Appendix A.

Rotameter Calibration Procedure

A bubble flow meter was used to calibrate the rotameter and it is considered one of the simplest techniques for rotameter calibration. Figure A1 shows the average flow rate measured via the bubble flow meter vs the rotameter set value. The flow rate of bubble flow meter was calculated from Eq. (A1) as follows,

$$\text{Flow rate} = \frac{Calibrated \quad volume \quad between \quad marks}{Transit \quad time} \left(mL / \min\right) \tag{A1}$$

Eq. (A2) was found from the calibration data using a line of best fit and subsequently used to calculate the set value of the rotameter.

$$y = 1.0492x - 0.0072 \tag{A2}$$

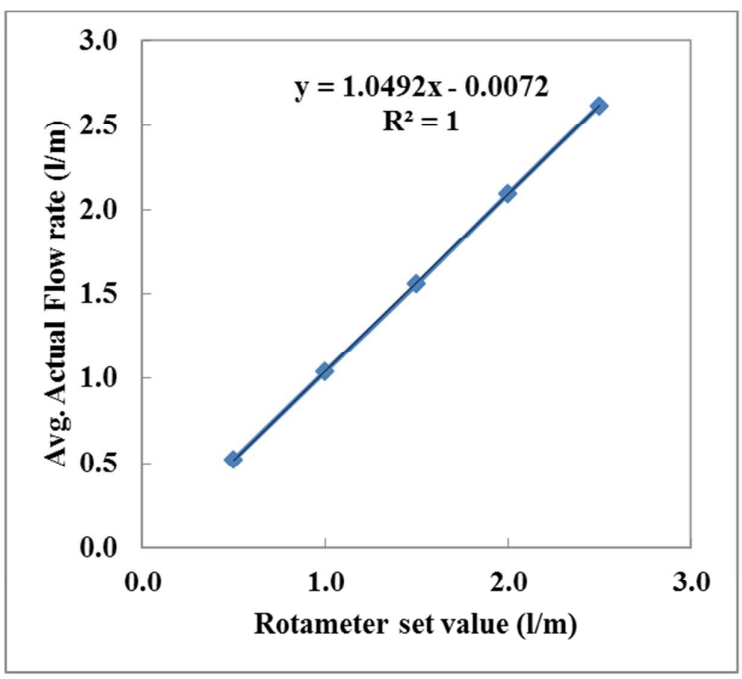

Figure A1. Average actual flow rate Vs Rotameter set value

Appendix B.

Random error analysis

The average or mean value ($\bar{x}$) of x is found from Eq. (B1)

$$\bar{x} = \frac{1}{n}\sum_{1}^{n} x_i \tag{B1}$$

where,

n= a total number of measurements

x_i = the value of each measurement

The standard deviation (σ) of x is calculated from Eq. (B2),

$$\sigma = \sqrt{\frac{\sum_{1}^{n}(x_i - \bar{x})^2}{n-1}} \tag{B2}$$

The standard error or the error in the mean (σ_m) is calculated as follows,

$$\sigma_m = \frac{\sigma}{\sqrt{n}} \tag{B3}$$

Appendix C.

Supplemental data

(1) Size distribution

a) 0.24 wt% of Fe_3O_4/DI-water

5 ml/min			10 ml/min			15 ml/min		
Size (nm)	Mean Number (%)	SD* for mean number (%)	Size (nm)	Mean Number (%)	SD* for mean number (%)	Size (nm)	Mean Number (%)	SD* for mean number (%)
18.17	0	0	21.04	0	0	21.04	0	0
21.04	0	0	24.36	0	0	24.36	0	0
24.36	1.6	0.1	28.21	1.2	2.30	28.21	1.7	0.5
28.21	5.8	0.3	32.67	6.5	3.70	32.67	5.5	0.3
32.67	14.0	1.7	37.84	15.1	1.0	37.84	8.9	1.2
37.84	23.2	3.8	43.82	20.2	4.50	43.82	12.7	2.8
43.82	23.3	2.0	50.75	18.8	2.80	50.75	16.2	1.4
50.75	15.1	1.3	58.77	13.8	0.50	58.77	15.8	1.0
58.77	7.6	2.3	68.06	8.8	0.50	68.06	11.9	1.6
68.06	3.5	1.7	78.82	5.2	0.70	78.82	7.7	1.2
78.82	1.7	0.9	91.28	3.0	0.50	91.28	4.7	0.6
91.28	0.9	0.4	105.70	1.8	0.40	105.70	2.9	0.3
105.70	0.6	0.2	122.40	1.2	0.20	122.40	2.0	0.1
122.40	0.5	0.1	141.80	0.9	0.10	141.80	1.6	0.1
141.80	0.4	0.3	164.20	0.7	0.10	164.20	1.5	0
164.20	0.4	0.5	190.10	0.7	0.10	190.10	1.5	0
190.10	0.4	0.1	220.20	0.6	0.20	220.20	1.4	0
220.20	0.3	0.1	255.0	0.5	0.30	255.0	1.2	0.1
255.0	0.3	0.1	295.30	0.4	0	295.30	1.0	0.3
295.30	0.2	0.1	342.0	0.3	0	342.0	0.8	0.1
342.0	0.1	0.1	396.10	0.2	0	396.10	0.6	0.1
396.10	0.1	0	458.70	0.1	0	458.70	0.4	0.1
458.70	0.1	0	531.20	0.1	0	531.20	0.2	0
531.20	0	0	615.10	0	0	615.10	0.1	0
615.10	0	0	712.40	0	0	712.40	0	0
						825.0	0	0

(b) 0.55 wt% of Fe_3O_4/DI-water

5 ml/min			10 ml/min			15 ml/min		
Size (nm)	Mean Number (%)	SD* for mean number (%)	Size (nm)	Mean Number (%)	SD* for mean number (%)	Size (nm)	Mean Number (%)	SD* for mean number (%)
18.17	0	0	28.21	0	0	28.21	0	0
21.04	0	0	32.67	0	0	32.67	0	0
24.36	2.3	0.0	37.84	4.1	1.3	37.84	0.7	0.3
28.21	7.2	0.6	43.82	14.5	3.0	43.82	10	1.2
32.67	12.0	0.5	50.75	22.0	2.5	50.75	24.6	0.4
37.84	14.7	1.0	58.77	20.4	0.3	58.77	25.1	1.4
43.82	14.7	0.3	68.06	14.2	1.5	68.06	13.9	1.7
50.75	13.7	1.0	78.82	8.5	1.2	78.82	5.5	1.2
58.77	11.8	1.4	91.28	4.8	0.8	91.28	2.1	0.6
68.06	8.3	1.1	105.70	2.8	0.6	105.70	1.3	0.2
78.82	5.0	0.6	122.40	1.7	0.4	122.40	1.4	0.3
91.28	2.9	0.2	141.80	1.3	0.3	141.80	1.6	0.
105.70	1.7	0.1	164.20	1.1	0.2	164.20	1.9	0.2
122.40	1.1	0.2	190.10	1.0	0.3	190.10	2.1	0.3
141.80	0.8	0.2	220.20	0.9	0.2	220.20	2.2	0.1
164.20	0.7	0.3	255.0	0.8	0.2	255.0	2.0	0.2
190.10	0.7	0.3	295.30	0.6	0.1	295.30	1.7	0.1
220.20	0.6	0.3	342.0	0.5	0.1	342.0	1.4	0
255.0	0.5	0.3	396.10	0.4	0.1	396.10	1.1	0.3
295.30	0.4	0.2	458.70	0.3	0.1	458.70	0.7	0.2
342.0	0.4	0.2	531.20	0.1	0	531.20	0.4	0.1
396.10	0.3	0.1	615.10	0.1	0	615.10	0.1	0.1
458.70	0.2	0.1	712.40	0	0	712.40	0.1	0
531.20	0.1	0	825.0	0	0	825.0	0	0
615.10	0	0				955.40	0	0
712.40	0	0						

(c) 1.4 wt% of Fe_3O_4/DI-water

5 ml/min			10 ml/min			15 ml/min		
Size (nm)	Mean Number (%)	SD* for mean number (%)	Size (nm)	Mean Number (%)	SD* for mean number (%)	Size (nm)	Mean Number (%)	SD* for mean number (%)
24.36	0	0	28.21	0	0	32.67	0	0
28.21	0	0	32.67	0	0	37.84	0	0
32.67	3.7	0.7	37.84	0.3	0.2	43.82	1.7	0.5
37.84	11.2	0.9	43.82	6.0	0.5	50.75	9.0	1.2
43.82	17.7	2.0	50.75	17.4	0.8	58.77	18.2	2.8
50.75	21.5	0.9	58.77	22.5	1.3	68.06	19.8	1.4
58.77	18.7	0.8	68.06	18.2	0.3	78.82	14.4	1.0
68.06	10.9	1.2	78.82	11.6	0.6	91.28	8.8	1.6
78.82	5.0	0.9	91.28	6.6	0.8	105.70	5.2	1.2
91.28	2.1	0.5	105.70	3.7	0.7	122.40	3.4	0.6
105.70	1.0	0.3	122.40	2.2	0.5	141.80	2.7	0.3
122.40	0.8	0.1	141.80	1.6	0.3	164.20	2.5	0.2
141.80	0.8	0.1	164.20	1.4	0.1	190.10	2.6	0.1
164.20	0.9	0.1	190.10	1.4	0	220.20	2.5	0.2
190.10	1.1	0.2	220.20	1.4	0.1	255.0	2.3	0.1
220.20	1.1	0.1	255.0	1.3	0.2	295.30	2.0	0.3
255.0	1.0	0.4	295.30	1.1	0.3	342.0	1.7	0.1
295.30	0.9	0.3	342.0	1.0	0.3	396.10	1.3	0.1
342.0	0.7	0.5	396.10	0.8	0.3	458.70	0.9	0.2
396.10	0.5	0.3	458.70	0.6	0.2	531.20	0.5	0.1
458.70	0.3	0	531.20	0.4	0.1	615.10	0.2	0
531.20	0.1	0	615.10	0.2	0.1	712.40	0.1	0
615.10	0	0	712.40	0.1	0	825.0	0	0
712.40	0	0	825.0	0	0	955.40	0	0
			955.40	0	0			

*SD= Standard deviation

(2) Zeta potential

NH_4OH addition rate (ml/min)	0.24 wt%		0.55 wt%		1.4 wt%	
	Zeta potential (mV)	SD* for zeta potential (mV)	Zeta potential (mV)	SD* for zeta potential (mV)	Zeta potential (mV)	SD* for zeta potential (mV)
5	-50	0.40	-41.7	0.94	-34.9	1.19
10	-45	0.72	-37.5	0.62	-30	1.10
15	-38.5	1.17	-29.6	0.26	-23	1.43

*SD= Standard deviation

(3) Viscosity

a) 0.24 wt% of Fe_3O_4/DI-water

5 ml/min			10 ml/min			15 ml/min		
Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)	Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)	Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)
5.591	0.93	0.009	5.592	1.11	0.018	5.591	1.19	0.001
7.769	0.88	0.0084	7.769	1.08	0.018	7.769	1.12	0.025
10.8	0.86	0.0059	10.8	1.05	0.017	10.8	1.09	0.015
15	0.86	0.0045	15	1.02	0.014	15	1.058	0.026
20.84	0.87	0.0034	20.84	0.99	0.018	20.84	1.011	0.013
28.96	0.86	0.0034	28.96	0.99	0.019	28.96	1.028	0.022
40.24	0.84	0.0030	40.24	0.98	0.015	40.24	1.01	0.024
55.91	0.83	0.0026	55.91	0.97	0.009	55.91	1.001	0.012
77.69	0.82	0.0027	77.69	0.96	0.008	77.69	0.9922	0.097
108	0.82	0.0025	108	0.95	0.008	108	0.9853	0.099
150	0.81	0.0024	150	0.95	0.008	150	0.9815	0.006
208.4	0.80	0.0022	208.4	0.95	0.007	208.4	0.9733	0.0005
289.6	0.80	0.0021	289.6	0.95	0.009	289.6	0.9699	0.0008
402.4	0.79	0.0020	402.4	0.95	0.011	402.4	0.9725	0.003
559.1	0.79	0.0018	559.1	0.94	0.009	559.1	0.9714	0.002
776.9	0.80	0.0016	776.9	0.95	0.005	776.9	0.9799	0.003
1050	0.82	0.0015	1050	0.97	0.011	1050	0.9987	0.004

(b) 0.55 wt% of Fe_3O_4/DI-water

5 ml/min			10 ml/min			15 ml/min		
Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)	Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)	Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)
5.592	0.98	0.011	5.592	1.15	0.025	5.591	1.23	0.021
7.769	0.96	0.011	7.769	1.12	0.025	7.769	1.20	0.002
10.8	0.95	0.009	10.79	1.082	0.025	10.8	1.15	0.013
15	0.96	0.026	15	1.06	0.014	15	1.13	0.02
20.84	0.97	0.018	20.84	1.04	0.006	20.84	1.13	0.023
28.96	0.96	0.011	28.96	1.032	0.024	28.96	1.10	0.026
40.24	0.95	0.025	40.24	1.024	0.013	40.24	1.08	0.021
55.91	0.94	0.009	55.91	1.008	0.007	55.91	1.06	0.009
77.69	0.94	0.004	77.69	0.9979	0.003	77.69	1.04	0.001
108	0.94	0.003	108	0.991	0.006	108	1.03	0.001
150	0.93	0.003	150	0.9827	0.002	150	1.02	0.007
208.4	0.93	0.003	208.4	0.9766	0.002	208.4	1.01	0.002
289.6	0.93	0.003	289.6	0.9701	0.005	289.6	1.00	0.002
402.4	0.92	0.003	402.4	0.9682	0.005	402.4	1.00	0.002
559.1	0.93	0.002	559.1	0.9675	0.003	559.1	1.00	0.002
776.9	0.94	0.002	776.9	0.9742	0.002	776.9	1.01	0.002
1050	0.96	0.002	1050	0.9916	0.002	1050	1.03	0.002

(c) 1.4 wt% of Fe_3O_4/DI-water

5 ml/min			10 ml/min			15 ml/min		
Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)	Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)	Shear rate (1/s)	Viscosity (Pa.s)	SD* for viscosity (Pa.s)
5.591	1.16	0.019	5.591	1.2	0.0244	5.592	1.261	0.017
7.769	1.135	0.014	7.769	1.165	0.023	7.769	1.22	0.016
10.8	1.12	0.006	10.8	1.15	0.023	10.8	1.2	0.015
15	1.09	0.003	15	1.141	0.024	15	1.175	0.016
20.84	1.06	0.019	20.84	1.101	0.0140	20.84	1.158	0.016
28.96	1.082	0.015	28.96	1.101	0.013	28.96	1.12	0.009
40.24	1.044	0	40.24	1.075	0.021	40.24	1.106	0.024
55.91	1.04	0.007	55.91	1.064	0.009	55.91	1.088	0.007
77.69	1.03	0.008	77.69	1.055	0.001	77.69	1.08	0.003
108	1.026	0.001	108	1.048	0.008	108	1.07	0.003
150	1.022	0.002	150	1.041	0.007	150	1.06	0.002
208.4	1.02	0.003	208.4	1.037	0.003	208.4	1.042	0.001
289.6	1.015	0.001	289.6	1.027	0.008	289.6	1.039	0.001
402.4	1.003	0.002	402.4	1.02	0.004	402.4	1.037	0.002
559.1	1.009	0.002	559.1	1.022	0.009	559.1	1.035	0.001
776.9	1.01	0.002	776.9	1.025	0.001	776.9	1.04	0.002
1050	1.021	0.003	1050	1.038	0.001	1050	1.055	0.002

*SD= Standard deviation

(4) Thermal conductivity

NH_4OH addition rate (ml/min)	0.24 wt%		0.55 wt%		1.4 wt%	
	Thermal conductivity (W/m.K)	SD* for thermal conductivity (W/m.K)	Thermal conductivity (W/m.K)	SD* for thermal conductivity (W/m.K)	Thermal conductivity (W/m.K)	SD* for thermal conductivity (W/m.K)
5	0.5939	0.002	0.6044	0.003	0.61	0.003
10	0.5854	0.002	0.597	0.001	0.606	0.003
15	0.582	0.004	0.590455	0.004	0.6	0.005