Hybrid Two-Phase Cooling System for High Performance Microprocessor by using Micro-Cooling Technology

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1. Background

- **Datacenter energy consumption crisis**
- Energy consumption by datacenters and mainframe computers continues to increase at a rate of ~15% annually.
- Total consumption is currently about 2% of total electricity consumption in US.
- World’s largest supercomputer currently consumes about 14MWe.
- New electrical production is increasing at a rate of only about 1% annually.
- In 2050, all electrical energy in US will be consumed by one supercomputer!

- **Power trends in datacenters**
- **On-chip two-phase cooling (multi microchannel evaporator)**
- 60% or more improvement in energy efficiency.
- Heat can be recovered - Reused elsewhere.
- Can operate at higher temperatures and still be cooled efficiently.
- Occupies less space.

2. Objectives

- Propose and develop a hybrid heat pump system with microevaporators (multi microchannel evaporators) for cooling the computer boards.
- Work with two-phase flow, using a compressor or/and liquid pump, which can reduce the demand of cooling energy by an impressive amount.
- Develop a mathematical model to evaluate the performance of the hybrid cooling system for different system configurations (compressor, liquid pump, condenser, capillary tubes, electric expansion valves, etc.) in steady state and transient conditions.

3. Experimental Campaign

- **A hybrid experimental facility has been built at LTCM able to evaluate three candidate cooling cycles for on-chip two-phase cooling of datacenter.**
  - Liquid Pump Cycle
  - Vapor Compressor Cycle
  - Hybrid Cycle

- **Some Major Control Strategies:**
  - SMV’s aperture or mini compressor stroke controls the ME’s outlet vapor quality.
  - Condenser liquid pump controls the condensing pressure or the water temperature at the outlet of condenser.

- Controllers showed fast response and are effective (satisfy the design requirements).

- **Preliminary results**
  - **Simulation**
    - Liquid water cooling cycle has a pumping power consumption 5.5 and 4.4 times that obtained for the two-phase R134a and R1234ze cooling cycles, respectively (liquid pump as a driver).
    - **Maximum pseudo chip temperature variation of 1.5°C for a periodic disturbance of 1.4 seconds.**
    - The PI controller developed for the ME’s outlet vapor quality shown to be effective and satisfy the design requirements.

4. Conclusions

1. Proposed, simulated, built and experimentally evaluated a hybrid two-phase cooling cycle to cool microprocessors and auxiliary electronics.
2. Simulations showed a higher driver energy consumption when using a vapour compressor. Such a driver is only justified when the appeal is energy recovery.
3. Experimental results showed that the liquid pumping and vapour compression cooling cycles were able to maintain the pseudo chip’s temperatures below of the limit of 85°C for an uniform heat flux of 36W/cm² and 30W/cm², respectively for pseudo chip 1 and 2.
4. Non-uniform flow distribution when using only one SMV for both ME’s and different heat loads per ME (90W for ME1 and 30W for ME2) provoked a maximum pseudo chip’s temperature difference of about 15°C. However this can be minimized when the set point of outlet vapor quality is reduced.
5. The preliminary PI controllers developed shown to be effective and satisfy the design requirements.