



Advanced Thermal Management for High Pressure Die Casting

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University of California - Irvine

Emergent Metal Casting Technologies
(EMCS)

AMC Technology Review

June 24-25, 2026





DURATION

Overview

AMC
AMERICAN METALCASTING CONSORTIUM

- **Needs and Benefits**

- Large castings exerts additional thermal loads on the dies which increases risk of early failure due to thermal fatigue, hot-spot induced failures such as die soldering and heat checking.
- Balanced and controlled temperature distribution within the tooling will increase lifetime and productivity.

- **Progress**

- The efficiency of four (4) heating technologies has been quantified and appropriate data for implementation in casting simulations has been collected.
- Industrial collaborator and insert for the first industrial trial has been chosen.

- **Transition**

- In-plant trials at RCM are to ease of implementation and benefits of technology.
- Results of these trails are presented and published at NADCA Committee and Congress meetings, as well as the Advanced Casting Research Center (ACRC) Meetings.

- **Cost Share**

- \$337,706 provided to date of \$394,000 proposed

Needs - Big picture

Giga Castings - High Pressure Die Casting
Reduce assembly complexity by parts consolidation.

- Large complex castings
 - Thin sections – Heating?
 - Needs to be heated to enable filling
 - Thick sections – Cooling Lines
 - Needs to be cooled for productivity
 - Large thermal load
 - Thermal fatigue of material
 - Large thermomechanical stresses
 - Hot spots
 - Heat checking
 - Die soldering



<https://www.theautopian.com/how-tesla-made-gigacasting-the-most-important-word-in-the-car-industry/>

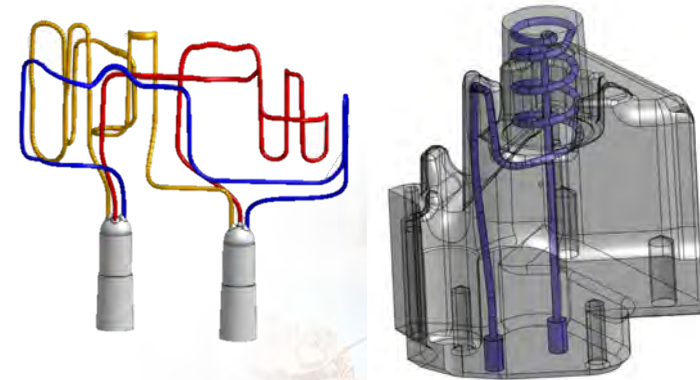


<https://www.linkedin.com/pulse/giga-press-transforming-teslas-manufacturing-danilo-onorino-cbroe>

Temperature profile of the die needs to be controlled to maintain tool lifetime while remaining productive.

- What are the most efficient ways of controlling temperature within the tooling?
- How can it be implemented and integrated into the tooling?

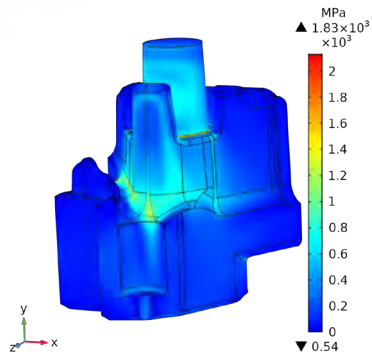
Control is measure and change...



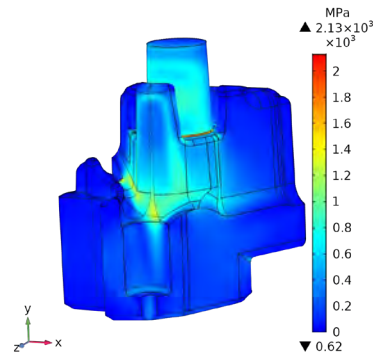
Needs – Small Picture

Increase Cooling → Increase TM Stress

WaterHTC(1)=20000 Surface: von Mises stress (MPa)

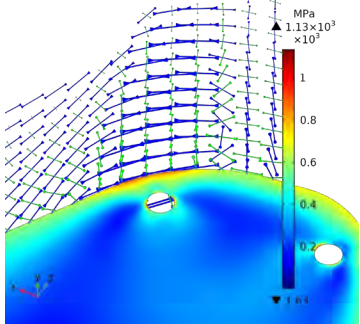


WaterHTC(3)=1E5 Surface: von Mises stress (MPa)



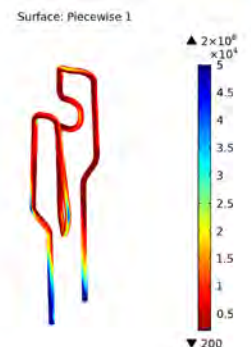
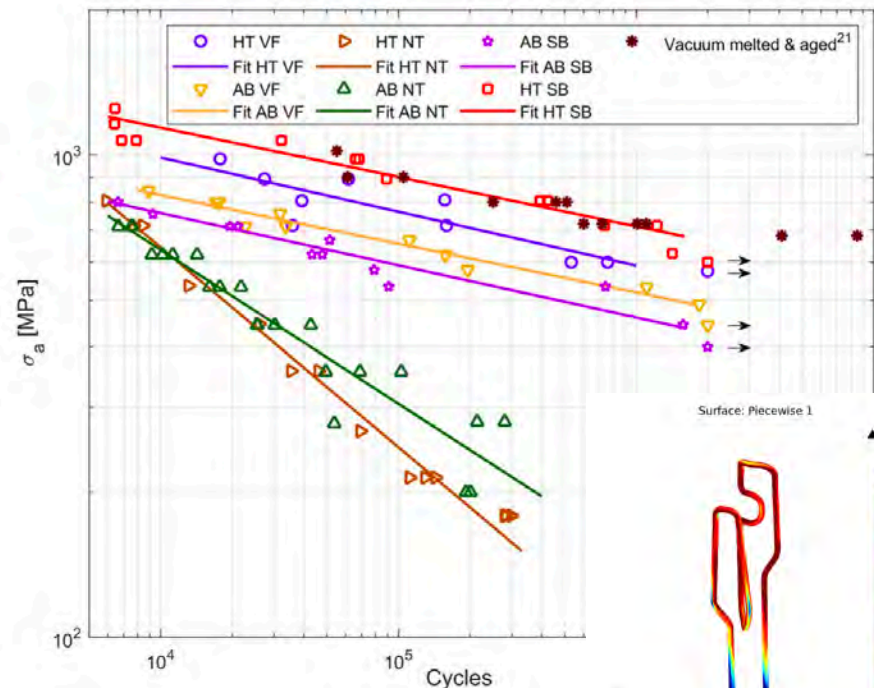
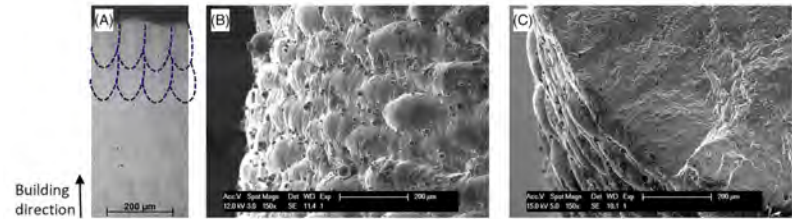
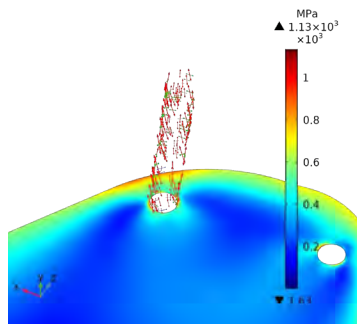
Surface Compressive Stresses

WaterHTC(3)=1E5 Principal stress Surface: von Mises stress (MPa)



Cooling Line Tension Stresses

WaterHTC(3)=1E5 Principal stress Surface: von Mises stress (MPa)



ORIGINAL CONTRIBUTION

Post-treatment selection for tailored fatigue performance of 18Ni300 maraging steel manufactured by laser powder bed fusion

Chola Elangerwaran¹ | Koppila Gurung² | Raphael Koch² | Antonio Cutolo¹ | Brecht Van Hooreweder¹

Benefits

Heat transfer rules solidification

Improved thermal management

- Shorter cycle time
 - Rapid heat extraction around thick sections of the casting
- Improved mechanical properties
 - Focus on solidification pathways for porosity placement
- Controlled die/tool temperature
 - Higher temperatures around thin sections
 - Improve filling and increase flow lengths
 - Lower temperatures around thick sections
 - Decrease solidification time
- Improved Tooling Lifetime
 - Managing temperature gradients to reduce thermomechanical fatigue

Milestones/Tasks

Completed

- Laboratory Benchmark of Traditional Thermal Technologies
 - Hot oil/water,
 - Induction
 - Cartridge
 - Infrared
 - Direct flame
- Laboratory Benchmark of Novel Thermal Technologies
 - Phase Change Material

Milestone at 12 months (January 2025)

Milestone at 24 months (January 2026)

In Progress

- Laboratory Benchmark of Novel Thermal Technologies
 - Phase Change Material – Complete
 - Porous Inserts – 95% Complete
 - Heat pipes – 35% Complete
 - Integrated heat exchanger – 70% Complete
- Industrial Trial 1 – 10% Complete

Milestone at 24 months (January 2026)

Delayed but will complete by
September 2027

Milestone at 36 months (January 2027)

Planned

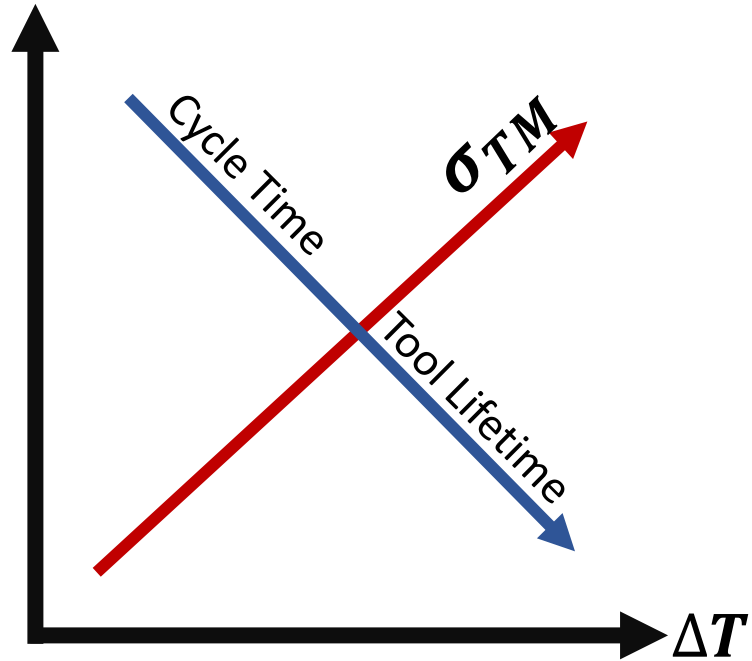
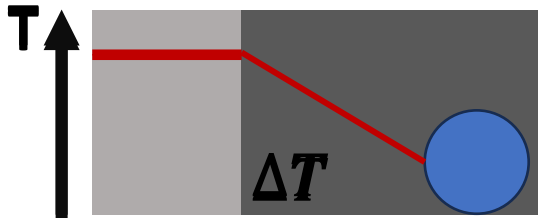
- Industrial Trial 2
- Industrial Trial 3

Milestone at 48 months (December 2027)

Milestone at 60 months (December 2028)

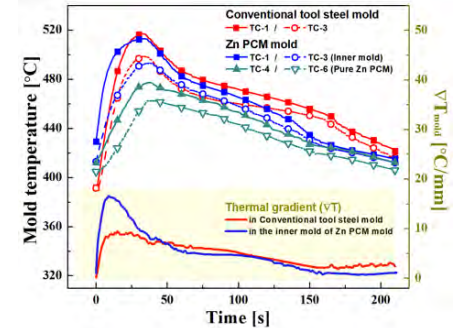
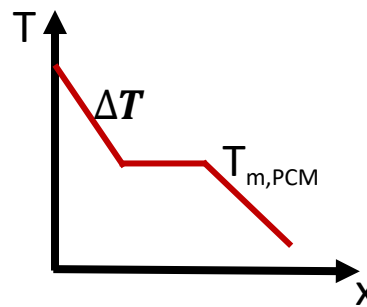
Technical Progress

$$\sigma_{TM} \sim \Delta T$$



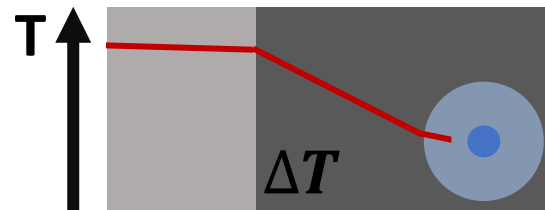
Phase Change Material (PCM Mold)

Control TM Stress establishing the thermal gradient by selecting suitable PCM.

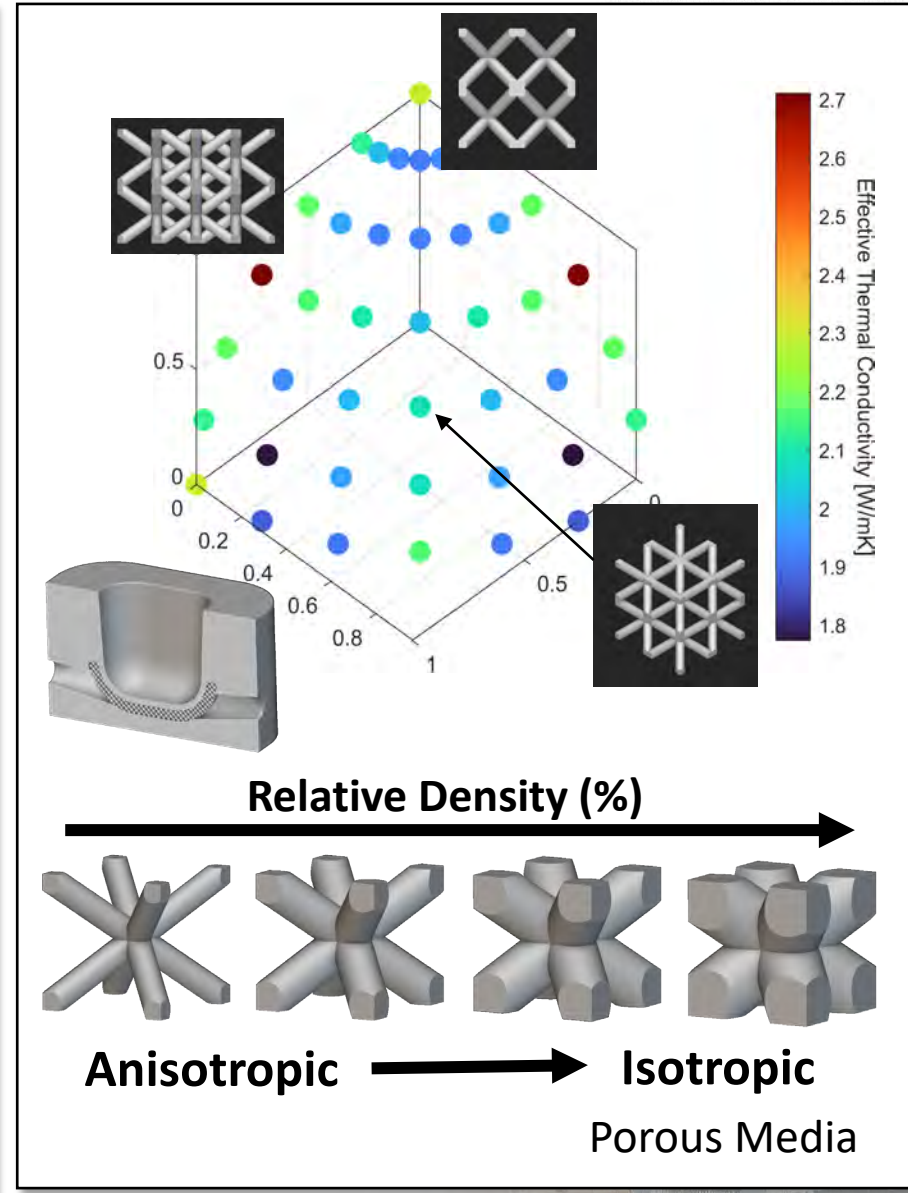
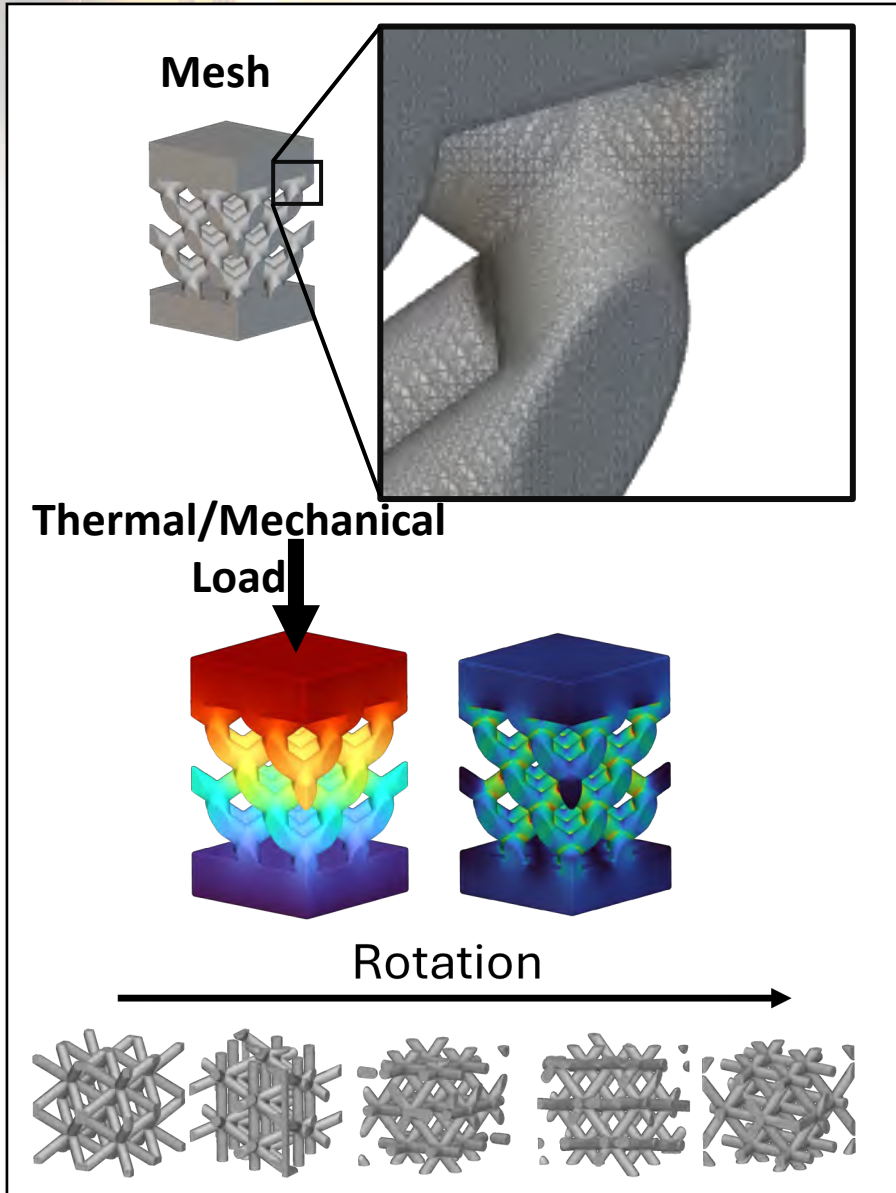


Porous Channels / Lattice Channels

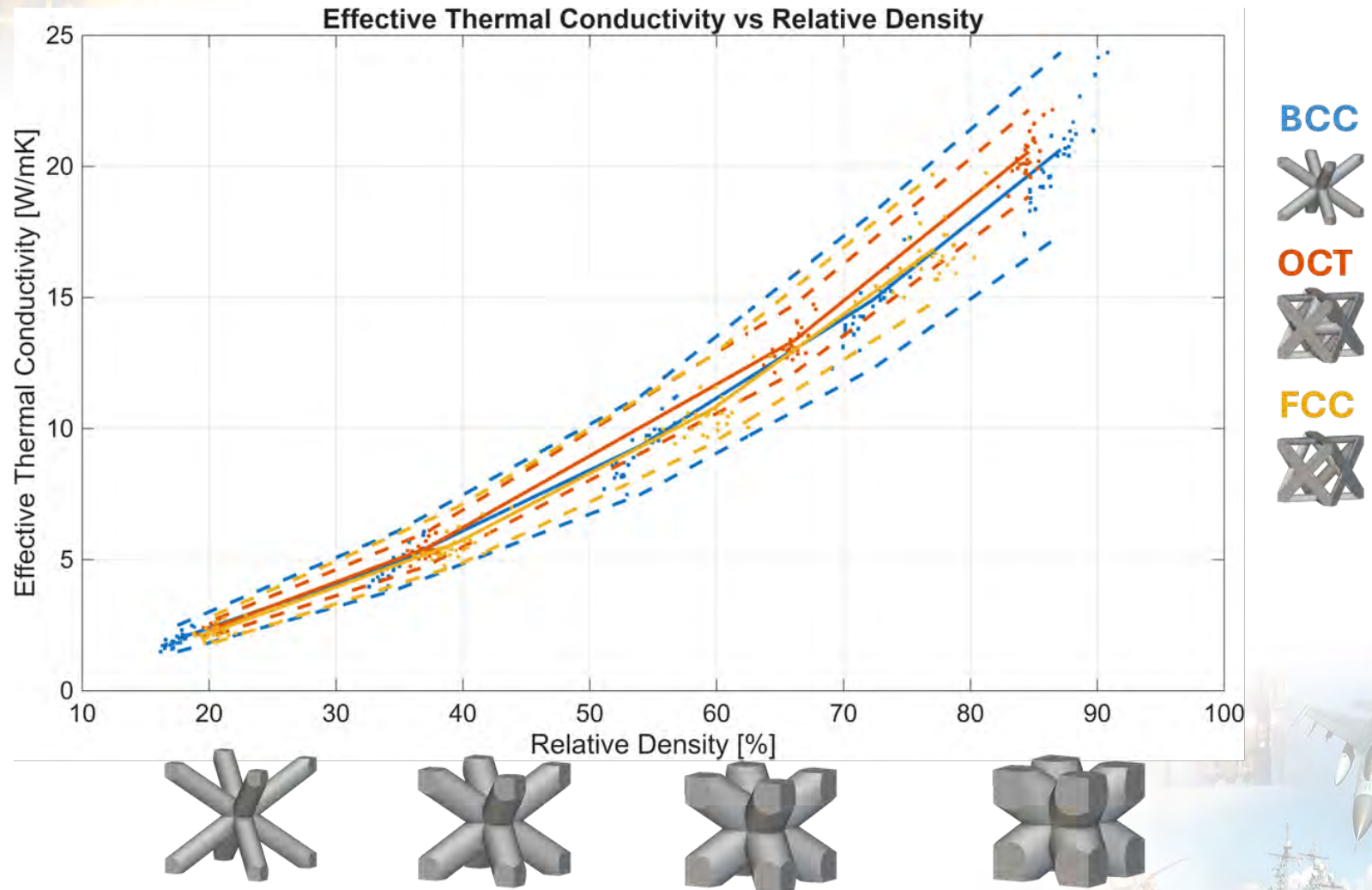
Diffuse the boundary and spread the load.
Strengthen Channels



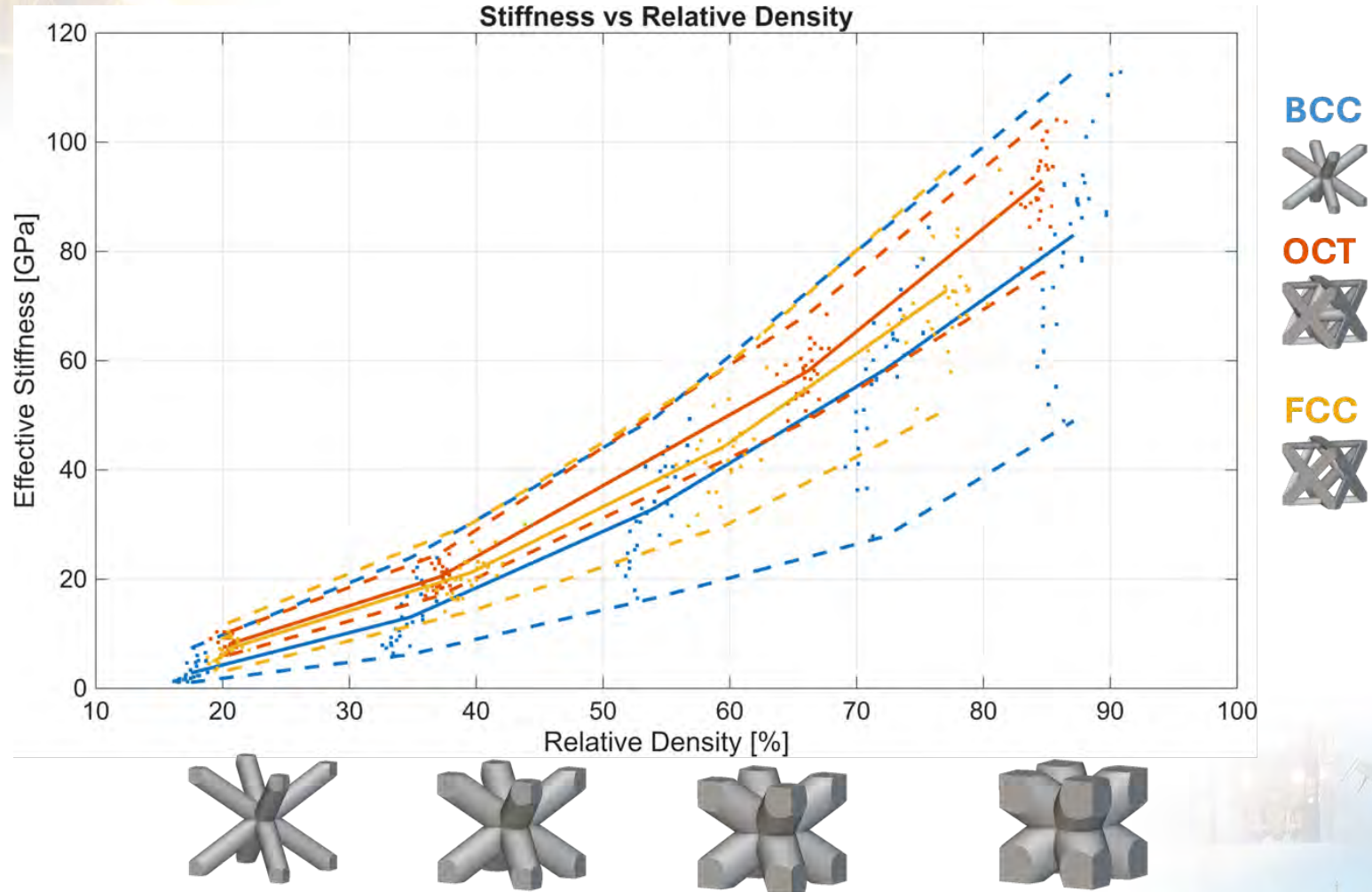
Technical Progress - Lattice



Technical Progress - Anisotropy

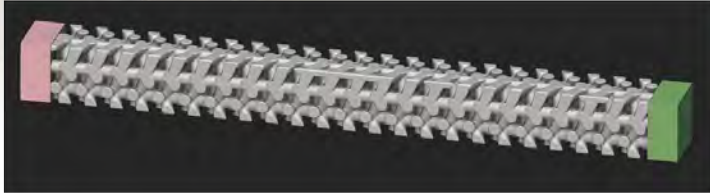


Technical Progress - Anisotropy

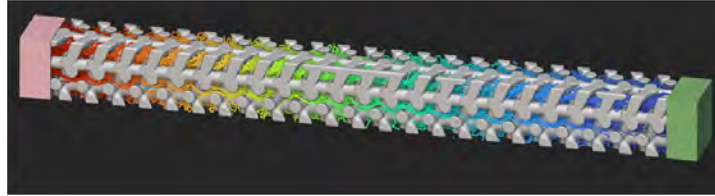


Technical Progress – Fluid Flow

Lattice



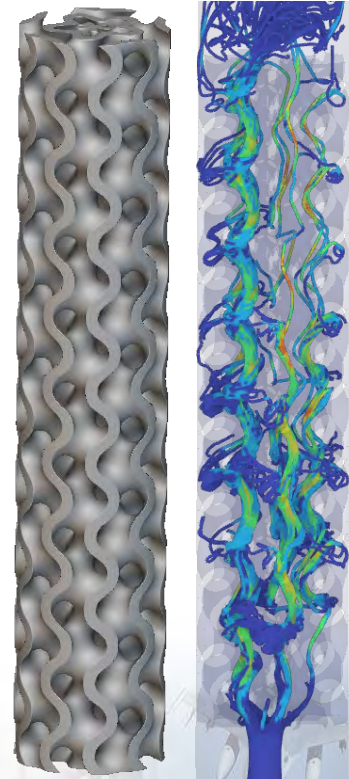
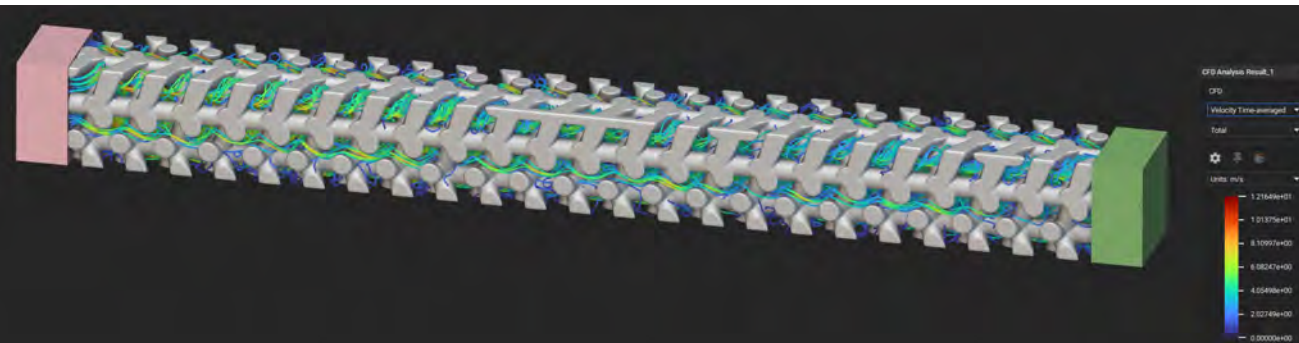
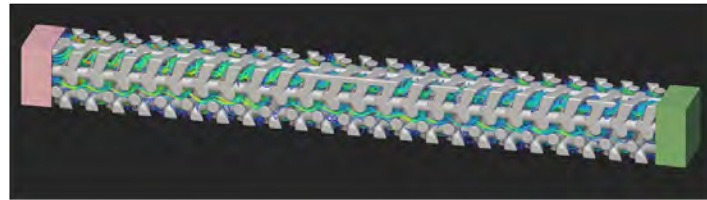
Pressure



Fluid Volume

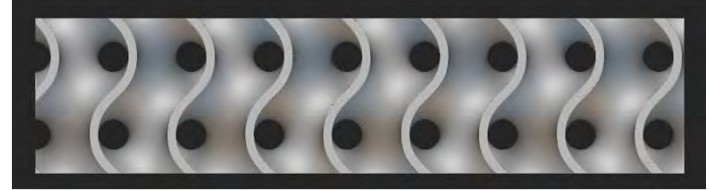
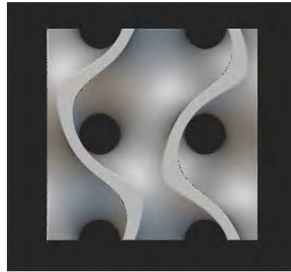
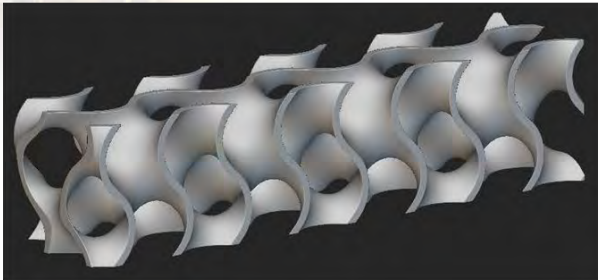


Velocity

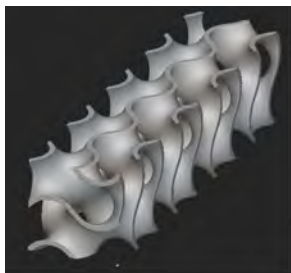
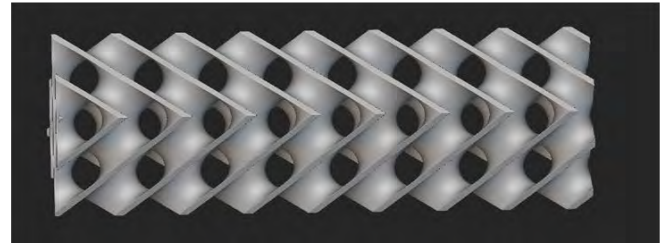
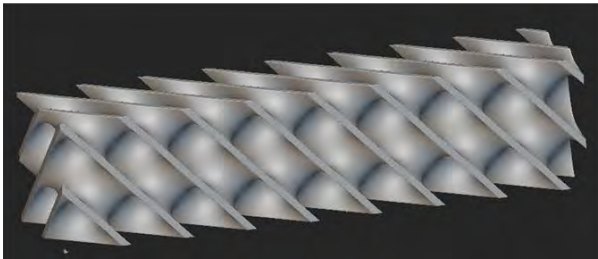


Technical Progress – Fluid Flow

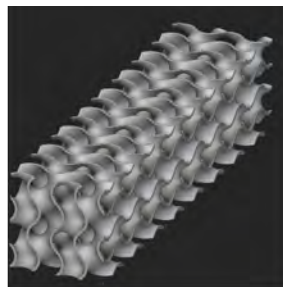
Gyroid



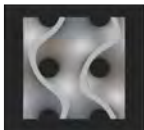
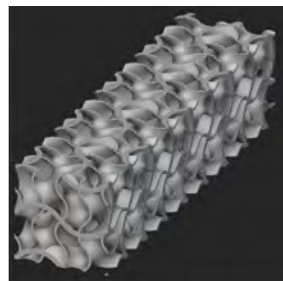
Diamond



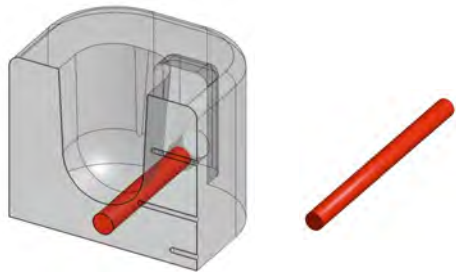
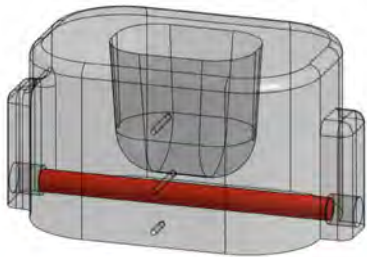
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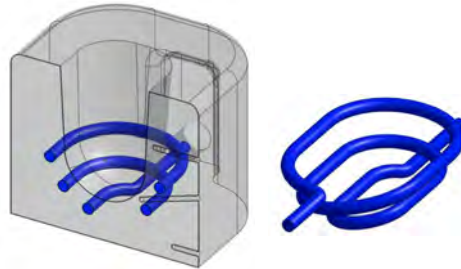
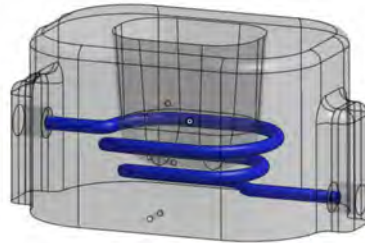


“Drilled”



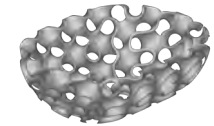
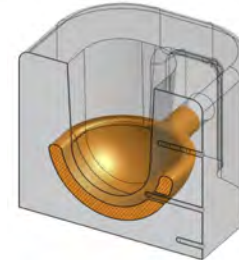
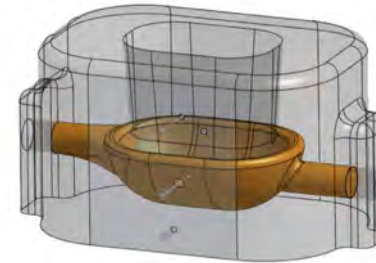
Maraging 250
 Diameter: 0.375 in
 Distance to cavity: 0.2 in

Conformal Channel

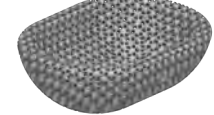


Maraging 250
 Diameter: 0.2 in
 Distance to cavity: 0.2 in

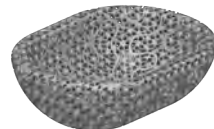
Conformal Surface



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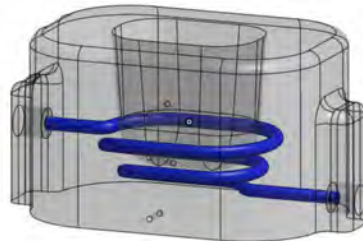
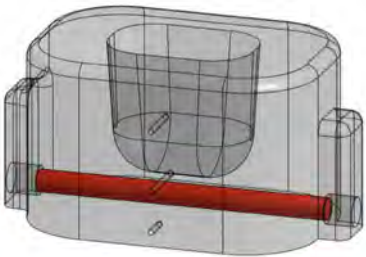
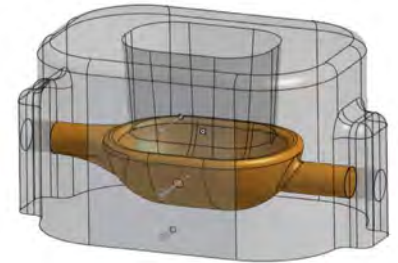


Maraging 250
 Lattice Parameters

Large
 Unit cell size:
 15 mm
 Wall Thickness:
 1.3 mm

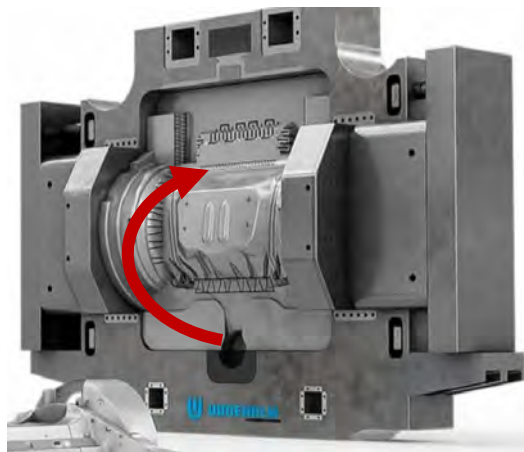
Small
 Unit cell size:
 4 mm
 Wall Thickness:
 0.7 mm

Technical Progress – Printed Molds

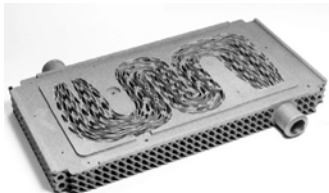


Heat Exchanger

Additive allows for “free” design complexity. Can heat from hot part of the die be used to heat colder sections?

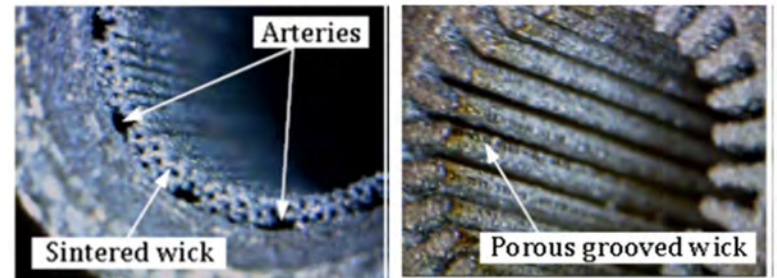
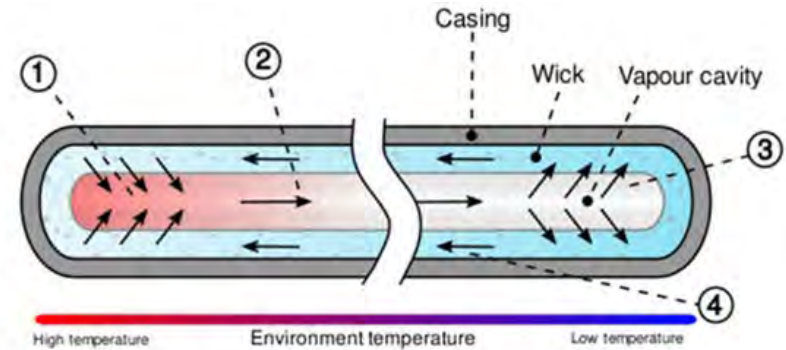


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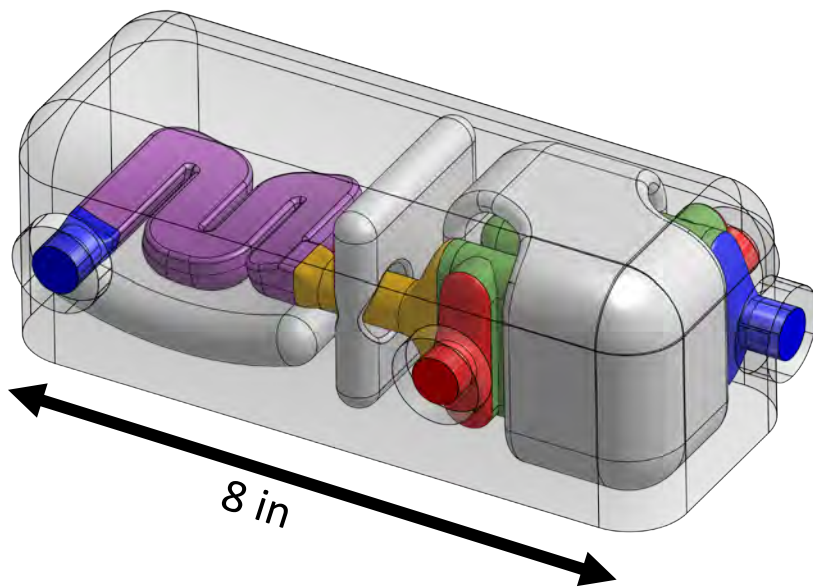
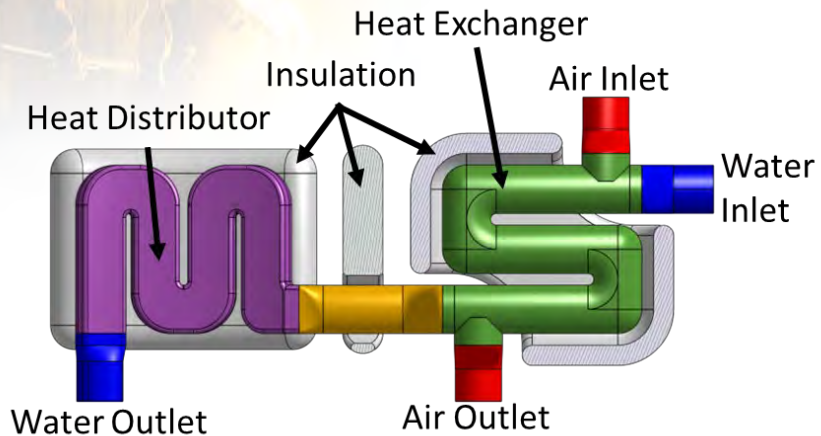
<https://www.ntop.com/resources/blog/heat-exchanger-design-with-additive-manufacturing/>

Heat Pipe- Rapid cooling

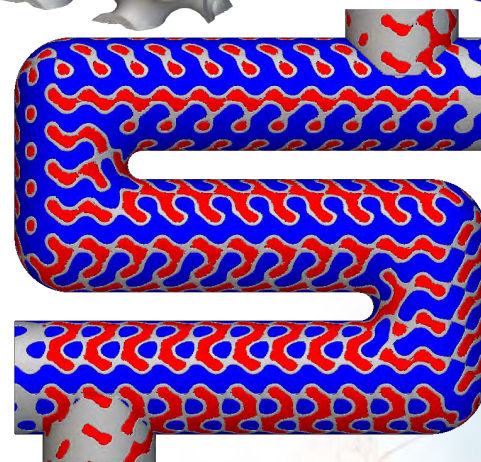
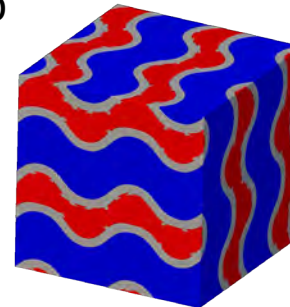
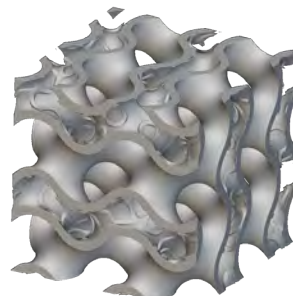
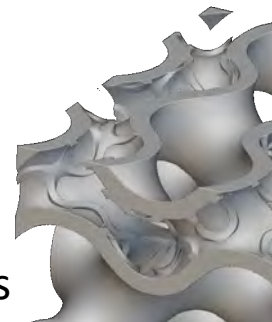


Szymanski P, Mikielwicz D. Additive Manufacturing as a Solution to Challenges Associated with Heat Pipe Production. *Materials*. 2022; 15(4):1609. <https://doi.org/10.3390/ma15041609>

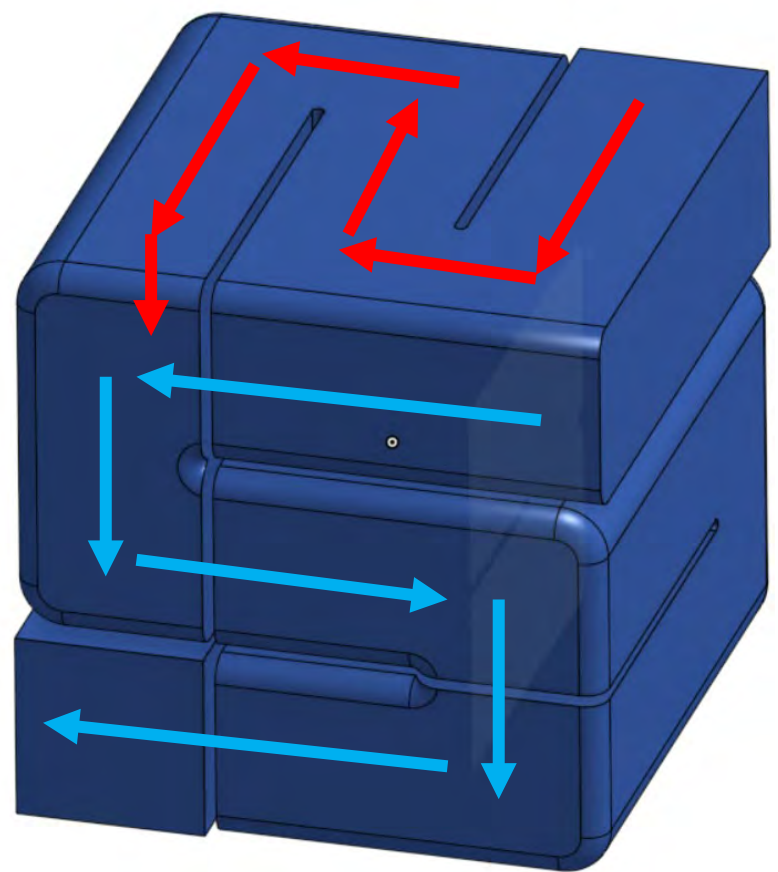
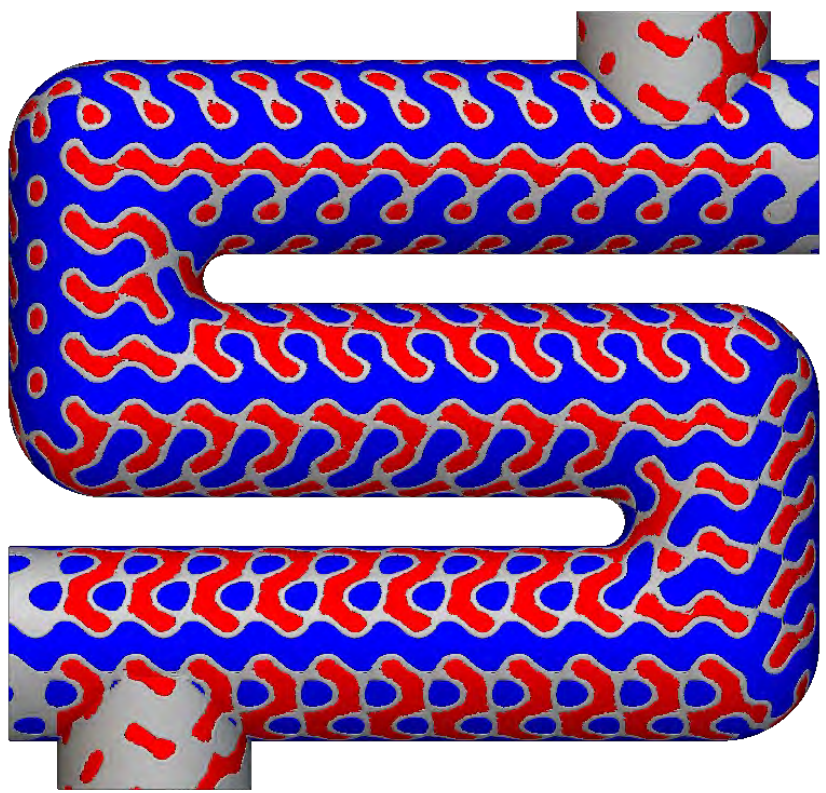
Technical Progress – Heat Exchanger



Walled TPMS
Gyroid
Baffles in Air Duct
Larger Water Channels
for less Pressure drop



Alternative – Air Flow Design



Progress to Date: Industrial Trial 1

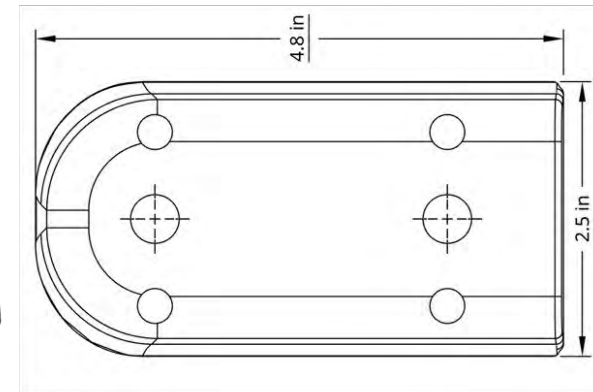
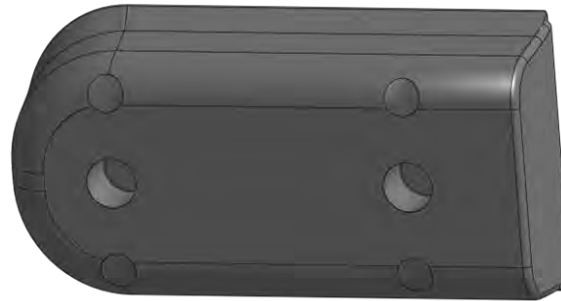
Collaborators

- RCM Industries
 - Rob Marconi
- North American Die Casting Association
 - Paul Brancaleon



Tank Track Shoe

- High Pressure Die Casting
- Aluminum A380 alloy
- ~1 lb
- Rubber encased
- Heat dissipation



Project Plans

- **Laboratory Benchmark of Traditional Thermal Technologies**

- **Completed**

Milestone at 12 months (January 2025)

- Hot oil/water, induction, cartridge, infrared, direct flame

- **Laboratory Benchmark of Novel Thermal Technologies**

- Phase Change Material – Complete

Milestone at 24 months (January 2026)

- Porous Inserts – 95% Complete

- Heat pipes – 35% Complete

Delayed but will complete by
September 2027

- Integrated heat exchanger – 70% Complete

- **In-Plant Trial 1 of 3**

- Insert selection – Completed

- Insert Design – In Progress (20% Complete)

- Trial – (0% Done)

Milestone at 36 months (January 2027)

Transition Plan

- Simulation using commercial software packages such as Magmasoft.
- Engaging die casters (RCM Industries) and additive manufacturing companies to commercialize the technology
- Present technology at the NADCA Congress and committee meetings
- Present information at UCI, ACRC meetings
- Webinars



Leveraging

- Additive manufacturing, tool design and build utilizes previous research from various sources.
 - Prior AMC project
 - Prior America Makes project
 - Prior and current NADCA funded projects
 - DOE project
 - ACRC project
- Collaborative work with industry partners for design and build using high thermal transfer materials
- Collaborative work with industry for in-plant trials
- Project is not part specific, and data can be utilized for general improved thermal management in tooling of any design.

Project Metrics

| Description | Baseline | Threshold | Goal | How Measured | Target Date | Progress | How Demonstrated |
|--|-------------------------------------|--|---|-------------------------------------|----------------------------------|-----------------|---|
| Laboratory Benchmark Heating & Cooling Technologies | Traditional drilled thermal control | 5% increase in heat transfer | 10% increase in heat transfer | Temperature difference | Jan 2025 | 100% | Laboratory measurements and heat transfer simulations |
| Laboratory Benchmark Novel Technologies | No comparison exists | No increase in local solidification time | 10% decrease in local solidification time | Rate of Heat absorption and release | Jan 2026 | 75% | Laboratory measurements and heat transfer simulations |
| Plant trials – performance 3 Trials | Traditional existing tooling | 5% improvement in temperature uniformity | 10% improvement in temperature uniformity | Thermal camera measurements | Dec 2026 Dec 2027 Dec 2028 | 10% 0% 0% | In-plant Trials |
| Plant trials - tool life 3 Trials | Traditional existing tooling | 5% increase in die life | 15% increase in die life | Number of shots to failure | Dec 2026 Dec 2027 Dec 2028 | 0% 0% 0% | In-plant Trials |

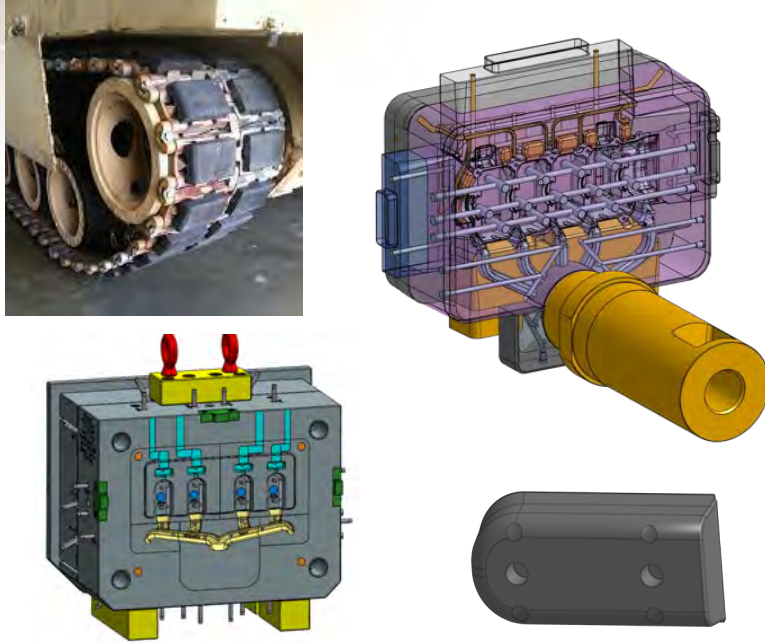
Acknowledgements

This research is sponsored by the Defense Logistics Agency Information Operations, J68, Research & Development, Ft. Belvoir, VA and DLA Troop Support, Philadelphia, PA.

Advanced Thermal Management for High Pressure Die Casting

DLA - POC: DLAR.DPR@dla.mil

AMC
AMERICAN METALCASTING CONSORTIUM



Problem:

- Large structural high pressure die cast components enable cost savings since they replace assemblies of multiple components however larger castings exert additional thermal loads on dies which increases risk of early failure

Objectives:

- Improve heating rate when compared to hot oil by 15%, improve cooling rate compared to a drilled channel by 15%, reduce cycle time by 10%, reduce scrap by 15%, and improve die life by 15%

Benefits to Warfighter:

- Increased productivity through decreasing cycle time, improved quality and reduction in scrap, and increased die life, resulting in reduced costs and lower lead times for DLA

Description of Project:

This project will enable a holistic approach to die design by precise local temperature control of the die without sacrificing productivity and energy efficiency of the process

Team: North American Die Casting Association, ATI, University of California Irvine

Milestones / Deliverables:

- Complete existing technologies benchmark experiments
- Complete laboratory experiments for active and passive thermal control
- Implement advanced thermal management in three sequential in-plant trials

NADCA

ATI
ADVANCED TECHNOLOGY INTERNATIONAL

UCI University of California, Irvine