SAND2022-16816C

Thermal Modeling of Hypersonic Wind Tunnel Heater Using Low-Fidelity Fluid Model

Alexander J Snyder

Sandia National Laboratories

SciTech, 23-27 January 2023

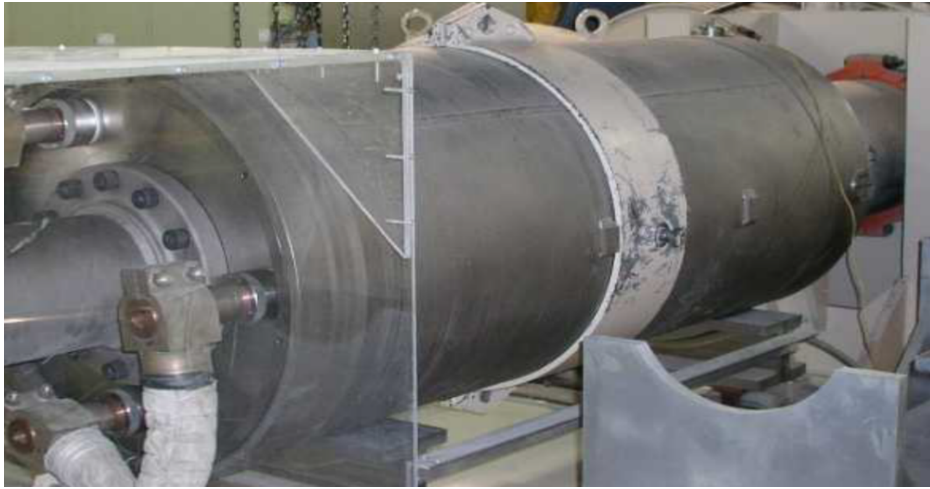
Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

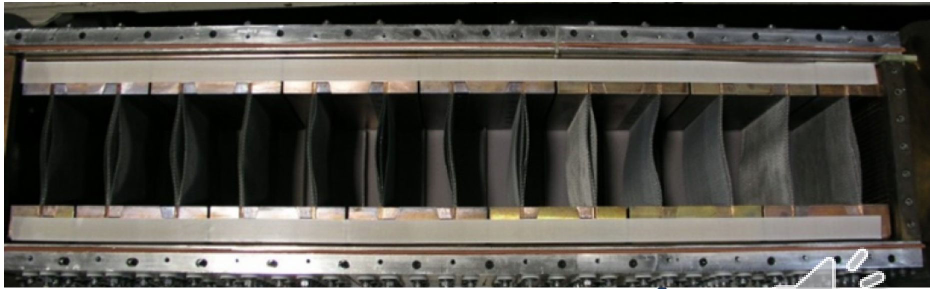
Overview

- Introduction
- Experimental Data
- Methods
- Results
- Recommendations

Introduction

- Sandia National Laboratories Hypersonic Wind Tunnel (SNL HWT) runs at Mach 5, 8, 14.
- 13 tungsten screen stations are used for heating.
- Initial thermal analysis completed in 1970s.
- Goal of analysis: Model heater material temperatures to provide guidance on HWT operation.





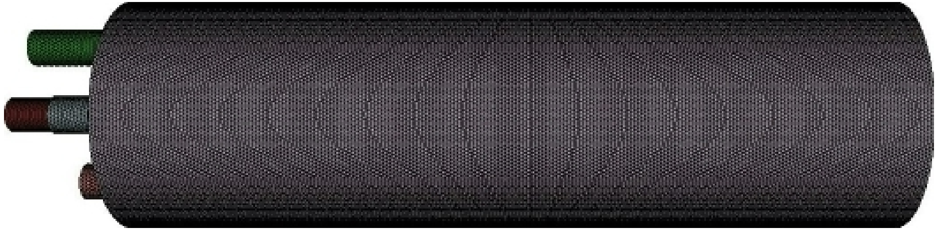
Experimental Data

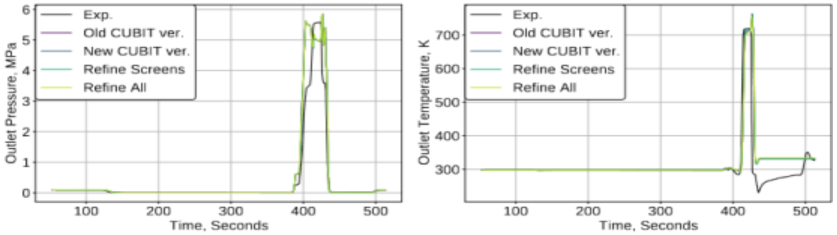
- 15 experimental cases provided inlet and outlet temperature and pressure values and voltage set point.
- Experimental data was used to calculate mass flow rate and total electric power.
- No solid temperature measurements.

	Case	P_0 [MPa]	T_0 [°C]	Voltage [V]
1	180-049	5.57	397.4	579.5
2	180-051	5.54	406.9	597.8
3	180-052	5.57	410.2	610.0
4	186-025	2.36	399.1	451.4
5	186-026	2.28	513.5	469.7
6	186-031	5.70	369.6	573.4
7	186-046	2.25	513.5	466.7
8	186-047	5.54	317.4	555.1
9	187-008	5.18	271.9	488.0
10	187-009	4.74	304.6	488.0
11	187-010	4.66	307.4	488.0
12	187-011	4.71	305.2	488.0
13	187-025	4.77	306.3	488.0
14	187-026	4.84	299.1	488.0
15	187-031	5.13	271.9	488.0

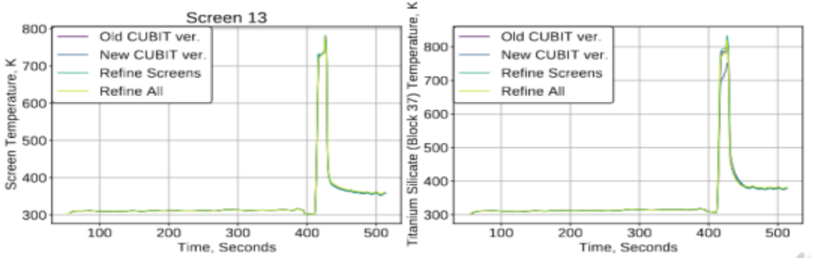
Methods- Computational Model

- Validation of model: matching experimental fluid outlet temperature and pressure to simulated values.
- Heater transfer parameters values of effective Nusselt number, heating efficiency, and pressure lose coefficient were determined through parameter sampling analysis.





(a) Mesh refinement study fluid domain.

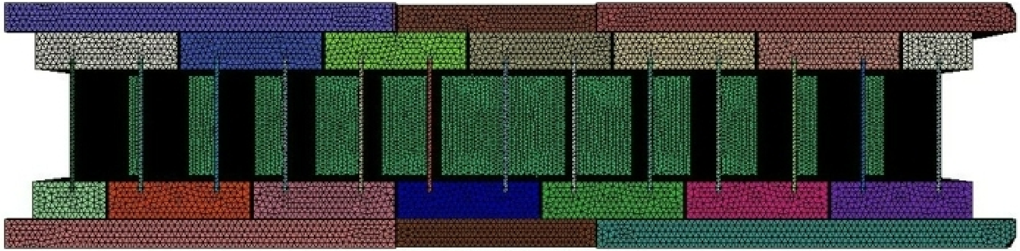


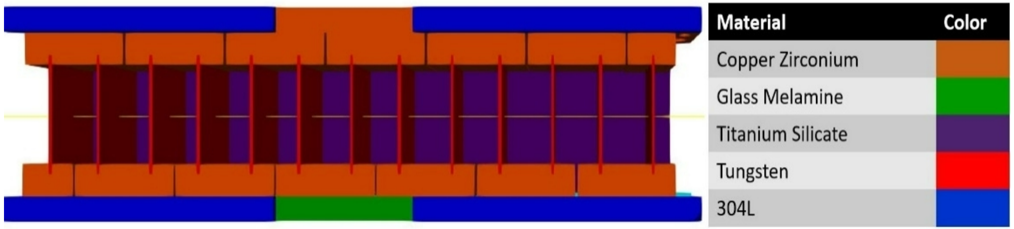
(b) Mesh refinement study structural domain.

SHAPING THE FUTURE OF AEROSPACE

Methods – Heat Transfer

- Two different heater processes were simulated, a single cycle and a multicycle representation.
- Fluid was represented using Aria tool-advective bar (low fidelity approach).

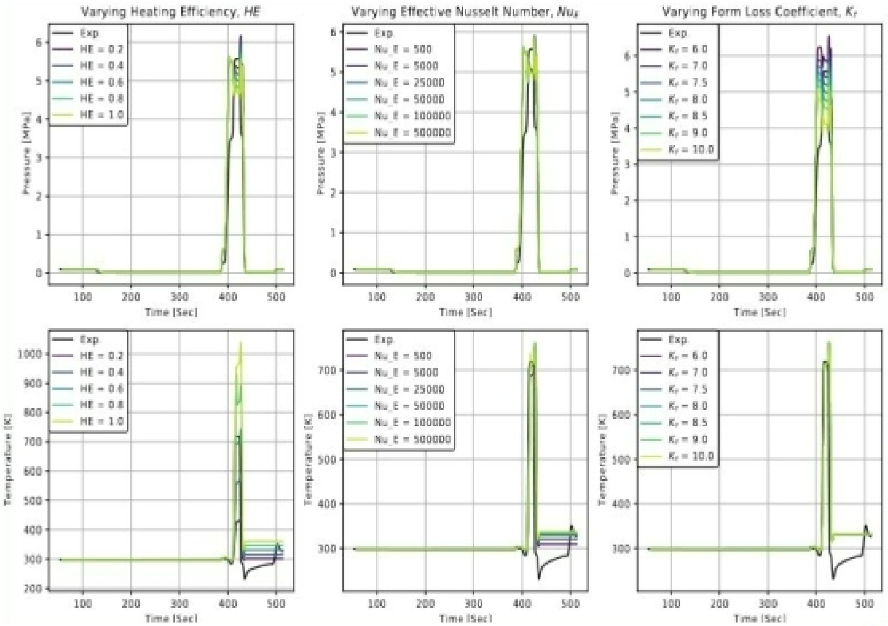




Results – Single-Cycle Analysis

- Single Cycle Heat Run

#	Effective Nusselt Number, Nu_E	Form Loss Coefficient, K_f	Heating Efficiency, HE
1	50,000	8.0	0.2
2	50,000	8.0	0.4
3	50,000	8.0	0.6
4	50,000	8.0	0.8
5	50,000	8.0	1.0
6	50,000	6.0	0.625
7	50,000	7.0	0.625
8	50,000	7.5	0.625
9	50,000	8.0	0.625
10	50,000	8.5	0.625
11	50,000	9.0	0.625
12	50,000	10.0	0.625
13	500	8.0	0.625
14	5,000	8.0	0.625
15	25,000	8.0	0.625
16	50,000	8.0	0.625
17	100,000	8.0	0.625
18	500,000	8.0	0.625

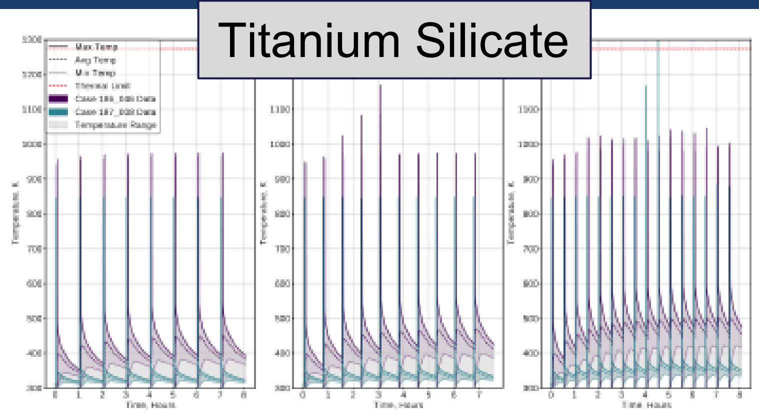


Process-Multi-Cycle Analysis

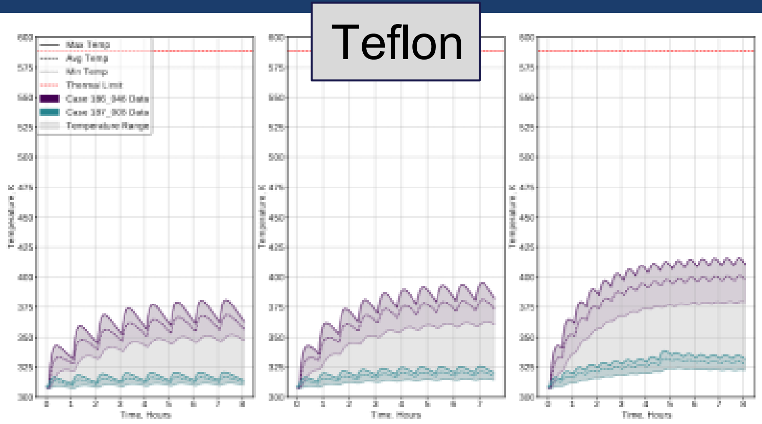
- Step 1: Latin Hypercube Sampling (LHS) to determine parameters for multi-cycle analysis
- Step 2: Perform multicycle analysis on the coldest inlet condition case 187_008 and hottest case 186_046.

- Multicycle analysis run consists of:
  - Heater start
  - Heat up
  - Heater stop
  - Cooldown period
    - (60, 45, or 30 minutes)
  - Restart

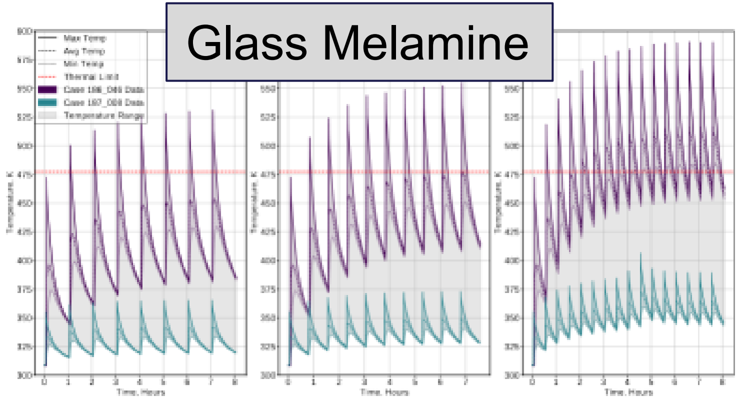
Results – Multi-Cycle Analysis



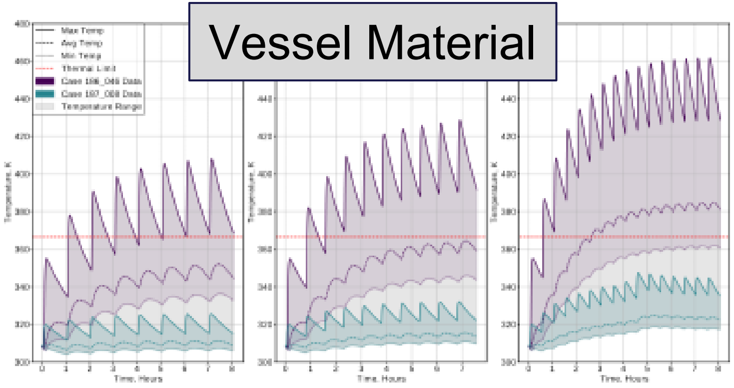
(a) 60 minute interval. (b) 45 minute interval. (c) 30 minute interval.



(a) 60 minute interval. (b) 45 minute interval. (c) 30 minute interval.



(a) 60 minute interval. (b) 45 minute interval. (c) 30 minute interval.



(a) 60 minute interval. (b) 45 minute interval. (c) 30 minute interval.

Recommendations

- Current recommendations for the HWT operators is that they can likely use a less conservative cooldown interval for lower temperature experiments, but additional model improvements are needed to inform the optimum cooldown duration.

Thank you!

Contact: Alex Snyder
ajsnyde@sandia.gov

Acknowledgement

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. 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.

AMERICAN INSTITUTE OF
AERONAUTICS AND ASTRONAUTICS