Effects of Geometry on the Drop Volume Sensitivity to Temperature in TIJ Printheads

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Abstract

During normal operation, thermal ink jet printheads generate waste heat that causes the temperature of the ink to rise. This, in turn, results in an increase of the volume of the ejected drops creating undesired effects which range from hue shifts to dry time issues. It is therefore important to find ways to minimize the temperature dependence of drop volume. The results are presented of a series of experiments in which the drop volume dependence on ambient temperature was determined for a class of thermal ink jet drop ejectors of the side shooter type. Printheads were fabricated with syste-matic variations in the front channel length, the heater length, and the channel width. The experiments were used to pin down the critical dimensions that influence such dependence.

Introduction

It is well known that the drop volume and velocity in a thermal ink jet device increase with the ambient temperature. During printing, thermal ink jet devices generate waste heat. As a result of this phenomenon, changes in drop volume can occur which create undesired effects. It is therefore of practical importance to find ways of minimizing the temperature dependence of drop volume.

There are several possible causes of this temperature dependence. One factor originates in the ink viscosity change with ambient temperature. In the inks normally used the viscosity decreases with temperature. This results in a reduction, at high temperatures, of the viscous losses during drop ejection which makes the process more efficient. For a discussion on the origin of this dependence see, for example, reference 1. In this report, the results are presented of a set of experiments in which the drop volume dependence on ambient temperature was determined for a variety of drop ejector designs.

Experimental Results

All the drop ejector structures tested were of the side shooter type. The channels were fabricated with an orientation dependent etching process which results in a triangular cross section. The heaters are located at the bottom of "pits" which are etched in a polymer layer. In order to conduct these tests, printheads were fabricated with systematic variations in the heater length, front channel length, and channel width. The length of the heater is measured along the channel axis, the front channel length is defined as the distance between the front of the heater and the front face, and the channel width is defined as the base of the triangular cross section of the etched channel. Each series consisted in varying one dimension alone. Four levels were used for each parameters varied. Table I shows the nominal and variable values used.

Table I

Parameter	Nominal (μm)	Variable (μm)
Heater length	220	160, 190, 220, 250
Front channel length	110	80, 110, 140, 170
Channel width	45	39, 42, 48, 51

In a first set of tests, a general characterization was conducted where drop velocity and drop volume were measured for all the geometries at 32 °C. The results of this first series of experiments are shown in figures 1 through 6. The data shown in these plots are consistent with previous experiments conducted in this type of drop ejector geometries. The heater length controls drop volume and velocity fairly equally in terms of percent change per micron. The length of the front channel affects drop velocity much more than it affects drop volume. Finally, the drop volume is substantially more sensitive to channel width than the drop velocity is, and the corresponding sensitivities have opposite signs. These characteristics of the side shooter geometry are quite attractive from an engineering point of view. They imply that the front channel length and channel width are design parameters that can be used to independently tune drop velocity and drop volume, respectively. The heater length, in turn, can be used to raise or lower both quantities in parallel.

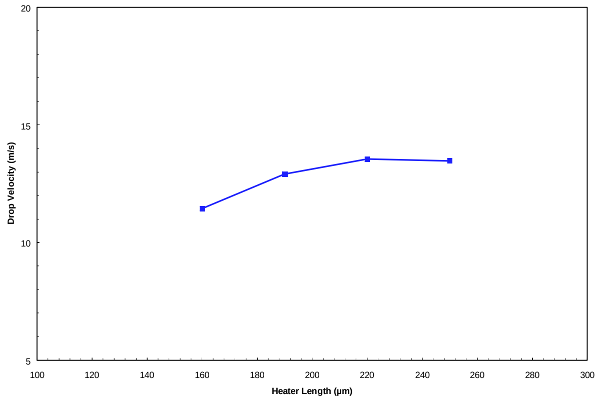

Figure 1: Drop velocity as a function of heater length at 32 °C

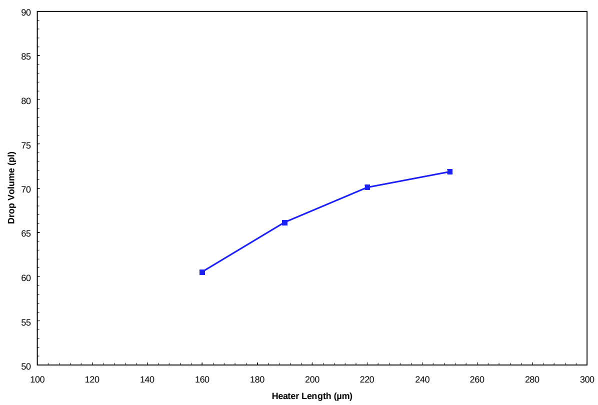

Figure 2: Drop volume as a function of heater length at 32 °C

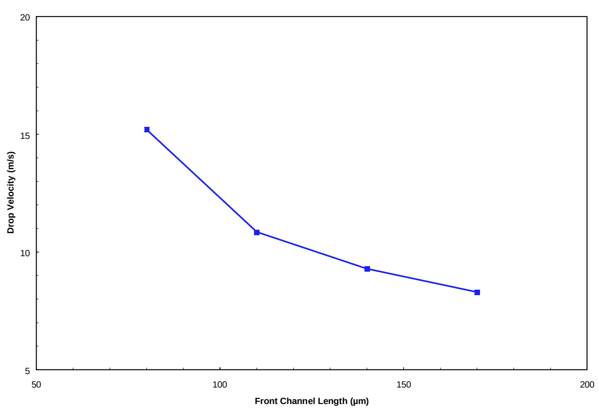

Figure 3: Drop velocity as a function of front channel length at 32 °C

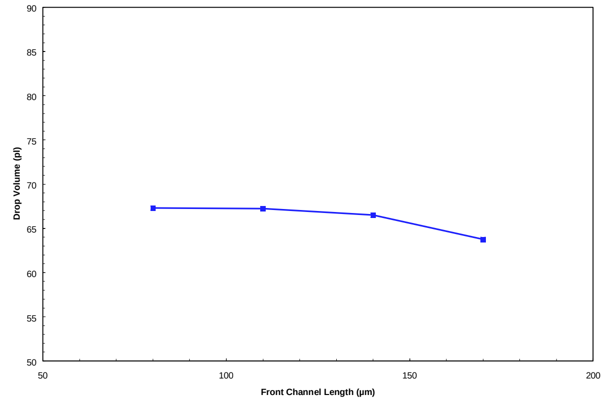

Figure 4: Drop volume as a function of front channel length at 32 °C

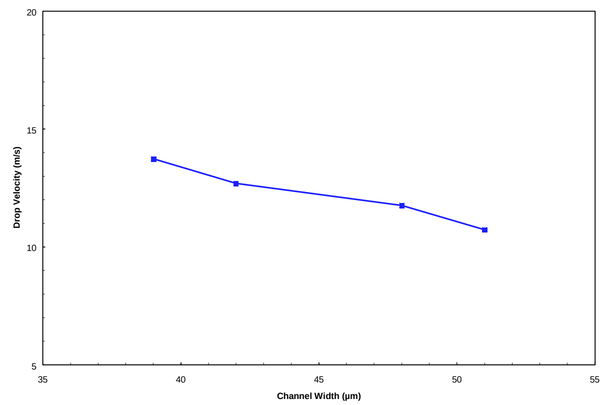

Figure 5: Drop velocity as a function of channel width at 32 °C

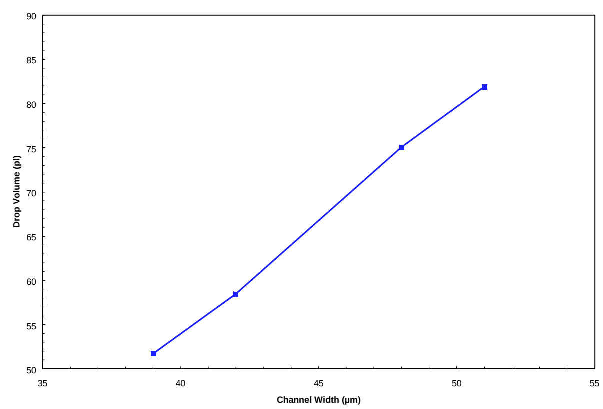

Figure 6: Drop volume as a function of channel width at 32 °C

The second set of experiments consisted in making drop volume determinations as a function of ambient temperature for each of the geometries studied. Five data points were obtained at temperatures between 25 and 40 °C. The drop volume dependence on ambient temperature is quite linear over the measured range. The temperature coefficients can then easily be calculated performing a regression fit for each of the series. Figures 7 through 9 show the plots of the temperature coefficient as a function of heater length, front channel length, and channel width, respectively.

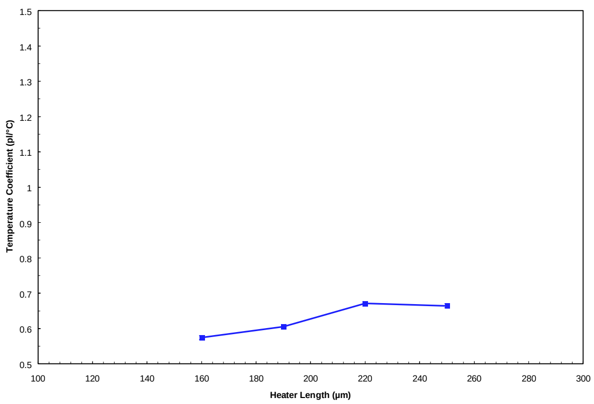

Figure 7: Drop volume temperature coefficient as a function of heater length

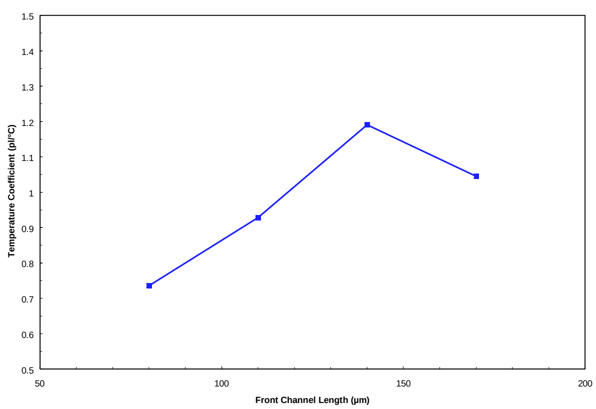

Figure 8: Drop volume temperature coefficient as a function of front channel length

Before the analysis of the data, a comment should be made about the measurement errors. The heater length and front channel length series share one common design. The third data point in figure 7 was obtained with a drop ejector geometry equal to the one used for the second data point in figure 8. That geometry would be equal to a data point in figure 9 at the 45 µm channel width. Based on the differences seen one can estimate the measurement error for the temperature coefficients to be on the order of 0.1 pl/°C.

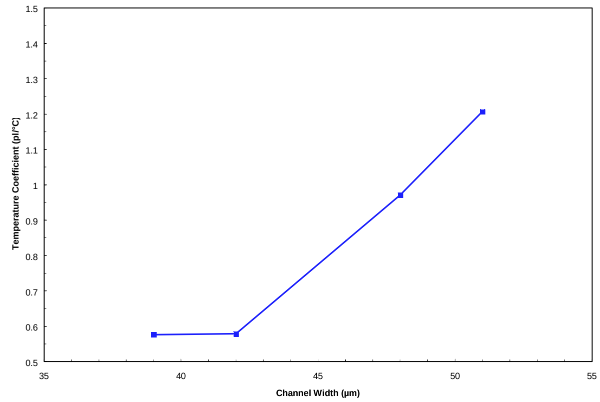

Figure 9: Drop volume temperature coefficient as a function of channel width

The data shown in figure 7 is consistent with the picture in which the drop volume increase with temperature has its origin in a reduction of the viscous losses in the front channel region due to a decrease in the ink viscosity. If the origin of the dependence was through changes in the initial impulse, for example, one would expect the heater area to have a stronger effect on the coefficient. The results shown in figures 8 and 9, however, are not consistent with that simplistic model. In that model the temperature dependence enters only through the fluidic resistance of the front channel. The resistance of a circular pipe is proportional to $L\mu/R^4$, where L is the length of the pipe, µ is the viscosity, and R is the radius. The behavior of the temperature coefficient as a function of the length and the radius should therefore be opposite. In other words, if the coefficient *increases* with L, it should *decrease* with R. Clearly that is not the case with the data presented in figures 8 and 9. We have to conclude that the drop volume must substantially depend separately on either the channel width or the front channel length. Given the geometry of the drop ejectors used, in which the triangular channel covers the whole structure including the heater pit, the channel width probably affects the impulse transfer from the heater to the front channel region.

It should be pointed out that the above analysis was focused on the absolute temperature coefficient. The trends are not significantly different for the relative or percent coefficient.

The results presented suggest a guideline for the design of robust drop ejectors of the type studied. In order to minimize the undesired drop volume changes during printing, short and narrow channels are preferred over long and wide. Obviously one cannot make that choice freely. There are several other considerations that go into the de-sign of a drop ejector such as the appropriate drop volume for the desired resolution. It is interesting to note that in that case, the results shown in figures 4 and 6 indicate that the guideline is quite practical because the drop volume sensitivities to front channel length and channel width have opposite signs.

Conclusions

The drop volume temperature coefficient was measured a function of heater length, front channel length, and channel width using a series of drop ejector designs of the side shooter type. The data obtained indicates that the coefficient is fairly insensitive to heater length but in-creases with both front channel length and channel width. These results imply that, in order to minimize the unde-sired effects due to drop volume changes during printing, short and narrow channels should be used whenever poss-ible over long and wide. The drop volume dependence on front channel length and channel width was also deter-mined and found to be compatible with the rule stated above.

Acknowledgments

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References

1. E.M. Freire, Ink Viscosity Effects on Drop Generation, IS&T's 47th Annual Conference, Volume II, (May 1994).