Mahmoud Hawary: 86 + 4 = $\boxed{90}$

① Research reactor has relatively low operating temperature, and smaller core size compared to LWR. Also, there are varity of fuels that can be used in the research reactor and different designs (including the dimensions and the geometry). In research reactor, we can use plate fuel type, where in LWR we have to use the cylindrical fuel shape ✓

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- enrichments + high power density

② The main reason of amorphization concern is the void swelling occurs following amorphization. Most of the intermetallic fuels are known to amorphize following irradiation even at low temperature. ✓

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- why does this occur in research reactors?

③ USi has high U-density than UAl, as using Al lead to accompined with using of high enrichment-U to achieve the needs of high-power. ✓

UMo achieves higher U-density ✓

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- drawbacks of USi?

high, unstab.

(4) U_3Si, even though it has a highe U-density than U_3Si_2, it's of concern because it higher swelling rate than U_3Si_2. Void swelling in U_3Si is high and unstable. In U_3Si_2, swelling may still be high but stable. This is belived to be due to the higher opor volume in U_3Si which allows for high vacancy mobility. Also, the high number of Si bonds exist in U_3Si_2 contributer to th better swelling behavior.

6/6

(5) Because irradiation causes disordering of γ' phase which retain the γ-phase and make it predominent. Without irradiation the γ-phase should decompose into α-phase and γ'-phase. Irradiation terminate this prtictarid interaction.

- slow kinetics of phase transformation

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(6)

0/6

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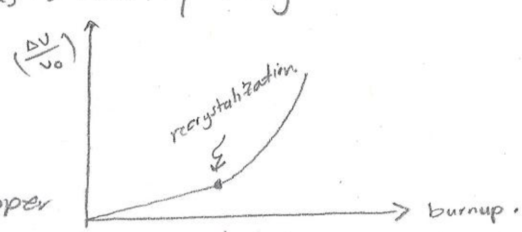
(7) U Mo has a unique fission gas swelling behavior. This swelling includes two stages

① At low burnup ⇒ small: swelling rate increases with burnup (almost linear relationship)

② At high burnup ⇒ high ~ ~ ~ ~ ~ (~ quadratic ~)

This transition between the stages occurs suddenly and as a result of recrystalization/ refinment process occurs under irradiation.



* <u>At low burnup</u>: small voids may observed along the GBs.

T.E.M inspection show that U-Mo has a fission gas supper lattice with size of a few nm. Althouge these supper lattices have a high numer density, they are too small to cause a considerable swelling.

* <u>At intermediate burnups</u>: larger voids formed along the already exist GBs and the newly formed one as aresult of the refinment process that is occuring.

* <u>At high burnups</u>: Voids uniformly span over the whole material as the refinment process is completed.

- gas bubbles, not voids

(8) The addition of Zr-layer into the monolithic fuel was proposed to eliminate the interaction between the fuel particles and the matrix. This interaction has chemical products that are unstable and have negative impacts on the fuel behavior. In addition to eliminating the interaction between U-Mo and Al, adding Zr-layer increased the U-density in the fueled zone. Also, it adds some flexibility to the fabrication process of U-Mo fuel. On the othe othe hand, adding Zr-layer adds anothe layer of interaction, so now we have an interaction between Zr and Al in addition to U-Mo and Zr. This interaction produces many phases that may affect the fuel behavior.

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(9)

Generally, Al has many advantages, such as: 8/8

① Reasonable strength ✓

② Good Corrosion resistance ✓

③ hydriding resistance

④ cheap ✓

⑤ weldable and machinable ✓

However, it has a major drawback, which is the low melting point. This put Some limitations on the operating temperature. For Commerical reactors, the operating temperature is $\approx 0.6-0.7 T_m$ of Al, which make it risky to use Al in Commerical LWRs. On the other hand, for research reactor, the Coolant temperature is $\approx 150\,^{\circ}C$ which is much lower than the T_m and make Al suitable for research reactors. In addition to this, it's suceptible to creep at $T > 150\,^{\circ}C$ and has some difficulties in welding process for high-tech applications.

(10)

Adding each elements may have diffrent oposing effect. For, example, decreasing the Cr Content will decrease the Corrosion resistance. However, incrasing Cr Content will increase the hardenability and promote δ-phase. ✓

→ this is only one example, what are other considerations? phases, strength, etc.

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(11) The Ferritic steels have better void swelling than the austenite steels because of

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① The free volume of interstitials in ferritic is much larger than austenitic, which means that the strain field is larger. This makes the material more rebeling for interstitials and attractive for vacancies. ✓

② The migration energy for vacancies in ferritic is lower than austenitic, which makes its mobility easier and enhances the recombination process. ✓

③ The carbide-vacancy binding energy is higher in ferritic which makes the vacancies trapped by carbides. ✓

④ The way of the interaction between the solute atoms and dislocations in ferritic makes it good sink of vacancies, where the solute atoms migrate and form an atmosphere around the dislocation. ✓

(12) The oxide particles in ODS steels have two main functions:

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① impede the dislocation motion during deformation which limits the plastic deformation, as dislocations are plastic deformation carriers, and increase the strength of the materials, espicially at high temperatures. ✓

② stabilize the microstructure at high thermal exposure and neutron fluence, which is a key element to have a better irradiation creep resistance material. ✓

ODS steels have:

① better swelling behavior ✓

② ~ irradiation creep ✓

③ ~ Corrosion resistance

④ ~ Compatibility with Na.

Same as FM steels