Influence of pressure history on jet dynamics in LIFT processes: simulation and experimental analysis

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Abstract: The complexity of the physics involved in LIFT processes induces secondary phenomena after the first ejection for both Newtonian and non-Newtonian fluids. In this study, some fluid dynamics observed in experimental pictures is simulated.

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Laser-Induced Forward Transfer techniques, also known as LIFT, are a direct-write technique in which the ink is not deposited through a contact process. Similarly to other direct-write techniques, the main features are flexibility in design (in opposition to those which need a prefabricated pattern, such as stamping, molding or lithographic masking) and allows the transference of very little volumes of liquid (even lower than pL). However, LIFT does not suffer from material compatibility of ink clogging, like inkjet printing does.

In order to simulate the physics below the process, a FEM CFD model [1] has been set in commercial software COMSOL 5.3a. The first assumption taken is that the whole system is fully symmetrical, so the physics may be approached by a 2D-axisymmetrical model and Phase Field equations, instead of Level Set methods that are typically used.

The modifications assumed in how the pressure which makes the fluid evolve is set, lead the simulation to follow the images taken in a closer way. Particularly, this simulation has been compared against BA-LIFT [2] experimental images. These secondary effects replicated in this study have been witnessed for both Newtonian and non-Newtonian fluids [3, 4].

In conclusion, even though traditional pressure function follows the interface in a proper way within the first microseconds, not everything is said in order to simulate the evolution of the jet. The assumptions taken in this study are a step forward in the path towards understanding the physics behind LIFT processes. The comparison between the typical evolution of the pressure in the model and the new one proposed to replicate the dynamics is shown in Figures 1 and 2. The images taken were shot during BA-LIFT process on 2 % sodium alginate.

Fig. 1. Typically-used-like pressure function comparison

Fig. 2. New pressure function comparison.

References

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Laser-Induced Forward Transfer (LIFT)

- Blister Assisted LIFT (BA-LIFT) with a polymeric intermediate layer
- Deposition of small volumes of material (even pl)
- Capability of printing user-defined high-resolution patterns
- Similar functionality to droplet-on-demand (DOD) without nozzle clogging
- Wide variety of fluids with any viscosity

Image acquisition

- Time-resolved shadowgraphy.
- Side-view images of blister expansion and fluid evolution
- Plasma-discharge ns-flash stroboscopic lamp

Understanding the blister

- Image acquisition of the initial stages of the blister
- The measurements of the maximum height of the blister shows an elastic rebound
- Modeled by a step-like function
- Blister is assumed to follow a gaussian dependence on the radius

BA-LIFT simulation – Basic model

- Two-Phase Flow, Phase Field interface
- Moving wall
 - Its velocity is set through experimental data
 - Moving Mesh node

- Navier-Stokes equations:

$$\rho \frac{\partial \mathbf{u}}{\partial t} + \rho (\mathbf{u} \cdot \nabla) \mathbf{u} = \nabla [-pI + \mu(\nabla \mathbf{u} + \nabla \mathbf{u}^T)] + \mathbf{F}_g + \mathbf{F}_{st} + \mathbf{F}_{ext} + \mathbf{F}$$

$$\nabla \cdot \mathbf{u} = 0$$

- Phase Field equations:

$$\frac{d\phi}{dt} + \mathbf{u} \cdot \nabla \phi = \nabla \cdot \left(\frac{\gamma \lambda}{\varepsilon^2} \nabla \psi \right)$$

$$\psi = -\nabla \cdot \left(\varepsilon^2 \nabla \phi + (\phi^2 - 1) \phi \right) + \left(\frac{\varepsilon^2}{\lambda} \right) \frac{\partial f_{ext}}{\partial \phi}$$

This basic model replicates LIFT transference in a close way for the initial stages of the process.

Long term effects

Some unexplained effects are seen in the transference depending on the rheological properties of the fluids for long times.

The source of that movement may be:

- Within the blister dynamics
- In the fluid itself during the transference

The analysis of long-term dynamics of the blister without fluid does not point out any unobserved movement

Thus, the cause of this secondary effects should be in the fluid itself

Simulating secondary effects

Including the effects of a secondary impulse caused by a bubble:

Adjusting the simulation parameters, the former effects for long term BA-LIFT processes may be followed:

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