Proceedings World Geothermal Congress 2026, Calgary, Canada, June 8—11, 2026

Maximizing Rate of Penetration in Deep Geothermal Wells Using a Novel Downhole Actuator

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INTRODUCTION

Mitigating drillstring vibration remains a challenge in deep geothermal well drilling, where greater depths, larger wellbore diameters, and harder, more abrasive formations amplify drilling dysfunctions. However, most of existing vibration control strategies:

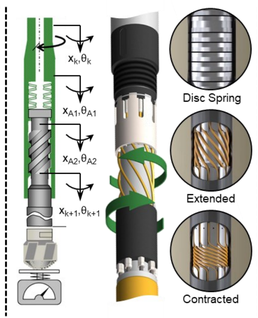
1. Operate passively and are developed for simplified drilling scenarios
2. Need parameter tuning and field trail-and-errors
3. Lack robustness against drilling nonlinearity, uncertainties, and coupled dynamics



Vibration-Related Damages (Dong & Chen, Shen et al.,)



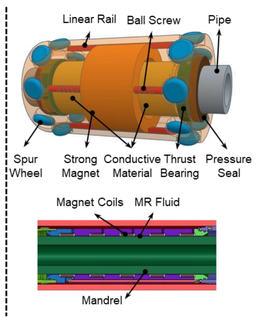
Shock Sub (NOV Inc.)



Stick-Slip Mitigators (Tomax, Neotork)



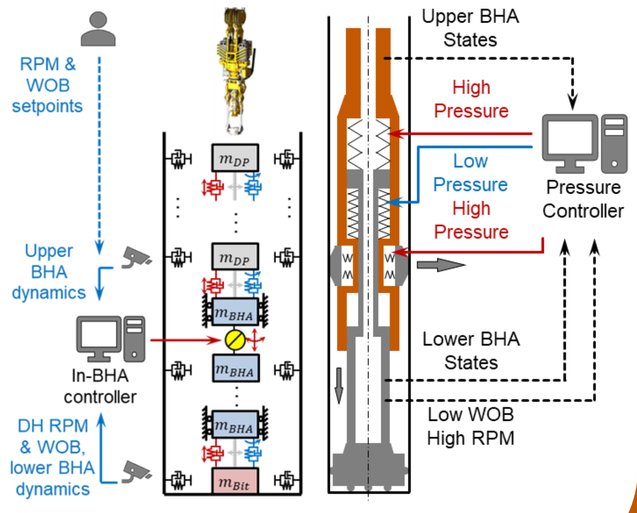
HFTO Dampers (SLB Ltd.)



Active Downhole Tools (NORCE, APS)

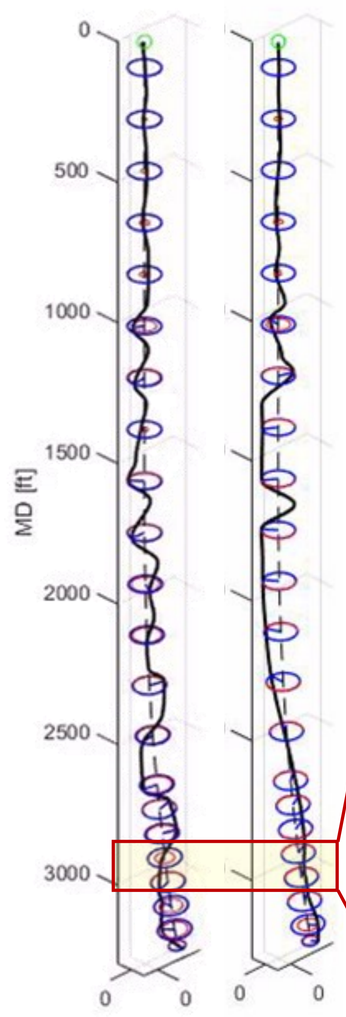
METHODS

1. A comprehensive and efficient drillstring dynamic model with coupled tri-axial dynamics is developed for vibration analysis.
2. An axial-torsional drilling actuator is designed to proactively control downhole WOB-RPM in the BHA.
3. Vibration mitigation strategies and algorithms are designed to achieve fast, efficient, and robust vibration control.
4. The design verified in challenging deep well drilling simulations, seeing effective mitigation of system vibrations and better performance than existing technologies.

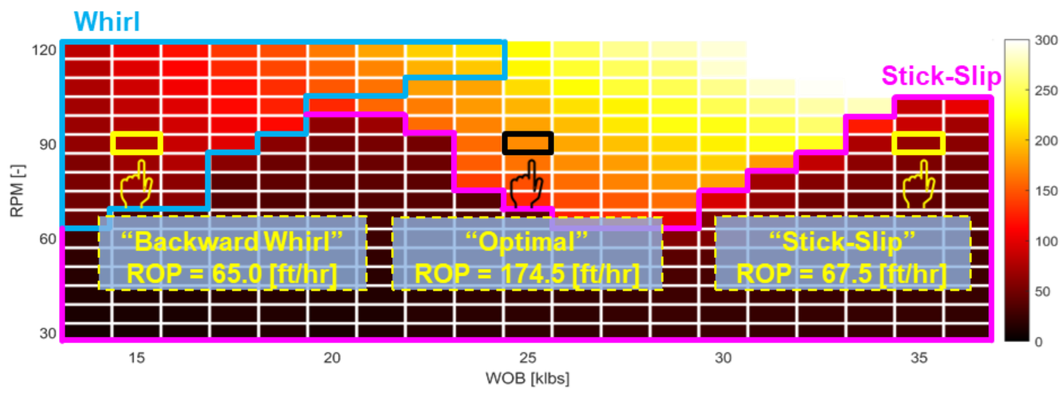


In-BHA WOB-RPM Control

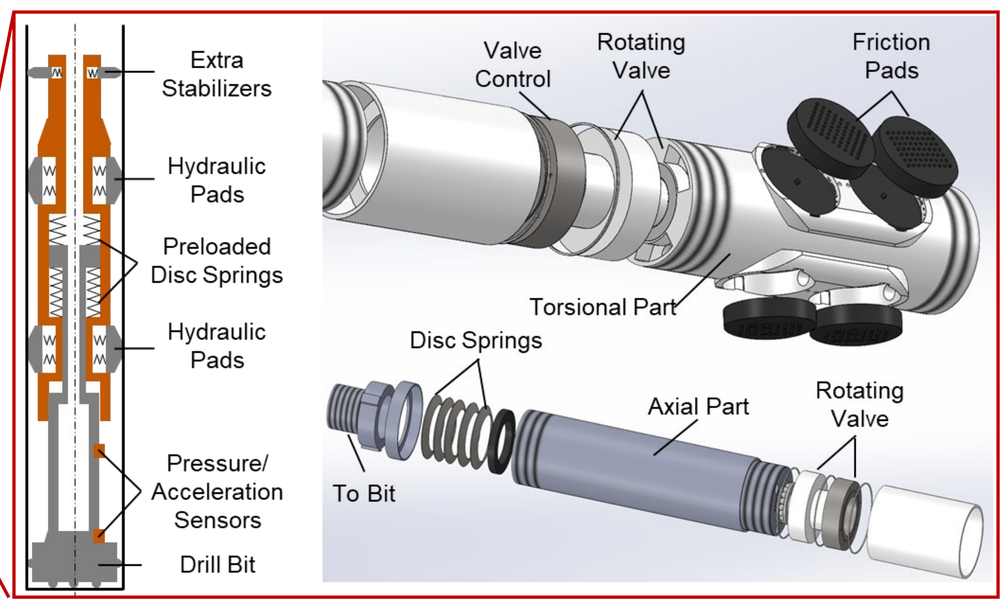
RESULTS



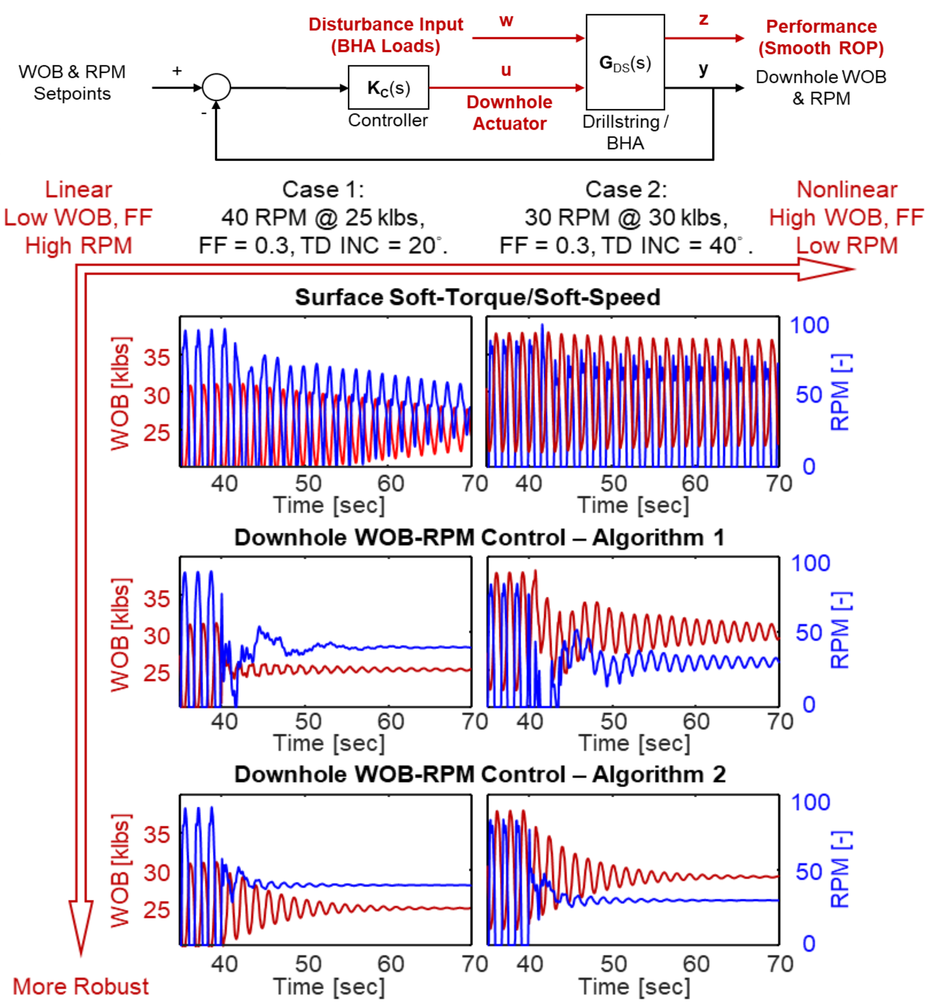
Drillstring Model



Simulated WOB-RPM-ROP Drilling Map and Dysfunctions



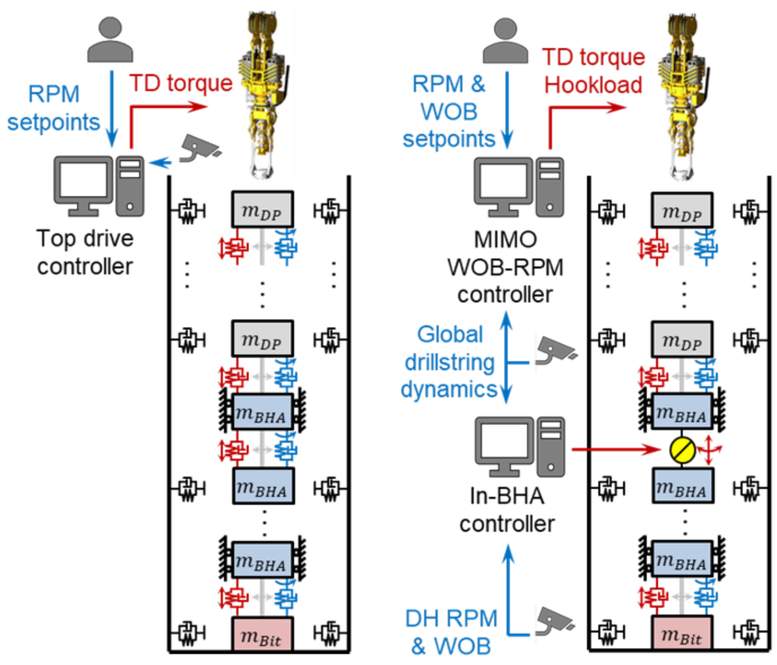
Design of Downhole WOB-RPM Actuator



Test of Downhole Tool and Control in Simulations

CONCLUSIONS

1. Coupled tri-axial vibrations in deep geothermal wells are ubiquitous and challenging to mitigate.
2. Downhole vibration control, with the proactive tool, shares a wide control bandwidth, strong robustness, and fast response compared with existing technologies.
3. Distributed (no surface communication) WOB-RPM controller receives clean measurements and act promptly directly in the BHA.
4. The drilling model and controller are ready for implementation. Future works involves prototyping and test of the actuator in the field.



Different Vibration Control Architectures

Feature	Surface Soft-Torque & Soft-Speed		Our Work: Downhole WOB-RPM Control 1		Our Work: Downhole WOB-RPM Control 2	
Sensor	Drillstring/Top drive torque values		DH RPM & WOB BHA dynamics		DH RPM & WOB	
Channel	(Near) surface to surface		Top/Bottom BHA to in-BHA processor		Bit to in-BHA processor	
Actuation	Top drive output RPM or torque		DH tool torque and axial loads		DH tool torque and axial loads	
Feedback	Output static		State static		Output dynamic	
Case	1	2	1	2	1	2
Axi Energy [kJ]	-	-	2.2	7.8	0.25	0.42
Max loads [klbs]	-	-	7.7	9.8	2.0	2.2
Tor Energy [kJ]	530.1	Fail	34.1	53.9	51.9	47.9
Max loads [kft-lbs]	4.8	Fail	0.42	0.53	2.9	2.8
Stab Time [sec]	>60	Fail	13.5	>30	6.0	8.2

= Tech is available = Tech needs refinement = Tech in development

Control Performance of Surface and Downhole Vibration Controllers

Acknowledgements

Support by the sponsors of the RAPID industry affiliate program (IAP) at The University of Texas at Austin is gratefully acknowledged. The authors would also like to thank the contribution of Hao Fu and Myung Sun Park to this project.

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