ODS STEEL DATA SURVEY AND ANALYSIS (2008-2014)

147 papers published since 2008 ; from Elsevier's data base, Science Direct.

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OECD/NEA HQ, Paris

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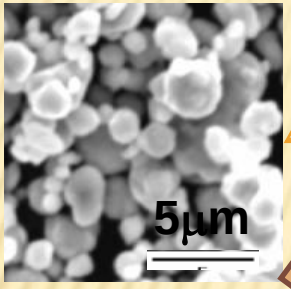
Oxide Dispersion Strengthened (ODS) Ferritic Steel



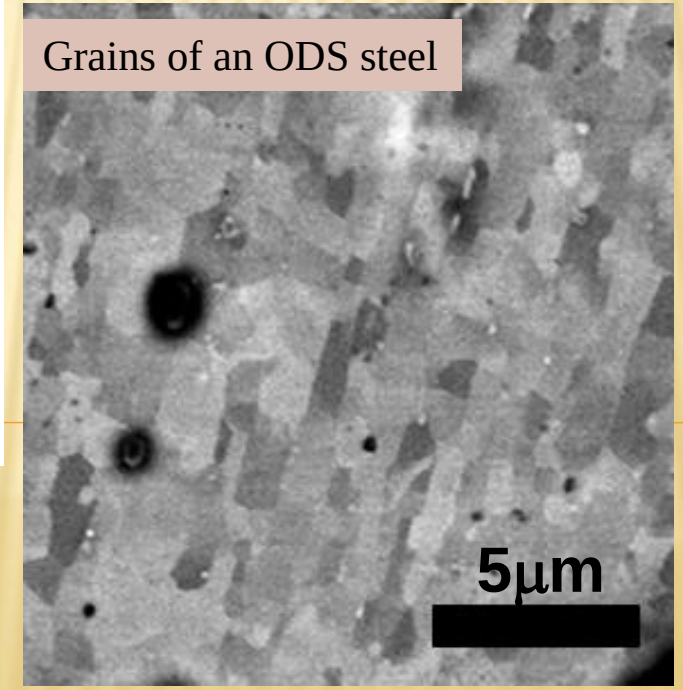
Powder raw materials/
Gas atomized powders

Mechanical Alloying (MA) by a plenary mill or an attritor device

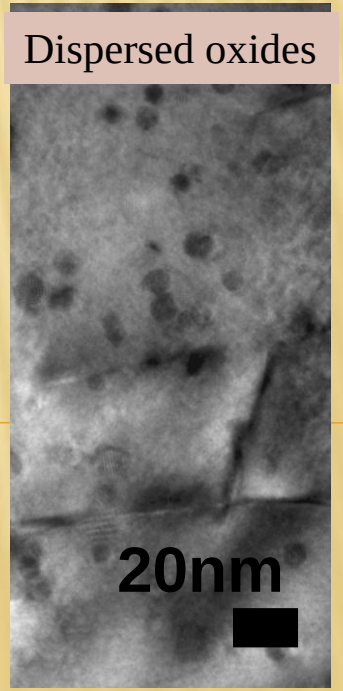
Consolidation by a hot isostatic pressing (HIP) or a hot extrusion methods

- Powder metallurgy
- Mechanical alloying
- Consolidation by sintering/solid phase diffusion
- Strengthened by dispersed fine oxides

Grains of an ODS steel



Dispersed oxides



A Quick View of ODS Steel R&D History for Nuclear Application

- *Start from heat resistant high Cr steels.*
- *Alloy design done for nuclear application; SFR, Fusion low activation and radiation damage tolerant steels*
  - *Late 80'; 8-9Cr/2W type low activation ferritic steels (JLF-1, F82H) followed by Eurofer 97*
  - *Early 90'; 9Cr/2W type ODS (JLF-OD for Fsion))*
    12Cr/2W type ODS (JNC ODSF14 for SFR)

- *European Fusion and Gen IV Programs have been intensively developed ODS steels; 9Cr/1W type*

- *US DOE programs for Fusion and Gen IV have been intensively developed ODS steels; 12CrWTiY, 14CrWTi*

Traditional ODS Steel Developments

- *Creep strength and high temperature strength*

These properties are owing to fine oxide dispersion. Yttria forms several tens nm diameters dispersed particles.
Titanium addition makes Y-Ti-O complex oxides finer to be 2-4 nm diameters.

- *Oxidation resistance*

Aluminum forms alumina layer on surface and enhances oxidation resistance.
However, Al has smaller oxide formation energy than Ti, and tends to form Y-Al-O complex oxides having two or three times larger diameters than Y-Ti-O. Al addition tends to degrade creep strength.

Although there have been many accomplishments, ODS steels such as MA956, MA957 and PM2000 are not commercially available after early 2000s

Recent ODS steel developments.

- For fusion reactors, 9Cr-2W type ODS steels (JLF-ODS; 1994) and 9Cr-1W type ODS steels (Eurofer ODS) without Al have been developed. 14YWT is also this type. These materials includes Y and Ti but no Al, These steels aim to reduce activation and fast decay.

- For Gen IV fission reactors and recently toward ATF R & D, new Al added ODS steels with fine dispersion of oxides such as super ODS steels are being developed.

ODS steel commercially available: ODM751

Based on limited information

Typical ODS steels (without Al addition)

Elements	ODS Eurofer97	12YWT	DY	14YWT	MA957
Fe	bal.	bal.	bal.	bal.	bal.
Cr	9	12	13	14	14
W	1.1	3		3	
Ti	-	0.4	1.5	0.4	0.9
Al					
Mo	-	-	1.5	-	0.3
Mn	0.4	-	-	-	-
V	0.2	-	-	-	-
Ta	0.12	-	-	-	-
C	0.11	-	0.015	-	0.01
Y_2O_3	0.3	0.25	0.5	0.3	0.25
Other	0.03N	-	$1Ti_2O_3$	-	-
Manufacturer	Plansee/FZK Institute	KOBE Metal	CEN/SCK, Dour Metal, CEA	ORNL	INCO Metals

12YWT is the same material as Japanese JNC ODS F14
ODS Eurofer, 12YWT and 14YWT are “Reduced activation ferritic” steels.
ODS Eurofer and 14YWT are under developments.

Typical ODS steels (with Al addition)

Elements	ODM751	PM2000	MA956	K2-K5 alloy	SUPER ODS			
					Super ODS-1	Super ODS-5	Super ODS-14	Super ODS-16
Fe	bal.	bal.	bal.	bal.				
Cr	16.5	19	20	14-22	16	16	16	16
W				2			2	2
Ti	0.6	0.5	0.5	0.3	0.1	0.1	0.1	0.1
Al	4.5	5.5	4.5	4.5	4		4	4
Mo	1.5		-					
Mn	-	-	-					
V	-	-	-	0.06				
Ta	-	-	-					
C	0.05	0.05	0.05	0.04-0.1	0.02	0.02	0.02	0.02
Y_2O_3	0.5	0.5	0.5	0.35	0.35	0.35	0.35	0.35
Other	-	-	-				0.5Zr	1Hf
Manufacturer	Dour Metal s.r.o.	Plansee GmbH	INCO Metals	Kyoto Univ./KOBE	Kyoto Univ./KOBE	Kyoto Univ./KOBE	Kyoto Univ./KOBE	Kyoto Univ./KOBE

There are many other Super ODS steels
ODM751 is commercially available

DATA Survey of ODS Steels

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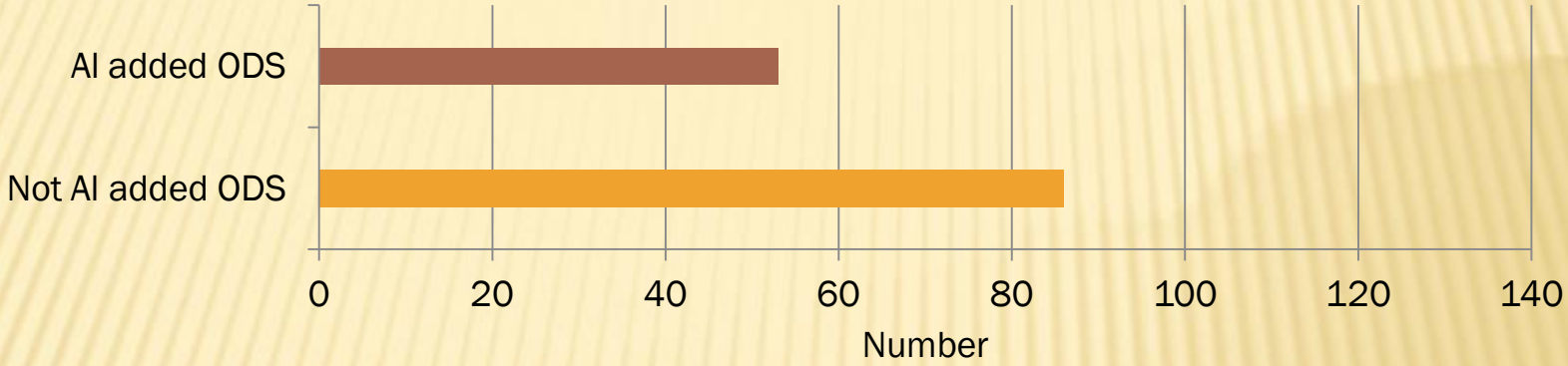

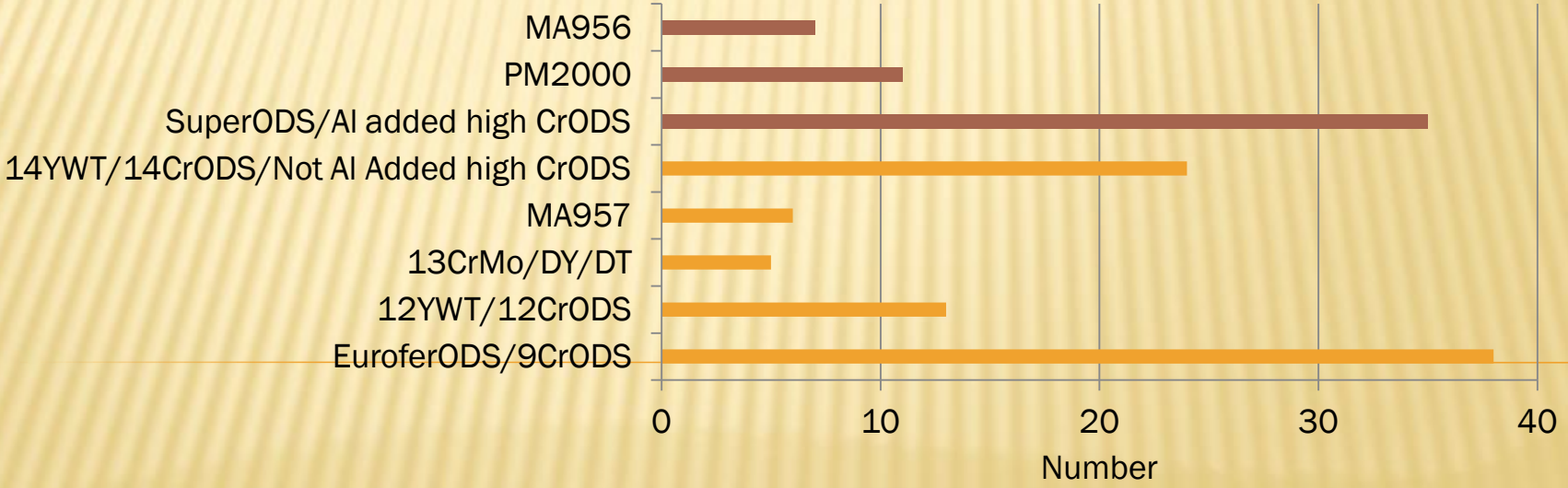

Baseline Properties

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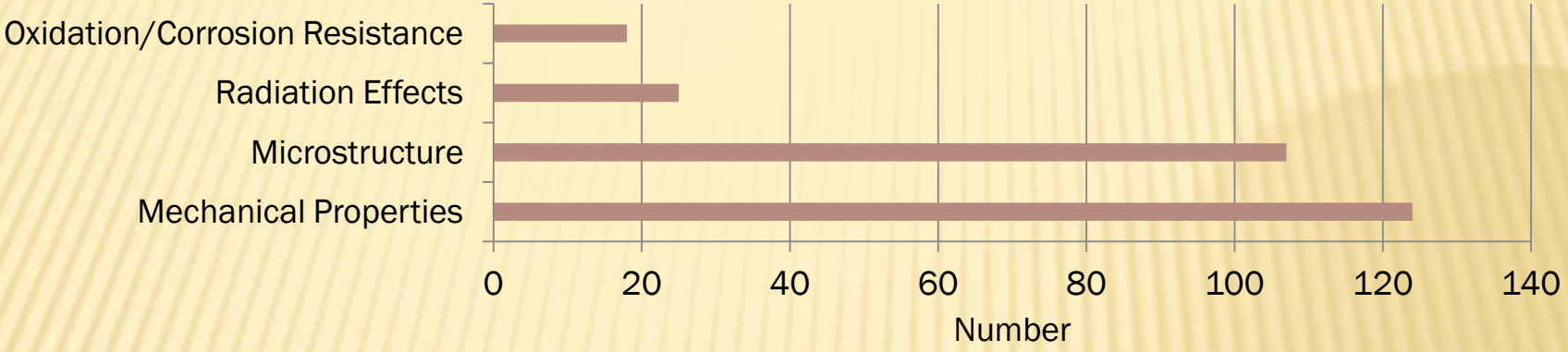
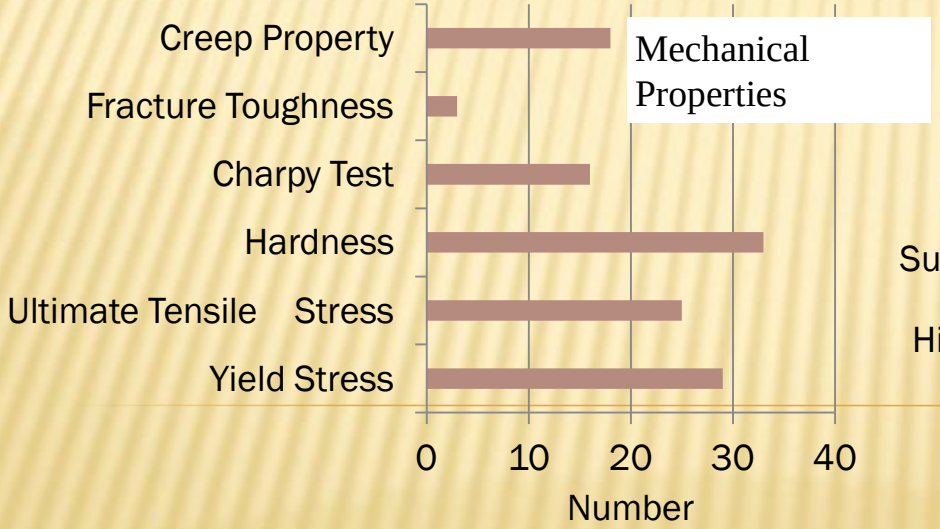
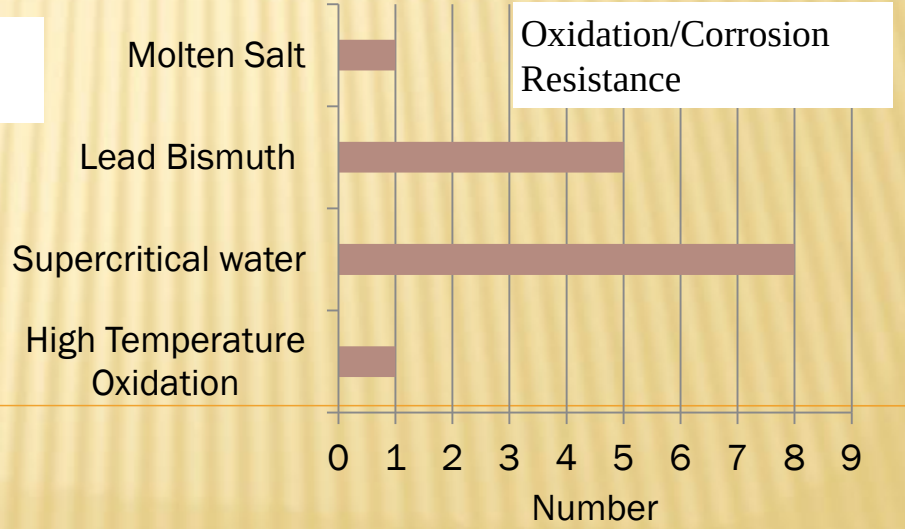
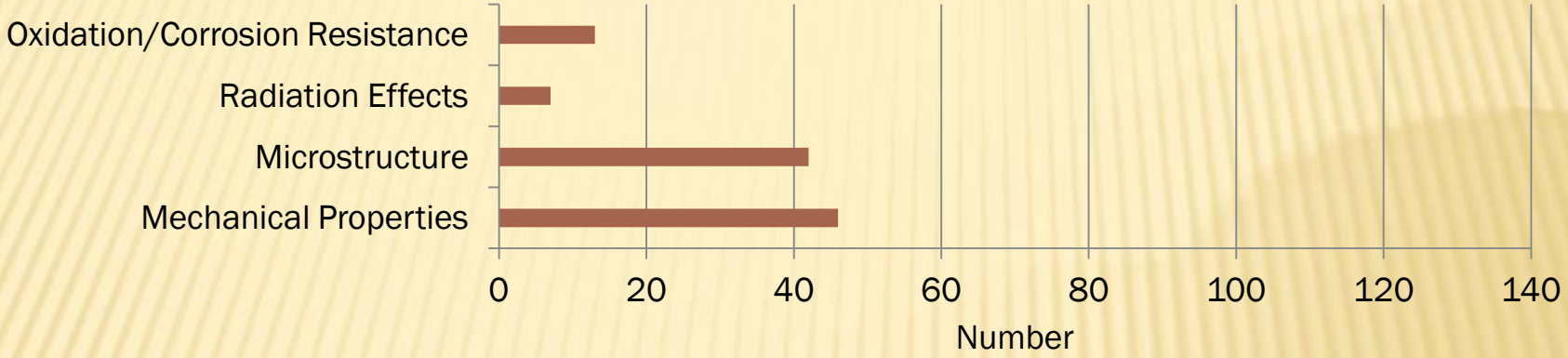


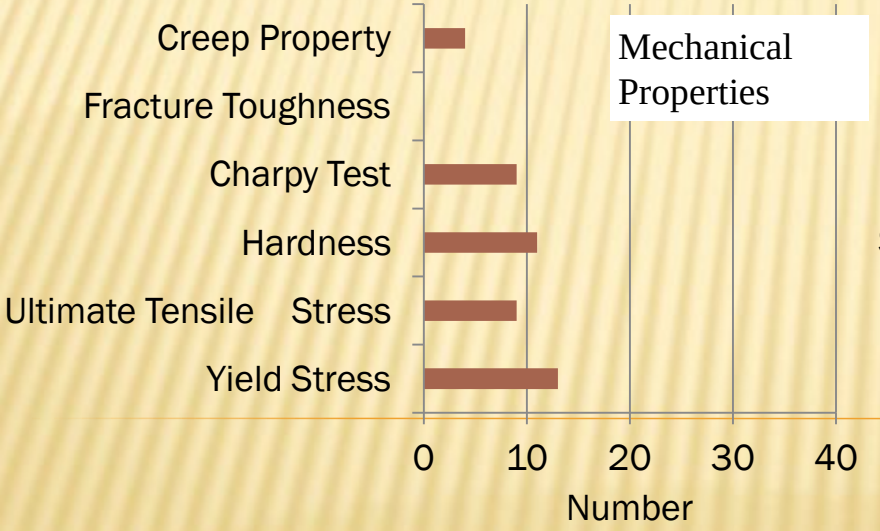


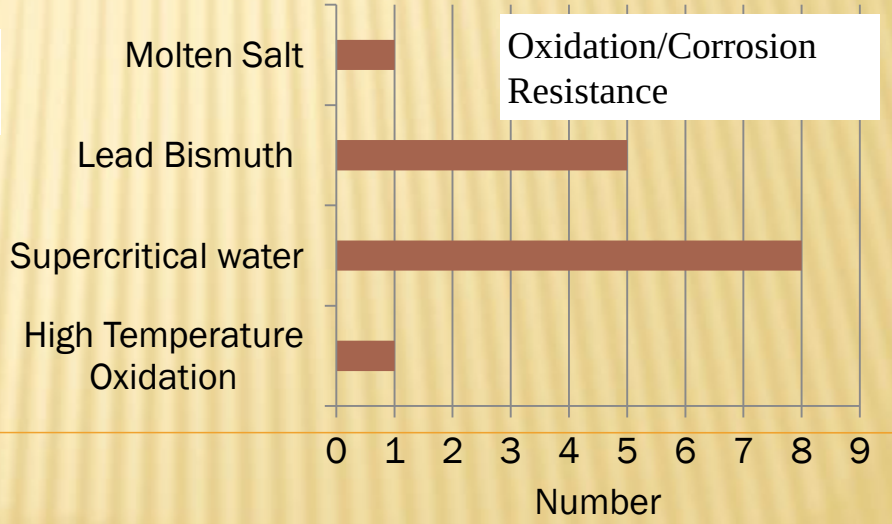


Major efforts are on mechanical properties and microstructure by small specimens

Baseline Properties (for Al Added ODS Steels)

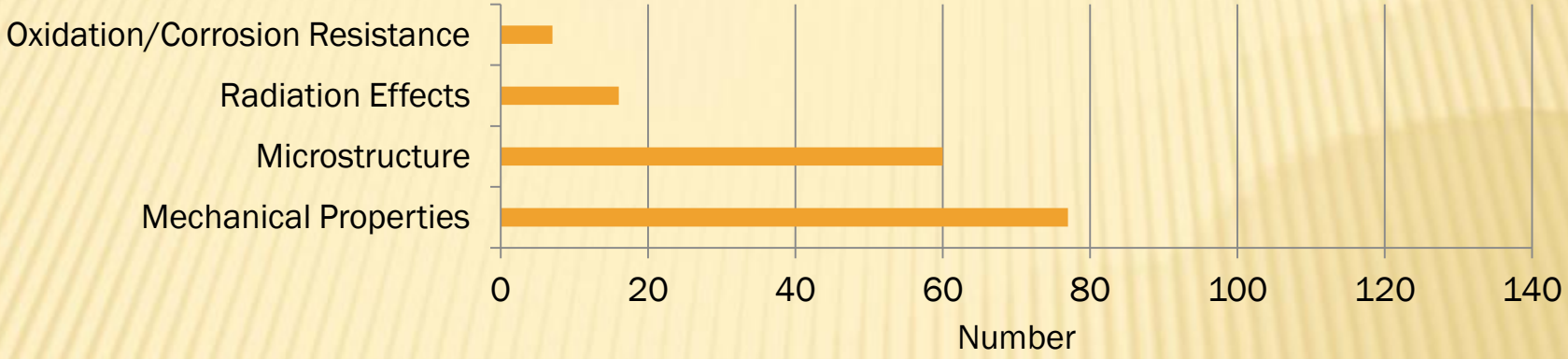


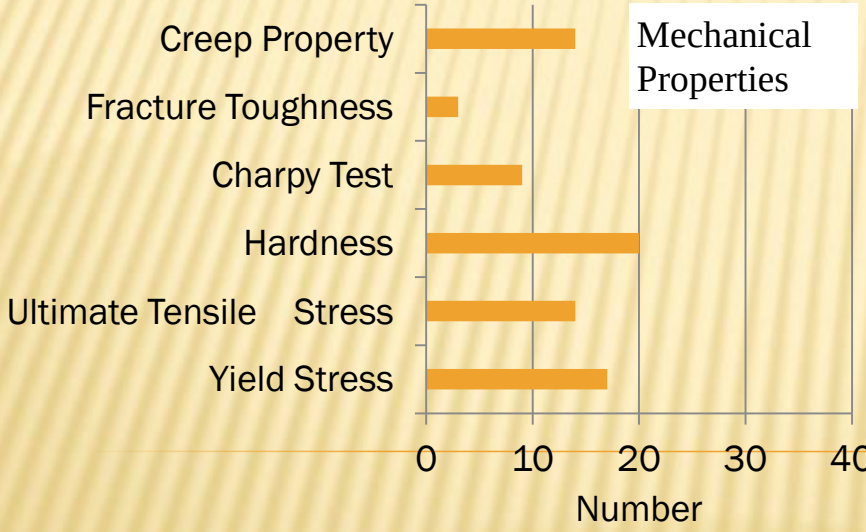


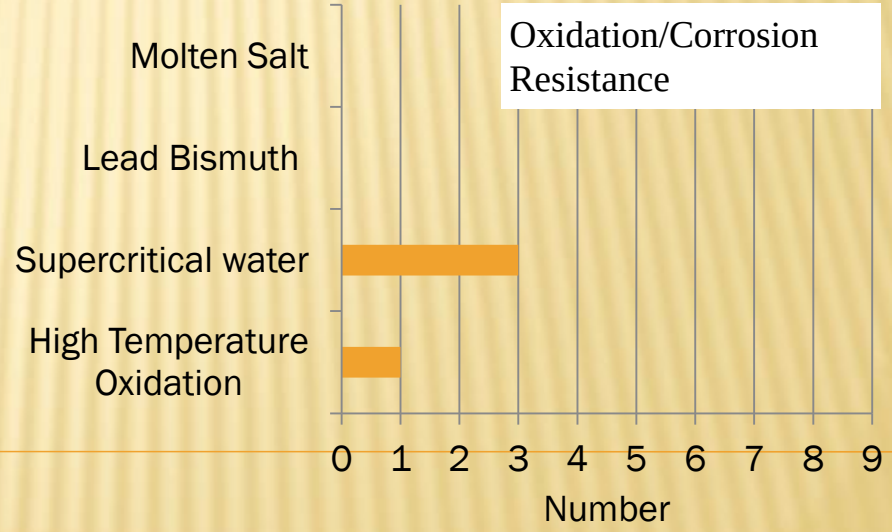


Major efforts are on material processing and environmental resistance evaluation.
A limited numbers of works for LWRs.

Baseline Properties (for non Al ODS Steels)







ODS Eurofer 97 (fusion material programs) and 14YWT has been developed over 15 years, Mechanical property database is well organized. Environmental resistance data is insufficient.

Development of High-Strength ODS Steels for Nuclear Energy Applications

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M. Li
Argonne National Laboratory, USA

ODS 2010 Materials Workshop

Qualcomm Conference Center
Jacobs Hall
University of California, San Diego
Nov. 17-18, 2010

Summary of R&D of advanced ODS ferritic alloys over the past 9 years

- Advanced ODS ferritic alloys strengthened by nanoclusters possess attractive high-temperature strength and creep properties
  - But ductility and failure mechanisms suffer
- Nanoclusters show remarkable stability during long-term creep; low (neutron) and high (ion) dose irradiations; and short-term high-temperature exposures
  - NC appear to trap He and possibly point defects, causing their recombination
  - But information about their structure and chemistry is still lacking
- Development of 14YWT has approached "maturity"
  - Numerous small heats have been produced for a variety of studies
- But:
  - *heat-to-heat variations still influence mechanical properties*
  - *Plus, anisotropy still affects the mechanical properties, even though the GAR is reduced with nano-size grains*

OAK RIDGE National Laboratory

By D. Holzer et al:

Summary

- R&Ds on ODS steels were very intensive for SFR and Fusion before 1990th and those accomplishments should be revisited and be utilized, carefully.
- Since 2008, not many research activities have been published, however the R & D direction looks clearly presented.
- Toward ATF application, processing and environmental tolerance of ODS steels should be intensively developed.
- Data on quality control and uniformity for large scale cladding production are strongly required.
- For this, international collaborative activity should be initiated immediately.