National Aeronautics and Space Administration

NASA

TECHNOLOGY SOLUTION

Mechanical and Fluid Systems

Additively Manufactured Oscillating Heat Pipe for High Performance Cooling in High Temperature Applications

Integrated Thermal Solution for Hypersonic Wing Leading Edge Applications

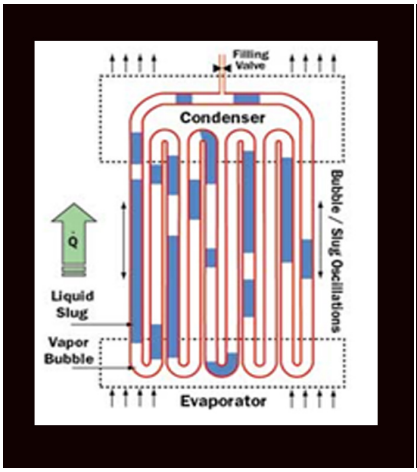
High performance cooling techniques for enhanced heat transfer for high temperature applications are increasingly important, particularly in the field of aerospace engineering. For example, leading edges of wings on hypersonic vehicles may reach upwards of 2000° C, and such heat quickly degrades the leading edge. Conventional heat pipes contain bends or welds in the material that can compromise the structural integrity of the wing leading edge. Oscillating Heat Pipes (OHPs) are a newer form of heat pipe which can cool more efficiently than traditional heat pipes, and are easier to manufacture. NASA Ames Research Center has developed a novel additive manufacturing technique to manufacture OHPs from Refractory High Entropy Alloys (RHEAs). These OHPs are effective in hypersonic vehicles with sharp, shape-stable wing leading edges. Additive manufacturing allows for enhancements such as alternating-diameter channels, allowing for changes in pressure.

BENEFITS

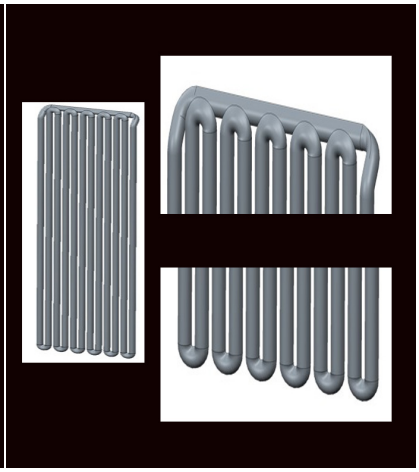
- Heat dissipation for leading edges of hypersonic vehicles
- Heat transport capacity of 10 to 100 times greater than currently employed solutions such as reinforced carbon-carbon leading edge cooling technologies or traditional heat pipes
- Fully passive and reusable
- Increases the ability to withstand body forces by an order of magnitude, and may be used at much higher Mach numbers
- Avoids thermal structural failure caused by bends and welds of traditional heat pipes
- Reduced form factor that allows better incorporation into sharp geometries
- Usable for any system that requires rapid dissipation of heat

THE TECHNOLOGY

The advent of additive manufacturing makes available new and innovative integrated thermal management systems, including integrating an oscillating Heat Pipe (OHP) into the leading edge of a hypersonic vehicle for rapid dissipation of large quantities of heat. OHPs have interconnected capillary channels filled with a working fluid that forms a train of liquid plugs and vapor bubbles to facilitate rapid heat transfer. Multiple additive manufacturing techniques may be used, including powder bed fusion, binder jetting, metal material extrusion, directed energy deposit, sheet lamination, ultrasonic, and electrochemical techniques. These high performance OHPs can be made with materials such as Refractory High Entropy Alloys (RHEAs) that can withstand high temperature applications. The structure of the OHP can be integrated into the constructed leading edge. The benefits include a heat transport capacity of 10 to 100 times greater than before. Integrated OHPs avoid the bends or welds in traditional heat pipes, especially at the locations where the highest thermal stresses might cause thermal-structural failure of a leading edge. Alternating the diameters of the OHP channels alleviate start-up issues typically found in liquid metal oscillating heat pipe designs in high temperature applications by aiding in the instigation of a circulating flow due to multiple forces acting upon the working fluid.



Oscillating Heat Pipes (OHP)



Pipe Design

APPLICATIONS

The technology has several potential applications:

- Efficient heat transfer devices that can operate at high temperatures
- Hypersonic wing leading edges
- Nuclear thermal propulsion
- Plasma facing materials in fusion devices
- Re-entry vehicles and shuttles
- Processor/microchip thermal straps
- Conduction cooled circuit card heat sinks
- Lithium-ion battery packs
- Radio-frequency device heat spreaders
- Energy recovery heat exchangers
- Optical equipment heat sinks

PUBLICATIONS

Patent Pending

technology.nasa.gov

NASA's Technology Transfer Program pursues the widest possible applications of agency technology to benefit US citizens. Through partnerships and licensing agreements with industry, the program ensures that NASA's investments in pioneering research find secondary uses that benefit the economy, create jobs, and improve quality of life.

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More Information

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