Creating Materials and Energy Solutions

Aluminum/calcium deformation metal-metal composites

Charlie Czahor

WESEP 594 Seminar

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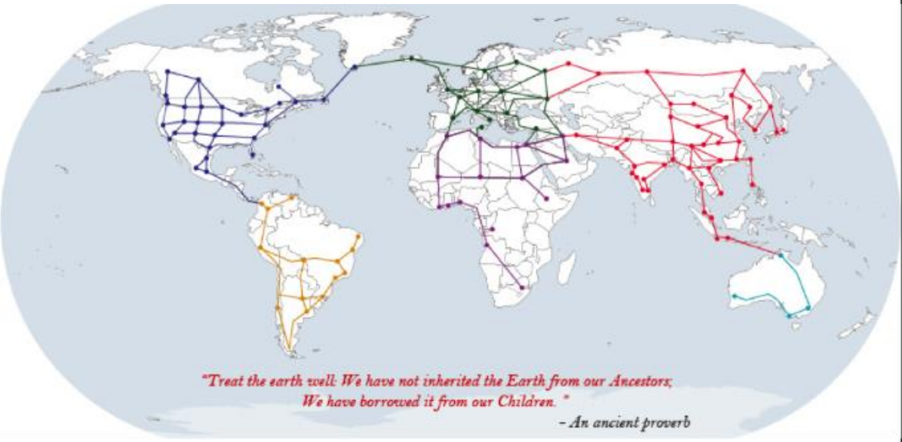
Overview

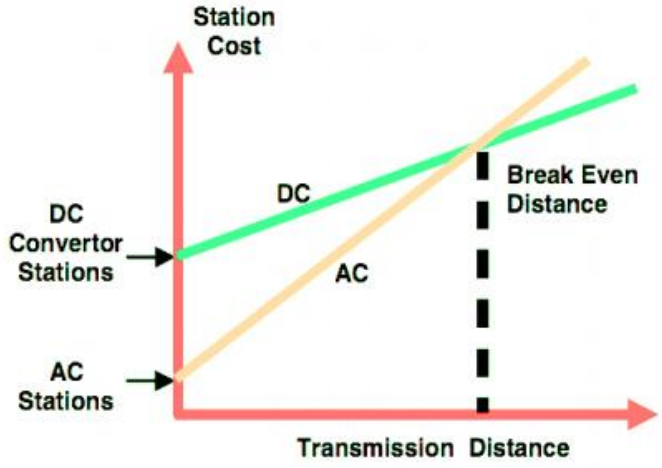
- Background and Motivation
- Sample Preparation
- Recent Results
  - Microstructure/Conversion
  - Conductivity
  - Tensile Strength
- Prospects for Installation
- Conclusions and Future Work



E. Morhardt, "Power Transmission: the Rise of the Supergrid", *The Economist*, 2017, pp. 71-72.

Background and Motivation

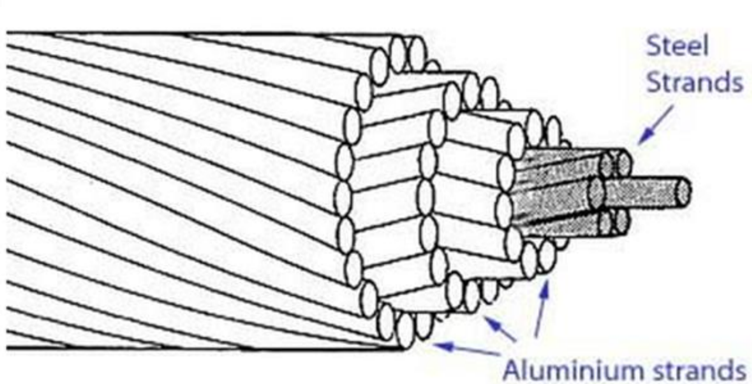
- **Objective**: Develop **<u>cost competitive, lightweight, high strength, high conductivity</u>** material for overhead power transmission.
- Increasing renewable generation capacity in remote areas requires long distance transmission to reach population centers.
- High voltage direct current (HVDC) is the preferred technology for long distance transmission.



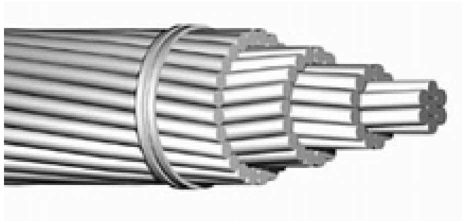
Current High Voltage Conductor Designs

- Aluminum Conductor Steel Reinforced (ACSR)
- All Aluminum Alloy Conductor (AAAC)
- Aluminum Conductor Composite Core (ACCC)
- Aluminum Conductor Composite Reinforced (ACCR)
- Aluminum Conductor Aluminum-Alloy Reinforced (ACAR)

ACSR

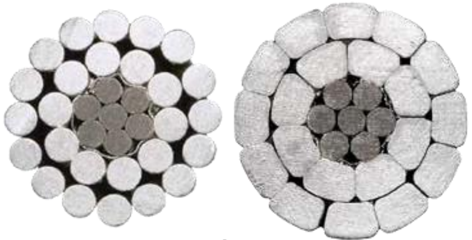


AAAC



ACCC

ACCR

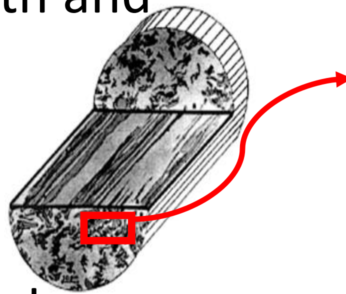


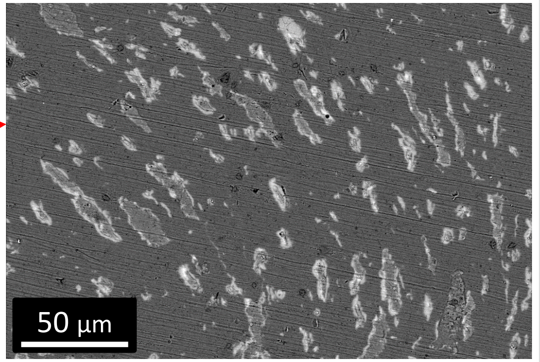
ACAR

ACSR catalog, 2012, Southwire, Carrollton, GA.

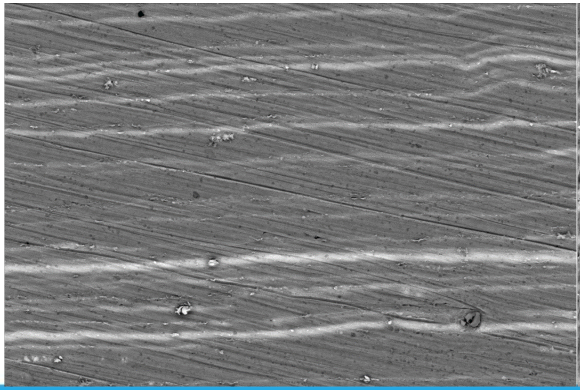
An Alternative Approach

- Deformation Metal-Metal Composites (DMMCs) can achieve both high strength and high conductivity.
- DMMCs utilize ductile metals in both the matrix and reinforcement phase.
- Extensive deformation allows filaments to reach sub-micron level.
- High strength with **no steel core**.

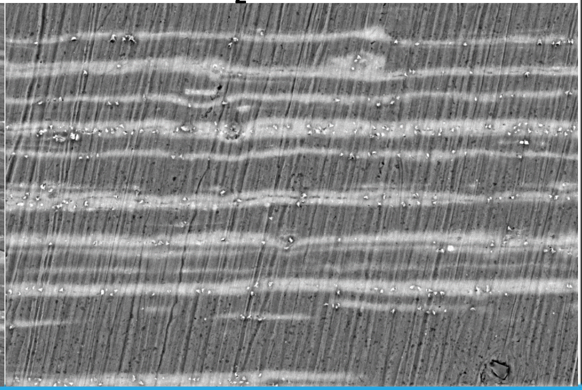




Unconverted
Al/Ca 11.5 vol. %



Converted
Al/Al_2Ca 18 vol. %



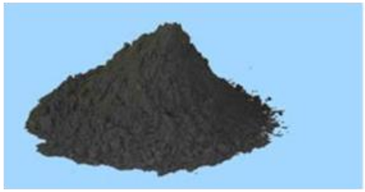
Element	Conductivity (IACS)	Cost	Density (g/cm^3)
Aluminum	61.0	Low	2.7
Calcium	48.7	Medium	1.5

Alan Russell, Scott Chumbley, Yu Tian, Adv. Engr. Matl., 2 (2000) 11-22.

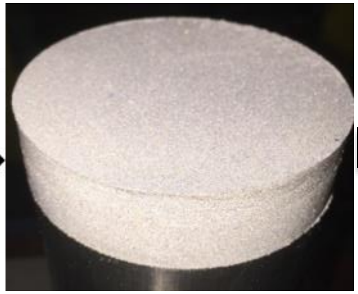
Sample Preparation

High purity atomized Al (88.5 vol. %)

+

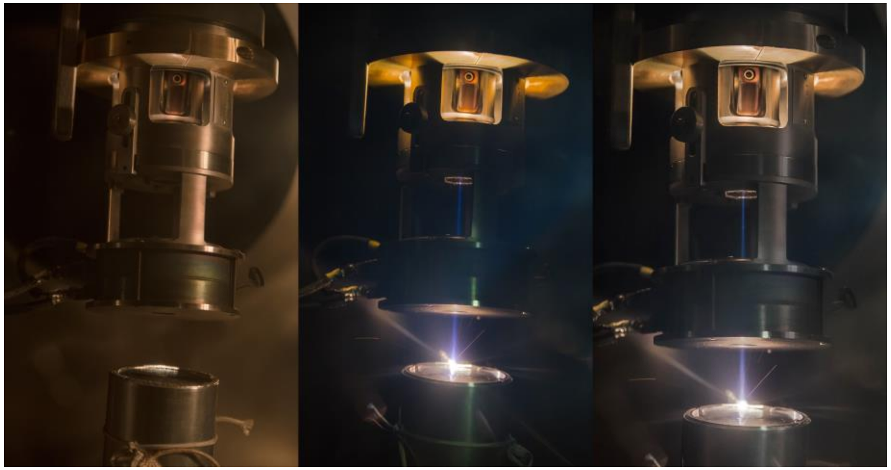


High purity fine atomized Ca (11.5 vol. %)

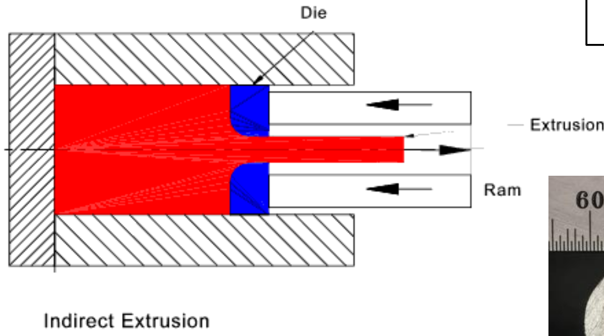


Blended powder compact

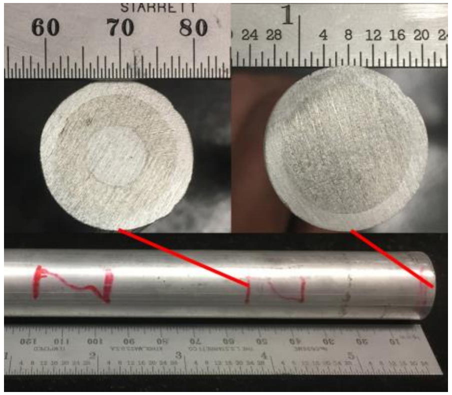
Extrusion can loaded with compacts



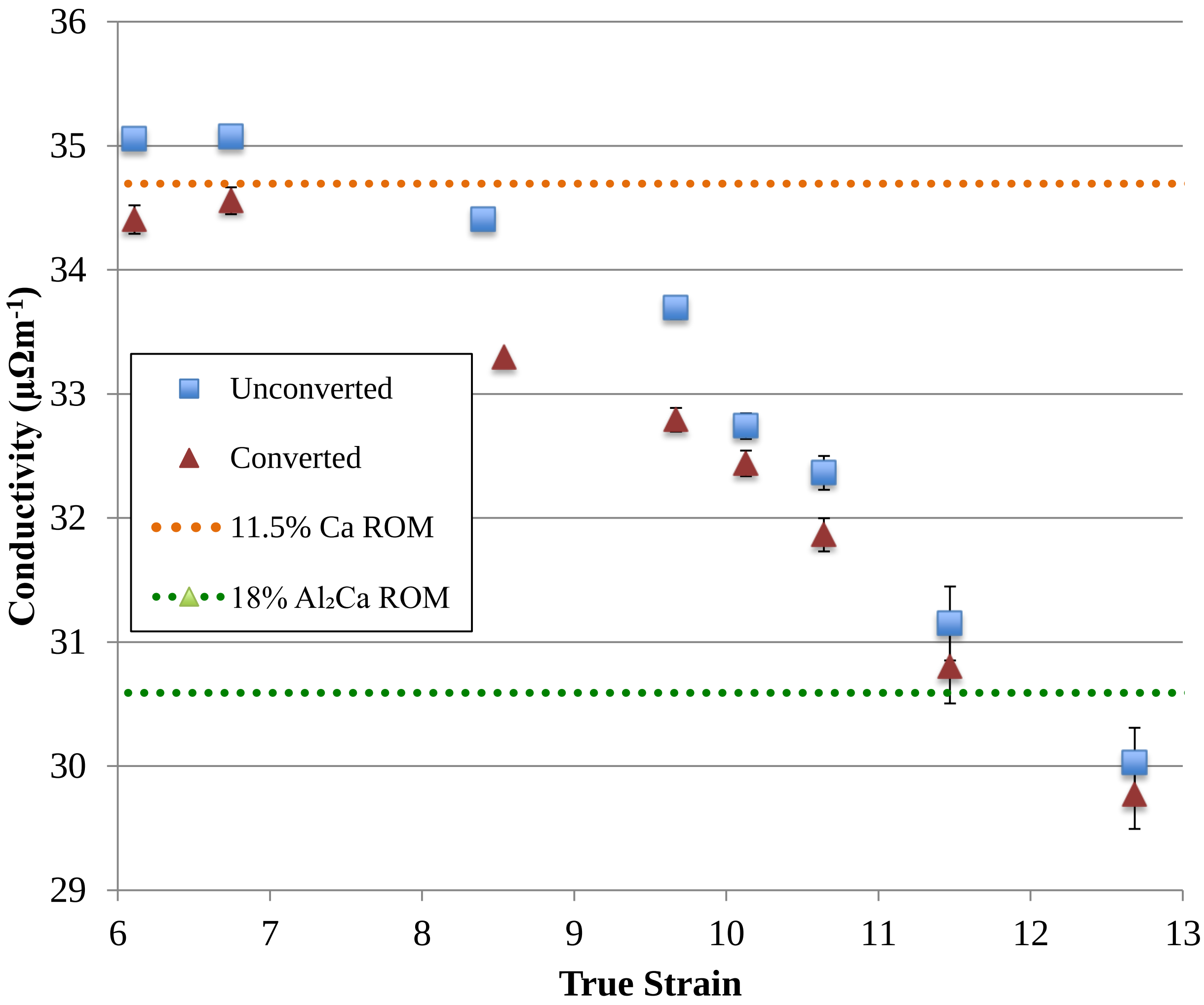
E-beam welding



Indirect Extrusion



Electrical Conductivity



- Close to rule of mixtures value at low strain
- Drop in conductivity at high strain from scattering at interfaces
- Conversion to Al_2Ca surprisingly has little effect

Ultimate Tensile Strength

- Hall-Petch strengthening with smaller filament size
- Al_2Ca reinforced wire stronger for all sizes

Filament Thickness

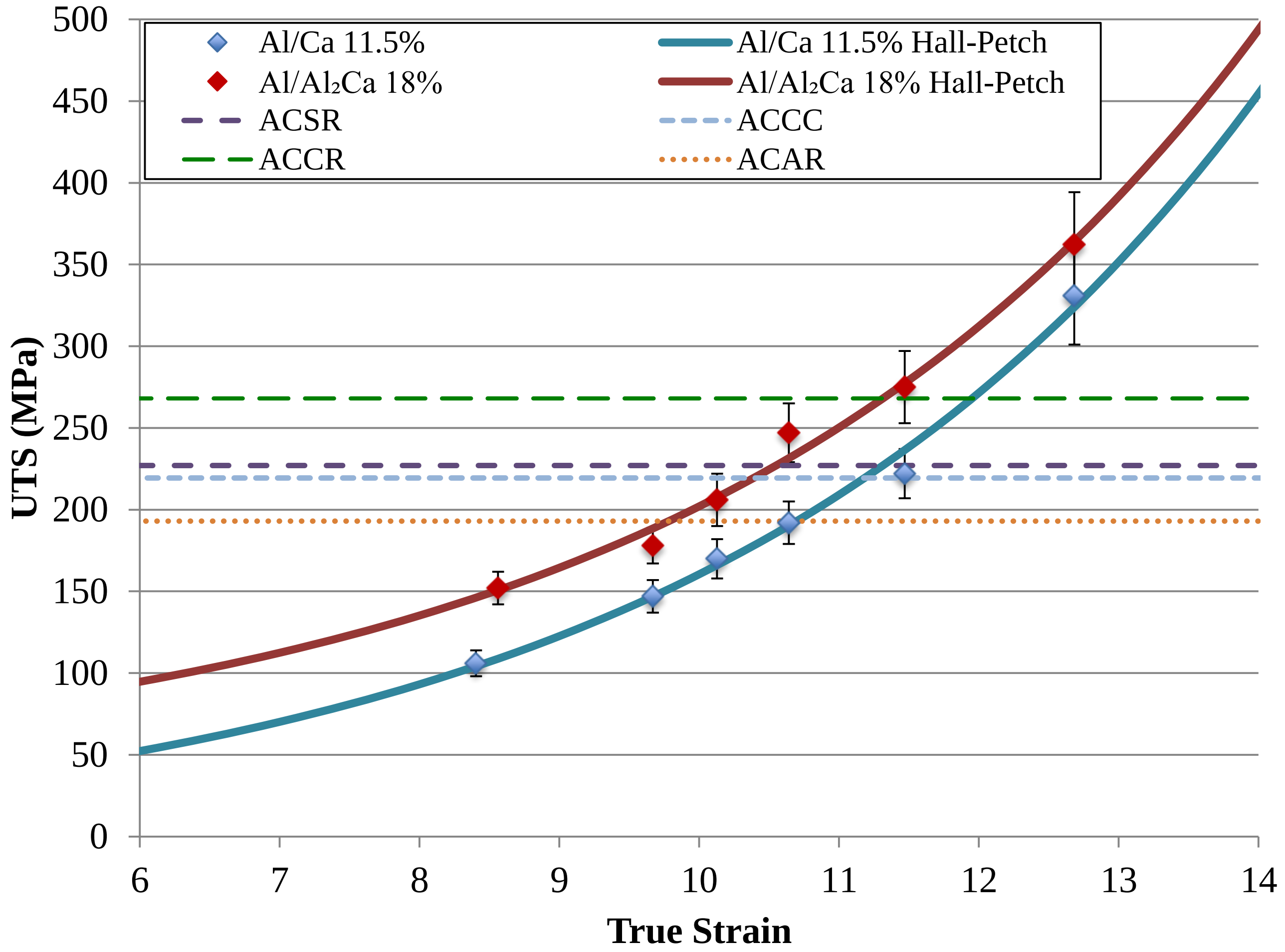
$$t = d_o e^{-\frac{1}{2}\eta}$$

Unconverted

$$UTS = -10.7 + \frac{148.0}{\sqrt{t}}$$

Converted

$$UTS = 32.3 + \frac{146.8}{\sqrt{t}}$$



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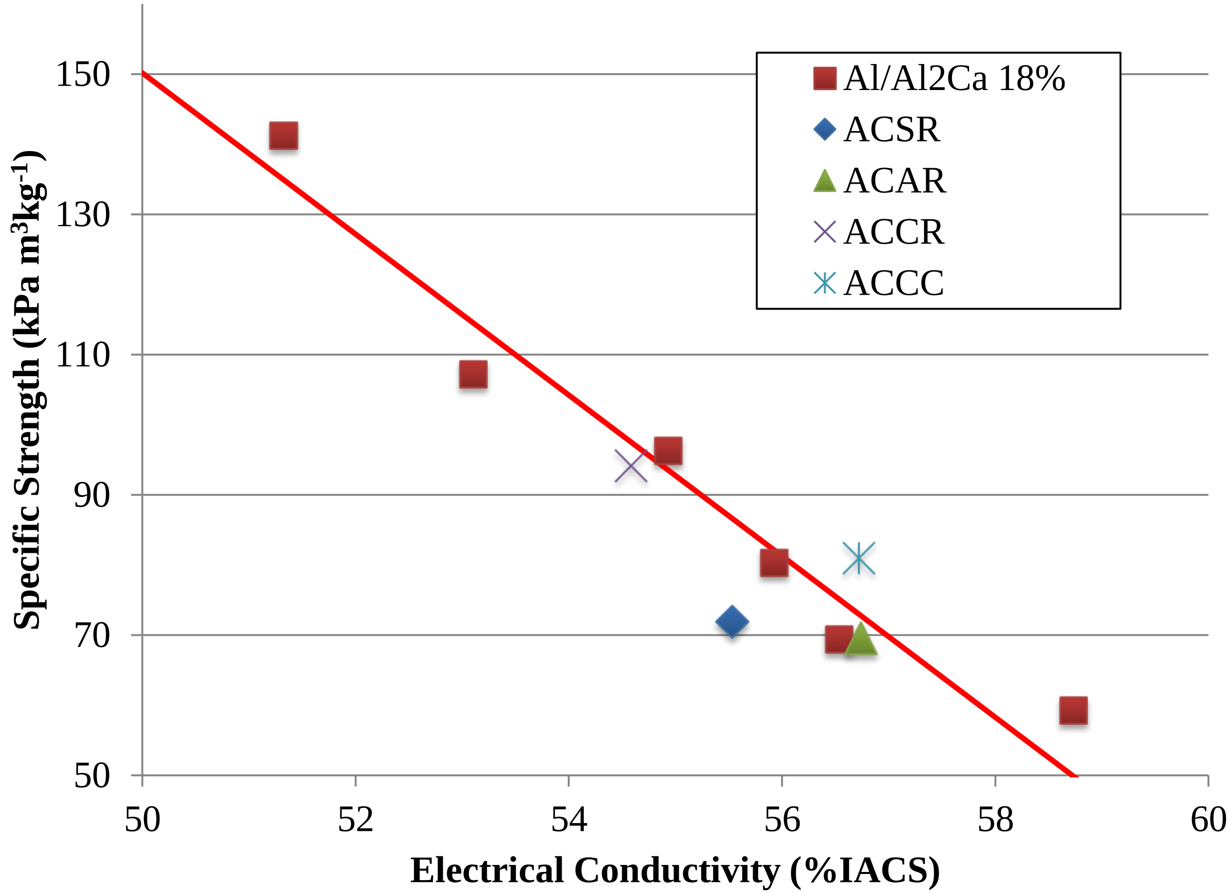
Comparison to Existing Conductors

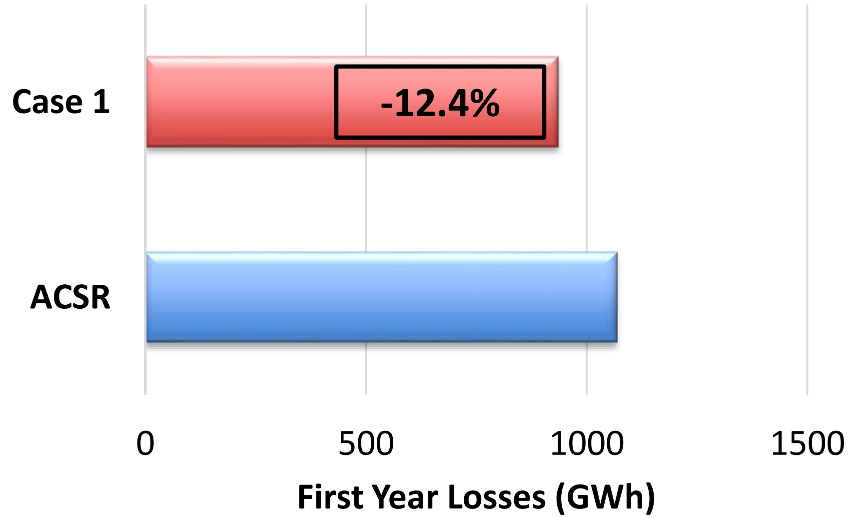
- Specific strength as great as two times that of ACSR
- Able to tailor composite properties for a specific application
- Modified properties with monolithic construction

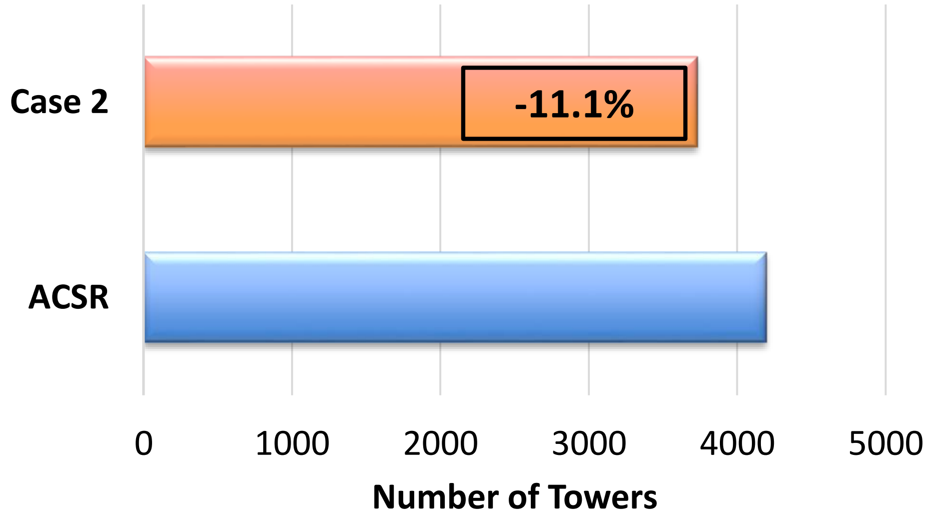


Potential Savings Using Al/Al_2Ca Composites

Scenario	Constant with base case	Varied
ACSR	As built	As built
Case 1	Tower spacing and weight per tower	Conductor Size
Case 2	Losses and weight per tower	Tower spacing and Conductor Size

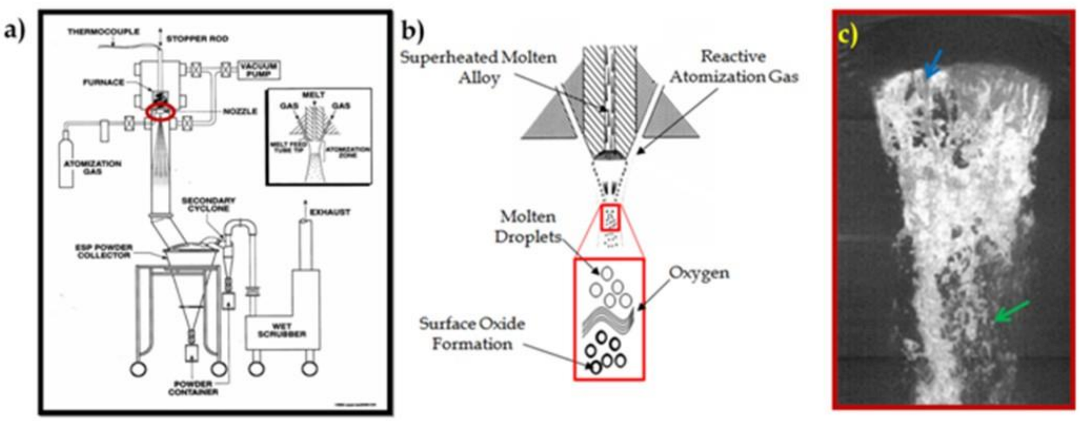
Design Parameters	
Conductor Cross Section	1171 mm^2
Voltage	±500 kV
Rated Power	3100 MW
Number of Towers	4200
Current	3100 A

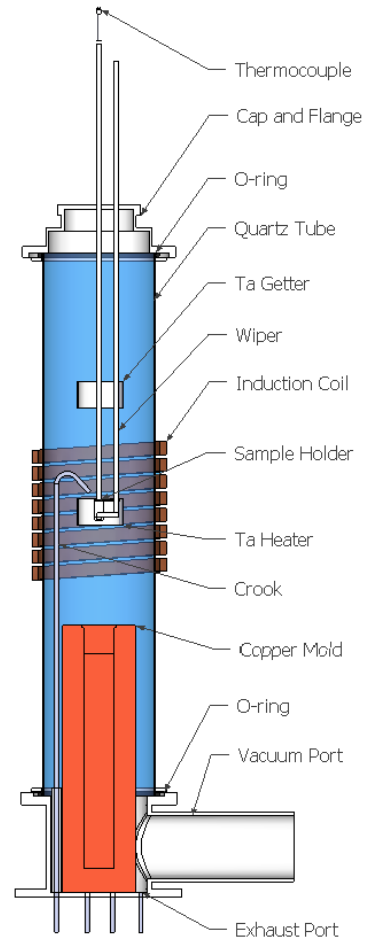




Ongoing and Future Work

- Development of gas-phase passivation for use during atomization of Ca powder.
- Enabling industrial production of high purity Al powder.
- Commercial extrusion sample for size conductor testing





Conclusions

- Metal-metal composites have potential to be used as overhead conductors.
- Converted Al/Ca composite were produced with **high strength, high electrical conductivity, and low density.**
- Weigh reduction and high strength can **increase tower spacing**.
- Several steps remain to move technology forward.

Acknowledgements

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Dave Byrd
Stephanie Choquette
Aaron Kassen
Emily Rinko
Tim Prost
Trevor Riedemann
Jordan Tiarks
Stacey Trytek
Dr. Emma White

Other Contributors

Extrusion: Soren Mueller-(TU Berlin)
Tensile Testing: Charles Spellman (Psylotech),
Matt Besser(Ames Lab)
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