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Additive Manufacturing Case Study

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Outline

- Background/Introduction
- Design goals
- Case study details
- Planned testing
- Summary

Background/Introduction

- Geothermal technologies include an extremely wide range of products required for well construction, completion, production, intervention and surface energy conversion activities.
- Advancements in Additive Manufacturing (AM) materials of construction, build volumes and part quality have transitioned the technology from primarily cosmetic prototyping applications to the point where AM can be used to make production parts, even for the most demanding applications.
- Oak Ridge National Laboratory (ORNL) and Sandia National Labs (SNL) recently completed a study of AM application to geothermal technologies [Polsky (2021)]
- Topology optimization was used as a design method to reduce the rotational inertia of the part while preserving sufficient rotational stiffness to transmit the torque required for the drilling application.

Polsky, Y., Armstrong, K., Price, C., Su, J., Wang, A., Post, B., and Chesser, P. (2021). Study of Additive Manufacturing Applications to Geothermal Technologies Final Project Report. https://doi.org/10.2172/1778076

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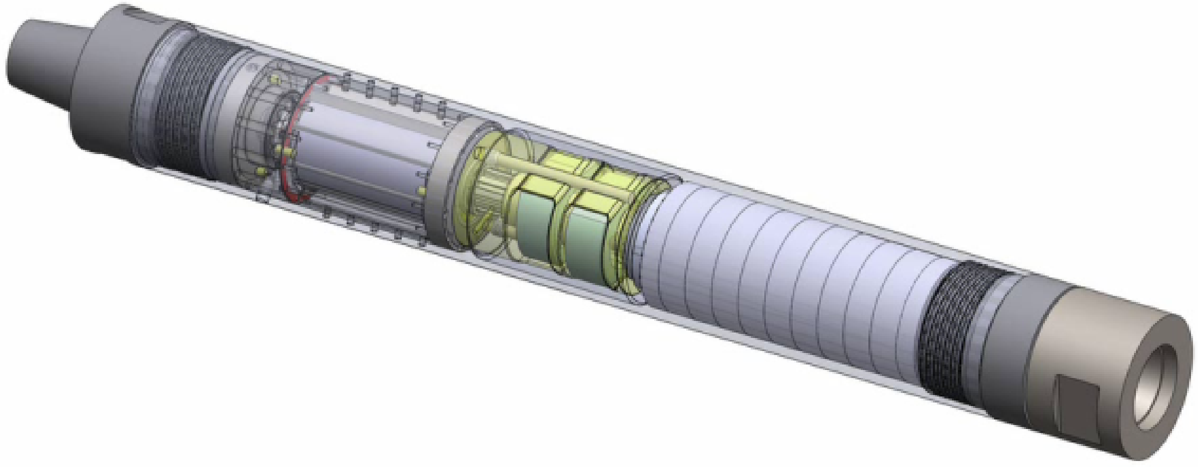


- Objective: Improve well construction capabilities to lower the cost of geothermal resources
- Use existing drilling techniques complemented by new technology to enhance drilling capabilities
- Innovation & Impact:
  - High-temperature downhole motor for use in geothermal drilling
  - Elastomer-free (high-temperature operation)
  - High peak torque in a small form factor
  - Performance targets: comparable to PDM
  - Promote the use of hammer drilling in geothermal formations
  - Enable advanced drilling techniques through downhole rotation

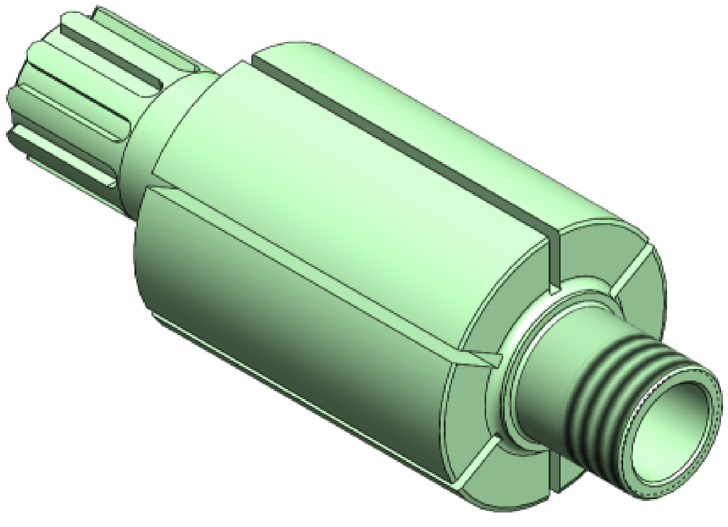
Design Goals

Advantages	Disadvantages
• High-temperature capable • Elastomer-free operation • Standard connections (American Petroleum Industry specifications) • Compact design • High peak torque	• Intermittent rotation • Additional shock loading in the bottom hole assembly (BHA) • May have difficulty in compliant mediums • Does not address other limitations of hammers in geothermal drilling

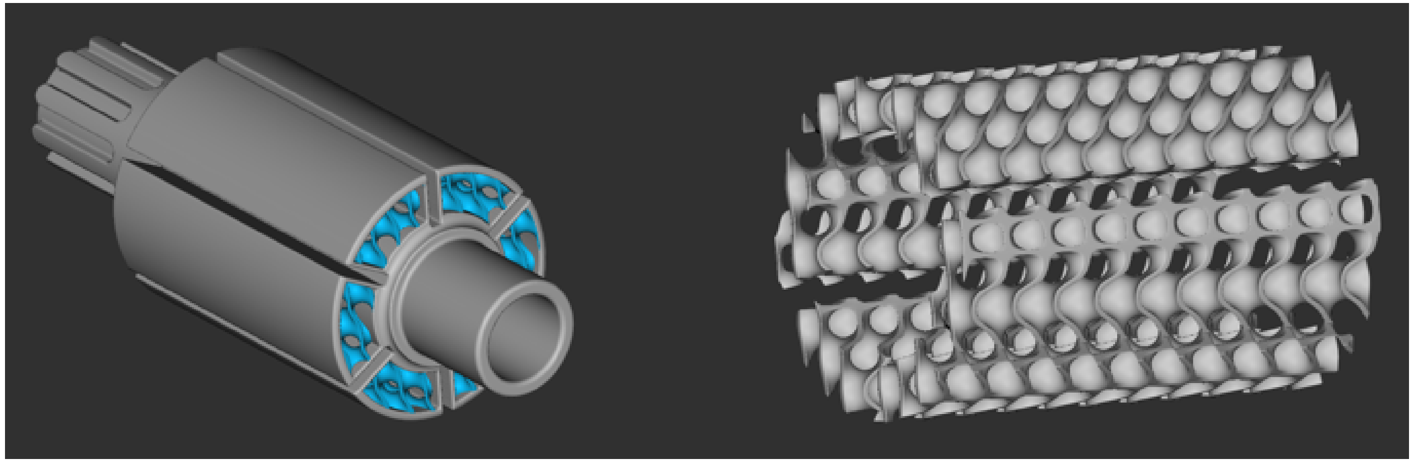
The impacting surfaces require hardness values on the order of 60 HRC, while the yield strength requirements exceed 100 ksi (~6.9 mPa). These requirements limit potential material choices to heat-treated steels or surface treatment.

Additive Case Study

Original Part



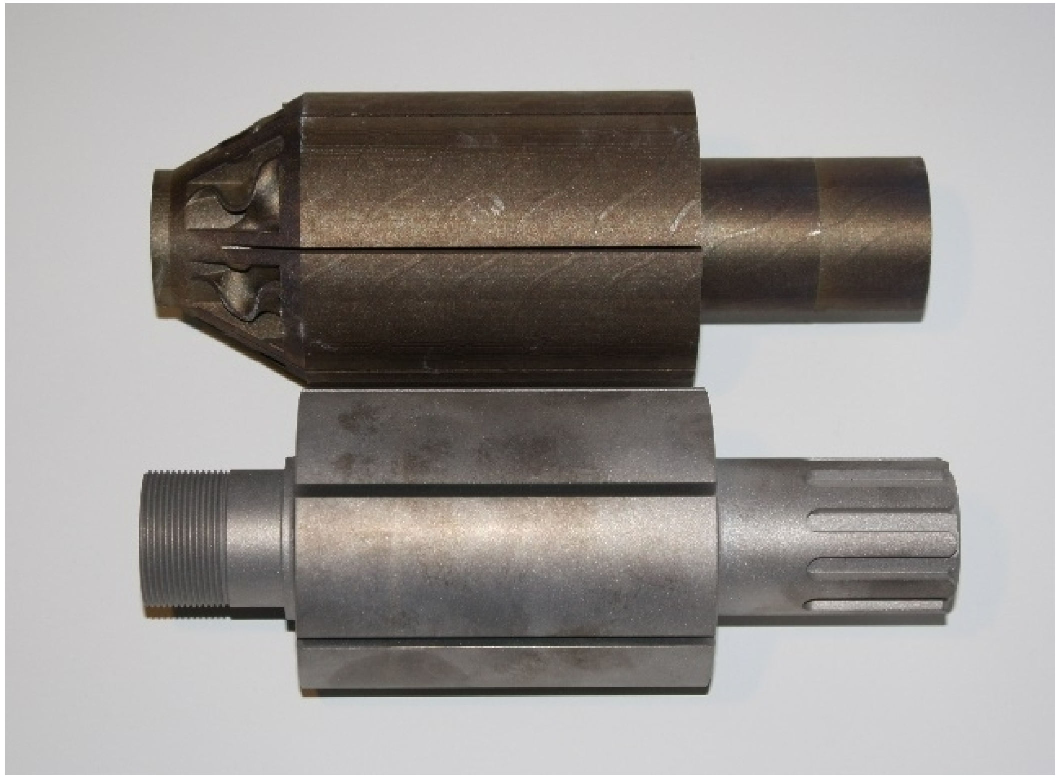
Topologically Optimized Part



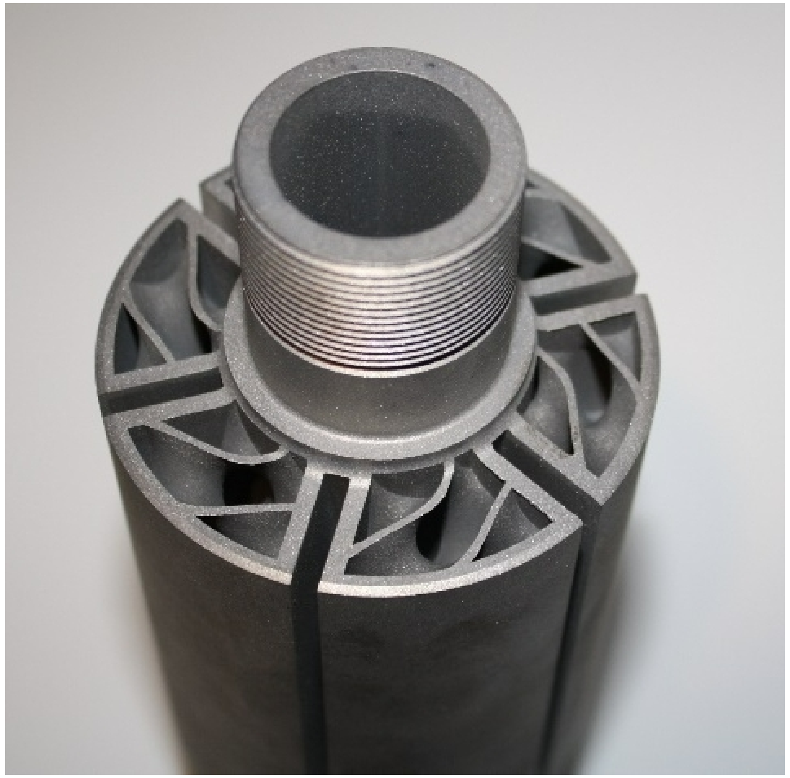
Able to reduce rotating mass/moment of inertial and maintain mechanical strength

AM Part Fabrication

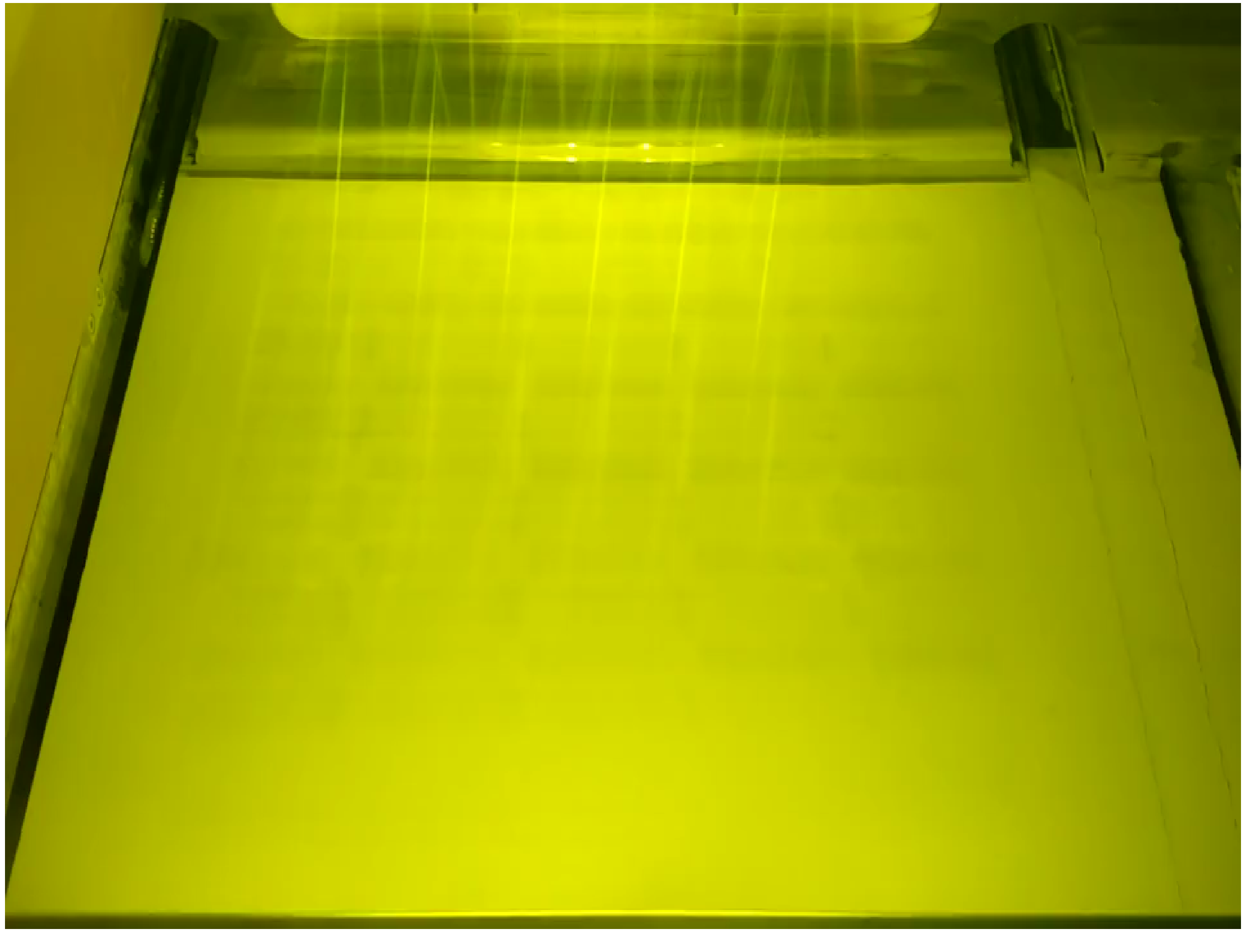
As Printed



Post Machining

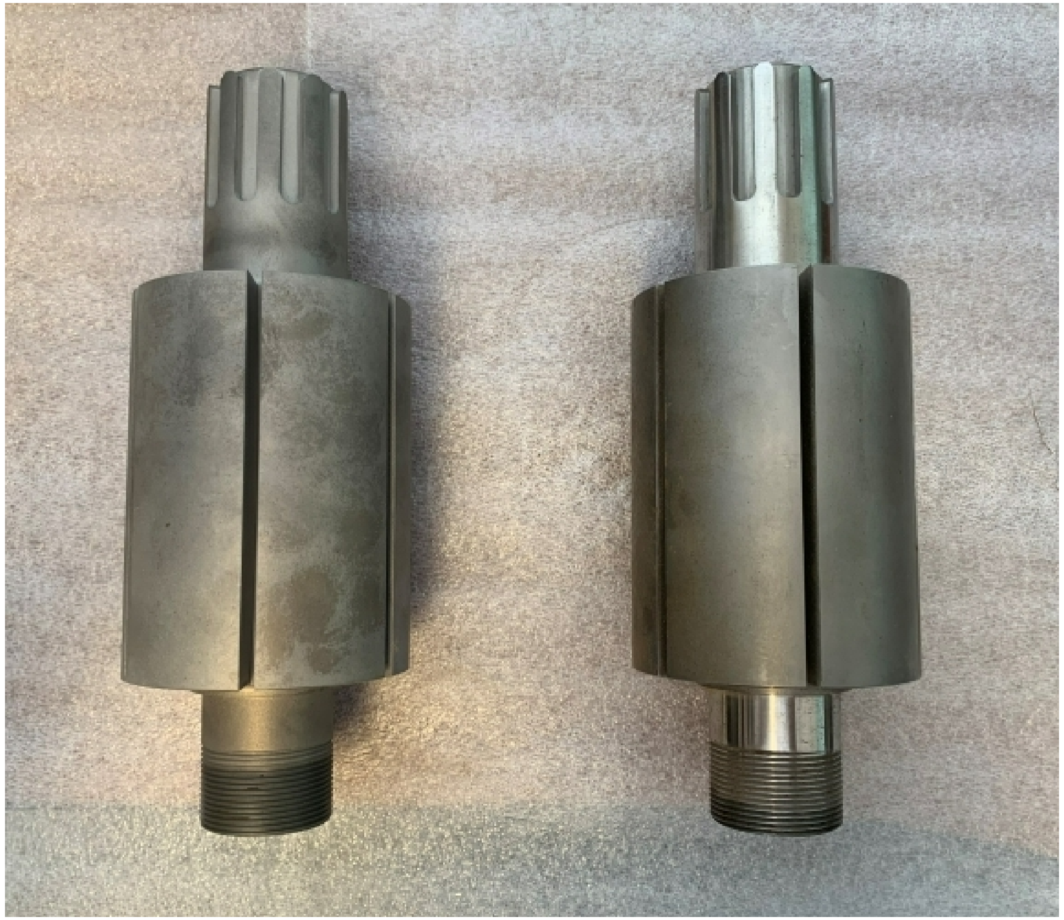


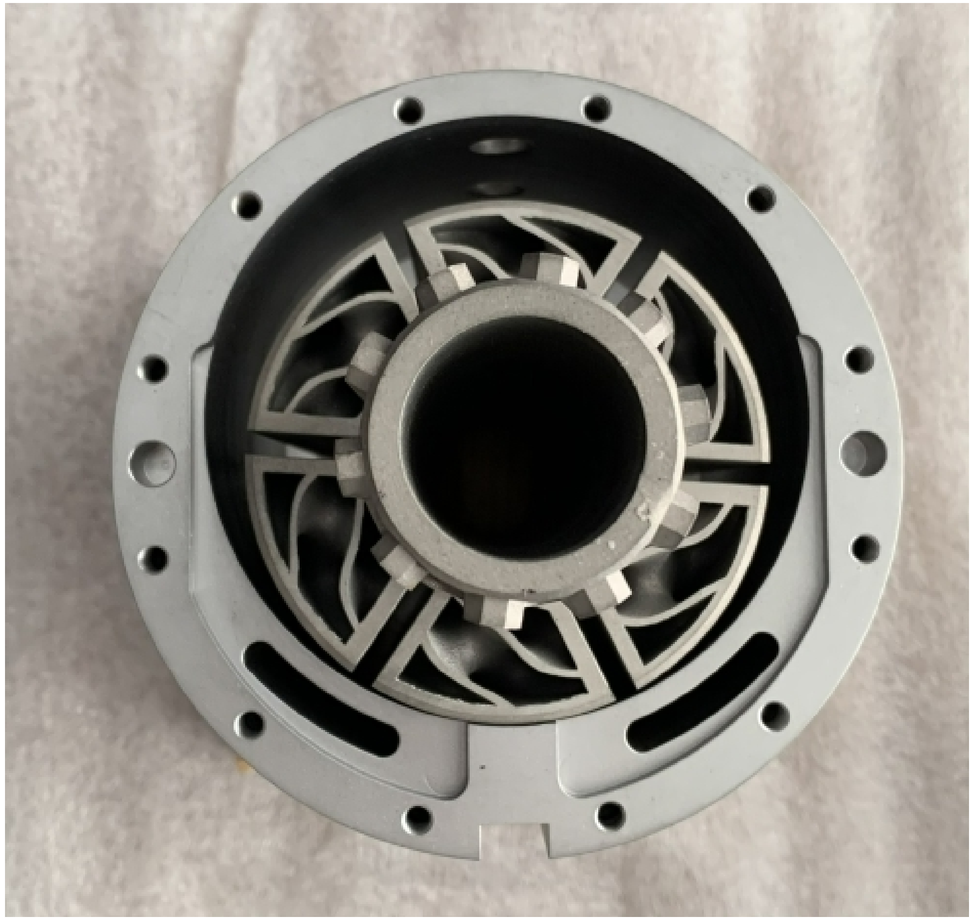
Laser Powder Bed Fusion



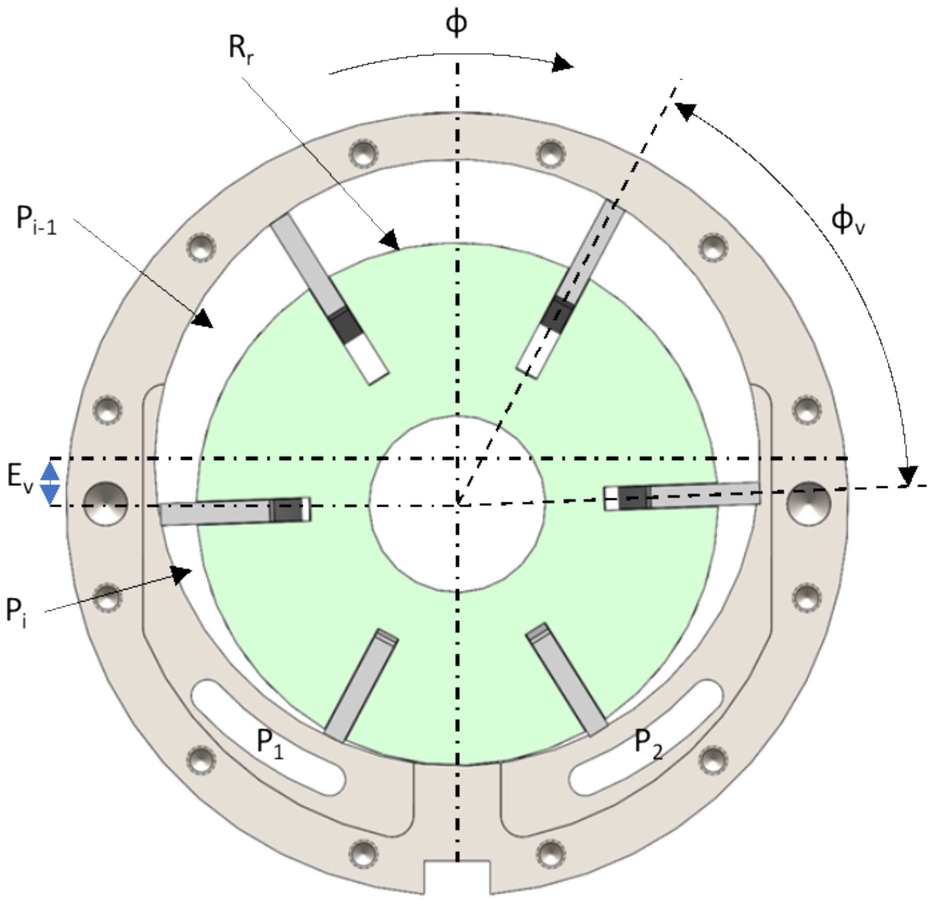
- AddUp FormUp 350
- Gas atomized 18Ni300 Maraging Steel
- Post-machine nitriding

AM Part Views



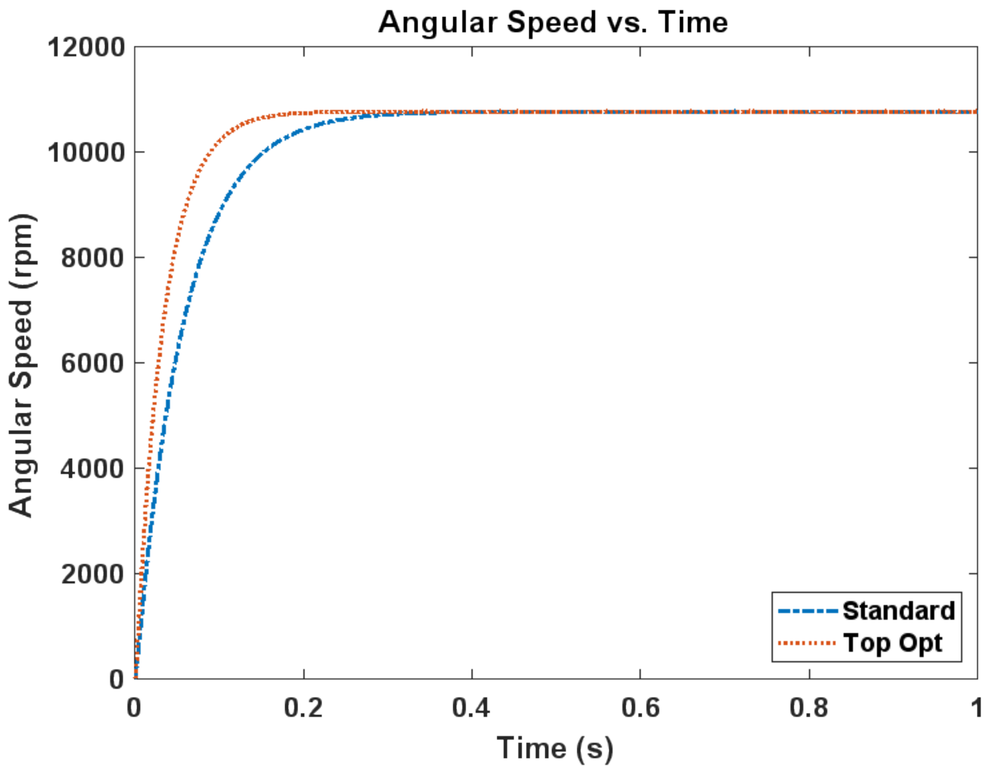


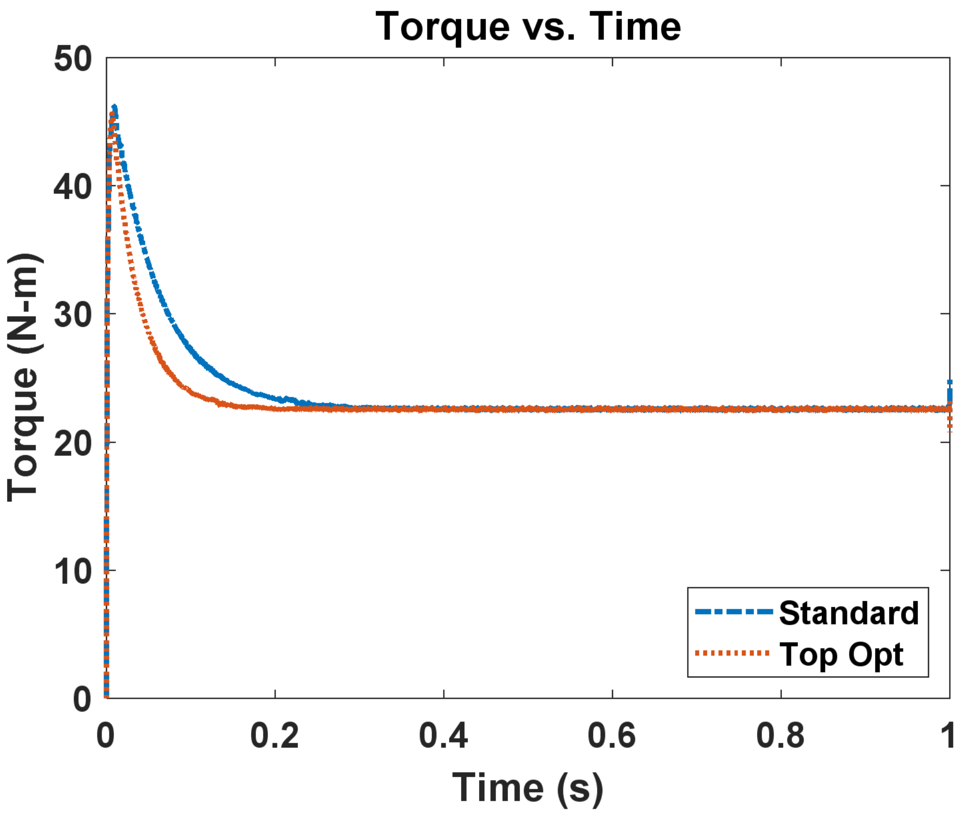
Vane Motor Modeling



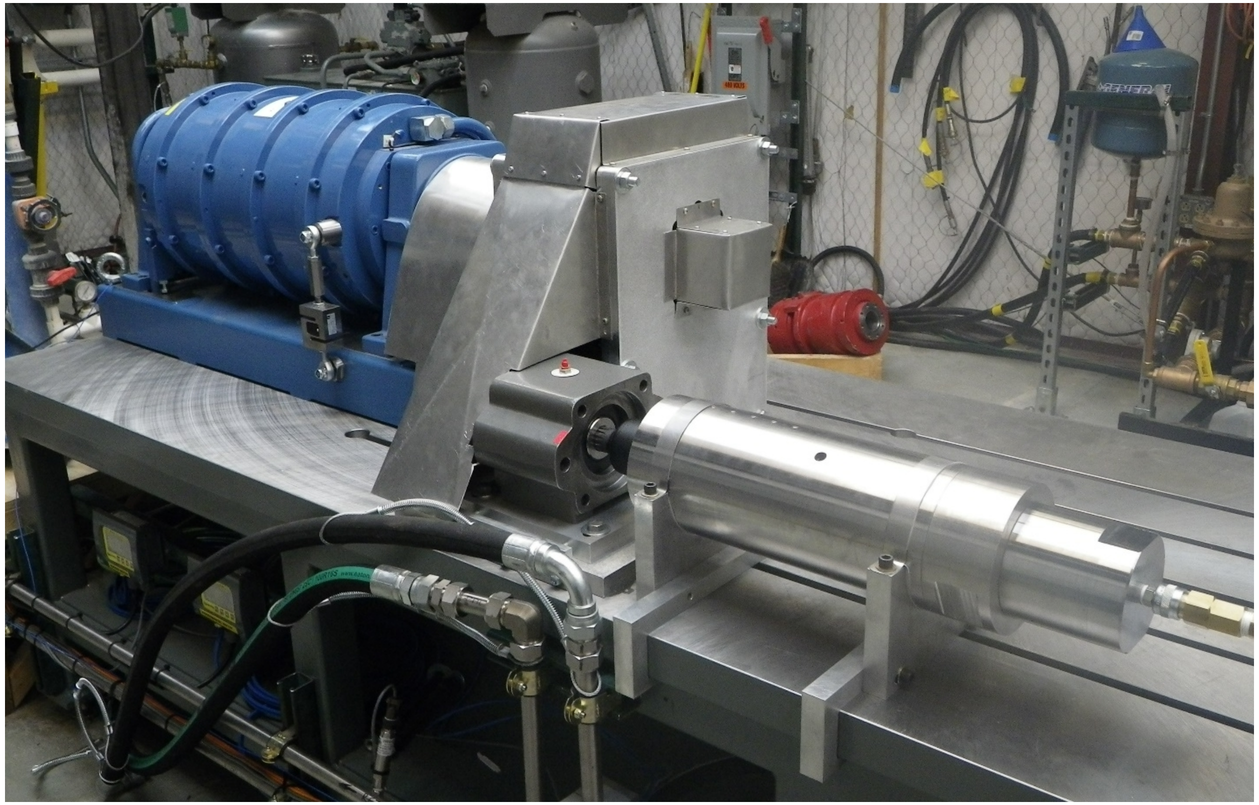
- Differential pressure between chambers creates force imbalance
- Solve differential equations describing the state of the air in each of the chambers as rotor spins
- The total torque of the motor is the sum of each of the torques in the adjacent chambers

Modeled Performance





Planned testing



Sandia Dynamometer (Magtrol 4PB15)

Summary

- AM build capabilities are being used in O&G applications
- Case study for geothermal downhole tool
- Physical properties (mass) of both parts within 1.6% of solid models
- System-level design considerations for maximum benefits

Funding Statement

- *This paper describes objective technical results and analysis. Any subjective views or opinions that might be expressed in the paper do not necessarily represent the views of the U.S. Department of Energy or the United States Government.*
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