Phenomenon and Mechanism of Spray Cooling and Supercritical-pressure Fluid Impingement Cooling on micro/nano hybrid structures

Pei-Xue Jiang, Rui-Na Xu, Kai Chen, Gao-Yuan Wang, Jian-Nan Chen

Key Laboratory for Thermal Science and Power Engineering of Ministry of Education,

Key Laboratory for CO_2 Utilization and Reduction Technology of Beijing,

Department of Energy and Power Engineering, Tsinghua University, Beijing 100084, China

Abstract:

Spray cooling is an efficient cooling method for high power device heat management. Spray cooling is particularly favorable because of its high heat flux dissipation capability, precise temperature control and reliable long-term stability. Micro, nano and micro/nano structures were fabricated to study the effects of these structures on the spray cooling heat transfer enhancement. The droplet impingement cooling was numerically studied first to identify the flow and heat transfer details and to offer insights into the spray cooling heat transfer mechanisms. Through the advanced experimental method, the impact flow and phase change of single microscale droplet were investigated to reveal the heat transfer enhancement mechanisms of spray cooling. The boiling phenomenon of the microscale droplet after impact was studied theoretically by combining the droplet impact process and the following phase change process. Then, the wetting characteristics and heat transfer performance of nano-structured surfaces and micro/nano hybrid surfaces were studied experimentally, which showed much higher HTC and CHF with these structured surfaces. The spray cooling heat transfer was also studied experimentally in a closed-loop spray cooling system using a refrigerant as the working fluid.

In the process of convection heat transfer of fluids at supercritical-pressures the phase change does not happen. Therefore, there is no dryout phenomenon and CHF for impingement cooling with the supercritical-pressure fluid. Jet impingement cooling with CO_2 at supercritical pressures was studied experimentally and numerically. It was found that the average HTC of jet impingement cooling of CO_2 at SCP is rather high than that with spray cooling when the cooling area is not very large compared to the nozzle diameter. Spray cooling consumes less coolant compared to jet impingement cooling with the same heat flux.

This study provides useful guidance on the heat transfer enhancement and heat transfer mechanisms for spray cooling and supercritical-pressure fluid impingement cooling on different structured surfaces.

Bio:

Peixue Jiang is a professor and Dean of the Department of Energy and Power Engineering, Tsinghua University, China. He received his bachelor's degree at Tsinghua University in 1986 and his Ph.D. degree in the Department of Thermo-Power Engineering at Moscow Power Engineering Institute in 1991. He then joined the Tsinghua University and took the full professor post in 1997.

His main research interests are convection heat transfer in porous media and enhanced heat transfer, convection heat transfer of fluids at super-critical pressures, transpiration cooling and film cooling, thermal transport in micro/nano-scale structures and spray cooling, migration of super-critical CO2 in porous media under conditions of geological storage and oil/shale gas recovery, Enhanced Geothermal

System (EGS). He has won the National Natural Science Award second prize, and he is the recipient of the National Science Fund for Distinguished Young Scholars from the National Natural Science Foundation of China, Chang Jiang Scholar of Ministry of Education, the leader of the Science Fund for Creative Research Groups from the National Natural Science Foundation of China. His research has resulted in more than 160 scientific publications in refereed international journals, 120 international conference papers, 160 papers published in refereed Chinese journals and 2 book chapters in Chinese.

Professor Jiang is now the Director of Institute of Engineering Thermophysics in Department of Energy and Power Engineering, Director of Key Laboratory for Thermal Science and Power Engineering of Ministry of Education, Director of Beijing Key Laboratory of CO2 Utilization and Reduction Technology. He is a council member of the Chinese society of engineering thermophysics, vice chairman of the Chinese heat and mass transfer society, member of department of energy and transportation in science and technology committee of the Ministry of Education, member of the Technical Expert Group on Renewable Energy and Hydrogen Energy of the 13th Five-Year Plan of China. He is an Honorary Professor of University of Nottingham (UK), Honorary Professor of Moscow Power Engineering Institute (Russia), and visiting Professor of University of Sheffield (UK).