SAND2019-3314D

AN AGILE APPROACH TO MODEL THE LIFECYCLE OF A GAS TRANSFER SYSTEMS COMPONENT

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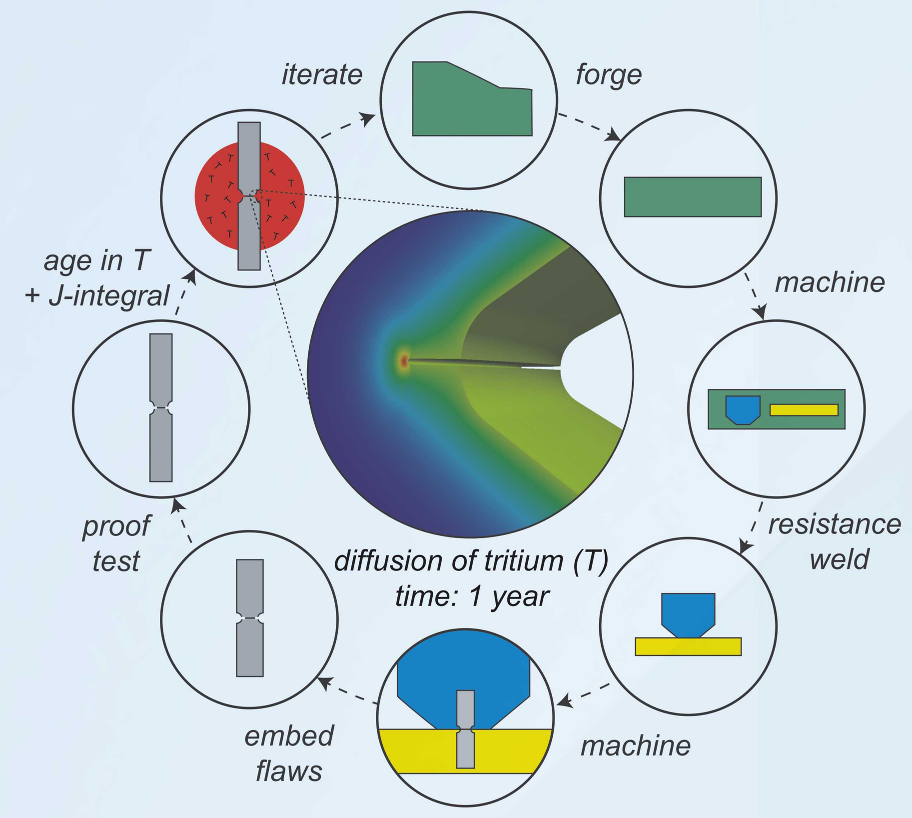
PROJECT DESCRIPTION & MISSION IMPACT

Utilize Sierra Aria and Solid Mechanics codes, in addition to Cubit and several python scripts to model the lifecycle for Gas Transfer Systems (GTS) components with defects to satisfy design requirements

- Interdependent physics via state variables
- Interdependent technologies (mapping/remeshing)

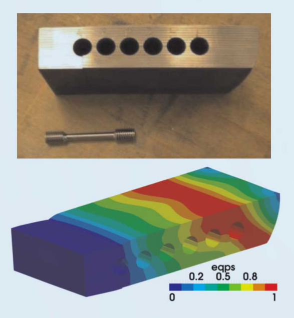


This multiphysics workflow has been developed, verified, and validated for simulating the evolving material state of a GTS reservoir through its life cycle as part of FY16 and FY17 L2 milestones, and features the following capabilities:

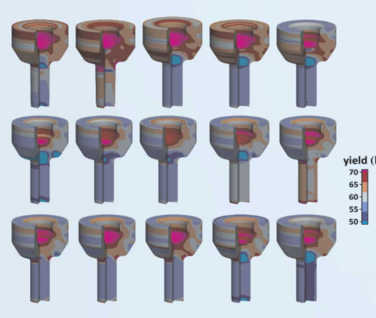
- Developed, validated, and employed models of crystallization for the design of new forgings
- Successfully simulated the electrical-thermal-mechanical coupled resistance welding process with new models of solid-state bonding
- Propagated residual stresses and uncertainty through the manufacturing process to impact aging
- Production capability for chemo-mechanical coupling and finite-deformation tritium diffusion and evolution of helium bubble structure
- Production capability to evaluate the J-integral for design with new methods to increase agility
- Capabilities implemented in production codes with a focus on new methods for remeshing/mapping for applications in forging, welding, machining, etc.
- A reservoir team owns technologies that are continuously tested with a focus on agile practices

This multiphysics workflow has been developed, verified, and validated for simulating the evolving material state of a GTS reservoir through its life cycle as part of FY16 and FY17 L2 milestones, and features the following capabilities:

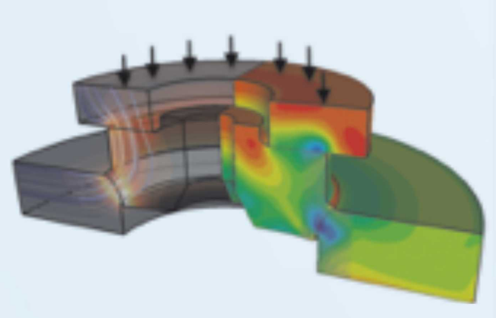
- Guides production process development
- Supports anomaly resolution
- Improves future designs
- Provides sustainability through teaming
- Interactions with National Security Center (NSC), Kansas City



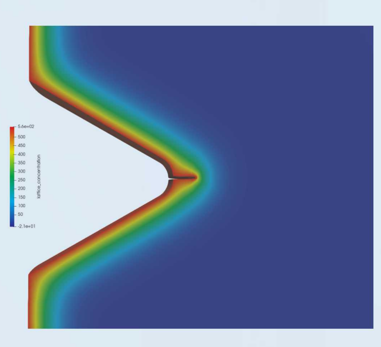
forging R&D



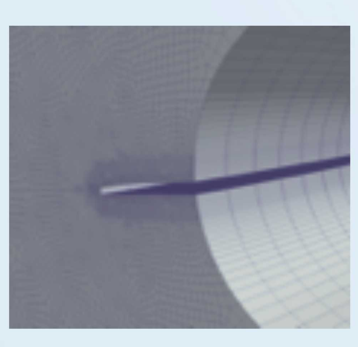
forging design



welding R&D



tritium/He R&D



J-integral

TECHNICAL APPROACH

Utilizing Dakota (Sandia design optimization software), we parameterized the initial preform with appropriate bounds and constraints and performed Latin Hypercube Sampling over 8000 samples:

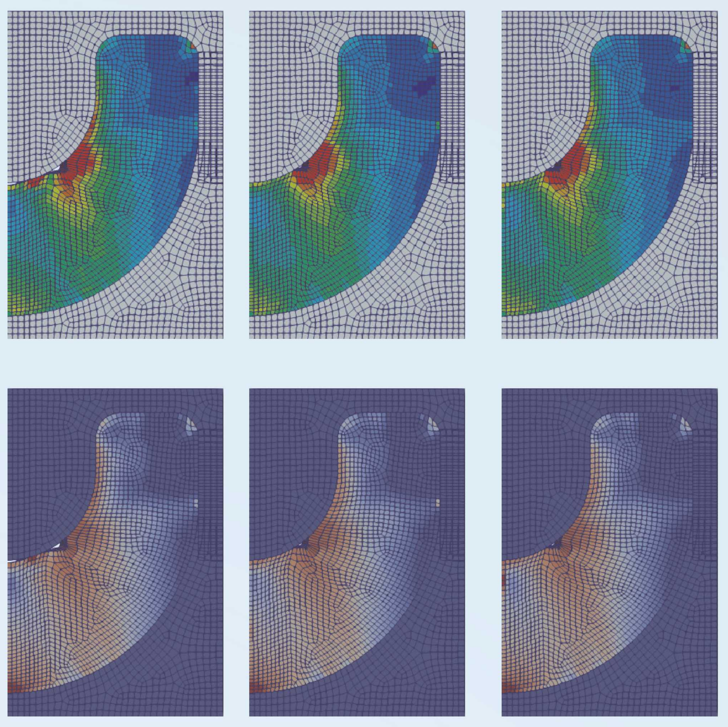
Challenges:
- Robustness in our workflow codes and tools over 14 steps
  - Implicit contact convergence
  - Overlap
  - Automated meshing (using CUBIT)
- Computational efficiency (35 hrs on 16 proc per run)
  - Required mass scaling investigation to deploy explicit dynamics

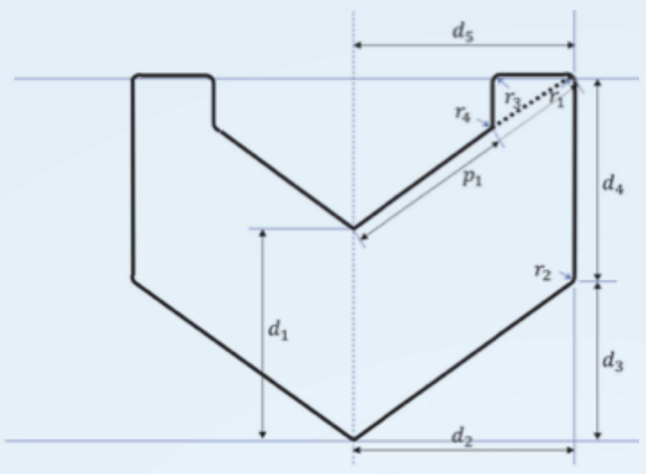
Employ an agile process to readily adapt our multiphysics workflow to redesign a forged geometry that did not meet specifications.

Varying Mass Scaling: *100x* *10x* *1x*

EQPS

Yield Stress





Design Requirements:
- Uniform yield strength in the range 55-75 ksi
- Close to the required volume (not overfull or underfull)
- Grain flow parallel to boundaries

Objective based on final yield stress predicted by Bammann-Chiesa-Johnson (BCJ) material model (assuming quasistatic loading rate $\dot{\varepsilon} = 10^{-3}\ 1/s$)

$$\sigma_y = (Y(\theta_0) + \kappa(\theta_0))\left(1 + \sinh^{-1}\left[\left(\frac{\dot{\varepsilon}}{f}\right)^{1/n}\right]\right)$$

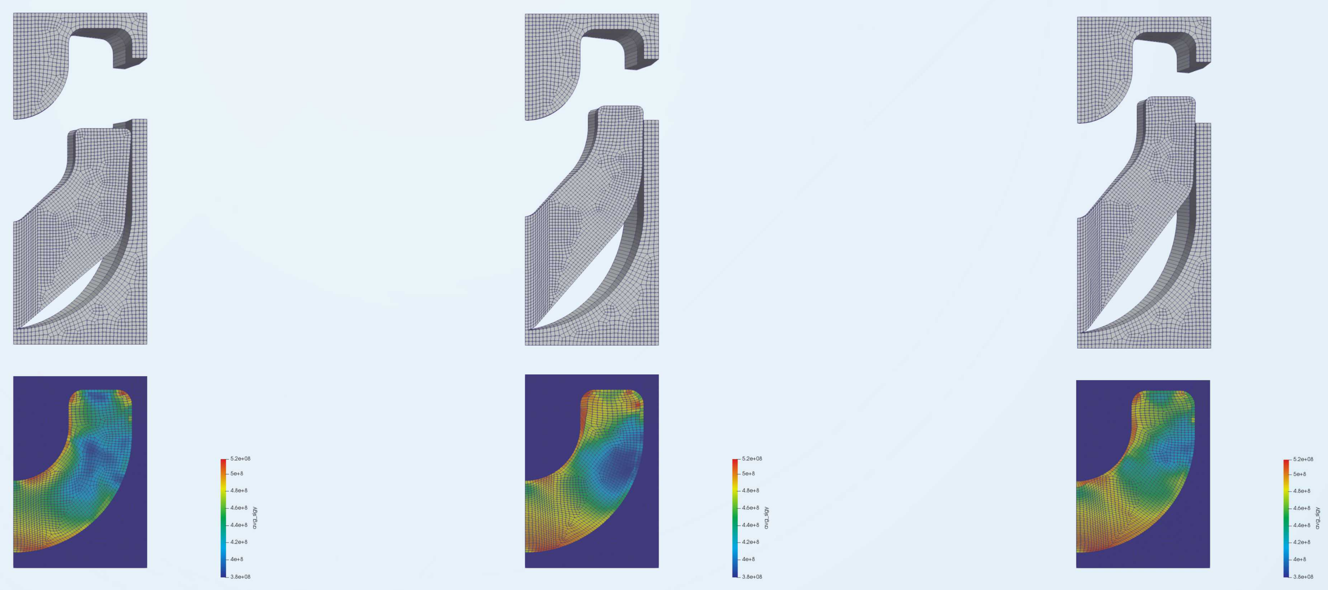
RESULTS

Final designs showed similar trends in preform geometry with yield strengths completely within targets:

#6861 *#3530* *#4790*

Preform Shape

Forged Yield Strength



Yield Strength Target: 55-75 ksi
- *0% volume outside range*
- *64.9 ksi mean*
- *4.3 ksi std.dev.*

Volume = 1.805 cu.in.

Yield Strength Target: 55-75 ksi
- *0.15% volume outside range*
- *66.5 ksi mean*
- *5.0 ksi std.dev.*

Volume = 1.804 cu.in.

Yield Strength Target: 55-75 ksi
- *0.28% volume outside range*
- *67.6 ksi mean*
- *3.8 ksi std.dev.*

Volume = 1.804 cu.in.

FUTURE WORK / DIRECTION

- Team with Dakota to efficiently incorporate uncertainties in the manufacturing process parameters in the optimization process
- Streamline and improve linkage with J-Integral calculations (start with an initial stress state nearing the end of the production cycle)
- Continue to implement verification and validation practices for individual processes (RFW) and series of steps
- Create and verify an agile library of cracks/flaws that can be readily inserted into lifecycle

ACKNOWLEDGEMENTS

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