Prediction and Improvement of Fatigue Life for Shape Memory Alloys

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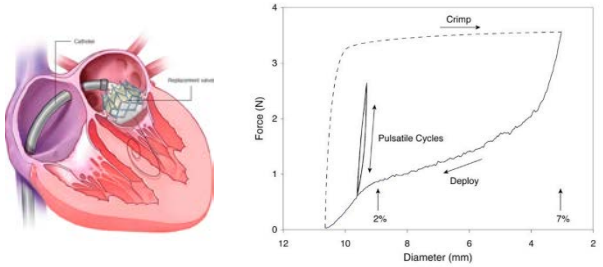
RESEARCH OBJECTIVE

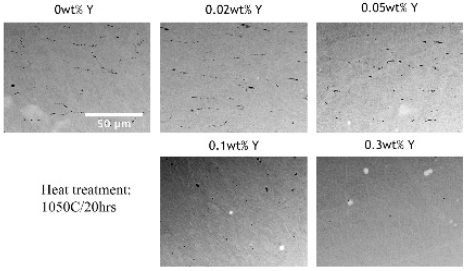
Development of models to capture the size effect of $Ti_4Ni_2O_x$ oxide inclusions on the ultra-high cycle fatigue life of NiTi artificial heart valves using both statistical analysis of fatigue data and finite-element methods. Quantification of mitral and aortic valve design requirements. Investigation of yttrium addition as an avenue to reduce inclusion size and volume fraction and integration of size effect models into materials design to predict improvement of fatigue life.

MOTIVATION



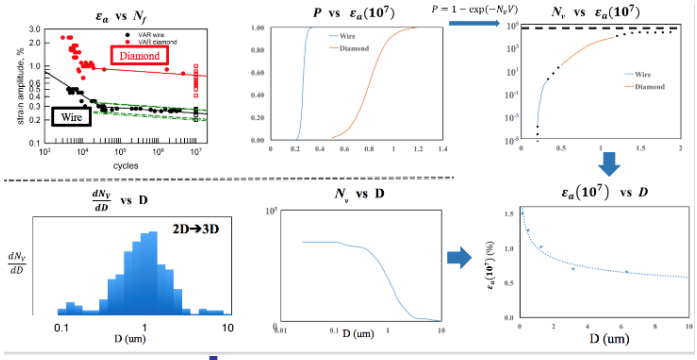
- High-performance SMA made of (Pd,Ni)(Ti,Al,Zr)
- Target of 600M cycles requires UHCF modeling
- Desirable to extend to AM processes

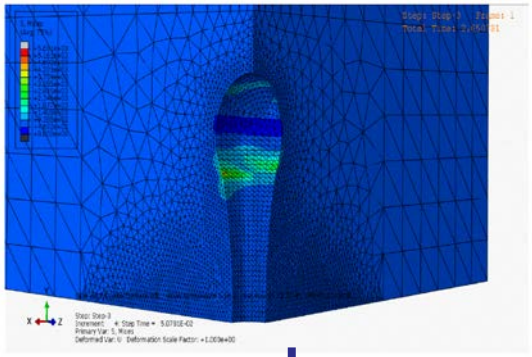
INCLUSION SIZE EFFECT



- Failure caused by largest inclusion
- Optimal Y content in order to minimize largest inclusion size
- Potential to reduce inclusion size by a factor of 3 or greater via O gettering

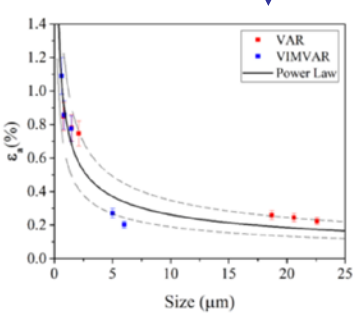
MODELING FRAMEWORK & RESULTS





Empirical Modeling

FEM Modeling



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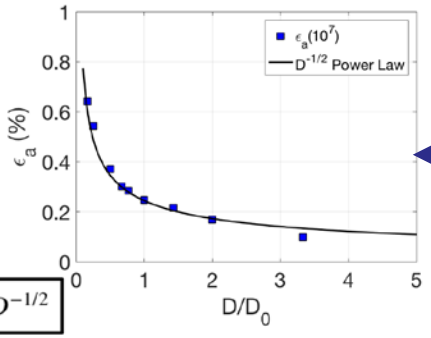

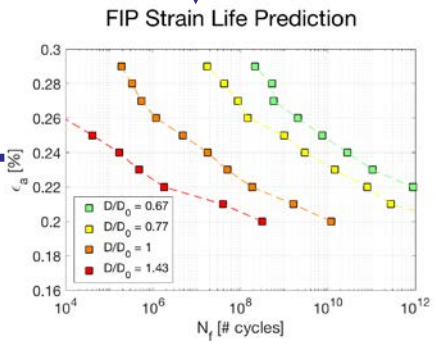

Size effect by empirical model ⟺ Size effect by FEM analysis

CONCLUSIONS

- Established agreement with empirical model power law and showed size effect is much stronger in NiTi than in steel
- Showed potential to reduce inclusion size by sequestering oxygen remnant from additive manufacturing processes into Y_2O_3

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