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Viscosity effect on Piezoelectric Actuated Nozzle In Generating Micro Droplet

Raman.I.[1,a], M.Syafiq[2,b], N.Sa'ude[3,c] M.Ibrahim.[4,d] M.S.Wahab[5,e]

[1~5,] Faculty of Mechanical & Manufacturing Eng., Universiti Tun Hussein Onn Malaysia, 86400 Batu Pahat, Johor, Malaysia

[a]hd090039@siswa.uthm.edu.my, [b]cd090150@siswa.uthm.edu.my, [c]gd100038@siswa.uthm.edu.my,[d]mustaffa@uthm.edu.my, [e]saidin@uthm.edu.my

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Abstract Inkjet printing has proven to be a promising and flexible process methodology for low cost and drop-on-demand pattern formation in small-scale devices with a functional material. In this paper, micro droplet deposition using 80 micron diameter nozzle with micro piezoelectric printhead was investigated using a mixture of three fluids, distilled water (DW) and solutions of two different percentage of glycerine (G) as an operating fluids. The droplet formation capability and stability was studied according to the influence of pulse amplitude, dwell time and fluid viscosity. The results show that the optimal drop velocity to obtain a stable printing range from 0.5 ~1.5 ms^{-1} which corresponds to pulse amplitude range of 25 to 100V and dwell time 15 to 35 μs. Respectively droplet formation and dispensing performance give benefit in dispensing application and build a solid background to inkjeting functional polymer material.

Introduction

In inkjet printing, the ink jetting quality is closely related to the ejected droplets, including the droplet size, droplet consistency and satellite formation. The droplet generation process is empirical observation with operating parameters such as pulse shape, pulse amplitude and dwell time. The droplet generation processes are not only sensitive to waveform [1], nozzle structure [2] but also to ink properties [3]. Since droplet formation process requires different viscosity, and operating parameters vary with materials properties [3,4], viscosity and surface tension of this suspension are identified as key parameters [5]. To explore the relationship between viscosity and driving voltage in dispensing, Meixner et. al [6] compared polymer inks with variable viscosity and surface tension based on Poly(3,4-ethylenedioxythiophene) poly(styrenesulfonate) (PEDOT:PSS). The results showed that for the same surface tension, the higher viscosity liquid required larger voltage to produce droplets. The same conclusion was also drawn by Tsai et al.[7], who observed that higher voltage was needed for silver suspension compared to DW. In this study, drop On demand (DOD) system of 80 micron diameter piezoelectric actuated nozzle, was utilized and the advantage of piezo actuation is that the pressure, pulse rise and fall time can be tailored to optimize monodisperse satellite free droplet production and dynamically alter the diameter the ejected drops. Furthermore, extensive investigation printhead variables and operation parameters is the key to obtaining stable droplet generation conditions. The research focus of this work is to characterize the 80 micron nozzle printhead and investigate the effects of viscosity, dwell time and pulse amplitude in droplet generation process for printing 3d structures with photoreactive polymer.

Experimet Detail

The study on droplet formation process of glycerine mixture with distill water in inkjet printing was conducted with a commercialized inkjetting system (Jetlab IV, Microfab Technologies Inc). Jetlab IV is a desk-top platform and inkjet printing was performed using a single-nozzle print-head actuated by a piezoelectric sleeve tube. The inkjet print- head consisted of a glass capillary bonded to a piezoelectric sleeve actuator, as shown in figure 1.

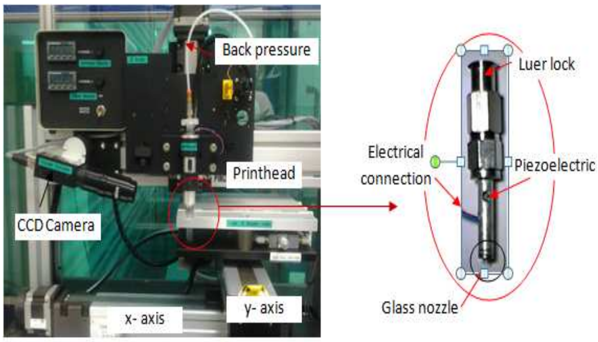


Fig.1 Glass nozzle tube with 80 μm inner diameter which is sleeved with a tube-type piezoelectric element.

The glass capillary tapered to a fine orifice with a diameter of 80 μm, through which droplets were ejected when a suitable electrical pulse was applied to the piezoelectric actuator. The droplet formation images are recorded by the CCD camera and an LED strobe are used at the specified delay time just after it was ejected. In this study, constant jetting frequency at 250 Hz, with unipolar waveforms was used in order to study the inkjetting behavior and generating microdroplet of a mixtured materials .

Materials

The materials used in inkjet printing are diluted solution or suspension with low viscosity [4][8]. In the present study, a mixture of three fluids, DW and solutions of different percentage of G was mixed with DW as an operating fluid. The Vibration Viscometer SV-10 was used to determine the viscosity of the fluid. The sample viscosity causes the vibration to be damped and the current required to maintain the vibration amplitude is measured continuously, and converted into a viscosity values. The polymer syringe reservoir with capacity of 3 ml was used and filled with 1 ml of mixed material in the reservoir as benchmark water level for each ejecting operation.

Piezoelectric Printhead Dispensing System

In piezoelectric printhead, several parameters influence droplet formation: pulse amplitude, dwell time and nozzle size (Nz). A unipolar waveform, as shown in Fig.2, was the simplest one for driving the piezoelectric actuator to generate a droplet. The critical parameters of this waveform were its amplitude *V* and dwell time (*t*D). The rise time (*t*R) and fall time (*t*F) was set up to 1 μs. The negative pressure applied was kept raging from -0.2 to -1.8 psi to maintains the suction within the orifice to hold the liquid. This prevents wetting of the orifice surface and thus allows the ejected droplet to travel faster without dissipating energy at the printhead outlet. In this study, the typical dwell time *t*D was ranging from 30 to 50 μs.

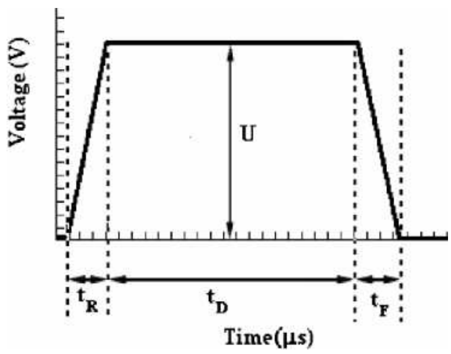


Fig.2 The unipolar waveform used to trigger jetting

Effect of viscosity on dispensing

The droplet diameter was measured using a known scale calibrated to the magnification shown on screen using Image J software. Under known frequency or delay, the droplet velocity can be estimated using the droplet's position over the time .The droplet velocity then was calculated with simple formula;

$$\text{Velocity, V} = \frac{\text{Distance traveled } (\mu m)}{\text{Time}(\mu s)}$$

A stable drop ejection with monodisperse drops, high droplet velocity and reduce droplet diameter can be achieved by emperical observation with different set of dwell time and amplitude voltage values. After optimization with the identification of a preferred values, we examined the variation of droplet jetting behaviour with respect to the dwell time and pulse amplitude.

Result and Disscussion

Materials

DW was added with certain percentage of Glycerene to get viscosity required and stirred in the100 ml beaker untill completely dissolved, then viscosity was measured and recorded as shown in Table 1. From the Fig.3, shows that the linear increased of viscosity values of each substance was mixed with diferent percentage of glycerine. The viscosity values can be easily tailored by increased the % Glycerol. The DW value 1.16 mPas was set as standard values for this experiment, this mixtured fluids of 46% G1 and 47.5% G2 was similar viscosity to actual photoreactive polymer liquid 9.52 mPas and 10.2 mPas. This fluids mixtured then used to investigate the the optimum parameters for droplet generation using 80 micron nozzle.

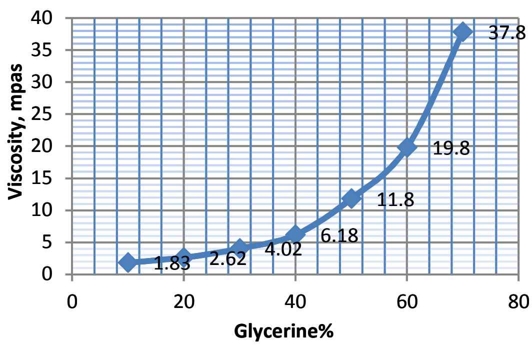


Fig.3. The mixture of % glycerine and Distill water

Table 1. The viscosity of mixtured DW with different percentage of Glycerine

Fluids	Viscosity
DW	1.16 mPas
G1(46%) + DW(54%)	9.52 mPas
G2 (47.5%) + DW(52.5%)	10.2 mPas

Piezoelectric printhead dispensing system

Prior to testing the droplet ejection, the characteristics of the droplet formation according to the viscosity was observed at t=48~600µs. Fig.4 shows the droplet formation for DW, G1 and G2 monodisperse droplet with stable jetting without tail droplet (sattelite drop). At a distance of 570 µm from the nozzle, droplet travel time was showed as viscosity increased, the time taken also increased. At the initial compression, more time was needed to push fluid out of the nozzle and form a droplet, a different time of fluid jet destabilization was observed at 68µs (DW), 85µs (GW1) and 122µs (GW2) due to three differnet fluids viscosity.

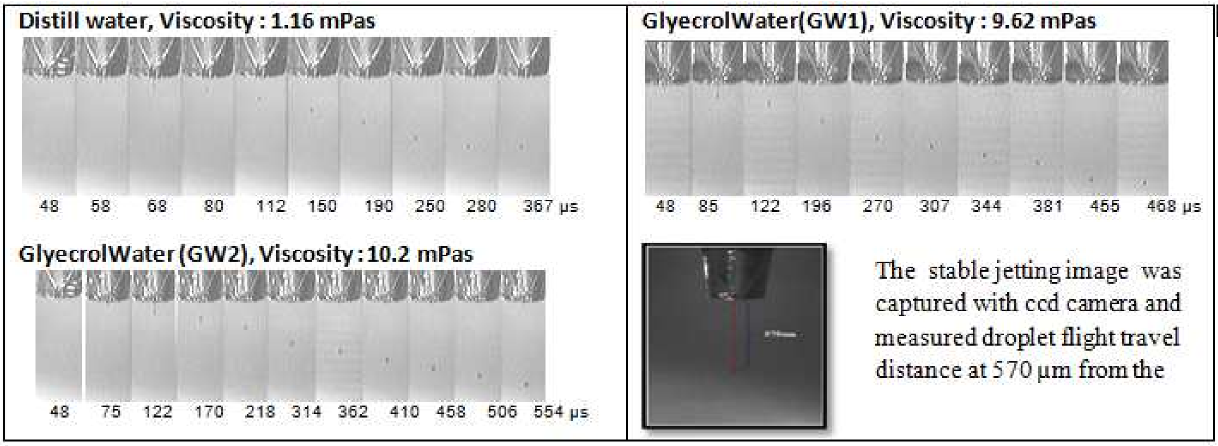
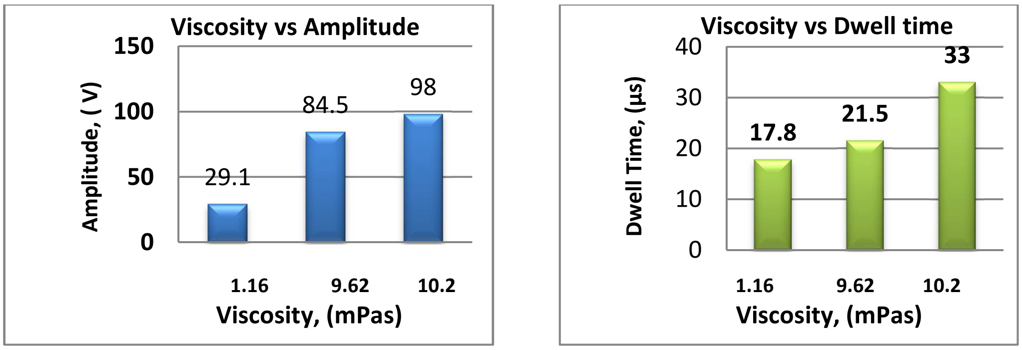


Fig.4 Droplet dispensing process with different fluids viscosity for 80 micron nozzle

Effect of viscosity on fluid dispensing.

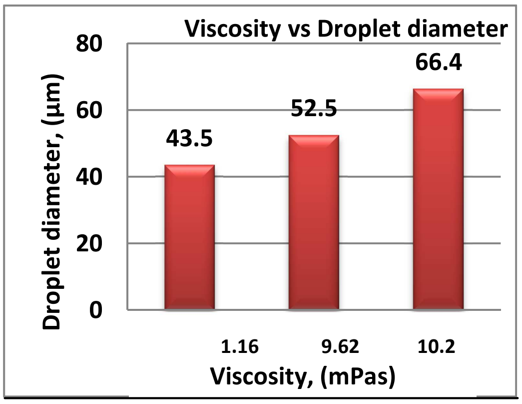
With different fluid properties, establishing the desired conditions for stable droplet formation requires assessing the influence of not only operational parameters, but also the fluid viscosity. Fig.5(a) show the required pulse amplitude voltage range from 29 to 100 V in single droplet generation for three type of viscosity. The graph show a linear amplitude voltage was increased and stable jetting with a single droplet was observed at amplitude voltage 29.1V for DW, 84.5V for G1 and 98V for G2. When increased the voltage the multiple drop was formed and produced sattelite drops, if the amplitude was decreased, the misdirect jetting induced split streams drops. For low viscosity fluid required low voltage but tends to producing satellite droplets. Fig.5(b) longer dwell required as the viscosity increased, the increased linear graph pattern indicated the significant relationship to the fluid viscosity.



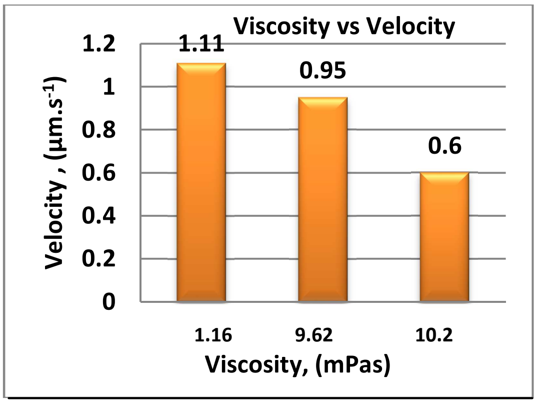
(a) Amplitude voltage (b) Dwell time

Fig.5 The effect of viscosity on (a) amplitude voltage (b) dwell time

As depicted in Fig. 5(c), the droplet diameter increased as the viscosity increased, this is due to the longer dwell time needed to propagate the fluid and thus increased the fluid volume to be ejected from the nozzle at required amplitude voltage. Fig 5(d) it has been observed that the different performance for droplet velocity was decreased as viscosity increased. The higher voltage also results in a large volume droplet, and a dramatic increase of droplet size.



c) Droplet size



(d) Droplet velocity on viscosity

Fig.5 (c) Droplet size (d) Droplet velocity on viscosity

Conclusion

To generate single droplet with piezoelectric printhead, understanding the drop formation process is the first step to realize a maximum jetting stability and to control and manipulate the drop formation with drop size modulation.The inkjetting behavior using the different mixtured fluid showed that applied amplitude and dwell time varied obviously with fluids viscosity. In addition, fluid viscosity also gave effect to behaviour and droplet size due to applied amplitude and dwell time. The jetting stability and uniformability were main factor to achieve a high resolution fabricated 3d structure. The results obtained from this experiment is still need to be expanded by some other study to achieve the optimum information with regards to the contribution of inkjet printing in fabricating 3d structure with photocurable resin.

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