



Engineering Sciences Experiences in Addressing Manufacturing Problems Relevant to Halliburton

SAND2007-8149P

Presented to
Halliburton Visitors
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December 19, 2007

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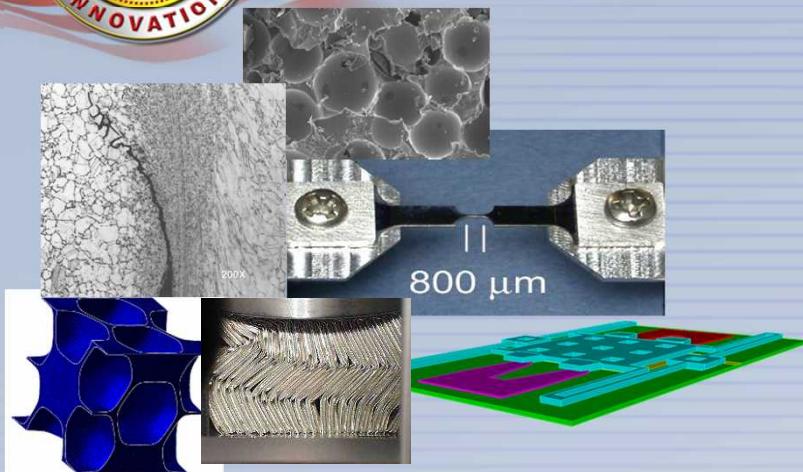


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ES Balances Analysis and Experimentation

R&D ensures capability to address evolving applications

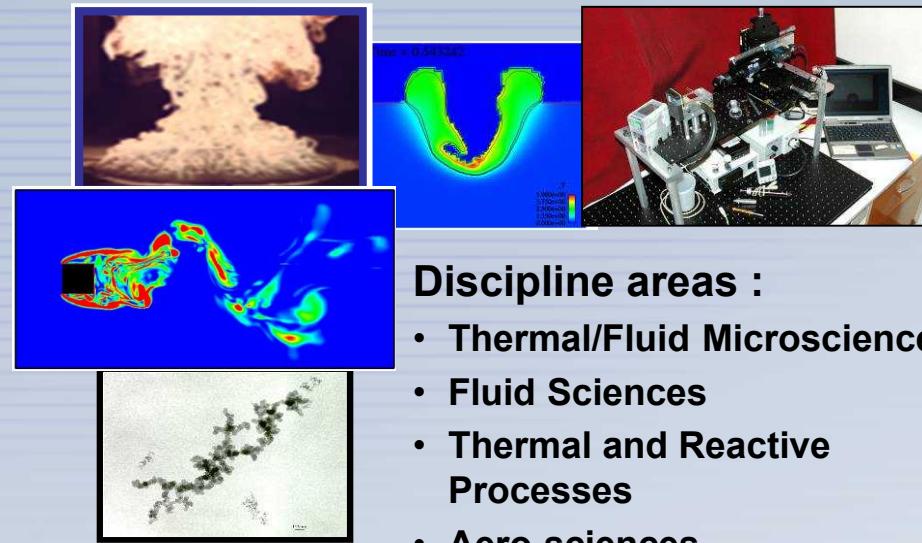


Solid/Material Mechanics & Structural Dynamics

Discipline areas:

- Solid Mechanics
- Structural Dynamics
- Material Mechanics

Thermal, Fluids & Aero-sciences



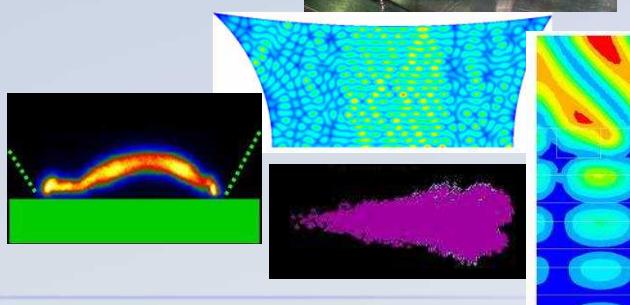
Discipline areas :

- Thermal/Fluid Microsciences
- Fluid Sciences
- Thermal and Reactive Processes
- Aero-sciences

Electrical Sciences*

Discipline areas:

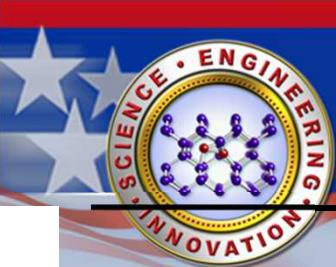
- Electromagnetics and Plasma Physics
- Electrical Processes



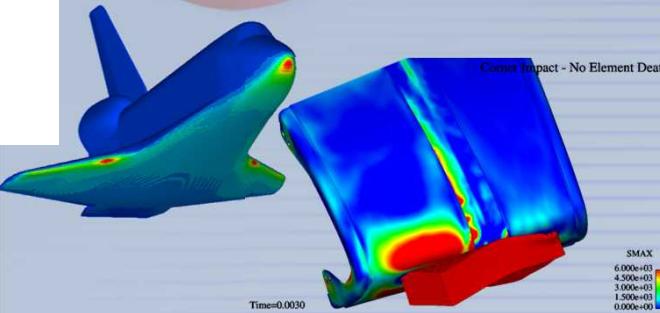
** Also supported by other Research Foundations*



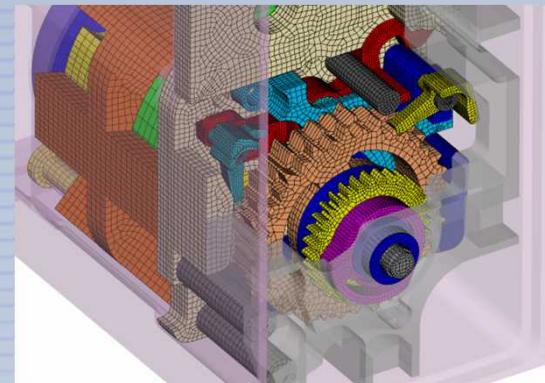
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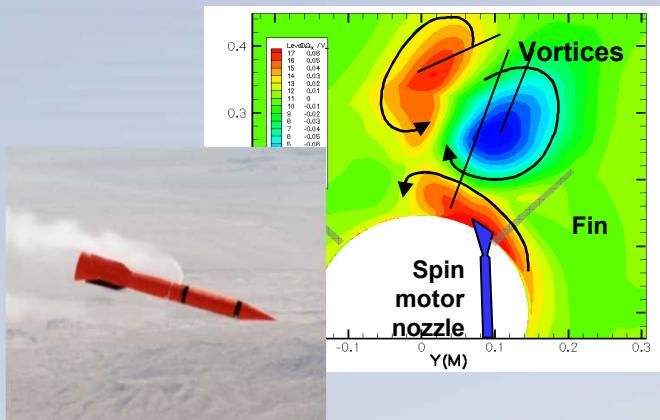
Experienced Staff Leverage Investments in Computational Simulation to Solve Problems of National Consequence



Analyses guide NASA Columbia orbiter accident investigation



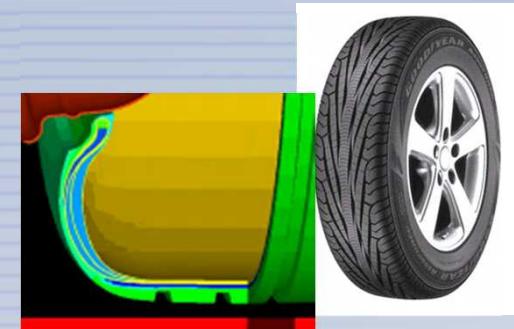
Design Issues: W76-1 Intent Strong-Link Shock-Unlock



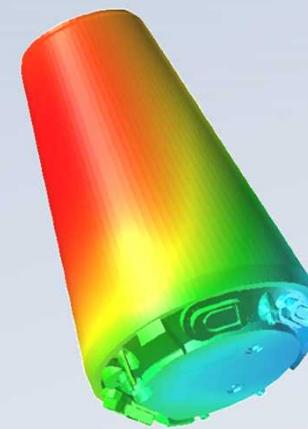
Resolution of B61 weapon Issues uncovered in surveillance



System Qualification:
Abnormal Thermal
Environment Characterization



Mod-sim provides Goodyear with competitive advantage



System Design Improvements:
W76-1 System in Abnormal Environments



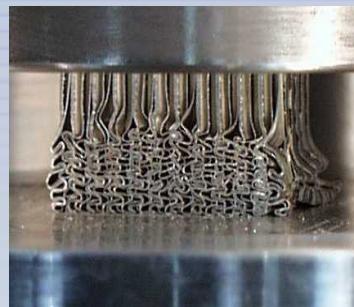
Solid Mechanics Analysis team supports an array of challenging multi-physics problems

System Level Analyses of Transient Dynamic Events

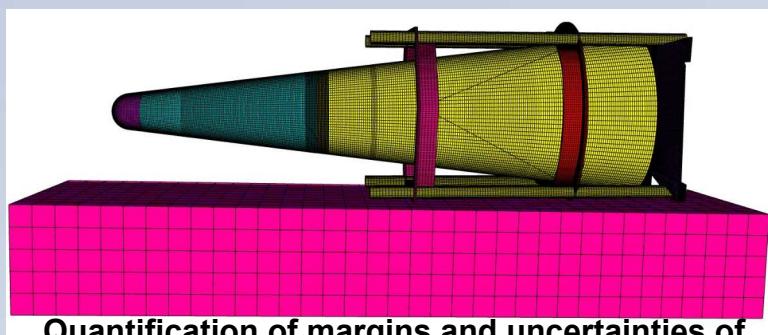


SGT accident scenario

Constitutive model development

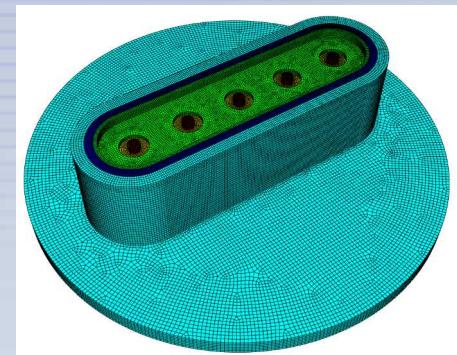


Crush of honeycomb energy absorber

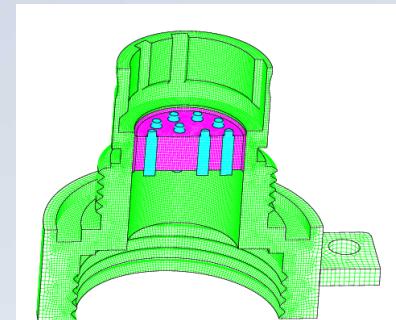


Quantification of margins and uncertainties of W76 exclusion region integrity

Component Manufacturing and Performance Analyses



W76 ISL Utility Header



LAC 13-pin glass-to-metal seal



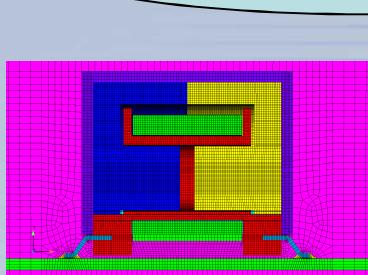
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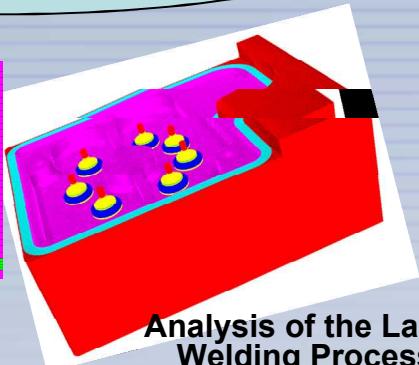
Component Analysis support is analogous to Halliburton example in drill bit production

Life Cycle Performance

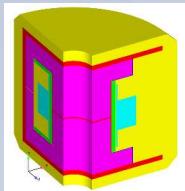
Manufacturing → Service → Failure



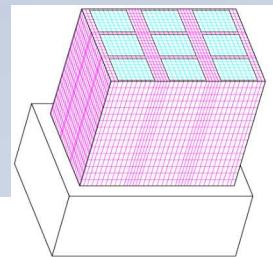
Encapsulation of an Inductor



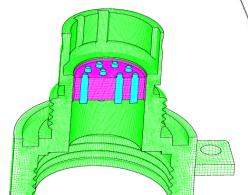
Analysis of the Laser Welding Process



Encapsulated High Voltage Transformer



Prototype thermopile



LAC 13-pin glass-to-metal seal

Capabilities

- Performance evaluation and margin assessment for components over entire lifecycle:
 - Evaluate design alternatives*
 - Design optimal manufacturing processes*
 - Achieve performance specifications*
 - Identify and mitigate failure mechanisms*
- Model development and application to include:
 - Complex nonlinear material behavior*
 - Thermo mechanical Response*
 - Complex Geometry*
 - Cohesive and Failure*
 - Adhesive Failure*
 - Thermal Stress*
 - Cooling and Curing*

Customers

- NW, DOD, DHS, NASA

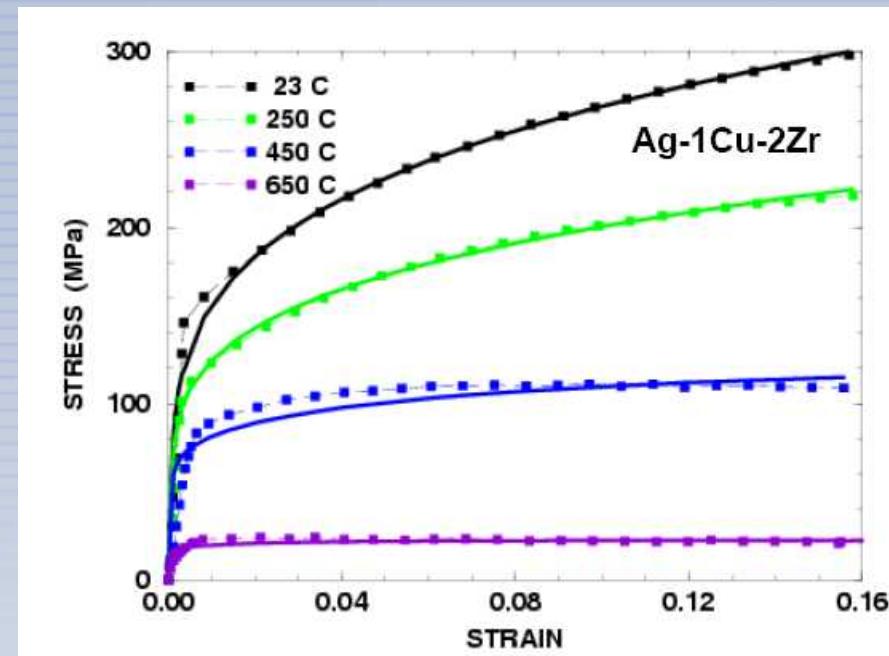


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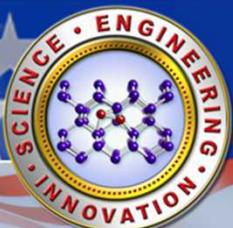


Brazing Process is critical to NW Product Development

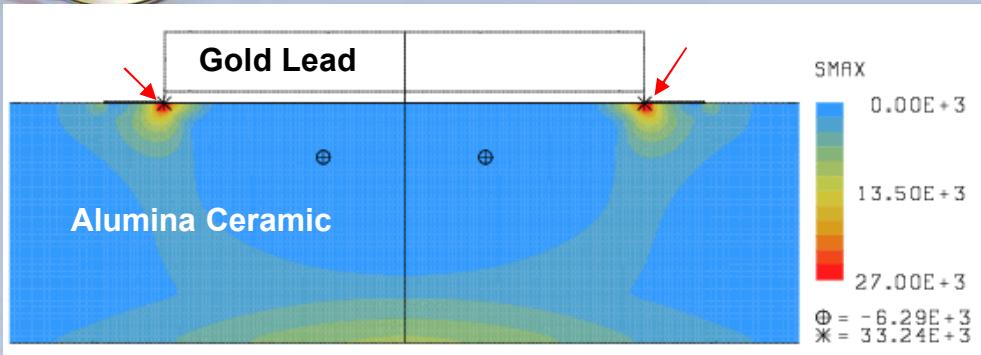
- Viscoplastic constitutive model developed to capture behavior of numerous braze alloys.
- Model parameters identified from Uniaxial compression and creep compression experiments
- Models used extensively to plan and resolve production issues associated with Braze induced residual stress and subsequent thermal cycling



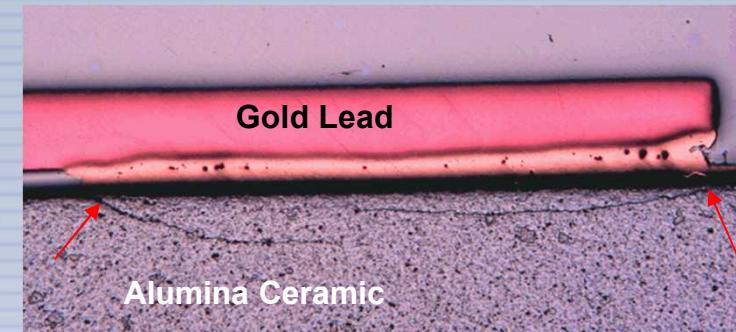
- solid lines show model predictions
- symbols show experimental results
- true strain rate of 1.67×10^{-4} per sec



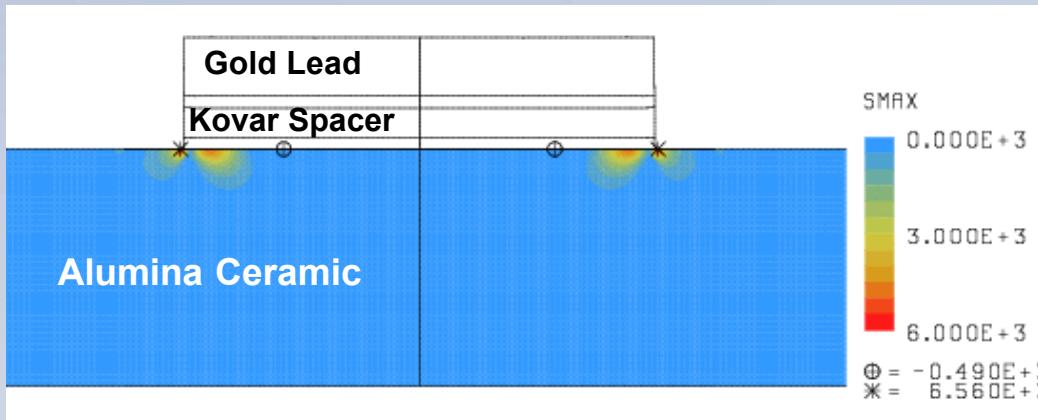
Braze Model Used to Solve Critical Production Issue



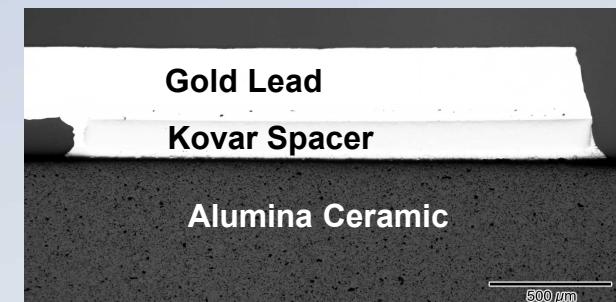
Without Spacer Model Predicts High Stress



Experiment Shows Cracks
After Braze with Incusil-10



With Kovar Spacer Model Predicts Acceptable Stress



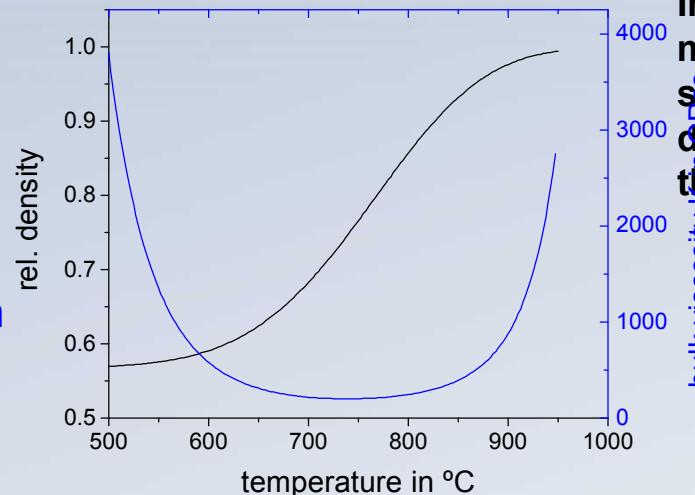
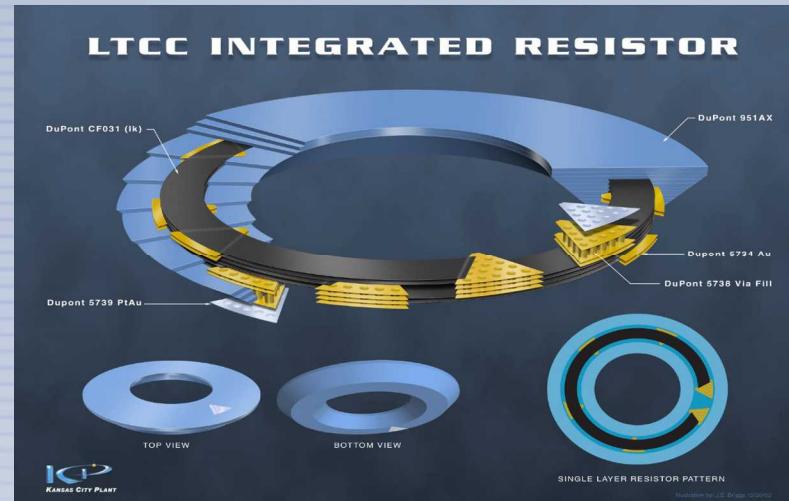
No Cracks

Braze Layers with Incusil-10 Braze, SMAX = Maximum Tensile Stress (psi)



Sintering is a related production process requiring specialized constitutive models

- Forming of ceramic components through powder compaction
- Outcome sensitive to process variations:
 - Shape deformation
 - Microstructure heterogeneities (e.g., cracks & porosity) degrade performance and reliability
 - Electrical properties depend on final geometry
- Viscous sintering constitutive modeling
- Constitutive Model parameters identified through coupon level sintering tests
- Distinct validation test provide confidence in model application validation tests
- Accurately predicts relative density and distribution



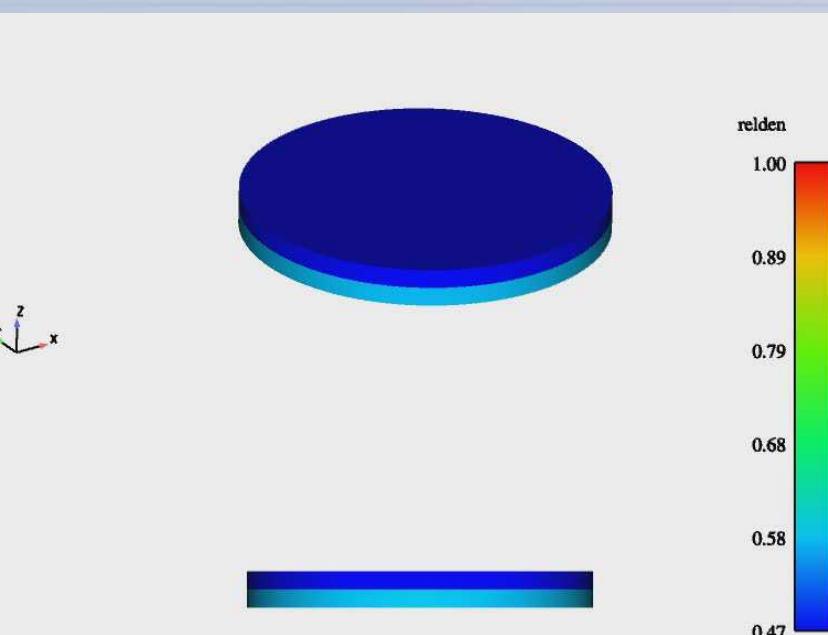
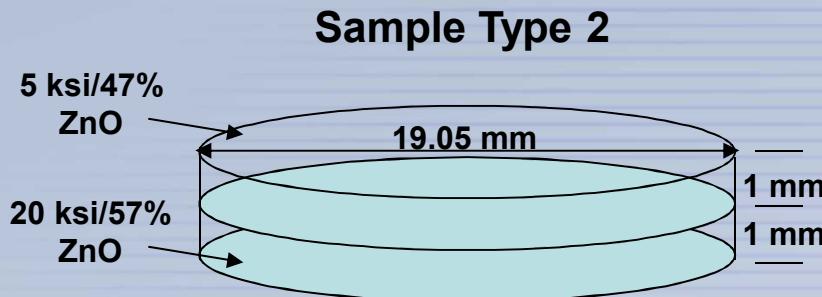
Integrated resistor manufactured by co-sintering of dielectric tape, resistor thick film and metallization



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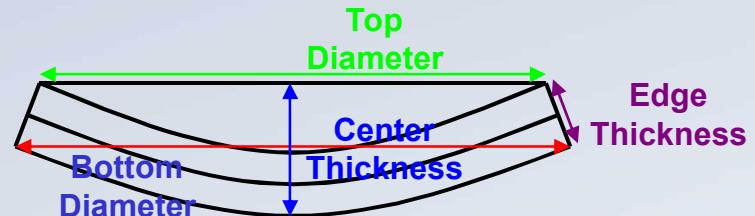


Validation of the Sintering Constitutive Model



Sintering of ZnO (0.2 μ m) Bilayer Disk Garino's Experiment vs. Simulation ($\rho_{0u} = 0.47$ & $\rho_{0l} = 0.57$)

At 925 °C	Experiment	Simulation	Difference
D_T (19.05 mm)	15.24	15.07	1.1%
D_B (19.05 mm)	15.98	15.77	1.3%
T_E (2.00 mm)	1.63	1.64	0.6%
T_c (2.00 mm)	2.72	2.45	9.9%





FEA relevant topics for Halliburton Fixed Cutter Drill Bit Issues (first cut)

- **Binder flow**
 - Determination of adequate infiltration
 - Multi-phase flow modeling could support flow optimization
- **Residual stress: post infiltration process**
 - Effects of non-uniform cooling
 - Material properties at various temperatures – does this fit existing braze material database?
 - Is interface stress sufficient to cause cracking?
- **Machining process**
 - Effects of stress redistribution
 - Is interface stress sufficient to cause cracking?
- **Welding**
 - Stress induced in heat affected zone
- **Response to environmental loading**
 - Aged properties
 - Dynamic Effects