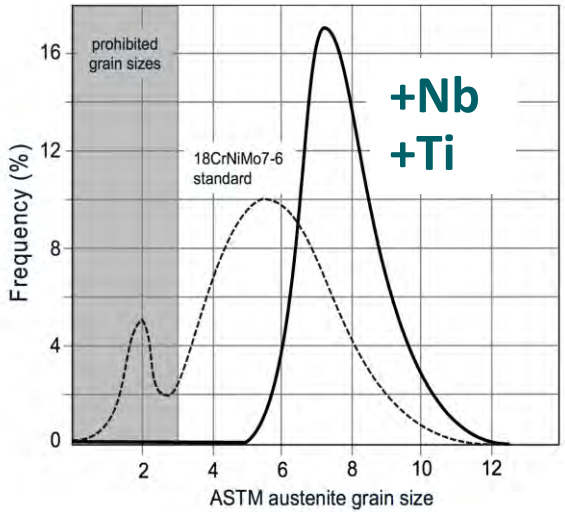
Typical composition:
0.15-0.25%C, 1.0-1.4%Mn, 0.02-0.04%Nb, others: B, Cr, Mo, Si

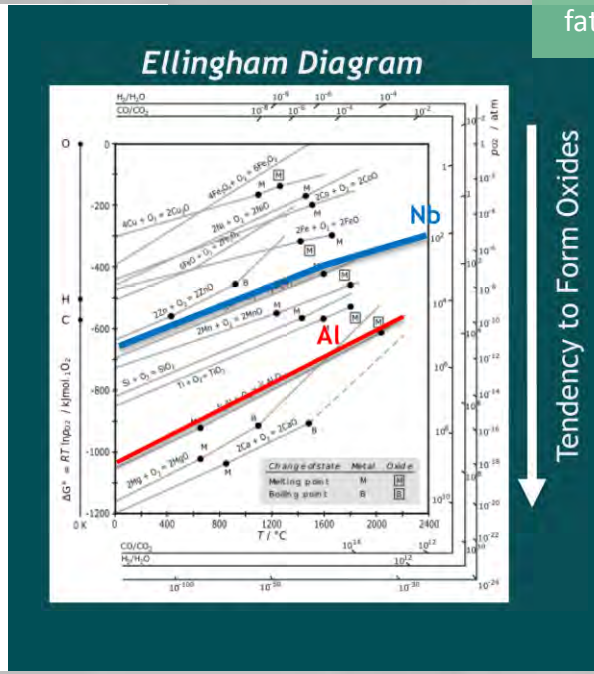
Strength and ductility range
(after heat treating – final condition):
YS: 1,000 MPa-1,900 Mpa Elongation (ef): 5%-10%

EXAMPLE 4:
GEAR STEELS

Niobium control in grain growth is more effective than Al, leading to:
i) smaller grain size and
ii) lower amount of Al inclusions.
Both factors lead to better fatigue life.

FINER GRAINS / POSSIBILITY HIGH T CARBURIZING





OTHER ADVANTAGES:
~30% less distortion
~10 to 20% better fatigue
+ cleanliness effect

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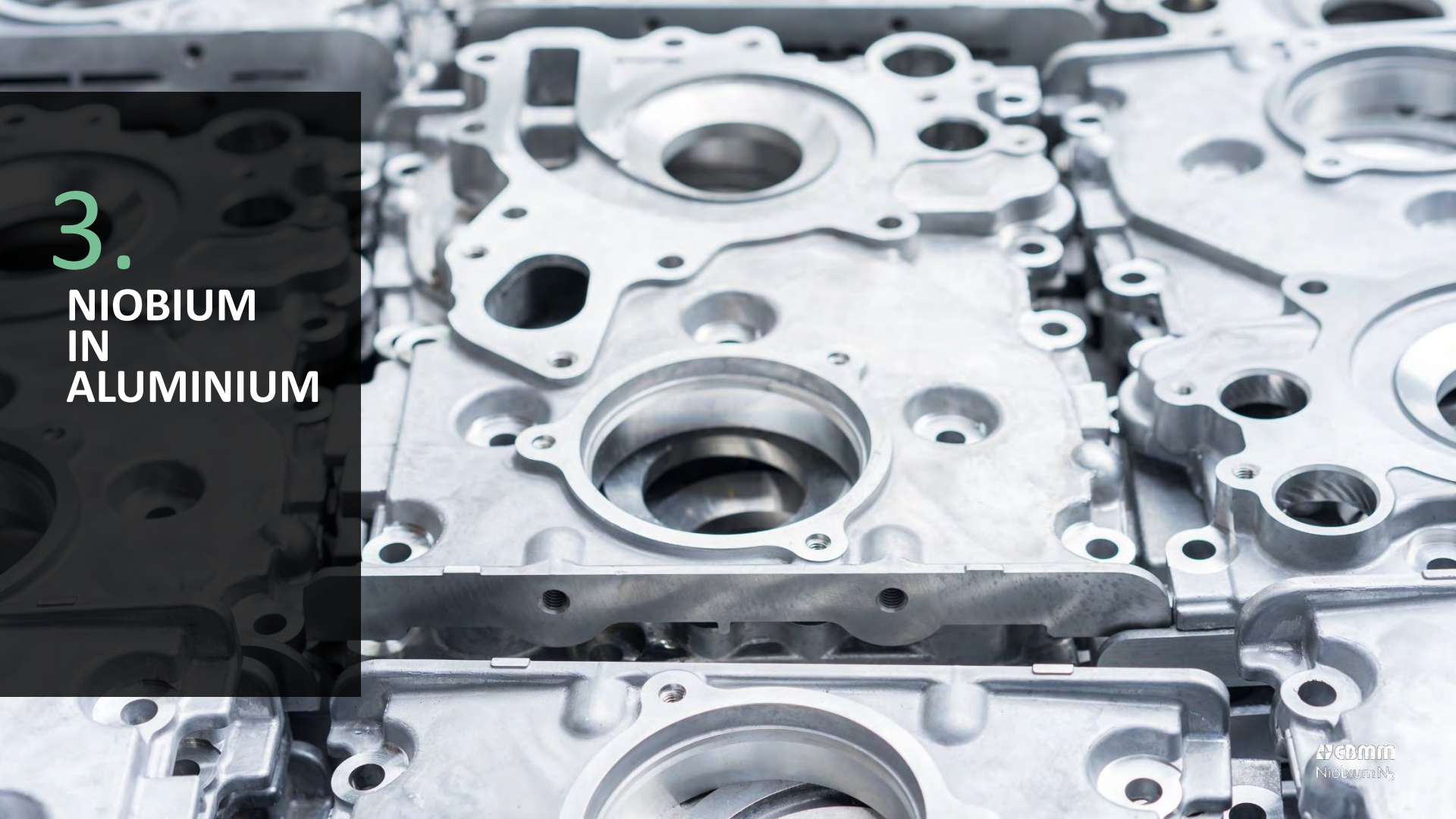
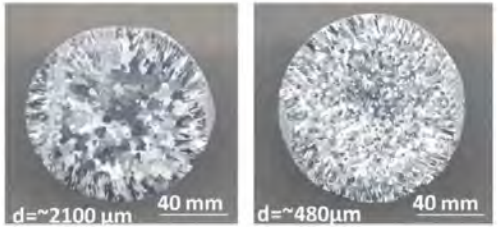
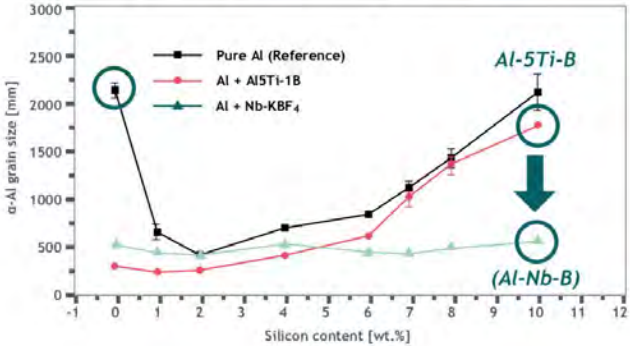


3.
NIOBIUM IN ALUMINIUM

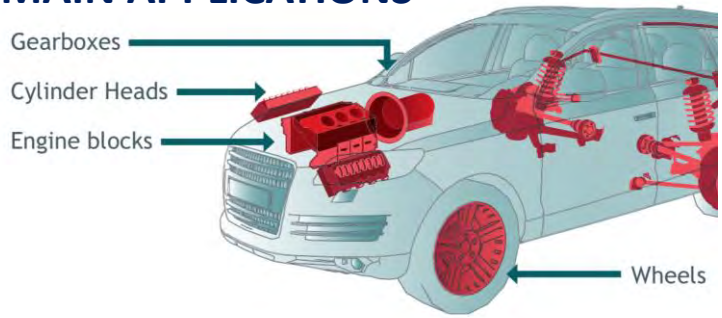
NIOBIUM IN ALUMINIUM CAST PARTS

BACKGROUND





MAIN APPLICATIONS



M. Nowak, L. Bolzoni , N. Hari Babu. Grain refinement of Al–Si alloys by Nb–B inoculation. Part I: Concept development and effect on binary alloys. Materials and Design 66 (2015) 366–375. BCAST

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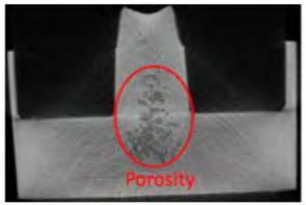
EXAMPLE 5:
IMPROVING CASTABILITY OF HIGH Si ALLOYS

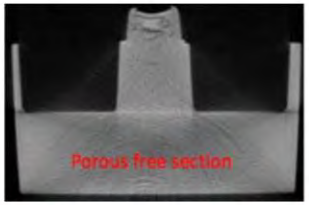
NIOBIUM ADDITION CREATES FINE AND UNIFORM GRAIN STRUCTURE

- Improving strength
- Reducing casting defects and shrinkage porosity
- Consistent across thin and thick sections

ENABLES LIGHTWEIGHTING



Al-9Si-2Cu alloy

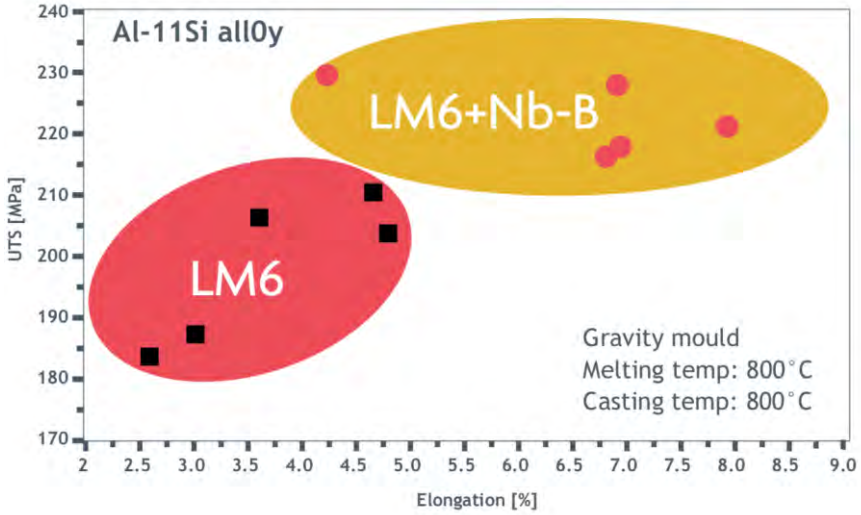


Al-9Si-2Cu alloy with Al-Nb-B

Fine and uniform grain structure in Al-Si alloy with Al-Nb-B master alloy addition

EXAMPLE 6:
IMPROVING MECHANICAL PROPERTIES AND RECYCLABILITY

HIGHER STRENGTH AND SAFETY



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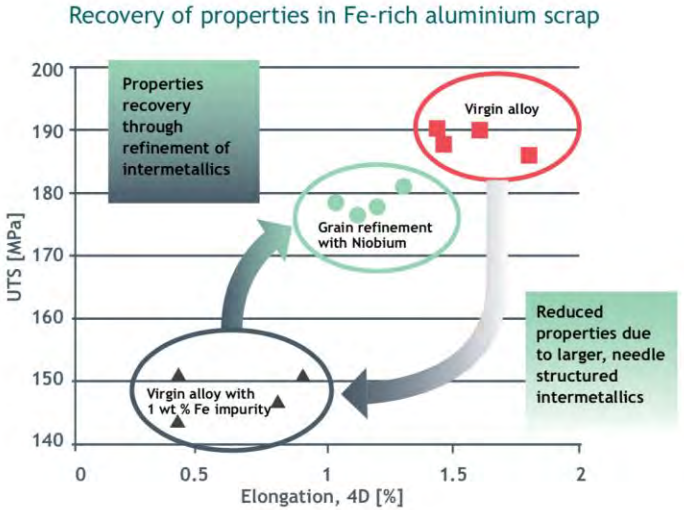
MORE TOLERANCE FOR IRON CONTAMINATION



SUMMARY AND CONCLUSIONS

- New advanced materials enable car makers to meet constant need to increase efficiency and safety whilst cutting cost and increasing performance
- Niobium steels have increased strength in combination with adequate formability (cost) and toughness (safety). Important either for current high strength steels and for new steels under development
- In Aluminum cast alloys, Niobium can reduce casting defects and potentially increase mechanical properties and recyclability
  - Enabling use of cast Aluminum alloys in new applications
  - Large scale production of Aluminum cast parts