Acoustical and optical characterization of air entrapment in piezo-driven inkjet printheads

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Acoustical and Optical Characterization of Air Entrapment in Piezo-Driven Inkjet Printheads

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Abstract— Air bubbles can cause nozzle failures in piezo-driven inkjet printheads [1]. The time development of the entrapped air bubbles has experimentally been studied [2]. It was found that the air bubble has a radius of $5\mu\text{m}$ just after the entrapment. The bubble then grows by rectified diffusion due to the applied pressure field, used for jetting droplets. Bjerknes forces drive the displacement of the air bubble. First, the bubble is pushed into the channel. After reaching the resonance size, given by the characteristic printhead frequency, the Bjerknes force reverses sign, pushing the air bubble towards the nozzle. At this time the air bubble has grown so large that it is not possible to jet it out, resulting in a nozzle failure.

I. INTRODUCTION

Air entrapment leads to malfunctioning of jet formation in a piezo-driven inkjet printhead. The entrapped air bubbles disturb the acoustics and in many cases cause the droplet formation to stop [1]. The nozzle diameter is $30\mu\text{m}$ or less. Droplets are jetted every $50\mu\text{s}$ and it is essential that the droplet formation remains stable for an extensive period. Though the droplet forming process is very stable for literally millions of droplets, from one to the next actuation cycle there may be an occurrence giving rise to a malfunctioning of the droplet formation. The time development of the entrapped air bubbles has experimentally been studied [2].

II. METHODS

The acoustical signal is monitored by using the piezo actuator as a sensor to measure the pressure in the channel after the pulse is applied [1]. This signal is employed to monitor deviations in the droplet formation and to trigger the optical setup. In particular, it detects the presence of an air bubble inside the ink channel, as an air bubble modifies the acoustical signal in a characteristic way. The development of the acoustical signal after entrapment of an air bubble can be seen in figure 1, from [1]. The difference compared to the reference acoustical signal (i.e., the signal without air bubbles) is plotted.

The optical measurements are performed with a range of high speed imaging cameras up to 1 Mfps, including the Brandaris 128 camera system [3].

Fig. 1. Development of the acoustical signals, as compared to the reference signal without bubbles, after air bubble entrapment.

III. BUBBLE DYNAMICS

Once entrapped, the air bubble has an initial radius of $5\mu\text{m}$ and oscillates with a frequency near 200kHz . Because of the acoustical field, the bubble oscillates. This oscillating causes a net growth of the bubble over an acoustical cycle. This process is called rectified diffusion [4], [5]. The radial growth of the bubble is found to be $0.3\mu\text{m/ms}$ for $20\text{ms} < t < 60\text{ms}$, as is shown in figure 2, from [2].

Fig. 2. The radius of the bubble as a function of time, here we have taken a moving average over 8 actuation cycles ($400\mu\text{s}$).

The primary Bjerknes force [6] moves the bubble into the channel because the bubble oscillates in phase with the sound field. When the bubble has grown and has a resonance frequency lower than the characteristic frequency of the printhead, the bubble starts to oscillate out of phase with the acoustical field, resulting in a Bjerknes force pushing the bubble towards the pressure node, here the nozzle. This process is shown in figure 3, from [2]. The bubble reaches velocities up to 20mm/s inside the ink channel.

Fig. 3. The displacement of the bubble in the ink channel.

IV. CONCLUSION

The acoustical signals from the piezo actuator can be used to detect air bubbles inside the printhead. When the air bubble is entrapped it is found that the bubble grows by rectified diffusion due to the acoustic field. The air bubble is moving by the primary Bjerknes force. The direction of the movement is determined by the resonance frequency of the bubble and therefore by its radius.

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