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Contribution ID: **743** Type: **Poster (+) Presentation**

Porous Media Flow as a Heat Sink in a Triple Layered Electromagnetic Heat Exchanger

Tuesday, 1 June 2021 20:00 (1 hour)

An electromagnetic (EM) heat exchanger (HX) converts EM energy into heat or useful mechanical work. Examples of EM HXs are microwave thermal thrusters where high-power microwave heating is utilized to produce thrust from compressed gases, solar-thermal panels where a fluid is heated through solar radiations, etc. Our research is focused on modeling an EM HX useful in wireless power beaming application where energy is transmitted in the form of EM waves through the atmosphere and the HX acts as a receiver end. The structure of such an EM HX includes a lossy ceramic material, which is heated by EM waves, and bounded on two sides by a rigid porous media, with perfect thermal contact between it and the lossy ceramic. A nonlinear phenomenon associated with EM processing of ceramic materials (without fluid flow), such as zirconia and alumina, is thermal runaway, where a small increase in incident EM power causes significant rise of ceramic temperatures (e.g., about 2000K for alumina). It is of interest to investigate if the phenomenon of thermal runaway can be utilized for efficient energy transfer between fluid and the ceramic along with safer operating temperatures.

We focus on modeling of this triple-layer porous-media-based EM HX subject to a pressure driven fluid flow through the porous regions. Plane EM waves are incident symmetrically on the structure; only the ceramic is heated by EM waves, and fluid in porous structure heats up due to thermal contact with the ceramic. We are motivated to investigate the problem because improved heat transfer between the ceramic and the fluid due to porous channels may lead to higher thermal efficiency of the power transfer, and the thermal runaway characteristics may be altered.

We consider Darcy flow of an incompressible fluid though porous channels and find that thermal efficiencies (based on thermal power delivered by the fluid) are low in the limit of low Péclet number. We then extend the model considering large Péclet numbers to include Taylor dispersion effects that are originated as a result of deviation of local microscopic velocity from the macroscopic Darcy-velocity. Since the axial heat-diffusion is expected to improve with Péclet number, we investigate how Taylor dispersion improves thermal efficiencies and affects the onset of thermal runaway in the ceramic. Temperatures during thermal runaway indicate that liquid coolants flowing through the porous channels rapidly change their phase into gases at STP. To better match experimental conditions, we consider compressible gases flowing though the porous channels, and incorporate work of thermal expansion done by the gases. Results from numerical model based on compressible Darcy flow in porous channels show that the work done by the gas can lead to Joule-Thompson cooling effect which then delays the onset of thermal runaway in the ceramic. Finally, we consider Forchheimer's correction to investigate how flow inertia affects the work of thermal expansion and Joule-Thompson cooling of the gas.

Time Block Preference

Time Block C (18:00-21:00 CET)

References

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Student Poster Award

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Session Classification: Poster +

Track Classification: (MS17) Thermal Processes, Thermal Coupling and Thermal Properties of Porous Media: modeling and experiments at different scales