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### Hot water drilling

Poster

Similarity-Based Model of Experiments for Analyzing Freezing and Melting in HOT WATER DRILLED BoreholeS

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In hot-water ice drilling, the melting rate of the borehole wall during drilling operations and the freezing rate leading to borehole closure during standstill periods are critical parameters for evaluating drilling efficiency and operational safety. However, in-situ measurements of these parameters present significant challenges, including high costs, operational uncertainties and delay of data acquisition. This necessitates systematic laboratory experimentation under controlled conditions.

As an engineering application of heat transfer theory, hot water drilling technology can benefit from scaled model experiments - a well-established methodology widely employed in heat transfer research for aerospace (Ran et al. 2024, Lin et al. 2022), permafrost (Yang et al. 2025, Chen et al. 2022), metal casting (Ren et al. 2024) and some other fields (Jia et al. 2024, Yang et al. 2024). Such modeling approaches have demonstrated considerable advantages in reducing experimental costs while improving data reliability.

This study proposes a comprehensive theoretical design scheme for model experiments addressing phase-change phenomena in borehole walls induced by hot water drilling in polar regions. Through dimensional analysis with borehole diameter variation rate and water temperature of outlet of annulus between hose and borehole wall as dependent variables, along with key physical variables influencing the freezing and melting processes as independent variables, a series of similarity criteria were derived. These include temperature similarity criterion, geometric similarity criterion, time similarity criterion, and flow rate similarity criterion.

Based on these similarity criteria, the core parameters for model experiments were determined according to capabilities and conditions of experimental equipment. The scaling ratios between actual engineering variables and model experimental parameters were established as follows: temperature similarity ratio 1:1, geometric similarity ratio 2:1, time similarity ratio 2:1, and flow rate similarity ratio 4:1.

This study innovatively designed a multifunctional experimental platform architecture, incorporating a high-temperature hot-water circulation system, low-temperature ice environment simulation chamber, temperature measurement system, and visual borehole diameter measurement apparatus. This theoretical design scheme establishes a foundation for subsequent physical simulation experiments of phase-change processes in hot water drilled boreholes and provides significant guidance for the scientific optimization of process parameters in polar hot water drilling operations.

References

Chen Z, Feng Y, Zhang X, et al. (2022) Similarity criterion for the nonlinear thermal analysis of the soil freezing process: considering the dual effect of nonlinear thermal parameters and boundary conditions. Acta Geotechnica 17:5709–5719.

https://doi.org/10.1007/s11440-022-01629-y

Lin A, Liu G, Yu X, Chang R, Feng Q (2022) Comprehensive investigations on fluid flow and heat transfer characteristics of a high-speed rotating turbine disk cavity system of aero-engine. International Communications in Heat and Mass Transfer 136:106170.

https://doi.org/10.1016/j.icheatmasstransfer.2022.106170.

Jia X, Yang Y, Xu C, Duanmu L, Wang Z (2024) New criterion number correlation and similarity theory application on the seepage and heat transfer of a beach well intake system of seawater source heat pump. Sustainable Energy Technologies and Assessments 64:103718.

<https://doi.org/10.1016/j.seta.2024.103718>.

Ran C, Zhao Y, Guo M, Lin A, Wang Y, Liu G (2024) Dimensionless analysis of flow and heat transfer characteristics in a high-speed rotor–stator disk cavity based on similarity criteria. Applied Thermal Engineering 238:122148.

 <https://doi.org/10.1016/j.applthermaleng.2023.122148>.

Ren M, Wang G, Li B, Wang Z, Fu H (2014) Flow equation and similarity criterion during centrifugal casting in micro-channel. Transactions of Nonferrous Metals Society of China 24:1506-1511.

https://doi.org/10.1016/S1003-6326(14)63219-2.

Yang L, Deng C, Li W, Zhao B, Li Q, Cai W (2024) Study on the similarity criterions for trans-critical flow and heat transfer of methane and nitrogen in PCHE. International Communications in Heat and Mass Transfer 159:107993.

https://doi.org/10.1016/j.icheatmasstransfer.2024.107993.

Yang S, Zhang M, Pei W, Wan X, Lu J, Yan Z, Bai R, Bi J (2025) Experimental investigation on the thermal stability and deformation behavior of a novel duct-ventilated embankment in a snowy permafrost region. International Communications in Heat and Mass Transfer 164:108774.

 https://doi.org/10.1016/j.icheatmasstransfer.2025.108774.