



Auto Indexer for Percussive Hammers

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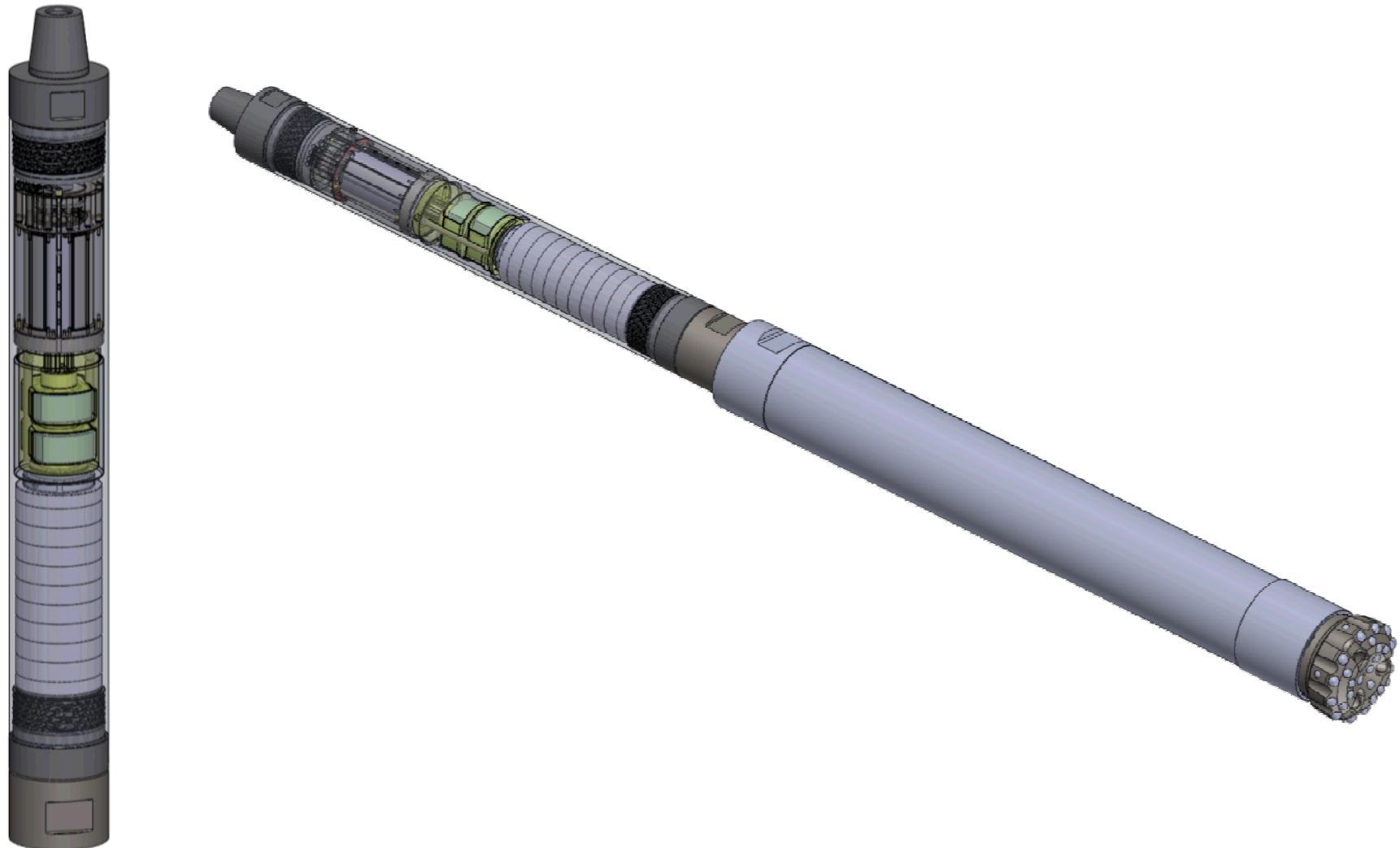
Research & Development Drilling

- Objective: Improve well construction capabilities to lower the cost of geothermal resources
- Barriers: Geothermal environments challenge existing drilling hardware and techniques
- Solution: Use existing drilling techniques augmented by new technology to enhance drilling capabilities
- Innovation:
 - High-temperature downhole motor for use in geothermal drilling
 - Elastomer-free (high-temperature operation)
 - High peak torque in a small form factor
 - Performance targets: comparable to PDM

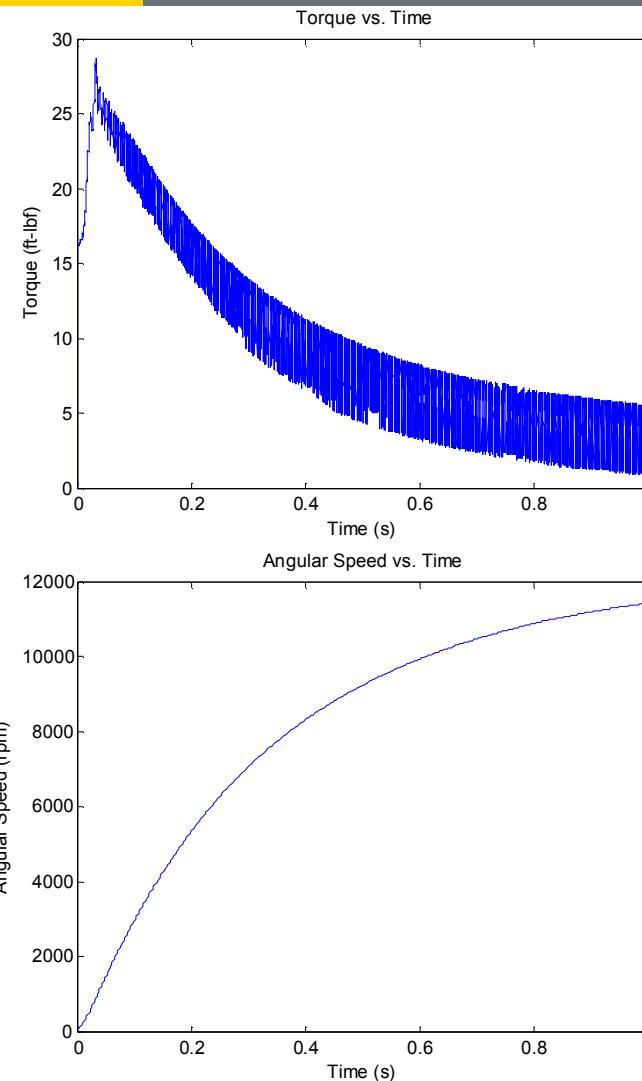
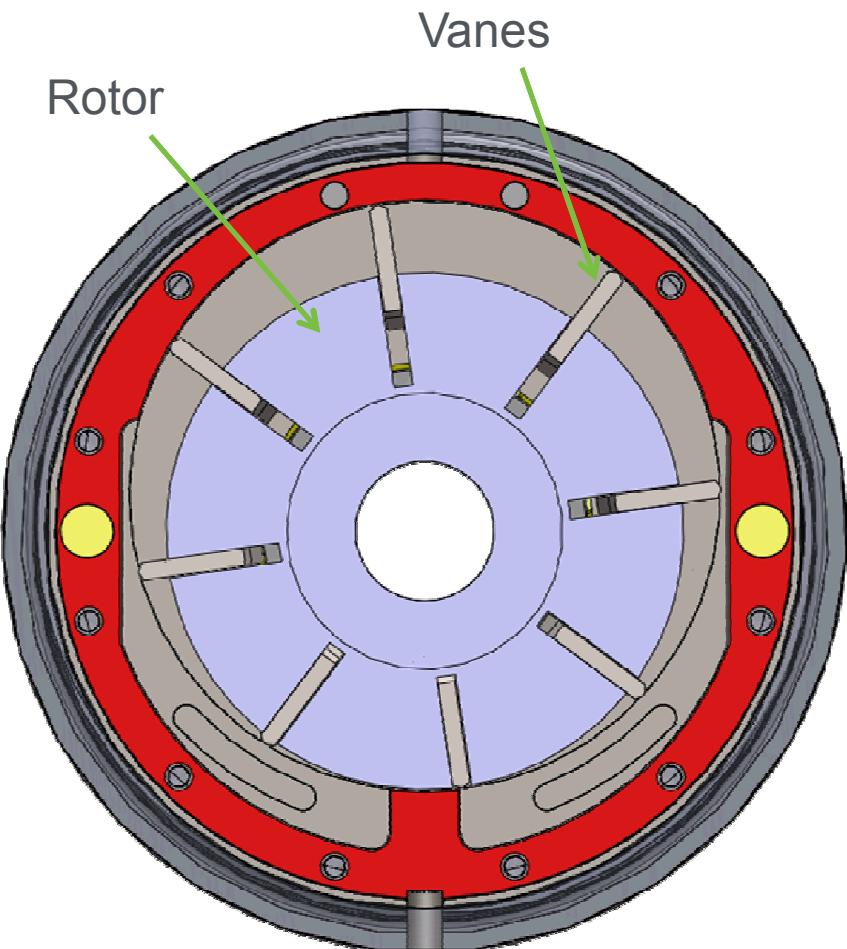
- Impact:
 - Enable advanced drilling techniques through downhole rotation
 - Promote the use of hammer drilling in geothermal formations
 - Improve penetration rates in hot, hard rock
 - Expand the driller's toolbox

- Adapt prior motor concept to work in a geothermal environment (TRL 2)
 - Impulsive torque device
 - Up to 40x torque compared to conventional motors
- Develop prototype from proof-of-concept (TRL 4/5)
 - Engineering design
 - Material selection
 - Fabrication
 - Laboratory testing
 - Modifications and improvements
 - Drill testing
- Pros
 - High-temperature capable
 - Elastomer-free operation
 - Standard joint connections
 - Compact design
 - High peak torque
- Cons
 - Intermittent rotation
 - Additional shock loading in the BHA
 - May have difficulty in compliant mediums
 - Doesn't address other limitations of hammers in geothermal drilling

Auto Indexer Assembly



Design (Analytical Modeling)

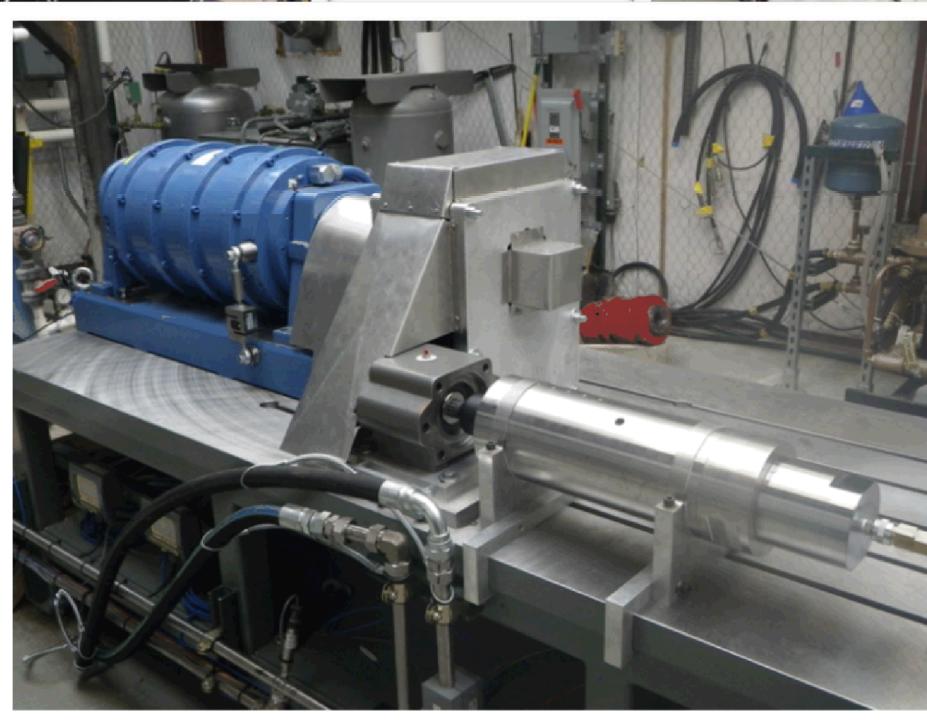
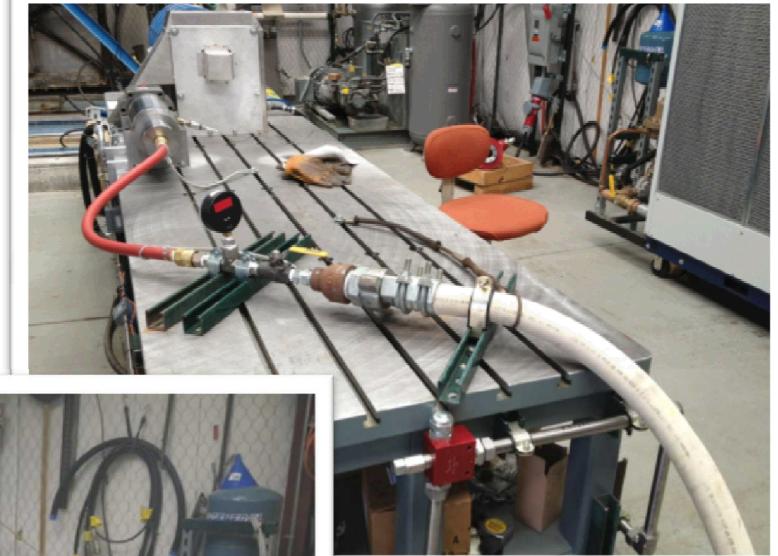


*Estimates for 70 psi inlet pressure

Dynamometer Testing

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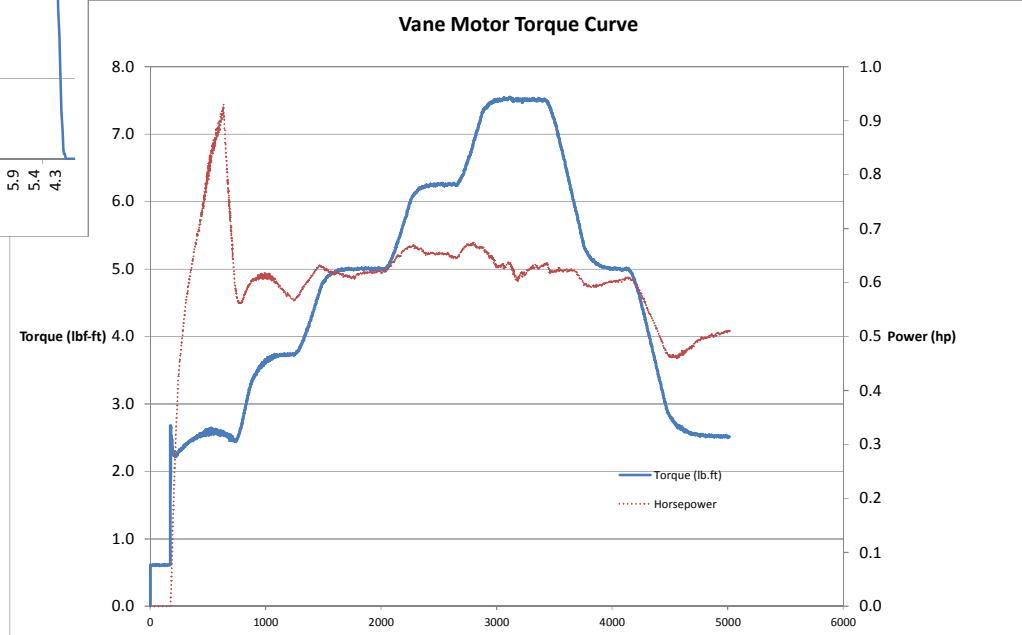
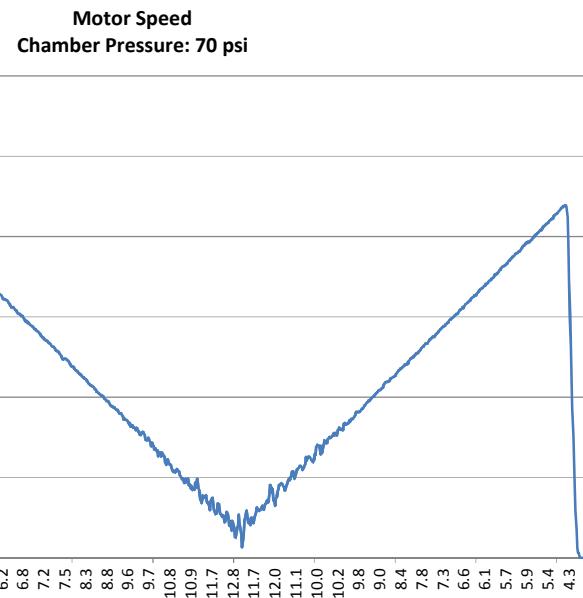
Energy Efficiency &
Renewable Energy



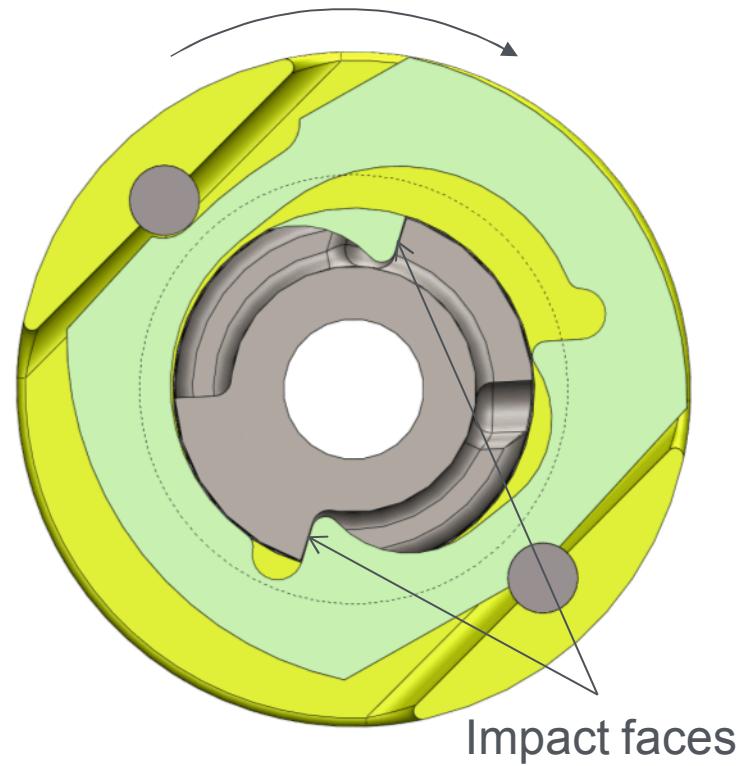
Dynamometer Testing

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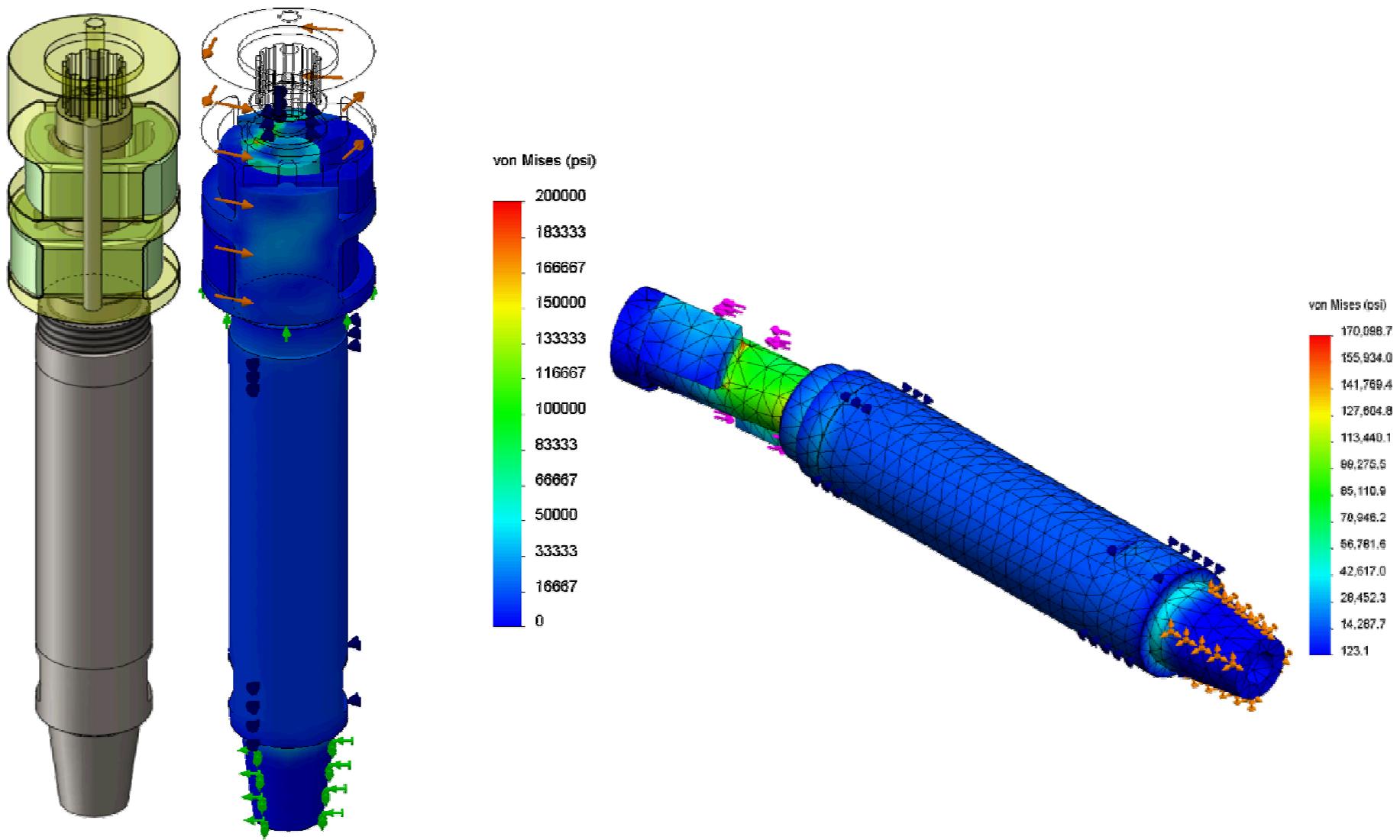
Energy Efficiency &
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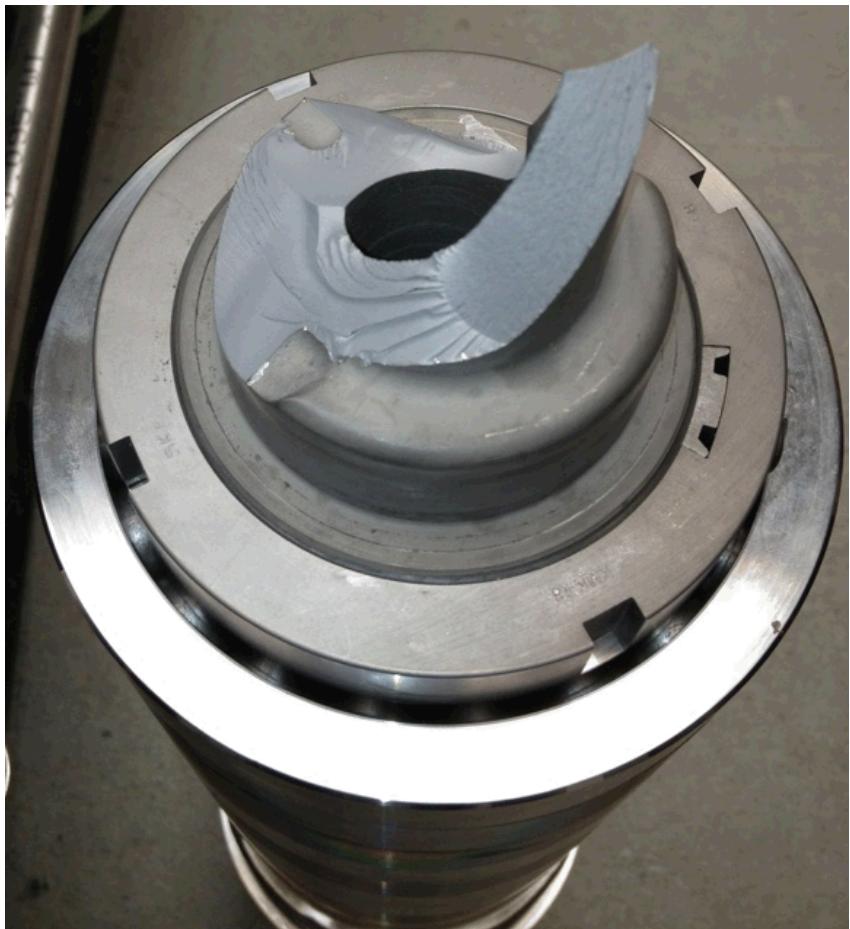


Drive Section Testing



Design (Stress Analysis)





Brittle failure of A2 drive shaft

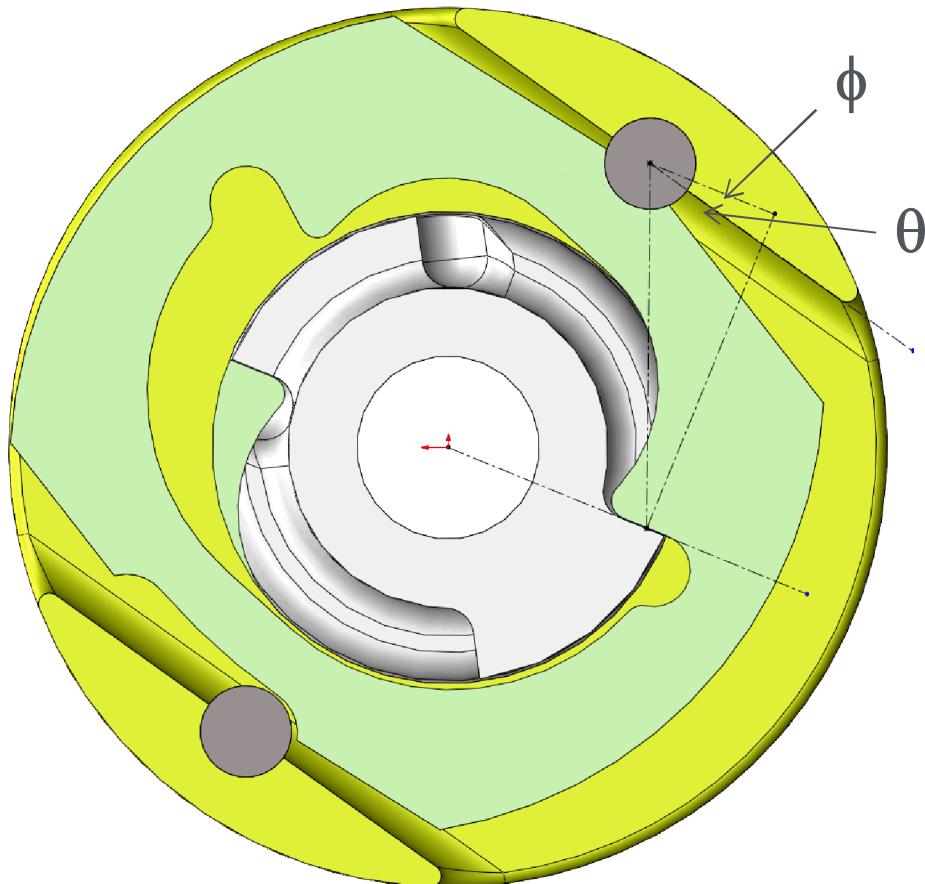


Alternate material selection: S7 shock steel

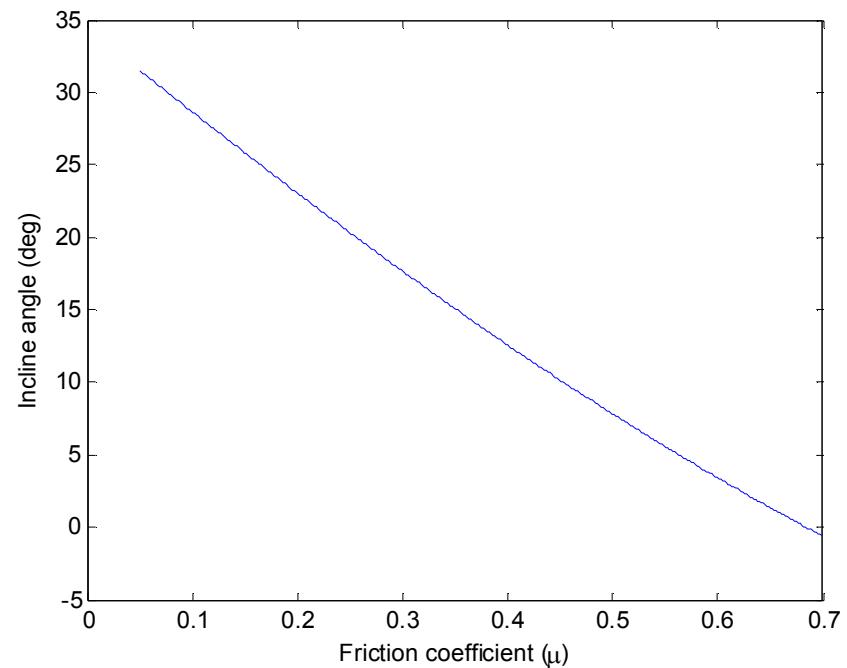
Drive Components (Hammers)

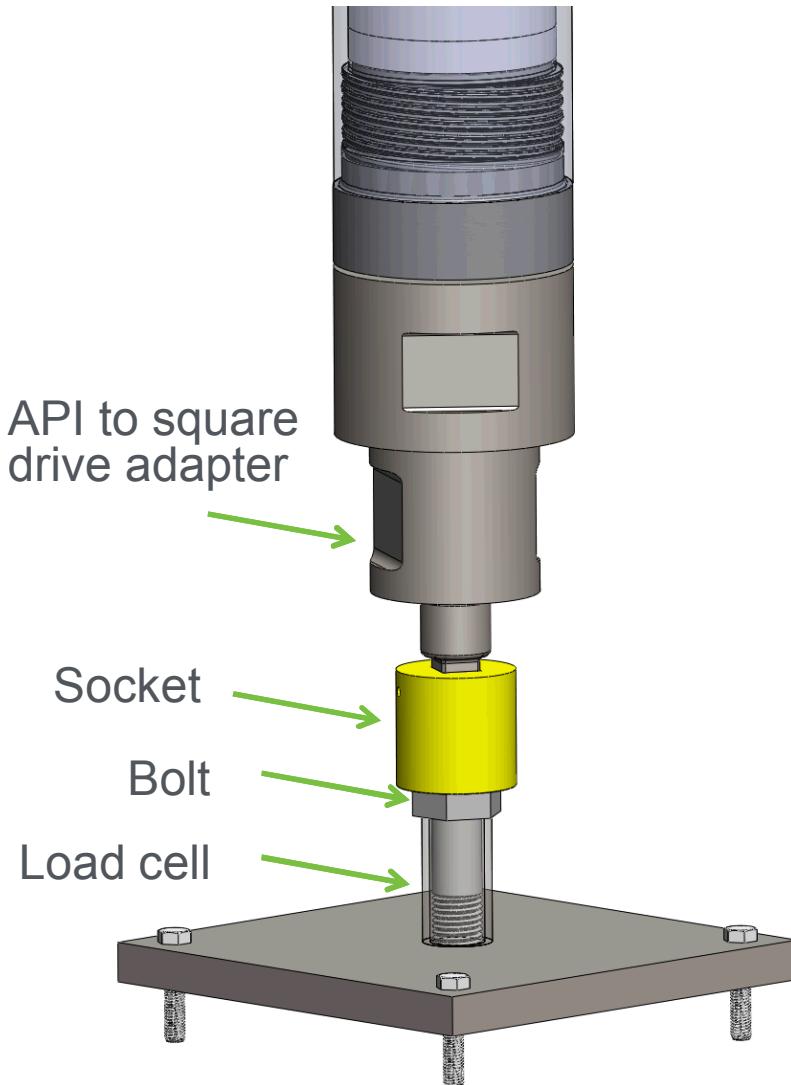


Drive Section Geometry



$$\phi = a \tan\left(\frac{1}{\mu}\right) - \theta$$





- Challenges:
 - Dynamometer not designed for impulse loading
 - Expensive/long lead for potential measurement tools
- Solution:
 - Drive bolt, measure axial load with load cell
 - Convert bolt load to torque through known relationships

$$T = F \cdot K \cdot d$$

Torque Results



P_{set} (psi)	$P_{measured}$ (psi)	Force (lbf)	Torque (lbf-ft)
200	90	64,600	1000
250	175	91,000	1420
300	250	117,000	1830
350	300	131,000	2040

Accomplishments, Results and Progress

- Technical Accomplishments/Progress to Date
 - Completed engineering design and analysis
 - Prototype fabricated
 - Power section tested on dynamometer
 - Completed drive section testing
 - Torque output of tool quantified
 - Functional testing of tool is continuing
- Challenges to Date
 - Material selection
 - Drive section geometry
 - Quantifying performance

	Key Activities	FY 2011	Q1 2012	Q2 2012	Q3 2012	Q4 2012
FY 11	Percussive hammer white paper	Paper delivered 04/05/2011				
	Engineering design and drawings	Completed by 07/20/11				
	Prototype fabrication	Completed by 11/21/11				
	Component level bench top testing			Completed		
	Prototype functional test				Completed	
FY 12	Component revisions				Ongoing	
	Test design revisions				Ongoing	
	Drilling tests					Pending
	Project reporting					Pending

- Additional testing
 - Continue prototype lab testing
 - Drilling tests with prototype
- Identify commercial partners
- Progress towards FY2013 milestones
 - Field testing activities (pending)
 - Communicating results (in progress)

- Prototype indexing tool designed, built and tested
- Performance in line with expectations
- Revisions being made to improve performance and durability

Project Management

Timeline	Planned Start Date	Planned End Date	Actual Start Date	Actual /Est. End Date
	2/1/2011	9/30/2013	4/1/2011	9/30/2013

Budget	Federal Share	Cost Share	Planned Expenses to Date	Actual Expenses to Date	Value of Work Completed to Date	Funding needed to Complete Work
	\$900,000	\$0	\$707,000	\$740,000	\$625,750	\$0

Additional Slides