NE 795: Advanced Reactor Materials

Fall 2023

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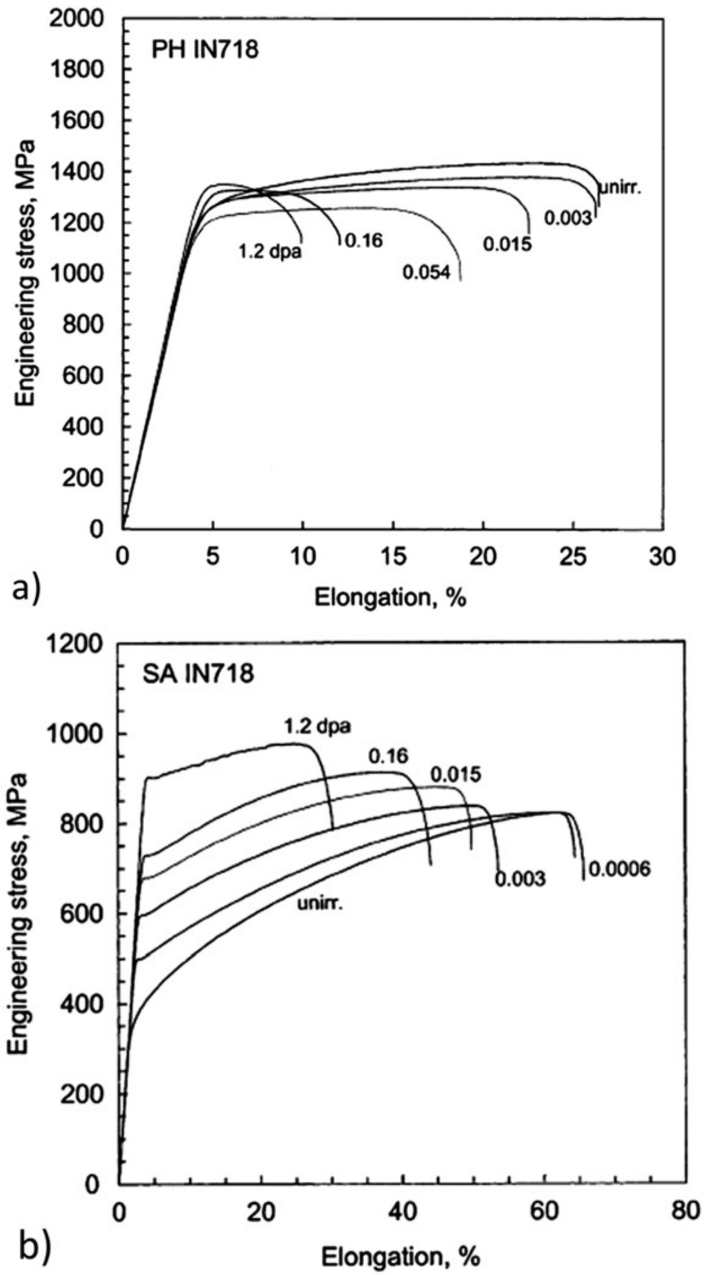
Last Time

- Rapid walkthrough of FeCrAl and ODS steels
- FeCrAl: fully ferritic; good mechanical properties and void swelling resistance; includes additional Al to improve high temperature steam corrosion; hardening and reduction in ductility saturates with irradiation; alpha’ precipitation leads to embrittlement
- ODS: Y2O3 or Y2Ti2O7 particles dispersed in steels, often F/M steels; oxide particles help to stabilize ferrite; excellent resistance to swelling; excellent creep resistance; minimal hardening; difficult to fabricate or shape
- Started Ni alloys

NI ALLOYS

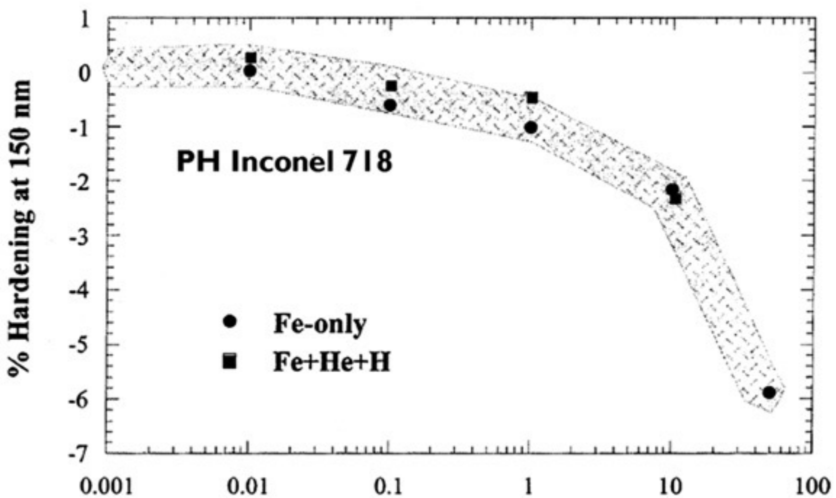
Irradiation Hardening

- Ni alloys can generally be categorized into two classes: solution-annealed (SA) or precipitation hardened (PH)
- The irradiation response is very different in these two classes
- PH materials irradiated at low temperatures (below 100C) and low doses exhibit reduced ductility, but minimal hardening
- SA materials exhibit substantial hardening in addition to a reduction in ductility



Higher Doses

- For PH materials, after an initial increase in RT yield and UTS at low doses, further irradiation can result in a gradual decrease in strength
- This has also been seen in PH-SS at elevated temperatures
- This does not occur for SA Ni alloys
- Softening due to dislocation recovery is likely the effect at high temperatures
- At low T, this is likely due to precipitate dissolution



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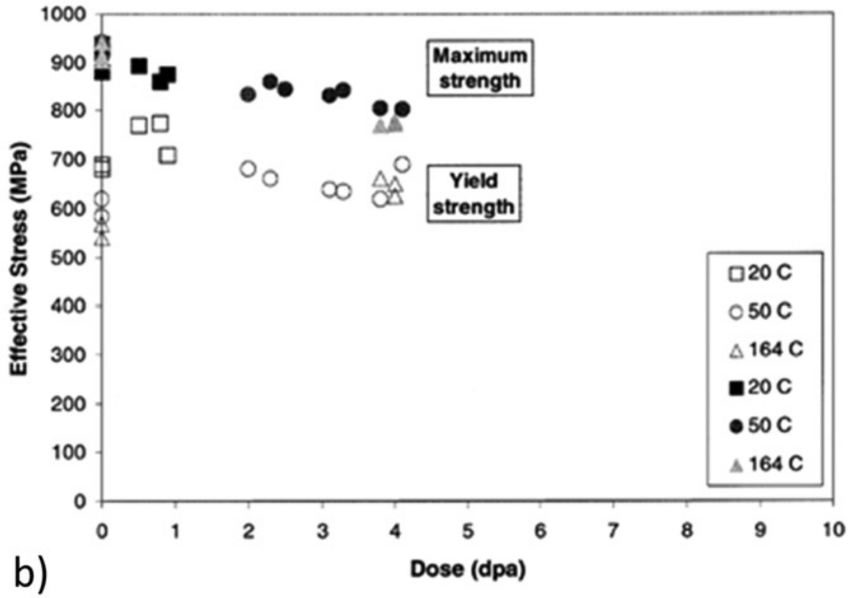

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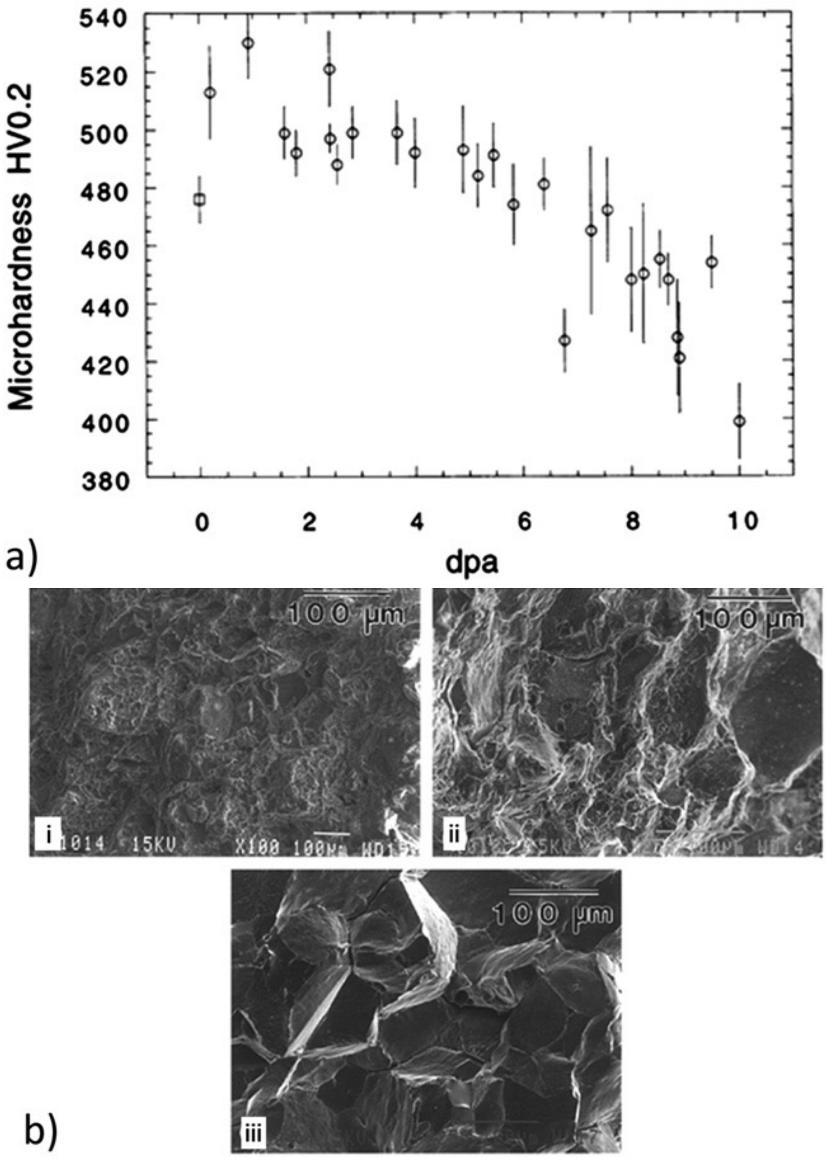
Embrittlement

- Despite softening, ductility continues to decrease, embrittling the PH Ni alloy
- There is a change from ductile intra-granular to brittle inter-granular failure with increasing dose at low T
- This is likely related to He generation, stabilization of He grain boundary bubbles, and embrittlement
- Thus, separate phenomena are leading to softening and embrittlement simultaneously
- This knowledge base is built on ion irradiations, and some effects may not fully transfer to fast reactor systems



Ni Alloys Summary

- Excellent high temperature behaviors, resistant to corrosion, reasonably compatible with molten salt, water, liquid Na
- Ni transmutation is an issue which generates He, which can lead to embrittlement (bigger issue in thermal reactors)
- Ni alloys are at least 28 wt% Ni, have an FCC phase, are either solid solution strengthened, or precipitation hardened (mostly PH)
- gamma’ and gamma’’ precipitates provide strength, hardening, and swelling resistance
- Alloys can soften with increased dose due to recovery of cold work at high T, but lose their ductility with increasing dose
- Don’t have enough good data on irradiation effects in fast reactor enrivonments