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Supplementary Materials

Magnetorheological Elastomer Peristaltic Pump Capable of Flow and Viscosity Control

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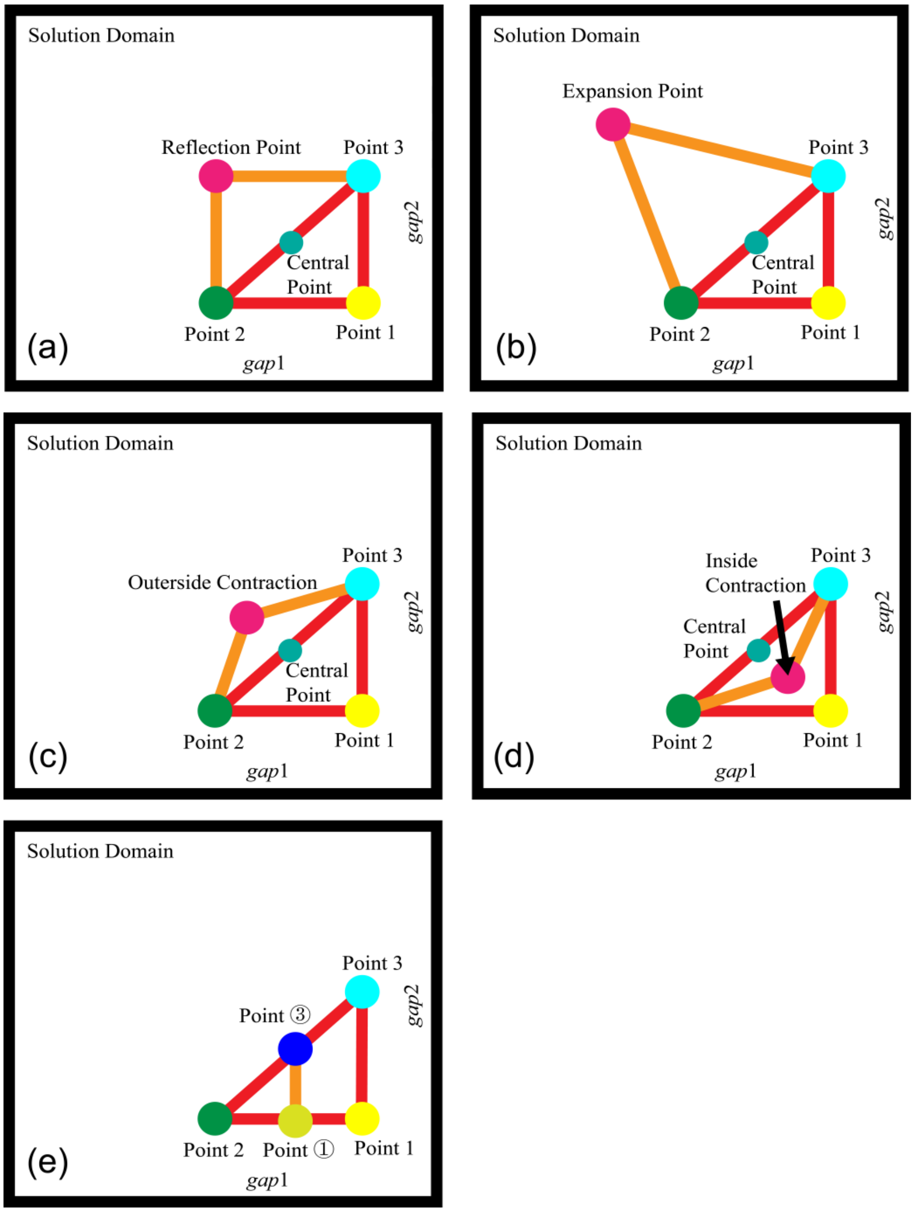

FIG. S1. Sketch of Nelder-Mead optimization operations including reflection (a), expansion (b), outside contraction (c), inside contraction (d), and shrink (e)

Figs. S1 shows the basic operation of Nelder-Mead optimization including reflection, expansion, outside contraction, and shrink (Lee and Wiswall, 2007). Two parameters (*gap*1 and *gap*2) can be optimized using triangle as simplex. First, the objective function at initial three points are computed. Without loss of generality, we assume that the point 1 and point 2, respectively, are the worst and the best point among initial points of point 1, point 2, and point 3. The value of the best point is closest to the aim (the smallest value in the simulations conducted to obtain the required net pumped volume) among three points.

First, the reflection operation is conducted to obtain reflection point (Fig. S1(a)). The expansion operation is performed if the reflection point is better than point 1(Fig. S1(b)). Otherwise, the outside and inside constrictions are applied (Fig. S1(c,d)). If all aforementioned operations are invalid for the search of better point, the shrink operation where the points 1 and 3 move to the midpoints in the line 1-2 and line 2-3 (Fig. S1(e)). With some limitations, like the region of parameters, some operations cannot be conducted and are replaced by other operations.

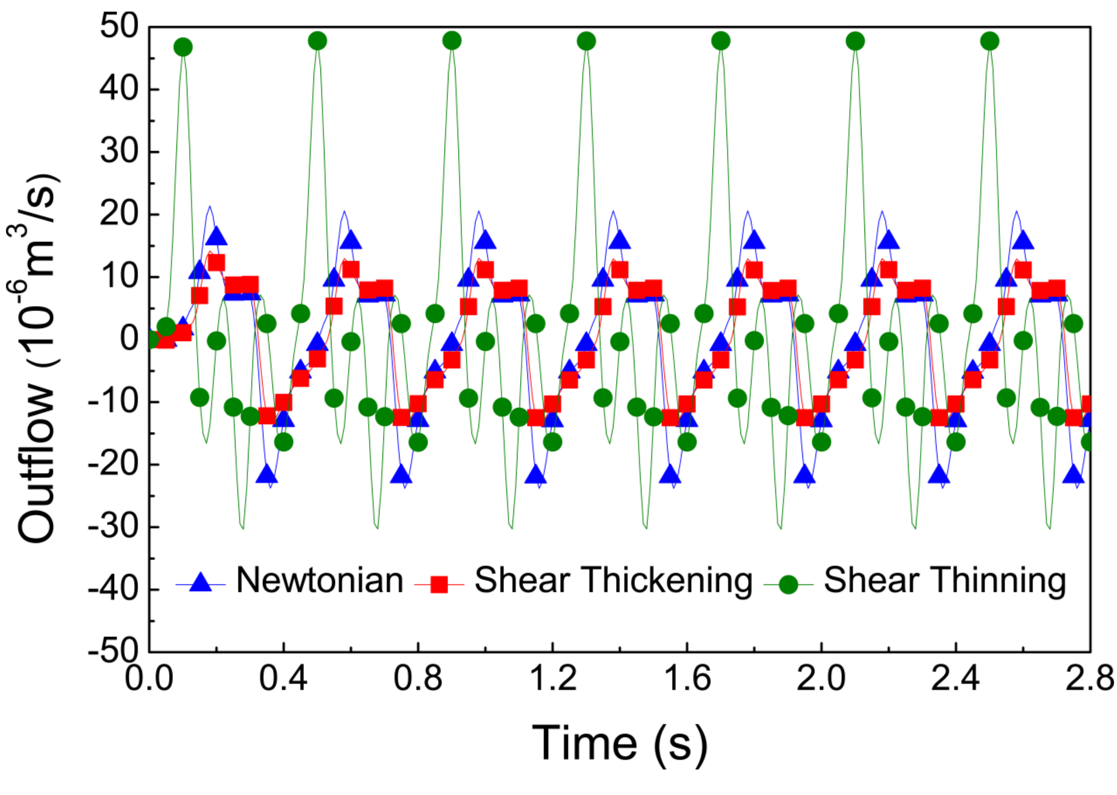

FIG. S2. Outflow of the shear thinning, shear thickening and Newtonian fluids during observing time from 0 s to 2.8s

Figure. S2 shows the outflow of the shear thinning, thickening and Newtonian fluids during observing time from 0 s to 2.8s. There are also obvious differences between patterns for the outflow of blood during nearly two working cycles before 0.8 s. After

0.8 s, the rate of flow can be used to compute the pumped volume of a steady working cycle. The time range from 2.4 s to 2.8 s is selected as the range of observing time.

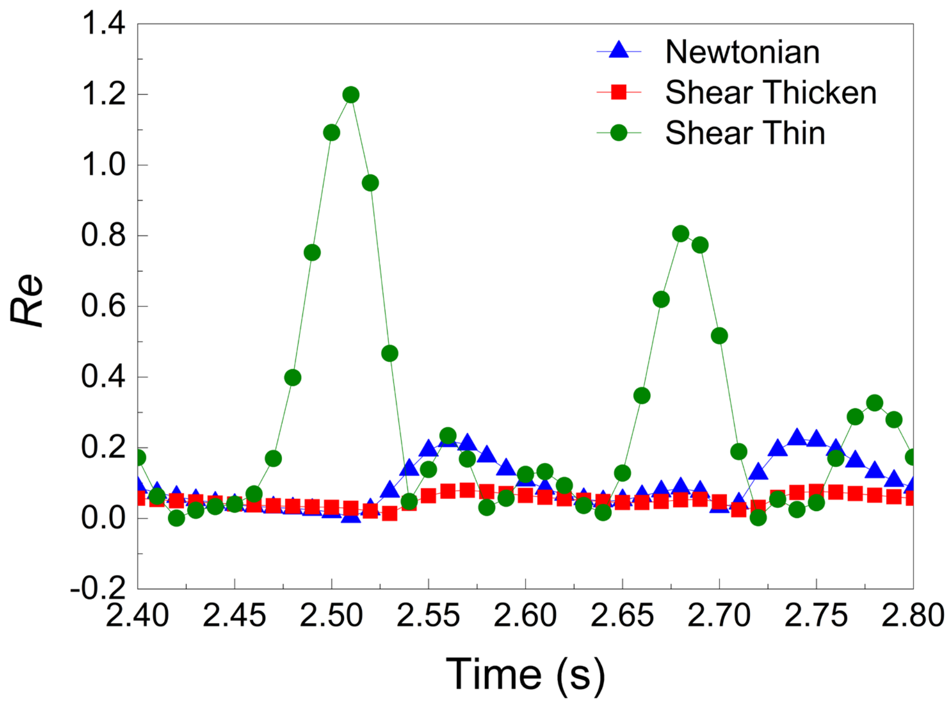

Fig. S3 Reynolds number of shear thinning, shear thickening, and Newtonian fluids in the MRE-PP.

Reynolds number (*Re*) is calculated as following

$$Re = \frac{pD_{\mathrm{h}}v_{avg}}{\eta}$$

Here, ρ is the fluid density (In order to simplify calculating, the density of all fluids in simulations are set at 1000 kg/m^3), D_{h} is the hydraulic diameter at the outlet, v_{avg} is the average of velocity in *x* direction at the outlet, and η is the viscosity of the fluid. Fig. S3 shows the *Re* of shear thinning, shear thickening, and Newtonian fluids. *Re* is much lower than 1 in shear thickening and Newtonian fluids, indicating that the viscosity force determine the fluid-solid-interaction, and the fluid load on MRE tube only depends on fluid pressure and velocity. Hence, similar outflow pattern between shear thickening and Newtonian fluids is observed in Fig.4. High values and very low values, respectively, are observed in shear thinning and thickening fluids, corresponding to obviously and feeble fluctuations illustrated in Fig. 4.

Table S1 Values of parameters in Carreau model and Power law model

Carreau model	
η_0	0.05 Pa·s
η_∞	0.001 Pa·s
λ	3.13
n_1	0.75
Power law model	
m	0.05
n_2	1.25

Table S2 Range of parameters in shear thickening, shear thinning, and Newtonian fluids

Fluids	Range of *gap*1 (s)	Range of *gap*2 (s)
Shear thickening	0.01-0.045	0.055-0.09
Shear thinning	0.01-0.03	0.07-0.09
Newtonian	0.01-0.045	0.055-0.09

Reference

Lee D. and Wiswall M. (2007) A Parallel Implementation of the Simplex Function Minimization Routine, *Computational Economics* 30: 171–187.