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Qualitative approach to understand fatigue behavior of CrAl-ODS-Zr alloy ATF cladding

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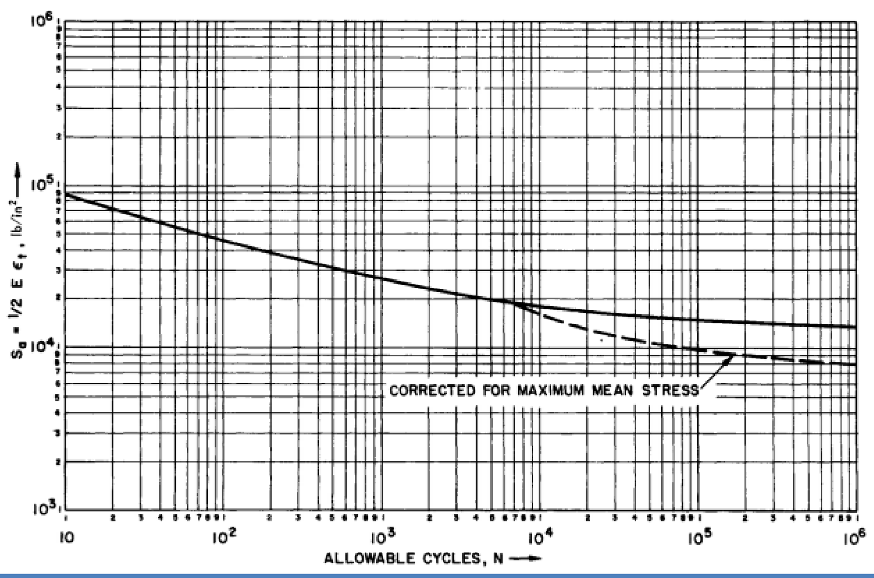
Introduction

- Cladding fatigue
  - Repetitive fatigue strain => Cause failure of fuel assembly
  - Acceptance criteria in SRP 4.2

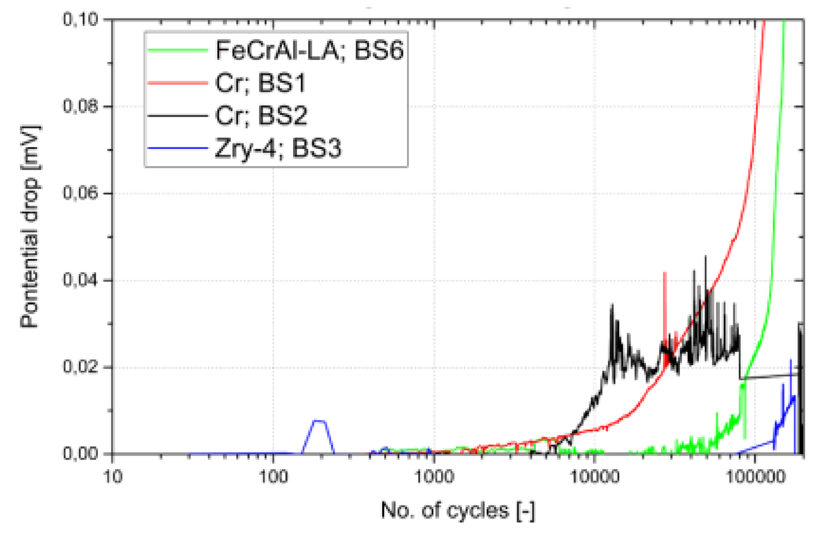
  : Cumulative strain cycles number << design fatigue lifetime

  (Based on appropriate data and includes a safety factor of 2 on stress amplitude or of 20 on the number of cycles (or other proposed limits)
  - Zr-alloy : O'Donnell and Langer's design curve [3]
- Coated ATF cladding
  - Couldn't simply apply O'Donnell & Langer's design curve due to limited relevant knowledge & data
- In this study, fatigue behavior of ATF cladding (CrAl-ODS-Zr alloy) is qualitatively studied and its effect on fuel in-reactor behavior is discussed for PIRT development study

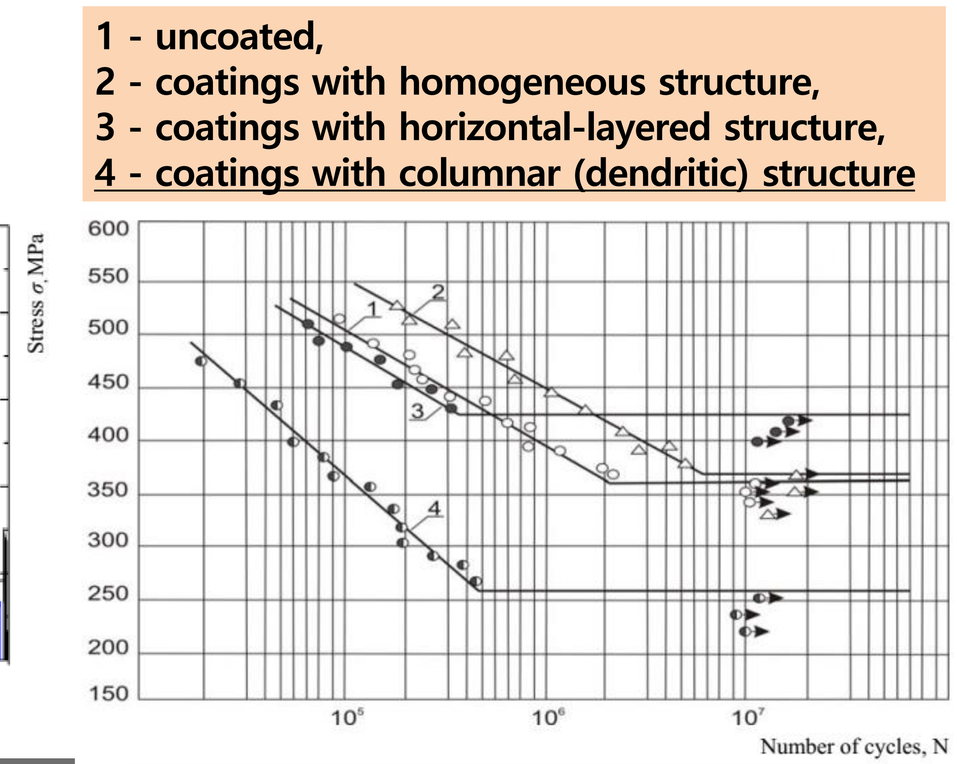


Fatigue design curve of irradiated Zircaloy component by O'Donnell and Langer [3]

- (M. Ševeček et al [6]) Fatigue failure observed significantly earlier in Cr-coated cladding by cold spray under NWC env.
  - resulting from stress concentration in the coating caused by the inhomogeneity created during the coating process
  - Can be solved by the optimization of manufacturing process and setting of appropriate limits
- (V. Kvedaras et al [8]) Cr coating for plated steel
  - Depend on microstructure : Improve or worsen
  - Cr coatings with columnar structure significantly decreased resulting from crack propagation along the GBs



Decrease in the fatigue resistance for Cr coated ATF cladding due to cracking [6]



Fatigue characteristics for Cr-coated plated steel [8]

- Fatigue behavior of CrAl-ODS-Zr alloy ATF cladding
  - Intact coating => would be improved by hard CrAl/ODS layers
    - Not columnar structure
  - Fatigue cracking in CrAl coating layer

    lead to propagate through cladding
  - Due to uncertainties resulting from limited data and cracking issues, it couldn't be concluded whether the fatigue resistance of CrAl-ODS-Zr alloy cladding is superior to that of Zr-alloy
  - New fatigue design curves based on the extensive irradiated test database

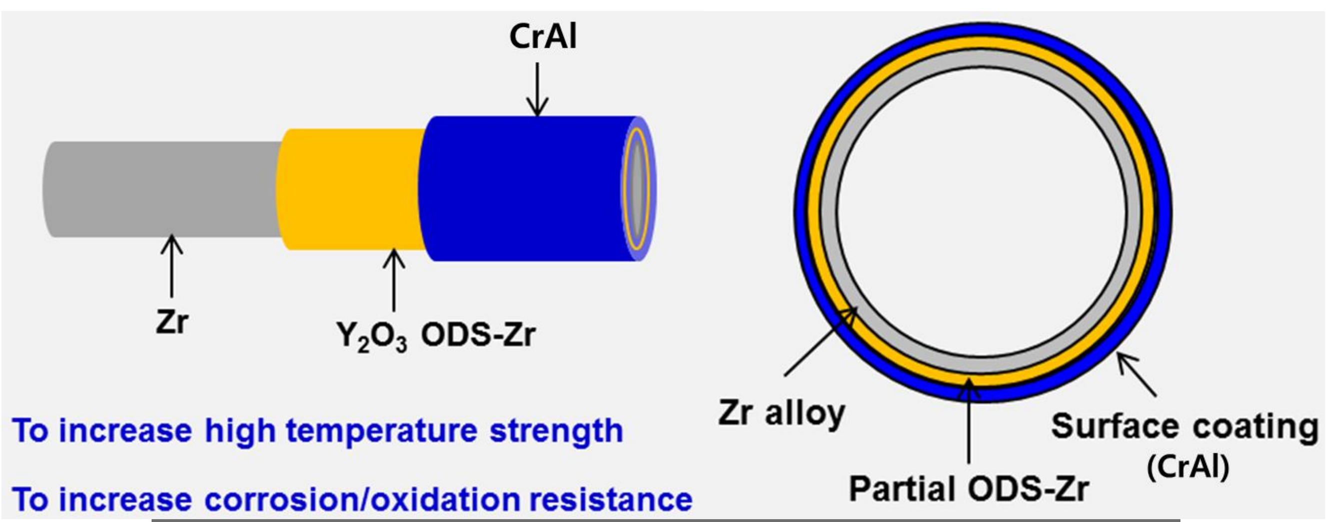
Fatigue behavior of CrAl-ODS-Zr alloy ATF cladding

- CrAl-ODS-Zr alloy ATF cladding [4]

  CWSR Zry-4 cladding

  \+ Partial ODS treatment using Y_2O_3 particles by laser beam scanning (LBS) process

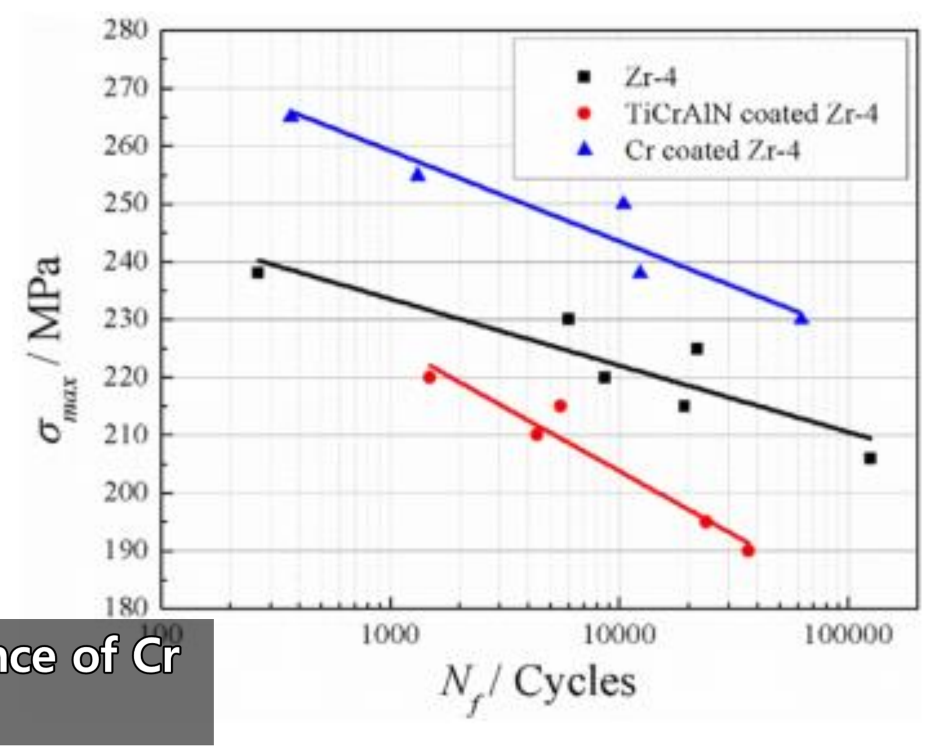
  \+ CrAl coating by arc ion plating (AIP) method



Structure of CrAl-ODS-Zr alloy cladding [4]

- Existing study for coated ATF cladding
  - (KAERI) Fatigue life of CrAl coated Zry-4 cladding is ~4.8 times longer than that of uncoated Zry-4 cladding

    (200 ppm hydrogen charged with air oxidation at 400℃ for 60 days, at hoop stress of 450 MPa)
  - (X. Ma et al [5]) Cr coated Zry-4 has significant improved fatigue resistance in vacuum environment
  - (P. Cavaliere et al [7]) Cold spray coating => Improvement in resistance by compressive residual stress



Improvement in the fatigue resistance of Cr coated ATF cladding [5]

Conclusion

- Fatigue resistance of CrAl-ODS-Zr alloy cladding would be improved by hard CrAl and ODS layers
- Current design curve for Zr-alloy is inapplicable for CrAl-ODS-Zr alloy ATF cladding due to to limited database and cracking issues
- Throughout the extensive irradiated tests, the new fatigue design curves considering a safety factor should be presented

Acknowledgements & References

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