Thermal/Fluid Analysis in Inkjet Printing

Christopher N. Delametter

Eastman Kodak Company
Rochester, New York 14650-2121
christopher.delametter@kodak.com

Inkjet printing has provided many interesting thermal/fluid problems, which reside in the regime of complex small-scale flows. Recently a number of novel problems have been investigated including, thermally driven jet breakup [1], thermally driven jet bending [2-4], and bi-layer thermal micro-actuated droplet generation [5]. However, little attention has been given to providing a complete, rigorous understanding of the complex problem of superheated vapor bubble driven droplet generation, even thought this represents the predominant mode of inkjet printing today.

The bubble driven droplet generation problem will be framed using a simplified axisymmetric representation. Commercial software [6] will be used to examine the various aspects of a typical superheated vapor bubble droplet generation. The examination will include detailed transient thermal calculation in the CMOS thin film heater structure as well as conduction into the adjacent liquid layer. Once the liquid layer adjacent to the heater structure attains its superheat limit a vapor bubble (model as homogeneous) begins to form. This explosive bubble formation causes fluid to be expelled from an orifice position above the heater structure. In addition, some of the displaced fluid is forced back into a liquid supply reservoir. As the vapor bubble expands, the energy stored in the thin fluid region adjacent to the vapor is depleted. Eventually the bubble growth can no longer be sustained and bubble collapses. It should be appreciated that small perturbations in either the bubble formation/collapse process or slight geometric variations can greatly impact the fluid flux exiting the orifice, thereby significantly affecting the characteristics of the droplet formation process. Much work is needed to provide a complete, rigorous, understanding of the various coupled phenomena involved in this droplet formation method.

[1] Furlani, E. P., "Temporal instability of viscous liquid microjets with spatially varying surface tension," J. Phys. A: Math. Gen. 38, 263-276 (2005).
[2] Chwalek, J. M., Trauernicht, D. P., Delametter, C. N., Sharma, R., Jeanmaire, D. L., Anagnostopoulos, C. N., Hawkins, G. A., Ambravaneswaran, B., Panditaratne, J. C., and Basaran, O. A., "A new method for deflecting liquid microjets," Phys. Fluids 14, L37-L40 (2002).
[3] Brenner, M. P., S. Paruchuri, S., "Thermal bending of liquid jets and sheets", Phys. Fluids (2003).
[4] Delametter, C. N., Trauernicht, D. P., Chwalek, J. M., "Novel Microfluidic Jet Deflection: Significant Modeling Challenge with Great Application Potential," MSM 2002, (2002).
[5] Delametter, C. N., Trauernicht, D. P., Lebens, J. A., Furlani, E. P., Pond, S. F. "Tapered thermal actuator," U.S. Patent 6,824,249 (2004).
[6] Flow-3D Theory and User's Manual, V9.0.2, Flow Science, Inc., (2005).