Low Cost Fabrication of ODS Materials

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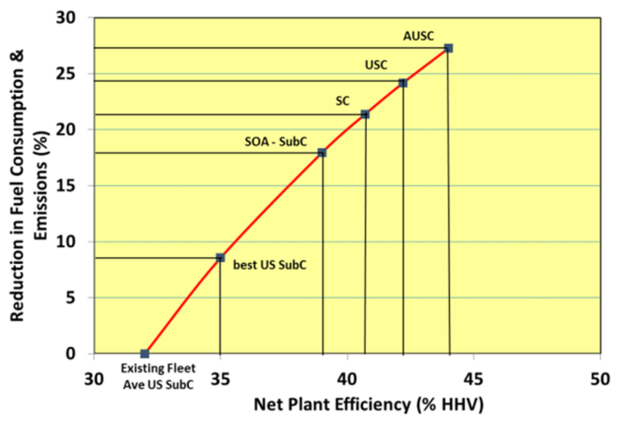
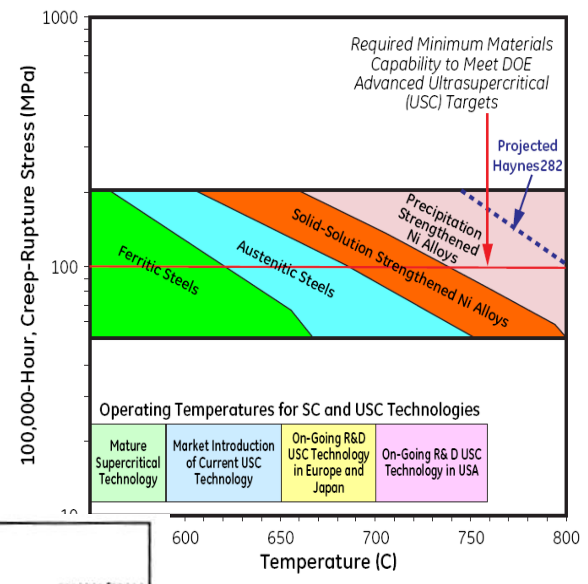
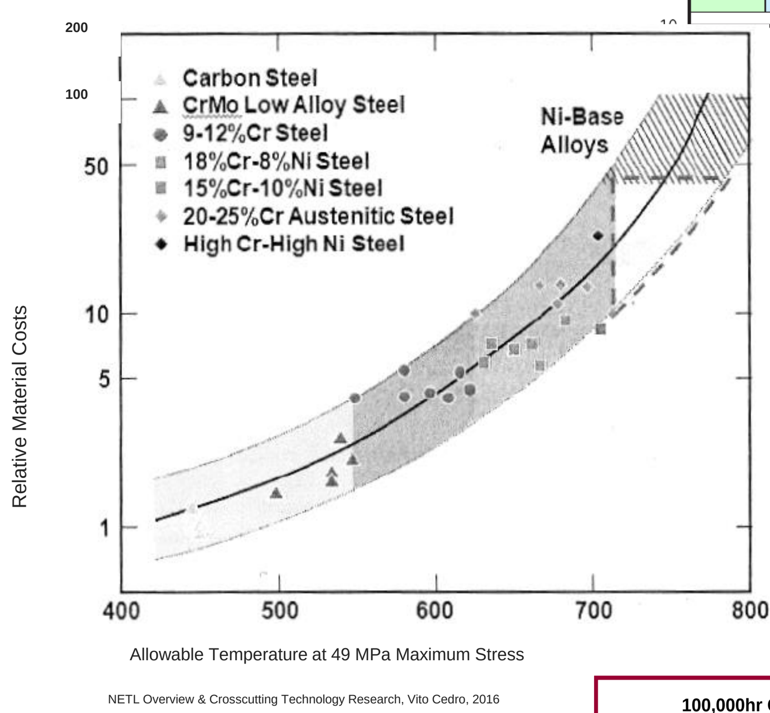
Motivation

The next generation of heat exchangers need to operate at higher temperature and pressure

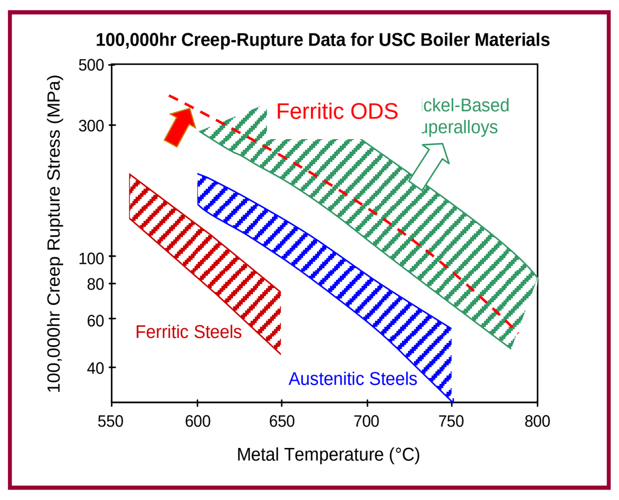






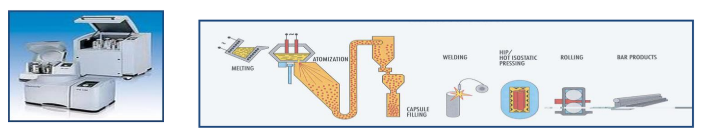
We need better creep and creep-fatigue performance above 700C, and we need it at a lower cost than Nickel alloys

Ferritic ODS can achieve properties



Why don't we have ODS Products

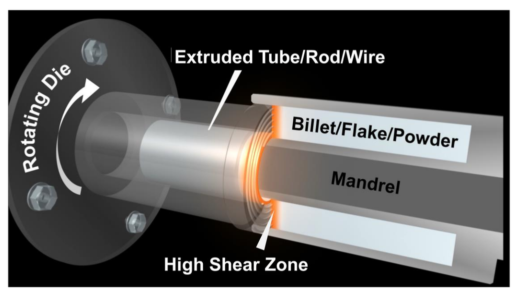
- **Manufacturing Cost - multistep process to make semi-finished products**
  - The high cost of ODS alloys and components is partially driven by the multistep , batch process of fabrication from powder to final product form
  - Traditional ODS materials prepared by MA routes are expensive because of sequential small batch processing. If volume demand was there, parallel processing could lower cost but the last ODS available, PM2000, was $400/ lb., reflecting the basic chicken – egg problem.

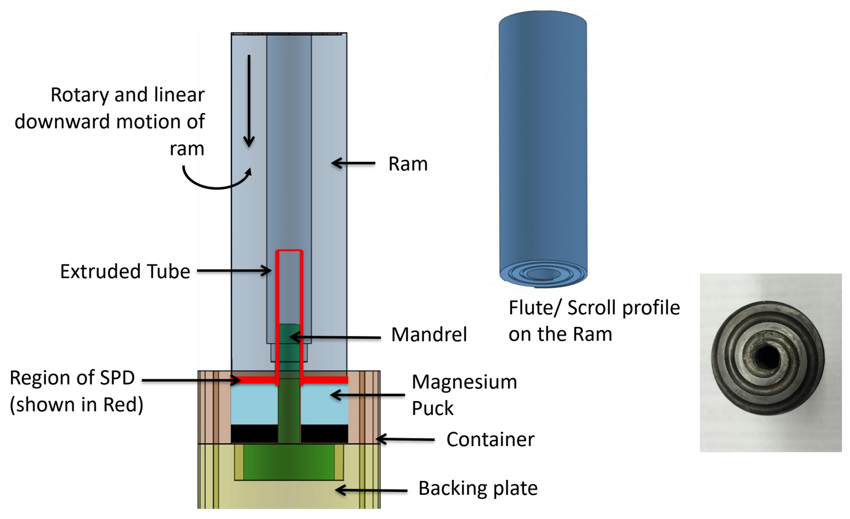


- **There are challenges associated with post processing, fabrication, microstructure control / stability**
  - ODS alloys can be hard to form, bend, pierce, draw, or pilger due to inhomogenaity that results in anisotropy, oxide stringering, and , in some alloys , low RT ductility

Are there alternative process routes that can remove the some of the costs and produce the right microstructure and workability when going from powder to semi-finished product ?

Shear Assisted Processing and Extrusion

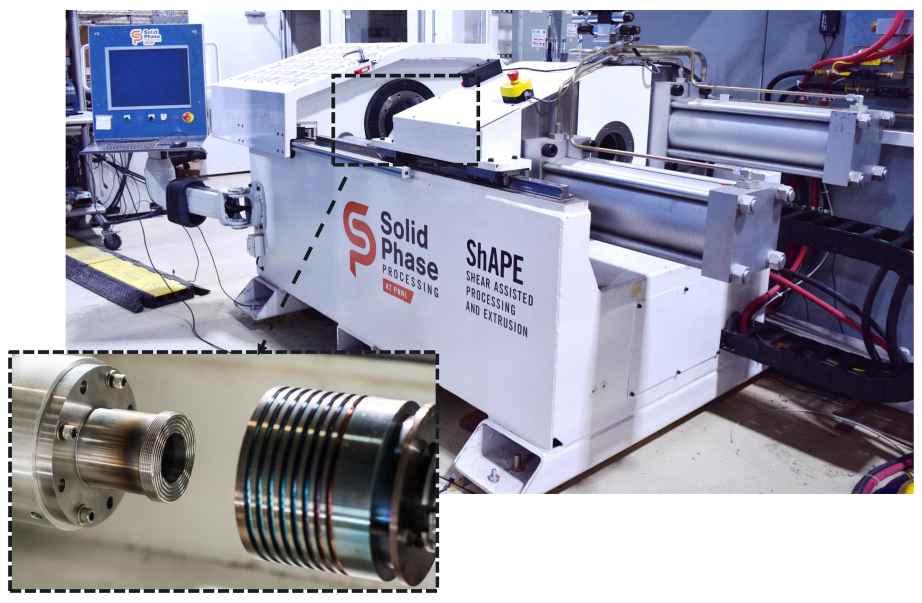


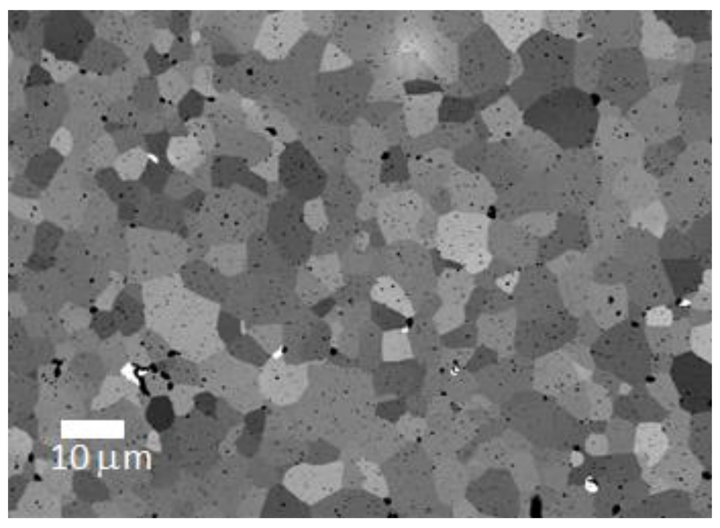


Can we make ODS materials this way?

	Mechanically Alloyed Powder	Gas Atomized Powder	Steel Powder + Y_2O_3
	Special Metals	*Sandvik Osprey*	*ATI Powder Metals*
	MA956	*Fe22Cr5AlYZr*	*Custom*
Fe	Bal	Bal	Bal
Cr	19.64	22.4	18.6
Al	4.87	6	4.94
Ti	0.39	-	0.5
Y_2O_3	0.5	-	0.5
Y	-	0.07	-
Zr	-	0.42	-
Oxygen	0.25	-	-
Si	0.07	0.21	-
Mn	0.09	0.2	0.04
Ni	0.06	-	-
N	0.031	-	-
C	0.02	-	0.02
Cu	0.02	-	-
Co	0.01	-	-
S	0.007	-	0.01
P	0.006	-	-

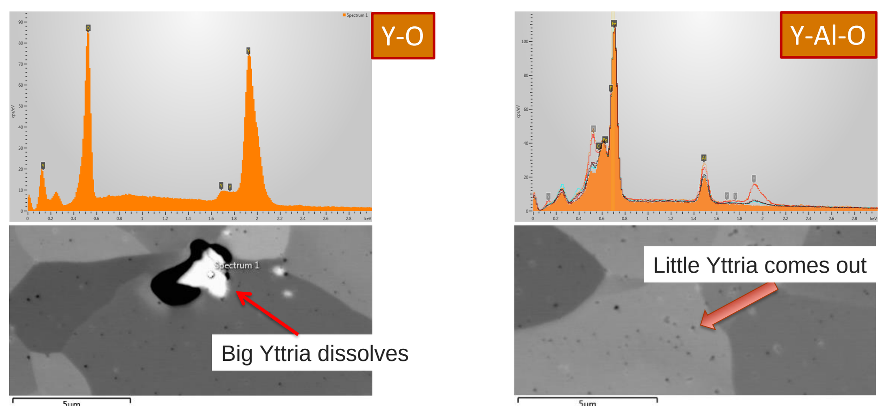
- MA – FCE can eliminate the downstream process costs but MA precursor still includes the up front MA cost
- GA - Reduces cost of "front end" powder step, but distribution of yttria may be a challenge (dependent on particle size?)
- Steel + Y - Further reduces cost of "front end". If the primary "mixing" occurs in the Friction Consolidation process, then the distribution of Yttria in starting powder may not be as important



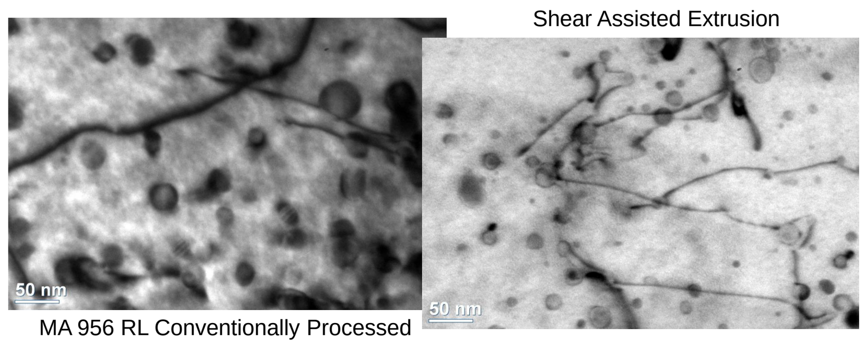


- For all three powder compositions and product forms, we were able to make fully dense compacts and extrudates
- Equiaxed 6 micron grain size
- Larger particles 100nm to 0.5 micron are Al-Y-O compounds: YAP and YAG
- Particles were distributed homogeneously

- Grain are NOT elongated in the longitudinal direction.
- Particles are homogeneous
- No oxide stringering

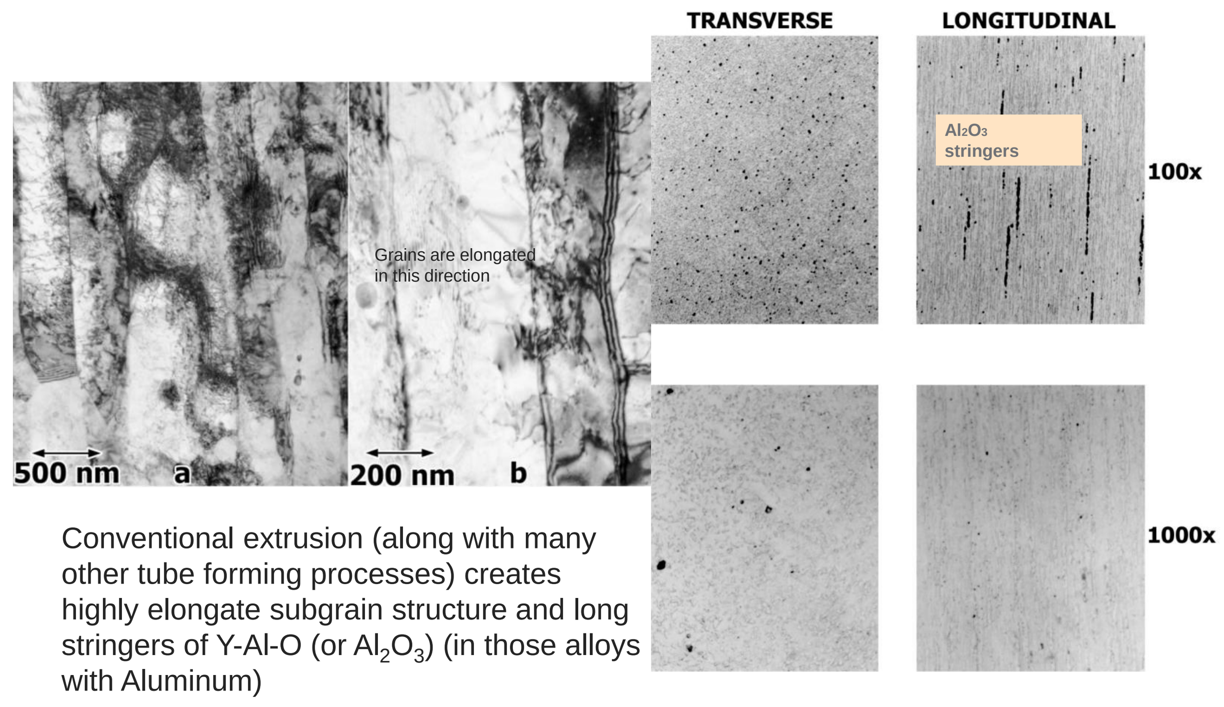


- This powder started as a 40µm steel powder mixed with 0.5% 1 to 5 µm yttria particles. Final compact shows very little coarse yttria.
- Process dissolves coarse yttria and re-precipitates dispersoid Y-Al-O



- TEM shows similar size dispersoids in the ShAPE processed pucks as in conventionally processed MA956
- Small 5 to 20 nm dispersoids are Al-Y-O and Y-O
- The ShAPE process may be able to make the right microstructure in one process step

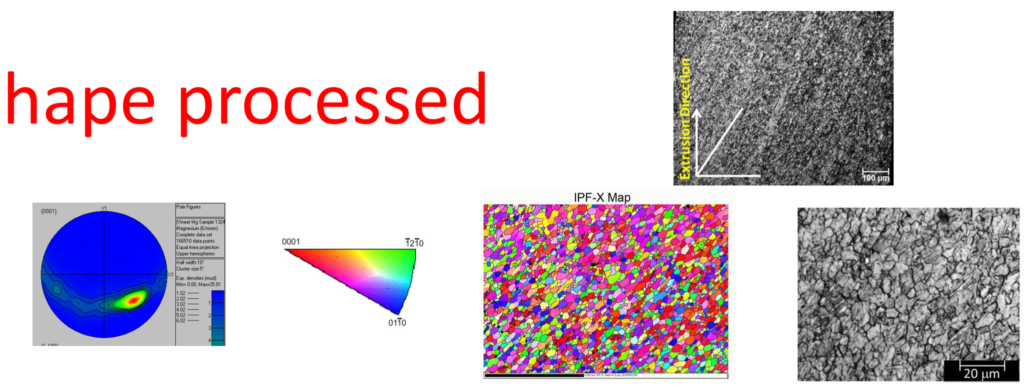
Texture and elimination of mechanical anisotropy



Conventional extrusion (along with many other tube forming processes) creates highly elongate subgrain structure and long stringers of Y-Al-O (or Al_2O_3) (in those alloys with Aluminum)

This can have a negative effect on properties needed for post processing (rolling) and in service performance

Shape processed



- Grain size less than 5 microns and oriented 45deg to the extrusion axis
- The texture direction is influenced by the ratio of the rotation rate to the extrusion rate
- In ODS alloys that have secondary recrystallization behavior, this may allow for growth of elongated grains in a unique (spiral) direction in the tube/pipe

Anticipated Project Outcome

- **Ability to produce product forms directly from powder, eliminating numerous /costly processing steps (e.g. mechanical alloying, canning, HIPing, extrusion, etc.**
  - Application to near-net shape processes (Rod or shaped extrudate)
  - Application to tubing and piping
- **Process has the potential to produce appropriate microstructures for post processing or application**
  - Process can create equixed microstructure – reduction of anisotropic behavior?
  - Process does not produce oxide stringers
    - reduced problems in roll processing
    - reduction in defects and low fracture toughness due to stringers
  - Strain induced mixing allows even poorly mixed Fe-Cr-AL-Y powders to be used as feed stocks, lowering feedstock cost
  - Process can produce customized texture in the extrudate not possible by other methods
- **Solid Phase processing has the opportunity to eliminate most of the steps in going from powder to semi-finished product**
- **Ability to process novel alloy compositions and microstructures without melt/solidification steps - critical to ODS alloys and other non-equilibrium systems**
- **The Shear Assisted Extrusion process loads are far below those of conventional extrusion allowing for:**
  - Reduced factory footprint (process intensification)
  - Reduced energy embedded in the semi-finished product.

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Solid Phase PROCESSING