High Thermal Conductivity Polymer Composites for Low-Cost Heat Exchangers

DE-EE0005775

United Technologies Research Center/ University of Massachusetts (Lowell)/ University of Akron

12/15/2014-09/30/2016

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UTC Climate, Controls & Security

Otis

UTC Aerospace Systems

Pratt & Whitney

U.S. DOE Advanced Manufacturing Office Program Review Meeting

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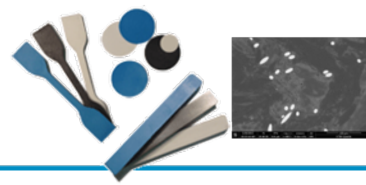
No technical data subject to EAR or ITA

Project Objective

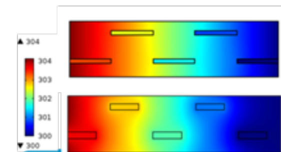
Identify and evaluate polymer-based material options for industrial and commercial heat exchangers

Goals: *Enable new designs*, reduce cost, weight, corrosion

Requirement definition (applications/ HX configurations)

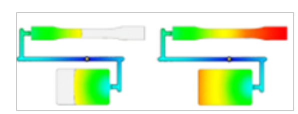


Composite material review (COTS, SOTA)



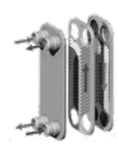
Model development (thermal conductivity, strength

Manufacturability study



HX concept design

Benefit assessment



(Demonstration not part of funded project)

United Technologies
Building & Industrial Systems

UTC Aerospace Systems
Where ingenuity takes off

No technical data subject to EAR or ITAR

UMASS LOWELL

The University of Akron 1870

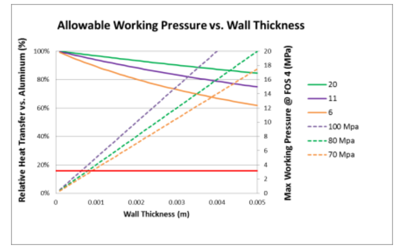
Technical Innovation

- Most heat exchangers are constructed from heavy and costly metals that are subject to corrosion and pose manufacturing constraints
- Identify commercially available com posite materials used for other heat transfer applications as a starting point
- Evaluate other relevant properties for heat exchanger applications such as strength at temperature, fluid compatibility, permeability, flammability and manufacturability
- What is innovative about your project and approach?
  - Couple unique materials and heat transfer expertise
  - Work with experts in the field:
    - University of Massachusetts, Lowell
    - University of Akron
  - Leverage UTC's market leadership in HVAC&R and Aerospace

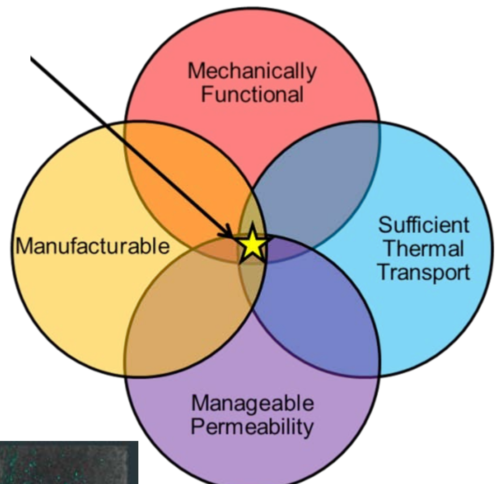
Technical Approach

Developed experimental and modeling tools

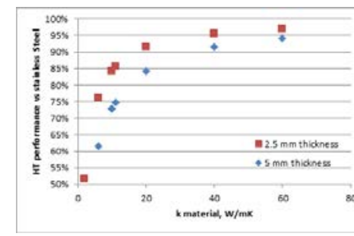
Inorganic filler addition to increase strength

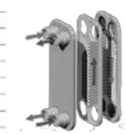


Injection molding trials
Other manufacturing techniques possible to allow new designs (Additive manufacturing)

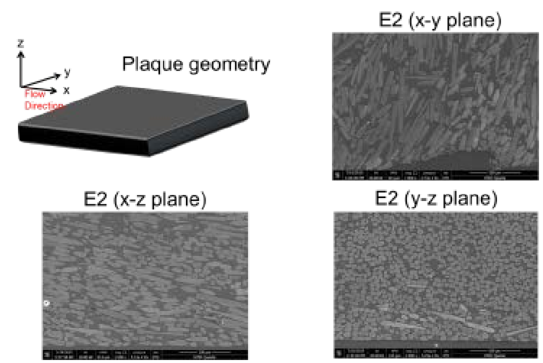


Target t/c >10 W/mK (refrigerant case)- Application dependent

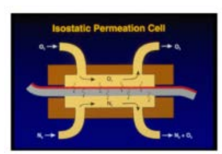




Enhanced thermal conductivity through addition of thermally conductive fillers



Permeability measurement at MOCON



Coatings to manage permeability

No technical data subject to EAR or ITAR

Transition and Deployment

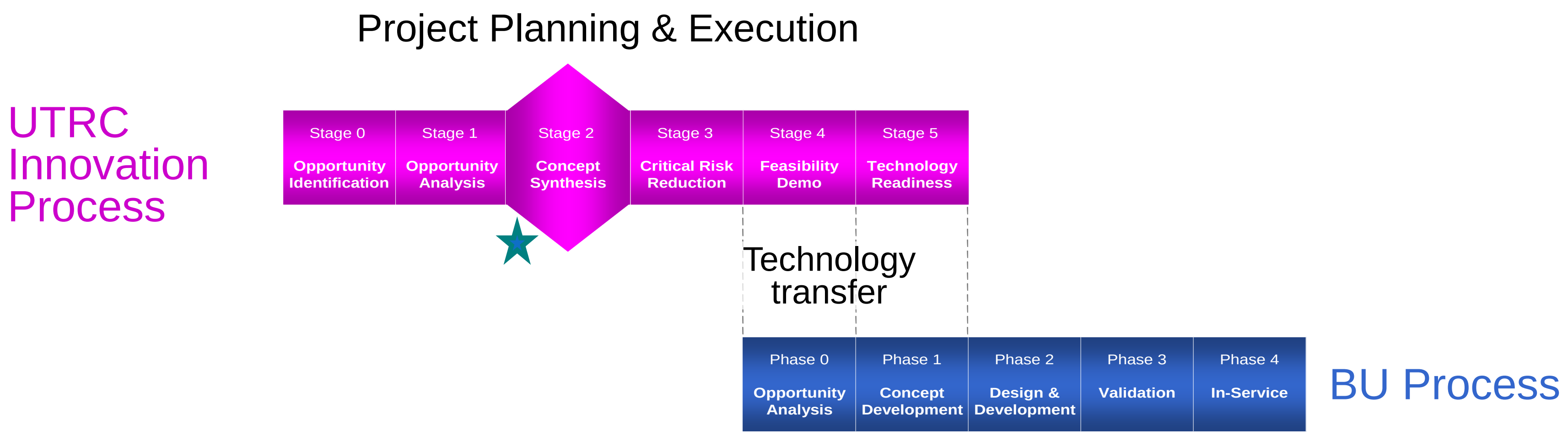
- End users
  - HVAC industry
  - Food Industry
  - Aerospace
  - Heat recovery at moderate temperatures

Carrier
turn to the experts

- Benefits
  - Lower cost
  - Lightweight
  - Corrosion resistance
  - Multifunctionality

Transition and Deployment

- The team is working closely with UTC business units, in particular Carrier Corporation (the world's largest manufacturer and distributor of HVAC&R equipment) to ensure specific requirements are integrated in material selection.
- The team is also following UTRC's project planning and execution process (PPE) to ensure continuity from research and development to commercialization.



- Leveraging synergy with thermal management for electronics, LEDs

Measure of Success

CURRENT PROJECT IMPACT

Thorough material database to enable selection of optimal material for industrial HX applications

FUTURE IMPACTS

- Projected 50% cost savings (Materials and Manufacturing)
- Increased energy productivity
- Reduction in GHG emission
- Fuel savings due to reduced weight (shipping / transport application)

Project Management & Budget

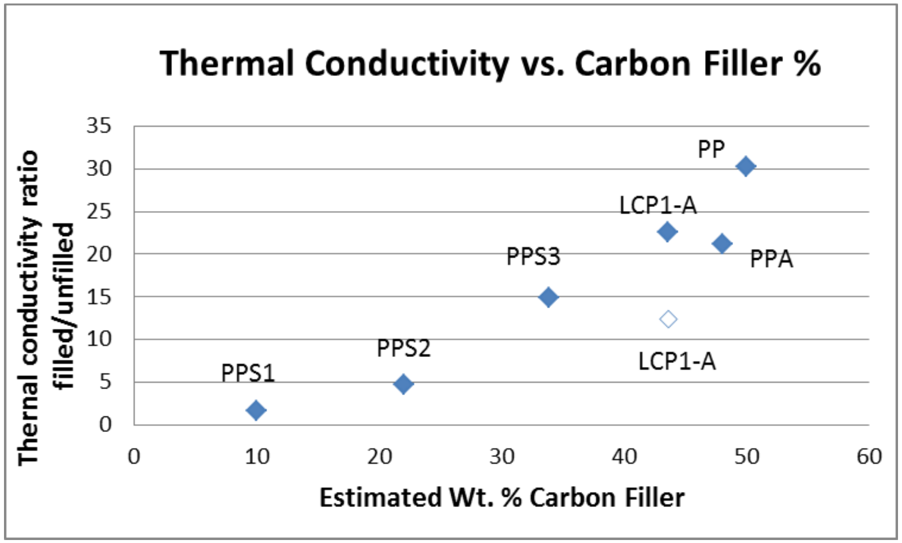
1.5 Year project – 12/15/2014 to 09/30/2016

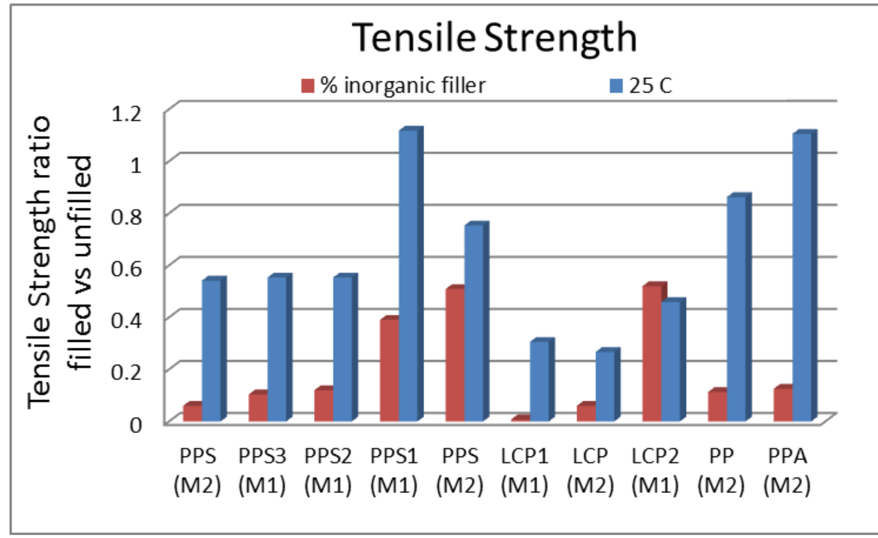
	Task Name	2015												2016						
		J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J
Project Management																				
M1.1	Program management plan																			
	Monthly meetings with EERE	X	X	X	X	X	X	X	X	X	X	X	X							
M1.2	Final report (submitted within 90 days after end of POP)																			
Materials Requirements definition																				
M2.1	List of potential applications																			
M2.2	Material properties requirements for three selected applications																			
Review of Commercially Available and State-of-The-Art Composite Materials (M1-M3)																				
M 3.1	Compilation of COTS and SOTA relevant properties																			
M 3.2	Updated compilation of COTS and SOTA relevant properties																			
Model based evaluation and optimization (M5-M10)																				
4.1	Modeling tools development																			
4.2	Validation of modeling tools																			
4.3	Virtual space Material Design																			
4.4	Manufacturability Study																			
M4.1	Predicted thermal conductivity and mechanical properties																			
Material Characterization and Model Verification (M5-M11)																				
5.1	Material characterization protocols																			
5.2	Material characterization of downselected composites																			
5.3	Coupon level characterization																			
M5.1	Characterization protocol report																			
M5.2	Identification of three most suitable candidates																			
HX concept development (M8-M12)																				
6.1	Brainstorming of HX system concepts including manufacturing options																			
6.2	Modeling of downselected HX system concept																			
6.3	Projected benefits for pteferred concept																			
6.4	Manufacturing risk assessment and waterfall chart																			
M6.1	HX concept, projected cost, performance and energy reduction impact																			

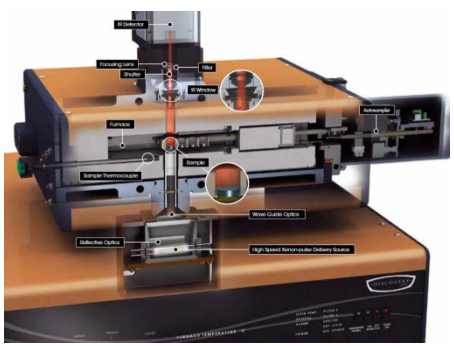
Total Project Budget	
DOE Investment	$ 744,154
Cost Share	$ 186,039
Project Total	$ 930,194

Results and Accomplishments

>20 commercially available materials characterized







Laser flash (DLF-1200)

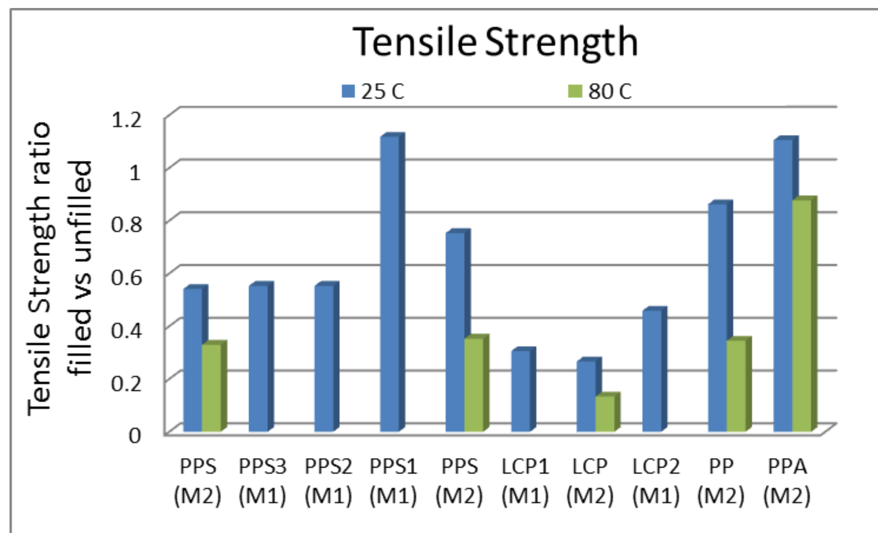


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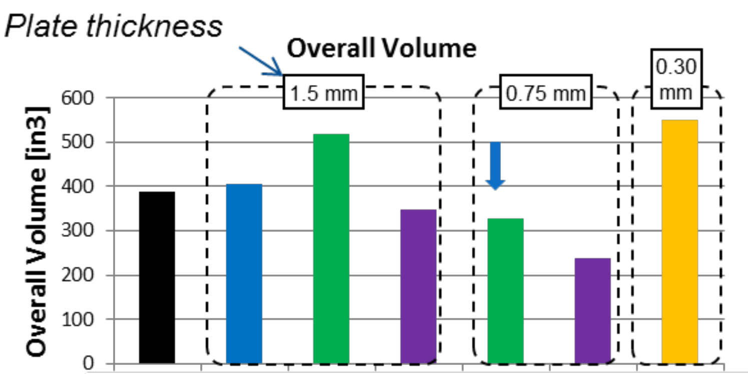
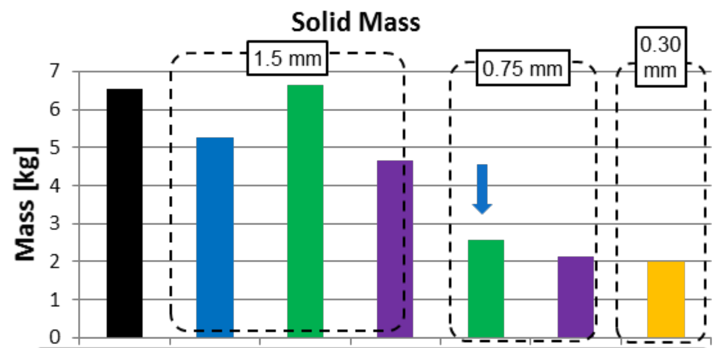
Plate and Frame Heat Exchanger

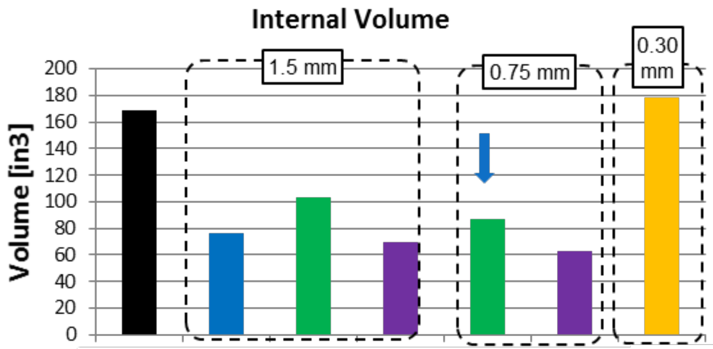
- Plate thickness is a bigger driver of HX size than material thermal conductivity

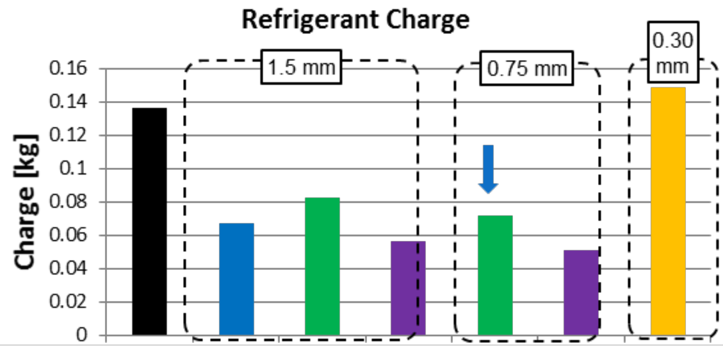




Optimization results keeping pressure drop and capacity constant

- Stainless Steel (Baseline)
- 1 0W/mK
- 4 W/mK
- 20 W/mK
- 0.3 W/mK



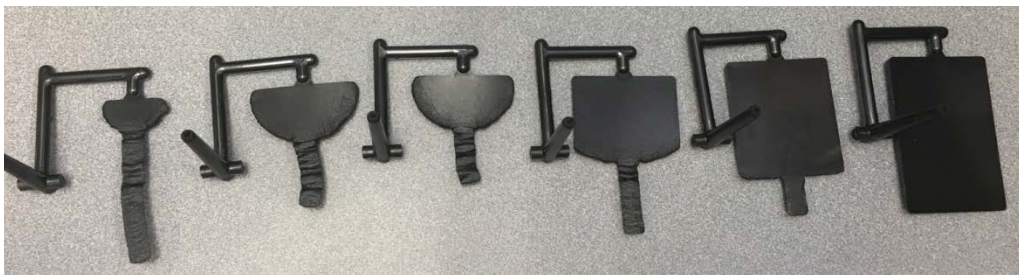


Thinning the plate reduces thermal resistance and material; increasing conductivity only reduces thermal resistance.

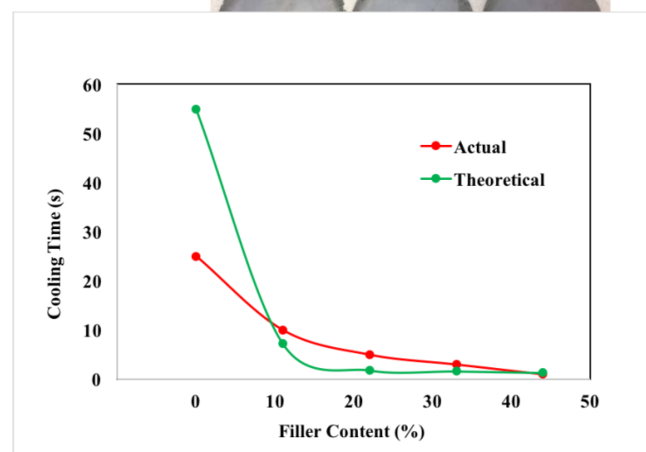
Fabrication via Injection Molding

- Composite materials are harder to injection mold than regular materials leading to thicker parts
- Less filled materials are easier to mold
- Thermal management due to higher thermal conductivity

25% filled



45% filled



Project output:
1 Master Thesis – University of Massachusetts Lowell
1 publication in review

Acknowledgement

This material is based upon work supported by the Department of Energy [Advanced Manufacturing Office] under award DE-EE0005775 [High Thermal Conductivity Polymer Composites for Low-Cost Heat Exchangers, PI: Dr. Catherine Thibaud-Erkey] to the United Technologies Research Center. This presentation was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, process, or process disclosed, or represents that its use would infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily reflect those of the United States Government or any agencies thereof. The authors are grateful for the support of the Department of Energy (DOE).