Ripple reduction in piezoelectric micropumps by phased actuation in parallel and damping

Özkayar, G.; Lötters, J.C.; Tichem, M.; Ghatkesar, M.K.

Publication date
2022

Document Version
Final published version

Published in
26th International Conference on Miniaturized Systems for Chemistry and Life Sciences (MicroTAS 2022)

RIPPLE REDUCTION IN PIEZOELECTRIC MICROPUMPS BY PHASED ACTUATION IN PARALLEL AND DAMPING

Conference Paper · October 2022

4 authors, including:


Gürhan Özkayar
Delft University of Technology


M. Tichem
Delft University of Technology


Murali Krishna Ghatkesar
Delft University of Technology

RIPPLE REDUCTION IN PIEZOELECTRIC MICROPUMPS BY PHASED ACTUATION IN PARALLEL AND DAMPING

Gürhan Özkayar[1*], Joost C. Lötters[1,2], Marcel Tichem[1], and Murali K. Ghatkesar[1]
[1]Department of Precision and Microsystems Engineering, Delft University of Technology, The Netherlands
[2]Bronkhorst High-Tech BV, Ruurlo, The Netherlands

ABSTRACT

Piezoelectric micropumps enable miniaturization in microfluidics for lab-on-a-chip applications such as Organs-on-chips (OoC). However, achieving a steady flow with these micropumps is a significant challenge because of the reciprocating motion of the displacing component. Although dampers are widely preferred for reducing ripples, they are not efficient at low flow rates. Here, we propose a phased-actuation of piezoelectric micropumps connected in parallel and a damper to minimize ripples at low flow rates. We are able to reduce ripples by 80% with our proposed configuration compared to a micropump-only configuration between 10-50 µl/min flow rate range.

KEYWORDS: piezoelectric micropumps, ripples, low flow rate, damping

INTRODUCTION

Microfluidics paves the way of facilitating nutrient administration and disposal of waste through perfusion in many fields of applications from dynamic cell cultures to OoC technology [1]. Piezoelectric micropumps are frequently used for the fluid displacement, because they are ideal for creating dynamic mechanical stress, do not require priming and can be easily miniaturized [2]. Flow is generated by applying a voltage with a certain amplitude and frequency to the piezoelectric actuator. Typical flow rates for commercially available piezoelectric micropumps are a few milliliters per minute with no back pressure, achieved with voltage and frequency ranges up to 250 V and 600 Hz, respectively. The generated flow by using piezoelectric micropumps is a pulsatile flow. However, minimizing ripples in the fluid flow and achieving low flow rates are important requirements in OoC applications to reduce the shear stress alterations on the cells [3].

To quantify a ripple factor in the flow, we define $RF_{fl.} = \sqrt{(Q_{RMS}/Q_{AVG})^2 - 1}$, in which Q_{RMS} is root-mean-square value of the fluctuating flow rate and Q_{AVG} is the average value of the fluctuating flow rate. In this work, we explore the limits of minimizing ripples in piezoelectric micropumps at low flow ranges (10-50 µl/min) by using off-the-shelf components.

EXPERIMENTAL

Four different microfluidic configurations were tested and the ripples generated in the flow rate were compared (Figure 1A). 1) Micropump only, 2) Micropump + damper, 3) Micropumps-parallel, 4) Micropumps-parallel + damper. A sinusoidal signal generated by an Arduino Nano Every microcontroller is used to actuate piezoelectric micropumps (mp6, Bartels Mikrotechnik GmbH, Germany). A flow sensor (MFS3, Elveflow, France) is used to measure the flow rate. A 400 x 400 µm channel microfluidic chip (microfluidic ChipShop GmbH, Germany) is used as a model application chip. A damper (mp-damper, Bartels Mikrotechnik GmbH) is used to damp the flow fluctuation. A fixed amplitude of 100 V and a varying frequencies of 0.5 Hz to 10 Hz is tested to keep the flow rates within the flow sensor range of below 80 µl/min.

RESULTS AND DISCUSSION

The flow rate with time in four different configurations were tested (Fig. 1A). A plot of flow rates measured in all four configurations is shown in Fig. 1B. In between different applied frequencies, no electrical signal was applied to the micropumps. The average flow rate (Q_{AVG}) increased with increased applied frequency to the micropumps. The Q_{RMS} value for each configuration was measured. To compare the performance of each configuration, the ripple factor value was calculated and plotted in Fig. 1C. The configuration with phased-actuation with damping significantly reduced the ripple factor in the flow rate. The improvement in the ripple factor in all the configurations compared to micropump-only configuration is plotted in Fig. 1D. The results indicate a ripple factor reduction of 80% with phased-actuation of micropumps connected in parallel with damper.

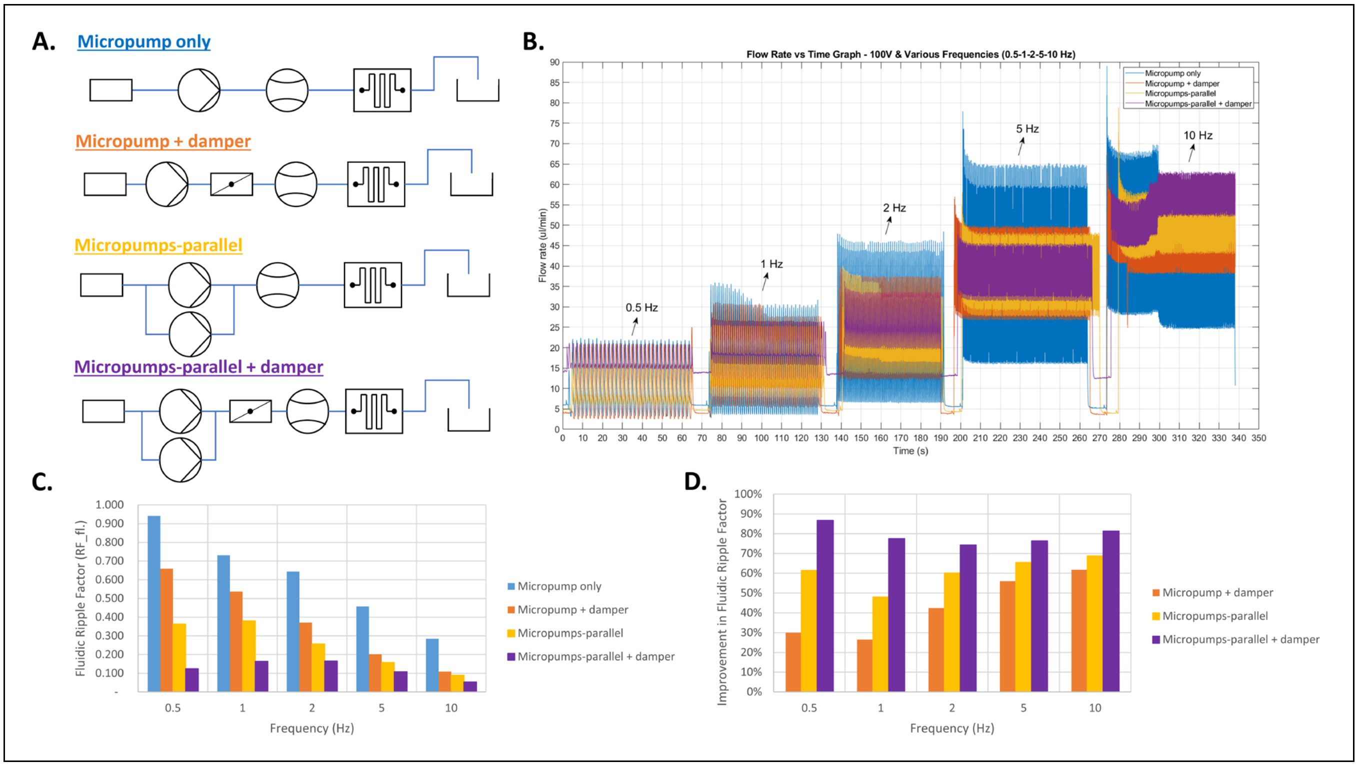

*Figure 1: Comparison of tested configurations for minimizing flow ripples in piezoelectric micropumps. **A.** Schematics used for calculating $RF_{fl.}$ values. **B.** Flow ripple formation at various frequencies. **C.** Calculated fluidic ripple factors for each configuration. **D.** Ripple factor improvement ratios of the configurations.*

CONCLUSION

An out of phase actuation of micropumps connected in parallel with damper is an effective approach to reduce ripples in low flows A ripple factor improvement of 80% was obtained compared to micropump-only configuration in the flow rate range of 10-50 µl/min. As a next step we will further investigate to identify the best configuration to combine and operate the piezoelectric micropumps to obtain a ripple factor close to zero for wide flow rate range from 0.5 µl/min and 500 µl/min, that covers the requirements of all OoC devices.

ACKNOWLEDGEMENTS

This work was supported by Top consortium voor Kennis en Innovatie (TKI) High Tech Systemen en Materialen (HTSM) and Nano Engineering Research Initiative (NERI) of the Delft University of Technology in collaboration with Bronkhorst High-Tech B.V under the iMicrofluidics project.

REFERENCES

[1] Q. Wu, *et al. Eng OnLine,* 19, 9, 2020.
[2] C. Jenke, *et al. Sensors*, 17, 755, 2017.
[3] S. Wang, *et al. Journal of Biotechnology*, 246, 52-60, 2017.

CONTACT

* G. Özkayar; phone: +31(0)-15-27 89995; g.ozkayar@tudelft.nl