

Influence of Transducer Control in DOD Printing

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Abstract

The performance of an ink-jet head depends not only on the mechanical construction of the head but also on the inks and the control of the driving signal of transducers. For a given print-head, the latter two parameters should be considered simultaneously in order to optimize the ejection of the droplet in terms of formation, velocity and size.

In this study, we focus on the design of the electronic control of transducers and the improvement of the Print Quality Optimization Apparatus (PQOA) which helps to investigate in detail the influence of the driving signal. On one hand, the computer controlled frequency function/amplifier has a versatile architecture and can be used to drive various print-heads between -30 and 200 Volts peak-to-peak. On the other hand, the upgrading of the PQOA allows to perform advanced signal processing both on the drive waveform and on the surface profile of the ejected filament.

In the course of our experiments, we have tested extensively the influence of the driving voltage for a given waveform thanks to the versatility of the generator. The results that we have obtained concern the size of drop, the length of the filament tail and the velocity of the droplet. They provide a better understanding of the relationships that exist between the initial perturbation and drop formation process.

Introduction

For an industrial ink-jet printing system, the main requirements are in terms of print quality, cost and reliability. A large number of works have been devoted in this area for DOD systems mainly in terms of ink formulations[1,2] so as to obtain drop formation under different operating conditions. Something which has been seldom considered to improve the overall performance of a print-head using a given ink is the driving signal[3] of the device although this aspect seems to represent a real richness for future DOD heads by the large number of waveforms which may be imagined. This has been shown for a limited number of experimental situations in continuous ink-jet printing[4].

A practical problem which is not really solved in the existing works is the fabrication of the waveform generator which should have excellent characteristics in terms of slew rate, amplitude of the signal, and dwell or holding time. In this paper, we will consider a specifically built generator capable of feeding highly reproducible and different waveforms to various commercially available piezoelectric print-heads. This capability to introduce well controlled signals to the print-head combined with the versatility of the Print Quality Optimization Apparatus (PQOA)[5] which has been considerably upgraded allow us not only to construct and monitor the signal which is fed to the piezoelectric transducers but also to follow the whole process from drop ejection to pinch-off.

Experimental Set Up

Hardware Architecture

To reach the goals introduced in the previous section, we have defined a versatile architecture that includes the waveform generator, the hydraulic print-head control and the PQOA.

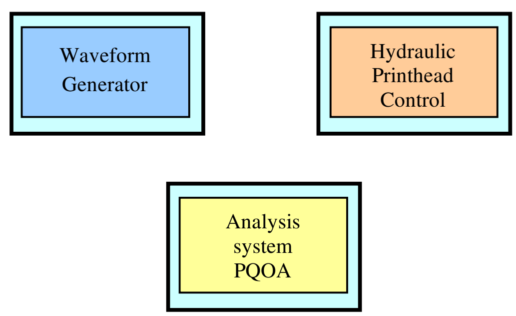

Figure 1. Hardware architecture

Waveform Generator

The design of the electronic system permis us to drive most of the commercially available piezoelectric ink jet with a large spectrum in terms of signal waveforms. As we have described in figure 2, the system includes a PC running under Windows [tm] environment, a specific power supply, an electronic rack and the analogic outputs for the printhead. The power supply delivers two voltages, +240V DC and –50V DC for a positive shape, +50V DC and –200V DC for a negative one.

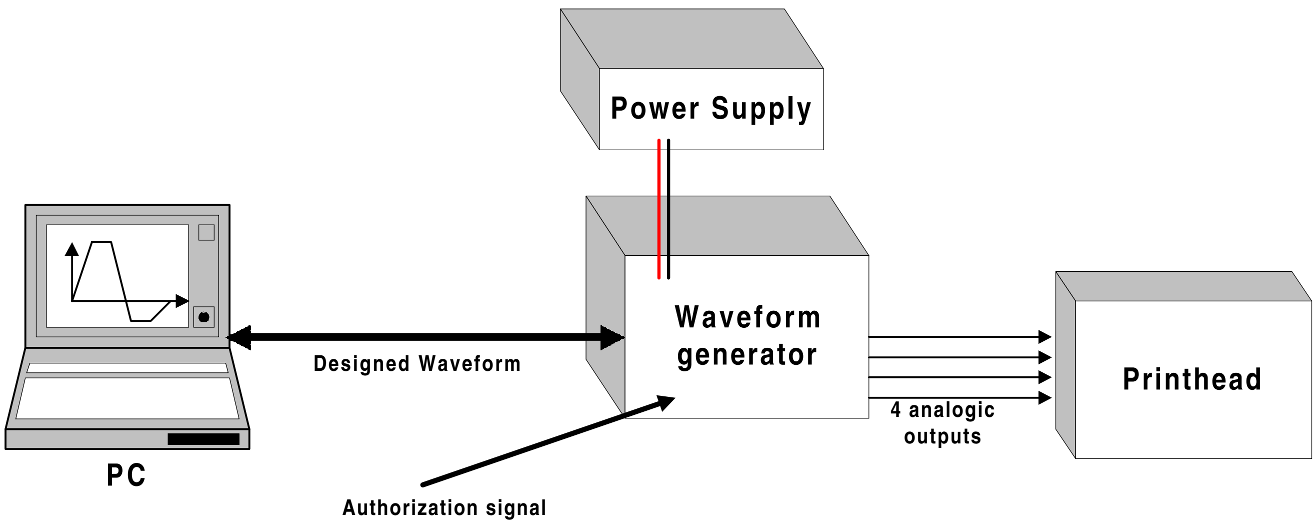

Figure 2. Principle of the electronic system

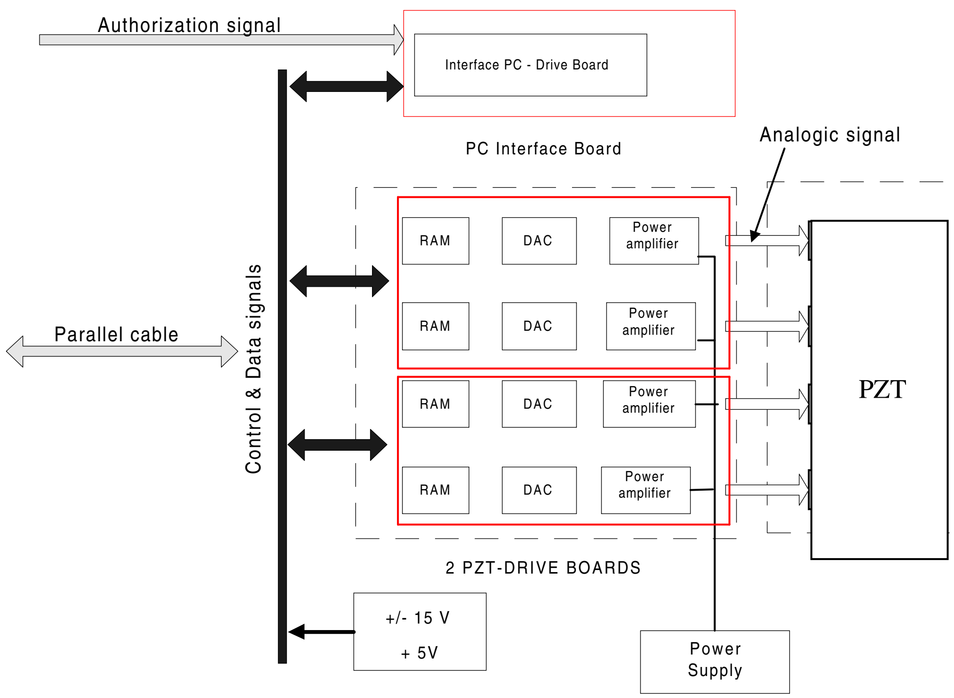

Figure 3. Architecture of the Waveform generator

This waveform generator is able to produce a signal having any shape either positive between -30V and +200V or negative between +30V and –200V. The waveform is defined by the user using a specific software.

The waveform generator includes one interface board and two control boards as described in figure 3 hereinafter. Each PZT Drive Board drives two piezoelectric elements. The rack can include as much as 8 PZT Drive Board. In this board, we can find a Read Access Memory (RAM), a Digital to Analog Converter (DAC) and a specific power amplifier. This board allows to apply a signal defined by the user. The signal is stored in the RAM and for each authorized signal the RAM sends the data through the DAC. The output signal of the converter is amplified and then applied on the piezoelectric elements.

The power amplifier component has to deliver an high amperage current for each piezoelectric elements (2A max). We have studied in detail the thermal dissipation of the device. In order to cool sufficiently the rack, heatsinks and a sophisticated ventilation system are used.

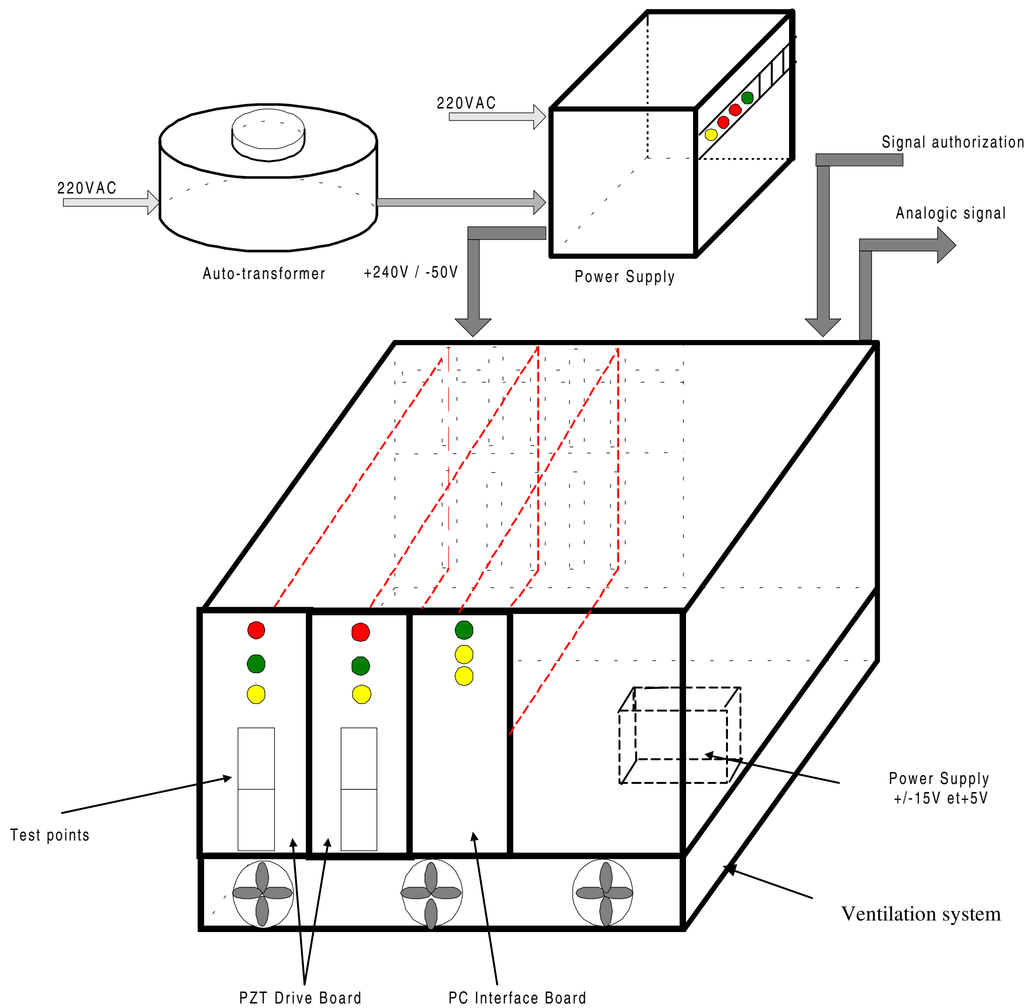

Figure 4. Global view of the Waveform generator

Print Head Control

At this time, we are able to provide a control kit of the print head (electronic and ink circuit) for most of the presently commercially available print heads.

PQOA and Analysis System

The Print Quality Optimization Apparatus[5] proposes a classical design for the study of drops in flight and printed spots on the media. We have also shown that the system is able to check for pollution on the nozzle plate. The most significant enhancement of the PQOA which has been carried out very recently is the possibility to examine drop impact under static and dynamic conditions.

Experimental Results

Case study #1 : Conventional Tests

First of all, we have tested our system under standard operating conditions. The experiments have been performed with an UV curing ink in a range of frequencies comprised between 4 kHz to 15 kHz. Drop volumes and velocities are similar to the data given by the printhead manufacturer. This provides a calibration procedure for our waveform generator. All the different case studies have been performed with a given piezoelectric DOD printhead with the same ink.

Case study #2 : Influence of holding time

The waveform generator allows us to control perfectly well the different holding times (noted Ht) in the signal waveform as show hereinafter.

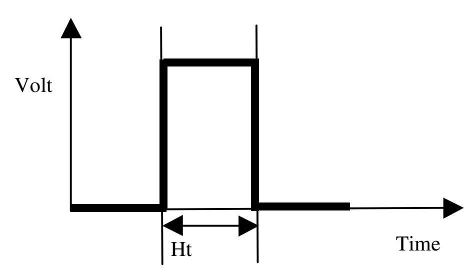

Figure 5. Driving signal with holding time

The performance of the print head in terms of drop formation were analyzed for signals with different Ht. In the following snap shots (figure 6), we can evaluate the influence of this parameter on drop formation. Each flying drop corresponds to respectively 4, 6 and 8µs holding time at a plateau voltage of 150V.

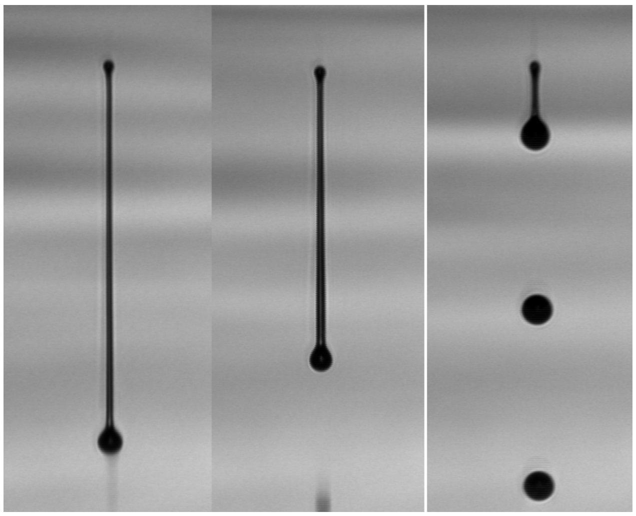

Figure 6. Influence of holding time on drop formation

We have noted that an increase of the holding time leads to reduced tail coalescence time. In an industrial environment this result is interesting in terms of print quality since pollution due to satellites is largely diminished. Unfortunately, the reduction of the length of the tail is linked with drastic decrease of the velocity of the drops from 6 m/s to 3 m/s. This phenomenon is not really well understood at this time although we can conjecture that it is due to the reduced elastic behavior of the ejection system. So from an industrial point of view, the increase of the holding time is perhaps not the best way to optimize the drop ejection processes.

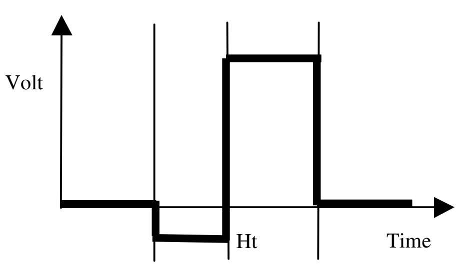

Figure 7. Driving signal

Case study #3 : Influence of pulling voltage upstream the drop ejection signal

In this case study, we have input a negative voltage upstream the drop ejection signal in order to test the influence on drop formation. We have noted that a short negative voltage is sufficient to give additional momentum to the piezoelectric element and thus to increase the overall velocity of the ejected drop.

Case study #4 : Influence of pushing voltage downstream the drop ejection signal

This case study considers negative voltage downstream the main signal. One can note (figure 8) that this has a considerable influence on the length of the filament as shown below. This type of waveform should prove to be extremely useful in the case of viscoelastic fluids which are known to lead to long filaments.[6]

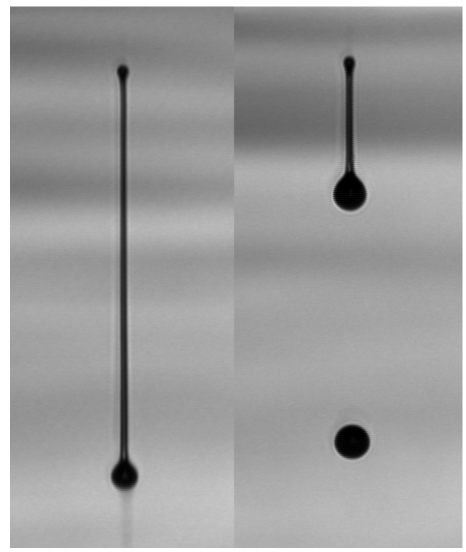

Figure 8. Influence of negative voltage on drop formation

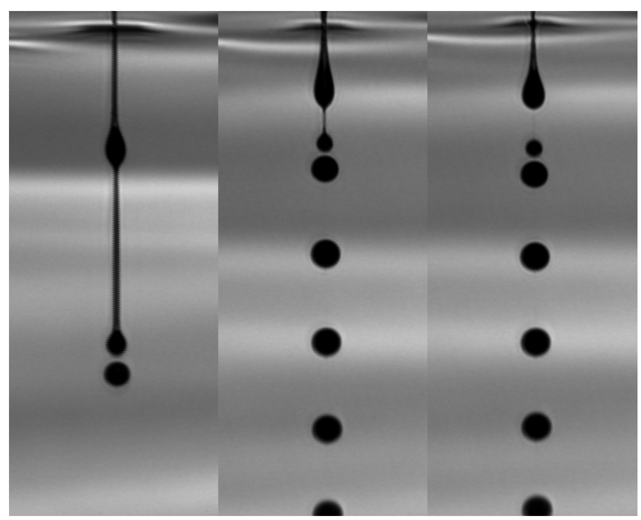

Figure 9. Drop formation under triple shot signal

Case study #5 : Influence of triple shot signal

The triple shot signal is composed of four steps with values of voltages ranging between 0V and 150V. To our opinion, this type of signal is essentially interesting to show the versatility of our electronic system and may also offer some possibilities in terms of theoretical understanding of the physical process.

As seen in figure 9 hereinafter, the signal leads to a string of drops which remain connected for several microseconds. Nevertheless our experiments tend to demonstrate that the pinch-off finally takes place without the formation of satellites.

Conclusion

The main objectives of this study were to optimize the drop formation under different operating conditions. With our electronic system we have performed a large number of experiments and demonstrated that small variations in the signal waveform can lead to drastic changes in the drop formation process (i.e. figures 6 and 8).

The results that we have obtained concern the size of drop, the length of the filament tail and the velocity of the droplet. They provide a better understanding of the relationships that exist between the initial perturbation and drop formation.

Our work leads us to believe that for a given print head, ink formulation and signal waveform should be considered simultaneously in order to optimize the ejection of the droplet in terms of formation, velocity and size.

References

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Acknowledgments

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Biography

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