CHANGING WHAT'S POSSIBLE

HITEMMP

PROJECT DESCRIPTIONS

Michigan State University – East Lansing, MI

Heat-Exchanger Intensification through Powder Processing and Enhanced Design (HIPPED) – $2,300,000

Michigan State University's HIPPED technology is a highly scalable heat exchanger suited for high-efficiency power generation systems that use supercritical CO_2 as a working fluid and operate at high temperature and high pressure. It features a plate-type heat exchanger that enables lower cost, powder-based manufacturing. The approach includes powder compaction and sintering (powder metallurgy) integrated with laser-directed energy deposition additive manufacturing. Each plate is covered with packed, precisely designed and formed three-dimensional features that promote mixing, intensify heat transfer, and provide stability to prevent large plate deformation under high pressure. The super-alloy plate composition provides good strength at the highest operating temperatures (1100°C) and a high degree of corrosion resistance.

Missouri University of Science and Technology – Rolla, MO

UHT-CAMANCHE: Ultra-High Temperature Ceramic Additively Manufactured Compact Heat Exchangers – $1,457,000

Missouri S&T will combine a novel additive manufacturing technique, called ceramic on-demand extrusion, and ceramic fusion welding techniques to manufacture very high temperature heat exchangers for power cycles with intense heat sources. Enabling turbine operation at significantly higher inlet temperatures substantially increases power generation efficiency and reduces emissions and water consumption. The developed heat exchangers will use ultra-high temperature ceramic materials and state-of-the-art design tools and manufacturing techniques to operate under temperatures of 1100-1500°C (2012-2732°F) and pressures of 80 to 250 bar (1160-3626 psi). Their high pressure and high temperature characteristics offer great potential for power plant size and cost reduction to enable future high efficiency modular power generation systems.

Michigan Technological University – Houghton, MI

High-Density SSiC 3D-Printed Lattices for Compact HTHP Aero-Engine Recuperators – $1,846,000

Michigan Technological University will use advanced ceramic-based 3D printing technology to develop next-generation light, low-cost, ultra-compact, high-temperature high-pressure (HTHP) heat exchangers. These will be able to operate at temperatures above 1100°C (2012°F) and at pressures above 80 bar (1160 psi). Current technologies cannot produce the high density, monolithic sintered silicon carbide (SSiC) material required for high temperature, high pressure recuperators. The team has invented a direct–ink writing technology for ceramics and techniques to 3D print high-density SSiC parts at scale, to reduce the risk of thermo-mechanical failure and ensure heat exchanger durability and quality.

Carnegie Mellon University – Pittsburgh, PA

High Energy Density Modular Heat Exchangers through Design, Materials Processing, and Manufacturing Innovations – $2,400,000

The Carnegie Mellon team will develop a modular radial heat exchanger that includes flow through diverging pin arrays and branching channel counter-flow headers. The team will fabricate the heat exchanger via laser powder bed fusion additive manufacturing, with nickel-based superalloys selected for maximum high temperature capability. Two different technologies will be used to smooth the heat exchanger components' internal passages to minimize pressure drop. Durable high temperature heat exchangers for use with supercritical CO_2 have potential applications in solar power, gas turbines, transportation, and power generation.

The Ohio State University – Columbus, OH

Additively Manufactured High Efficiency and Low-Cost sCO_2 Heat Exchangers– $1,500,000

The Ohio State University will design, manufacture, and test high-performance, compact heat exchangers for supercritical CO_2 power cycles. Two innovative additive manufacturing processes will enable high performance. One facilitates up to 100 times higher deposition rate than regular laser powder additive manufacturing. The other enables crack-free additive manufacturing of an advanced nickel-based superalloy and has the potential to print features as fine as 20 micrometers. These innovations will halve the fabrication cost and enable heat exchanger operations above 800°C (1472°F) and 80 bar (1160 psi). These systems have applicability in high-efficiency fossil energy, concentrating solar power, and small modular nuclear energy.

Thar Energy LLC – Pittsburgh, PA

High Temperature, High Pressure, and High Performance Compact Heat Exchanger – $2,000,000

Thar Energy will develop the next-generation metallic compact recuperator capable of stable and cost effective operation at 850°C (1562°F) and above 90 bar (1305 psi). The heat exchanger will incorporate an advanced, high temperature, corrosion and creep resistance alloy developed by the proposing team, using advanced manufacturing methods. The cost effective heat exchanger will enable high-efficiency, modular, and cost-competitive recuperated supercritical carbon dioxide (sCO_2) Brayton power cycle systems.

Massachusetts Institute of Technology – Cambridge, MA

Multiscale Porous High-Temperature Heat Exchanger Using Ceramic Co-Extrusion – $1,715,000

MIT will develop a high performance, compact, and durable ceramic heat exchanger. The multiscale porous high temperature heat exchanger will be capable of operation at temperatures over 1200°C (2192°F) and pressures above 80 bar (1160 psi). Porosity at the centimeter-scale will serve as channels for the flow of working fluids. A micrometer-scale porous core will be embedded into these channels. A ceramic co-extrusion process will create the channels and core using silicon carbide (SiC), a ceramic, in a single step. The core will significantly improve heat transfer and structural strength and minimize pressure drop, enabling very high power density.

University of California- Los Angeles – Los Angeles, CA

SHOTEAM: Superalloy Heat Exchangers Optimized For Temperature Extremes and Advanced Manufacturability – $2,200,000

UCLA will develop extreme-condition heat exchanger technology targeted to ultra high efficiency hybrid aviation power cycles. The heat exchanger will operate at 50 kW (thermal) at supercritical CO2 pressures of 80 and 300 bar (1160 and 4351 psi) in hot and cold streams, respectively and at an inlet temperature of 800°C (1472°F). A metallic superalloy capable of withstanding high temperature and pressure will be used to fabricate a shell-and-tube-based design supplemented with 3D-printed tube augmentations. This design will enhance overall heat transfer while maintaining a small overall form factor and low weight. The heat exchanger will dramatically improve efficiency and power density for new hybrid aviation power cycles.

Vacuum Process Engineering, Inc. – Sacramento, CA

Compact Diffusion Bonded Printed-Circuit Heat Exchanger Development Using Nickel Superalloys for Highly Power Dense and Efficient Modular Energy Production Systems – $2,279,000

Vacuum Process engineering will develop a superalloy-based printed circuit heat exchanger for operation at temperatures exceeding 800°C (1472°F) and pressures above 80 bar (1160 psi). The team will build the heat exchanger applying a diffusion solid-state welding manufacturing technique, which uses stacked individual metal sheets with semi-circular channels formed from a chemical treatment process. The goal is to create a highly effective, high temperature compact heat exchanger with a high-strength bond during the welding capable of containing the very high pressure fluid at elevated temperatures. This project will enable increased deployment of clean, efficient, compact, and cost-effective power dense power production systems that will reduce energy-related emissions.

International Mezzo Technologies – Baton Rouge, LA

Supercritical CO2 Micro Tube Recuperator: Manufacturing, Testing and Laser Weld Qualification – $1,640,000

International Mezzo Technologies will design, manufacture, and test a compact, nickel-based superalloy supercritical carbon dioxide (sCO_2) recuperator. The recuperator will incorporate laser-welded micro tubes and function at 800°C (1,472°F) and 275 bar (3,989 psi). Currently, the cost of recuperators of power systems operating in these conditions is prohibitive. Laser welding micro tubes offers a low-cost approach to fabricating heat exchangers, which will increase the economic competitiveness of sCO_2 power cycles.

CompRex, LLC – De Pere, WI

Compact Heat Exchanger for High Temperature High Pressure Applications Using Advanced Cermet – $1,455,000.00

CompRex, LLC aims to realize a transformational and disruptive advancement in heat exchange technology for high temperature (>800°C or 1472°F) and high pressure (80 bar or 1160 psi) applications through use of advanced metal and ceramic composite material, development of a new simplified manufacturing approach, and optimization of heat exchanger design. The proposed work has the potential to reduce manufacturing costs for heat exchangers and other types of pressure devices by 40% and bring performance and cost benefits to power, transportation, aerospace, and oil/gas/petrochemical applications.

General Electric Company, GE Global Research – Niskayuna, NY

Ultra Performance Heat Exchanger Enabled by Additive Technology (UPHEAT) – $2,500,000

The GE team will develop a metallic-based, ultra-performance heat exchanger enabled by additive manufacturing technology and capable of operation at 900°C (1652°F) and 250 bar (3626 psi). The team will optimize heat transfer versus thermomechanical load using new micro-trifurcating core structures and manifold designs. It leverages a novel, high-temperature capable, crack-resistant nickel superalloy, designed specifically for additive manufacturing. When completed, the heat exchanger will enable increased thermal efficiency of indirect heated power cycles such as supercritical carbon dioxide (sCO_2) Brayton power generation, reducing energy consumption and emissions.

The Boeing Company – Huntington Beach, CA

Highly Compact Metallic Heat Exchangers for Extreme Environments – $2,397,756.52

Boeing will develop a compact, extreme environment heat exchanger (EEHX) for application in supercritical carbon dioxide power cycles for hypersonic aircraft and distributed power generation. The metallic based heat exchanger will be capable of operation at 1000°C (1832°F) and pressure above 80 bar (1160 psi). The team will design topologically optimized geometries and develop multifunctional, complex concentrated alloys offering superior high temperature durability, resistance to oxidation, and thermal conductivity, as well as lower thermal expansion compared with state-of-the-art systems. The team will use advanced manufacturing approaches, including combinations of additive and subtractive manufacturing, powder metallurgy, superplastic forming, and solid state bonding to build the EEHX.

United Technologies Research Center (UTRC) – East Hartford, CT

Additive, Topology-Optimized Ultra-Compact Heat Exchanger – $2,100,000

UTRC will develop an ultra-compact, topology-optimized 800°C (1472°F), 250 bar (3626 psi) heat exchanger substantially smaller and substantially more durable than current commercial cross-flow heat exchangers. A quadruple optimization approach that addresses performance, durability, manufacturing and cost constraints provides the framework for the superalloy-based heat exchanger. UTRC will leverage extensive additive manufacturing research and aerospace and supercritical carbon dioxide (sCO_2) power generation experience to develop and commercialize the technology. The team will work on transitioning the heat exchanger into hybrid aviation with a potential 25% fuel burn savings in aviation transport. This would substantially reduce aviation fuel usage and carbon emissions.

United Technologies Research Center (UTRC) – East Hartford, CT

Low-Cost Glass Ceramic-Matrix Composite Heat Exchanger – $1,400,000

UTRC will develop a high-temperature, high-strength, low-cost glass-ceramic matrix composite heat exchanger capable of a long operational life in a range of harsh environments with temperatures exceeding 1100°C (2012°F) and pressure at 250 bar (3626 psi). UTRC designed its Counterflow Honeycomb Heat Exchanger (CH-HX) configuration specifically for this oxidation-resistant material developed initially for gas turbine applications. Its core features a joint-free, 3D-woven assembly of webbed tubes and cylindrical shapes to reduce stress and simplify manufacture. The CH-HX is devoid of nearly all secondary surfaces, which increases thermodynamic performance. Its light weight, reduced volume, and high-temperature robustness will enable its use in applications benefiting from high-efficiency supercritical CO_2 power cycles.