Int J Thermophys (2008) 29:1244–1256
DOI 10.1007/s10765-008-0503-0

Density and Viscosity Measurements of Dimethoxymethane and 1,2-Dimethoxyethane from 243 K to 373 K up to 20 MPa

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Received: 7 March 2008 / Accepted: 3 August 2008 / Published online: 21 August 2008
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Abstract Measurements of the density and viscosity of dimethoxymethane and 1,2-dimethoxyethane are reported over the temperature range from 243 K to 373 K and at pressures up to 20 MPa. The measurements were performed simultaneously using a vibrating-wire instrument operated in the forced mode of oscillation. The overall uncertainties of these results are 2.0 % in viscosity and 0.2 % in density. The measurements were correlated with a Tait-type equation for density and a hard-sphere model for viscosity. The maximum absolute deviation and the average absolute deviation (AAD) of the density measurements from the correlation for dimethoxymethane are 0.065 % and 0.012 %, respectively, and for 1,2-dimethoxyethane, are 0.16 % and 0.044 %. With regard to viscosity, the maximum absolute deviation and the AAD of the present results from the correlation for dimethoxymethane are 1.55 % and 0.40 %, respectively, and for 1,2-dimethoxyethane, are 1.05 % and 0.26 %. Comparisons of the experimental data and measurements from the literature with values calculated by the correlations at different temperatures and pressures are presented.

Keywords Density · 1,2-Dimethoxyethane · Dimethoxymethane · Vibrating wire · Viscosity

1 Introduction

Usages of oxygenated additives have been recognized as safe, efficient, and cost-effective means to reduce the levels of mainly soot and particulate emissions and to

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improve combustion. The reduction in the peak of the soot volume fraction is related to the oxygen content of the fuel. A large drop in the soot volume fraction and an increase in flame temperature were obtained when oxygenated fuels were used [1]. According to the literature, light alcohols and ethers offer different and specific advantages as clean fuels or fuel additives, which have good combustion characteristics. Therefore, ethers appear to have a promising future as alternative fuels, with which a marked reduction of all pollution emissions can be obtained.

Both dimethoxymethane (CAS Registry Number: 109-87-5) and 1,2-dimethoxyethane (CAS Registry Number: 110-71-4) all have large contents of oxygen (42 % and 35.5 % by mass, respectively), and are miscible in diesel fuel. Taking into account their high auto-ignition tendency and high oxygen content, dimethoxymethane [2,3] and 1,2-dimethoxyethane [1] were chosen as good fuels or fuel additives.

More and more applications of oxygenated fuels or fuel additives have resulted in an increased interest in their thermophysical properties. In recent years, the thermophysical properties of some alternative fuels and fuel additives have been determined by our group [4–8]. In this work, measurements of density and viscosity for dimethoxymethane and 1,2-dimethoxyethane were performed at temperatures from 243 K to 373 K and at pressures up to 20 MPa.

2 Experimental

2.1 Working Equations

The density and viscosity of the samples were measured simultaneously with a vibrating-wire instrument. It is based on a vibrating-wire sensor, which is composed of a sinker suspended from a thin metallic wire, both of which are immersed in the sample of fluid [9,10]. The characteristics of the oscillation of the wire are obtained by means of an electromagnetic coupling [11]. The response of the wire is related to the viscosity of the fluid through damping of the oscillations, and to the density mainly through the buoyancy force acting upon the sinker, which changes the tension of the wire. The theory of the method was described in detail in previous publications [9–13]; therefore, only a brief description of the working equations is given here.

The velocity of the wire in the fundamental mode of transverse oscillation is given by [12,13]

$$\mathbf{u} = \frac{\partial \mathbf{y}}{\partial t} = \frac{F(z)\mathrm{e}^{i\omega t}}{m_{\mathrm{s}}[\omega(\beta' + 2\Delta_0) + i\omega(1+\beta) + \omega_0^2/i\omega]} \tag{1}$$

where $\mathbf{y}$ is the transverse displacement and $F(z)$ describes the amplitude of the driving force per unit length as a function of a position coordinate, z, along the length of the wire. Equation 1 can be rearranged into the form $\mathrm{u} = u\mathrm{e}^{i(\omega t - \varphi)}$, the amplitude and phase of the complex velocity being given explicitly by

$$u = \frac{F}{m_{\mathrm{s}}\{\omega^2(\beta' + 2\Delta_0)^2 + [\omega(1+\beta) - \omega_0^2/\omega]^2\}^{1/2}} \tag{2}$$

$$\varphi = \tan^{-1} \frac{\omega^2(1+\beta) - \omega_0^2}{\omega^2(\beta' + 2\Delta_0)} \tag{3}$$

These two quantities are accessible to experiment. In the above equations, the quantity $m_\mathrm{s} = \rho_\mathrm{s}\pi R^2$ is the mass per unit length of a wire with a circular cross section of radius R and density ρ_s. The hydrostatic buoyancy effect manifests itself through a shift in the natural frequency from that observed in vacuo, $\omega_{0,\mathrm{vac}}$;

$$\omega_0^2 = \omega_{0,\mathrm{vac}}^2 - \frac{\pi \rho g M_\mathrm{w}}{4L^2 \rho_\mathrm{s} R^2 \rho_\mathrm{w}} \tag{4}$$

where M_w and ρ_w are the mass and density of the sinker, g is the acceleration of local gravity, ρ is the density of the fluid, and L is half the length of the wire. Typically, the true vacuum resonance frequency $\omega_{0,\mathrm{vac}}$ and the internal damping term Δ_0 are determined in calibration measurements and ω_0 is calculated for the state of interest from Eq. 4. The other parameters in Eqs. 1–3 are β and β', which are related to the density ρ and viscosity η of the fluid by hydrodynamic theory, given by

$$\beta = \left(\frac{\rho}{\rho_\mathrm{s}}\right) k \tag{5}$$

and

$$\beta' = \left(\frac{\rho}{\rho_\mathrm{s}}\right) k' \tag{6}$$

where k and k' are given by

$$k = -1 + 2\mathrm{Im}(A) \tag{7}$$

and

$$k' = 2\mathrm{Re}(A) \tag{8}$$

where Im and Re identify the imaginary and real components, respectively. In Eqs. 7 and 8, A is a complex quantity given by

$$A = i\left(1 + \frac{2K_1(\sqrt{i\Omega})}{\sqrt{i\Omega}K_0(\sqrt{i\Omega})}\right) \tag{9}$$

where

$$\Omega = \frac{\rho\omega R^2}{\eta} \tag{10}$$

In Eq. 9, K_0 and K_1 are modified Bessel functions of zeroth and first order, and Ω is related to the Reynolds number of the flow around the cylindrical wire.

2.2 Apparatus

As shown in Fig. 1, the vibrating wire and magnetic assembly were housed in a pressure vessel rated for operation at 40 MPa. The nominal radius of the wire was about 0.025 mm (obtained from Tiyuan Aurora Tungsten & Molybdenum Material Co., Ltd., China). The upper end of the wire was kept in place by a chuck, insulated from the support plate by PTFE washers. An aluminum weight attached to its lower end kept the wire under tension in the vertical position. A pair of samarium–cobalt magnets (supplied by Xi'an Siqiang Technology Corporation, China) was mounted onto a cage. The electrical connections of the vibrating wire were made using four copper leads, two for each end of the wire, which passed through the cap of the vessel by means of a custom-made feedthrough.

The wire was forced to oscillate in the fluid of interest by passing a sinusoidal current through the wire while it was exposed to the magnetic field generated by the two SmCo permanent magnets. A schematic diagram of the measurement circuit is shown in Fig. 1. The induced voltage across the wire with respect to the reference signal generated by a function generator (Agilent 33220A), used to drive the vibrating wire, was detected by the lock-in amplifier (Stanford SR830). The measuring process was controlled by a computer. The amplitudes and phases of the voltages detected over a typical resonance curve were used to determine the density and viscosity of the fluid by a nonlinear least-squares method.

The apparatus was immersed completely in a thermostatic bath (Fluke 7037). The temperature stability and uniformity of the bath were better than ±2 mK. The total uncertainty of temperature was less than ±10 mK. The pressure was measured, in the range of 0.1 MPa to 20 MPa, with a transducer (Micro Sensor Co., Ltd., China, Model MPM480, with a maximum operating pressure of 40 MPa) with an uncertainty of ±0.1 MPa.

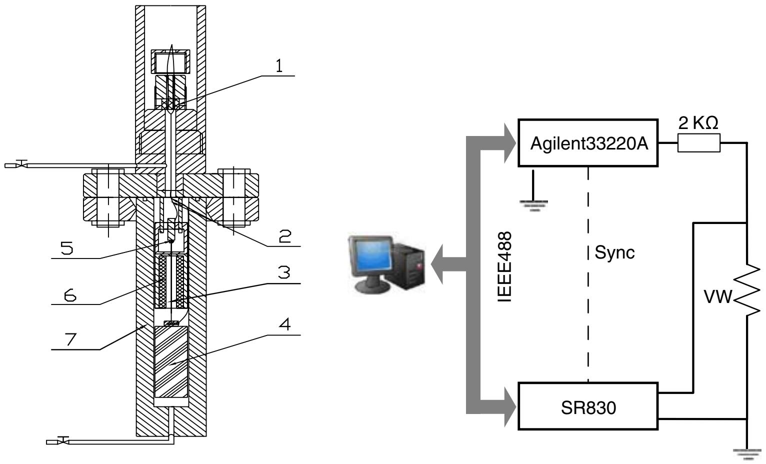

Fig. 1 Diagram of the vibrating-wire apparatus: (1) feedthrough; (2) feed wires; (3) tungsten wire; (4) weight; (5) upper clamp; (6) magnets; and (7) pressure vessel

Table 1 Parameters of the vibrating-wire sensor

Vibrating wire			
Half-length	L	(m)	29.91×10^{-3}
Radius	R	(m)	25.526×10^{-6}
Density	ρ_s	$(\text{kg} \cdot \text{m}^{-3})$	19.230×10^{3}
Young's modulus	E	(GPa)	406
Internal damping	Δ_0		4.97×10^{-5}
Sinker			
Mass	M_w	(kg)	0.06097
Density	ρ_w	$(\text{kg} \cdot \text{m}^{-3})$	2896.31

2.3 Calibration and Testing

Once the sensor parameters are known either by independent means or from a single reference experiment, no extensive calibration procedures are required for measurements at high pressure or at temperatures away from ambient conditions [12]. The sinker was weighed, the length of the wire was measured using a cathetometer, and the density and Young's modulus of the wire material were taken from the literature. The internal damping coefficient of the vibrating-wire, Δ_0, is determined experimentally from the resonance curve under vacuum. The radius of the wire and the density of the sinker were determined from the calibration experiment in toluene at $T_{\text{ref}} = 298.15\,\text{K}$ and $p_{\text{ref}} = 0.10\,\text{MPa}$. The reference datum was taken to be $\rho_{\text{ref}} = 862.5\,\text{kg} \cdot \text{m}^{-3}$, and $\eta_{\text{ref}} = 0.555\,\text{mPa} \cdot \text{s}$ [14]. The complete set of parameters describing the present vibrating-wire sensor is given in Table 1. Taking all factors into account, the uncertainties of the measurements were estimated to be 2.0 % in viscosity and 0.2 % in density.

2.4 Fluid Samples

The toluene was supplied by TEDIA Company, USA (minimum mass purity of 99.8 %), while dimethoxymethane and 1,2-dimethoxyethane were provided by Anhui Jixi Sanming Industry of Fine Chemicals Co., Ltd, China (nominal mass purity specification of 99.9 %). The fluid samples were used without any further treatment. The samples were fed to the measuring cell from the sample container with a reciprocating plunger pulsation-free pump (2PB05, Beijing Xingda Technology and Development Corporation, China), which can pressurize the samples automatically.

3 Results and Discussion

Measurements of the density and viscosity of dimethoxymethane and 1,2-dimethoxyethane were carried out along 14 isotherms at temperatures from 243.15 K to 373.15 K and at pressures up to 20 MPa, and the results are listed in Table 2. All the experimental results were correlated with a Tait-type equation for density and a hard-sphere model for viscosity. In order to assess the performances of the correlations, the average absolute deviation (AAD), maximum absolute deviation (DM), and average deviation (Bias) are introduced.

Table 2 Measurements of density and viscosity of dimethoxymethane and 1,2-dimethoxyethane

T (K)	p (MPa)	ρ (kg $\cdot$ m^{-3})	η (mPa $\cdot$ s)	T (K)	p (MPa)	ρ (kg $\cdot$ m^{-3})	η (mPa $\cdot$ s)
Dimethoxymethane							
243.15	0.10	917.773	0.6298	313.15	0.16	831.685	0.2682
	4.40	921.190	0.6510		4.44	837.579	0.2785
	9.42	924.889	0.6752		9.42	843.933	0.2905
	14.45	928.455	0.7003		14.45	849.923	0.3022
	19.44	931.885	0.7258		19.44	855.500	0.3137
253.15	0.10	905.693	0.5389	323.15	0.19	818.682	0.2436
	4.42	909.439	0.5560		4.39	824.990	0.2532
	9.41	913.399	0.5769		9.42	832.095	0.2644
	14.45	917.473	0.5975		14.46	838.549	0.2758
	19.44	921.171	0.6191		19.49	844.585	0.2866
263.15	0.10	893.705	0.4697	333.15	0.21	805.334	0.2202
	4.44	897.611	0.4857		4.39	812.279	0.2290
	9.44	901.958	0.5039		9.41	819.852	0.2401
	14.47	906.179	0.5215		14.45	826.872	0.2504
	19.47	910.144	0.5406		19.45	833.322	0.2610
273.15	0.10	881.433	0.4145	343.15	0.28	791.705	0.2009
	4.44	885.755	0.4285		4.43	799.263	0.2096
	9.44	890.380	0.4446		9.43	807.432	0.2203
	14.48	894.826	0.4615		14.46	815.084	0.2301
	19.54	899.081	0.4783		19.46	822.037	0.2400
283.15	0.10	869.282	0.3685	353.15	0.36	777.688	0.1837
	4.45	873.902	0.3818		4.37	785.794	0.1922
	9.43	878.977	0.3964		9.40	794.895	0.2024
	14.49	883.736	0.4114		14.45	803.147	0.2123
	19.55	888.330	0.4265		19.43	810.634	0.2217
293.15	0.10	857.043	0.3303	363.15	0.43	763.120	0.1688
	4.41	862.006	0.3420		4.40	772.066	0.1767
	9.46	867.484	0.3559		9.41	782.127	0.1868
	14.49	872.625	0.3692		14.45	791.118	0.1963
	19.55	877.530	0.3832		19.46	799.153	0.2059
303.15	0.10	844.252	0.2963	373.15	0.55	748.032	0.1551
	4.45	849.702	0.3076		4.37	757.736	0.1628
	9.45	855.591	0.3199		9.40	768.901	0.1728
	14.49	861.240	0.3323		14.45	778.770	0.1822
	19.55	866.565	0.3450		19.48	787.494	0.1914
1,2-Dimethoxyethane							
243.15	0.10	919.667	0.8856	313.15	0.10	843.765	0.3512
	4.54	923.045	0.9166		4.54	848.633	0.3641
	9.56	926.586	0.9502		9.50	854.082	0.3784
	14.59	928.901	0.9855		14.44	858.578	0.3922
	19.47	931.879	1.0166		19.42	863.033	0.4055
253.15	0.10	909.614	0.7464	323.15	0.10	832.929	0.3189
	4.55	912.595	0.7729		4.56	838.334	0.3303
	9.55	915.730	0.7995		9.53	843.798	0.3433
	14.45	917.844	0.8296		14.45	848.464	0.3562
	19.43	921.699	0.8580		19.46	852.959	0.3693
263.15	0.10	899.206	0.6420	333.15	0.10	822.133	0.2903
	4.56	901.757	0.6618		4.55	827.195	0.3018
	9.59	904.482	0.6849		9.57	833.307	0.3129
	14.59	908.179	0.7095		14.46	837.525	0.3256
	19.46	911.986	0.7337		19.43	842.805	0.3372

Table 2 continued

T (K)	p (MPa)	ρ (kg · m^{-3})	η (mPa · s)	T (K)	p (MPa)	ρ (kg · m^{-3})	η (mPa · s)
273.15	0.10	887.607	0.5585	343.15	0.10	809.480	0.2653
	4.56	890.738	0.5759		4.54	815.487	0.2754
	9.59	894.412	0.5961		9.56	821.858	0.2868
	14.55	898.792	0.6173		14.44	827.359	0.2985
	19.48	903.248	0.6392		19.42	832.794	0.3093
283.15	0.10	876.889	0.4904	353.15	0.36	798.071	0.2437
	4.55	880.455	0.5056		4.56	803.982	0.2539
	9.57	884.621	0.5250		9.57	810.723	0.2642
	14.46	889.180	0.5458		14.44	817.205	0.2754
	19.45	892.890	0.5619		19.42	822.843	0.2858
293.15	0.10	866.528	0.4341	363.15	0.16	785.420	0.2233
	4.53	869.991	0.4492		4.56	792.463	0.2330
	9.56	875.037	0.4673		9.57	799.914	0.2438
	14.46	879.707	0.4850		14.44	806.210	0.2557
	19.45	883.646	0.5011		19.42	812.462	0.2641
303.15	0.10	855.111	0.3896	373.15	0.20	772.627	0.2059
	4.54	859.667	0.4031		4.56	780.565	0.2157
	9.50	865.150	0.4197		9.58	788.637	0.2263
	14.44	869.454	0.4334		14.44	795.752	0.2355
	19.44	873.398	0.4494		19.42	802.700	0.2457

3.1 Data Correlations

The present results of density were correlated using the Tait-type equation, which represents the density as a function of pressure along each isotherm by two parameters, B and C;

$$\frac{\rho - \rho_0}{\rho} = C \log\left[\frac{B + p}{B + p_0}\right] \tag{11}$$

where ρ_0 is the density at the reference pressure ($p_0 = 0.1$ MPa) and is given by $\rho_0 = A_0 + A_1T + A_2T^2 + A_3T^3$. B is a quadratic function of temperature, with the form of $B = B_0 + B_1T + B_2T^2$, and the parameter C can usually be assumed to be constant. The AAD, DM, and Bias, obtained from the Tait-type correlations for dimethoxymethane and 1,2-dimethoxyethane, are listed in Table 3, together with the values of the parameters.

The viscosities of dimethoxymethane and 1,2-dimethoxyethane were correlated with the hard-sphere model proposed by Assael and Dymond [15,16]. The model defined a reduced dimensionless viscosity, η^*, which, using base SI units, is given by

$$\eta^* = 6.035 \times 10^8 \left[\frac{1}{MRT}\right]^{1/2} \frac{\eta V^{2/3}}{R_\eta} \tag{12}$$

where η is the viscosity, M is the molar mass, T is the temperature, V is the molar volume, and R is the universal gas constant. The proportionality factor, R_η, accounts for molecular roughness and departure from molecular sphericity, independent of

Table 3 Parameters for the density correlation of Eq. 11

Parameter	Dimethoxymethane	1,2-Dimethoxyethane
A_0	1365.69	1276.61
A_1	-2.99567	-2.18737
A_2	6.91444×10^{-3}	4.31663×10^{-3}
A_3	-8.92262×10^{-6}	-5.55908×10^{-6}
C	0.199	0.199
B_0	422.078	529.168
B_1	-1.81448	-2.31892
B_2	2.00468×10^{-3}	2.68213×10^{-3}
AAD (%)	0.012	0.044
DM (%)	0.065	0.16
Bias (%)	−0.00042	0.00084

pressure, and temperature. The reduced viscosity should be a function of the ratio of the molar volume to a temperature-dependent characteristic volume, V_0, only. This characteristic volume generally decreases linearly with increasing temperature. A universal curve of reduced viscosity as a function of density and characteristic volume has been established for a large number of substances:

$$\log(\eta^*) = \sum_{i=0}^{7} a_i \left(\frac{V_0}{V}\right)^i \tag{13}$$

We have, therefore, correlated our results of viscosity by superimposing the isotherms on this universal curve using the values for the coefficients a_i given by Assael and Dymond [15,16], and the obtained values of V_0 for each temperature are listed in Table 4. The best-fit values of R_η for dimethoxymethane and 1,2-dimethoxyethane are 1.136, and 1.183, respectively. The values of V_0 in Table 4 were represented by the empirical relation,

$$V_0 \times 10^6/(\mathrm{m}^3 \cdot \mathrm{mol}^{-1}) = a + b(T/\mathrm{K}) + c(T/\mathrm{K})^2 \tag{14}$$

The obtained parameters and the results for the hard-sphere model are presented in Table 5.

3.2 Comparisons

3.2.1 Dimethoxymethane

To the authors' knowledge, there have been very few measurements of density and viscosity of dimethoxymethane over wide temperature and pressure ranges. The density deviations for dimethoxymethane of the present measurements and results of other authors from the correlation are shown in Fig. 2. Comelli et al. [17] and Reddy et al. [18] measured the density of dimethoxymethane at 298.15 K and at atmospheric pressure, and the deviations are −0.59 % and 0.37 %, respectively. Francesconi and Comelli [19] reported measurements at 288.15 K and 298.15 K, with deviations of

Table 4 Values for the characteristic volume V_0

T (K)	$10^6\ V_0\ (\mathrm{m}^3 \cdot \mathrm{mol}^{-1})$	
	Dimethoxymethane	1,2-Dimethoxyethane
243.15	55.546	67.982
253.15	55.131	67.505
263.15	54.771	67.036
273.15	54.418	66.596
283.15	54.057	66.159
293.15	53.685	65.726
303.15	53.262	65.300
313.15	52.870	64.870
323.15	52.457	64.441
333.15	51.935	64.006
343.15	51.491	63.556
353.15	51.049	63.148
363.15	50.627	62.715
373.15	50.210	62.308

Table 5 Parameters for the viscosity correlations of Eqs. 12–14

Parameter	Dimethoxymethane	1,2-Dimethoxyethane
a	61.1461	79.7815
b	−0.0113613	−0.0519894
c	-4.84581×10^{-5}	1.38262×10^{-5}
R_η	1.136	1.183
AAD (%)	0.40	0.26
DM (%)	1.55	1.05
Bias (%)	0.0085	0.0043

−0.39 % and −0.73 % from the correlation. For the purpose of comparison with our previous work [5], obtained with the vibrating-tube densimeter, the small extrapolations of the present data to the saturation line were performed, and the vapor pressures were from Pan et al. [8]. The differences vary from −0.60 % at 233.16 K to 0.95 % at 363.11 K.

The viscosity deviations for dimethoxymethane between this work and literature results are shown in Fig. 3. Comelli et al. [17] also measured the viscosity of dimethoxymethane at 298.15 K, with a deviation of 0.07 % from this work. Five viscosity data were found from the literature of [20], and the deviations from the correlation were within 3 % except for the result of Timmermans [20] at 303.15 K, which amounts to −9.65 %. Comparisons of the present data and our previous work [5] were made with extrapolations of the viscosity correlation to the saturation line. From the plot in Fig. 3, it is observed that the present measurements agree with our previous results [5] very well over the temperature range from 263.07 K to 383.16 K, with a maximum deviation of −1.59 %. But at temperatures from 243.14 K to 258.12 K, larger deviations of −4.31 % to −10.06 % were observed. In our previous measurements, the capillary viscometer was used; therefore, the deviations may be caused by the influence of water content of the sample used previously.

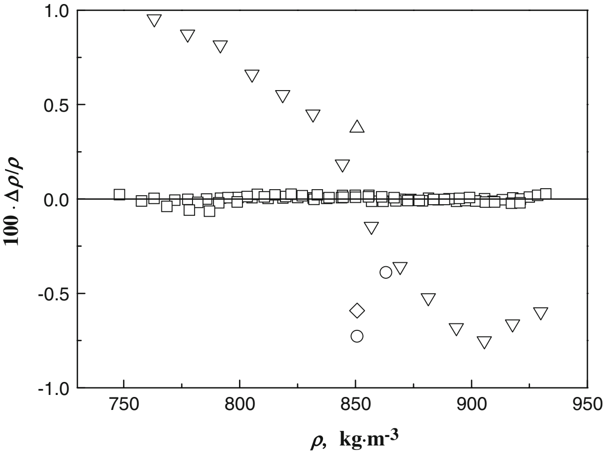

Fig. 2 Density deviations of dimethoxymethane, $\Delta\rho/\rho = \{\rho\ (\text{calcd}) - \rho\ (\text{exptl})\}/\rho\ (\text{calcd})$, of this work (Table 2) and other authors, ρ (exptl), from the correlation of the present results given by Eq. 11, ρ (calcd), as a function of density, (□) this work, (◇) Comelli et al. [17], (◯) Francesconi and Comelli [19], (△) Reddy et al. [18], and (▽) Wu et al. [5]

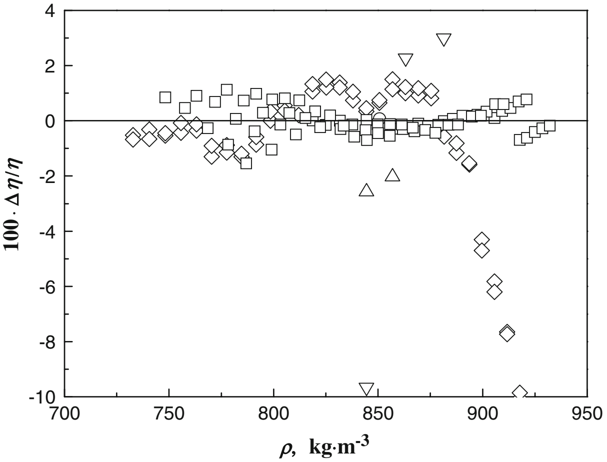

Fig. 3 Viscosity deviations of dimethoxymethane, $\Delta\eta/\eta = \{\eta\ (\text{calcd}) - \eta\ (\text{exptl})\}/\eta\ (\text{calcd})$, of this work (Table 2) and other authors, η (exptl), from the correlation of the present results given by Eqs. 12 and 13, η (calcd), as a function of density, (□) this work, (◇) Wu et al. [5], (◯) Comelli et al. [17], (△) Udovenko (1958) [20], and (▽) Timmermans (1928) [20]

3.2.2 1,2-Dimethoxyethane

The density deviations for 1,2-dimethoxyethane of the present measurements and literature results from the correlation are shown in Fig. 4. Until now, only limited literature density data for 1,2-dimethoxyethane are available in the compressed liquid region. The density data for the range between 283.15 K and 423.15 K at 1.0 MPa were published by Conesa et al. [24]. These data are in agreement with the correlation,

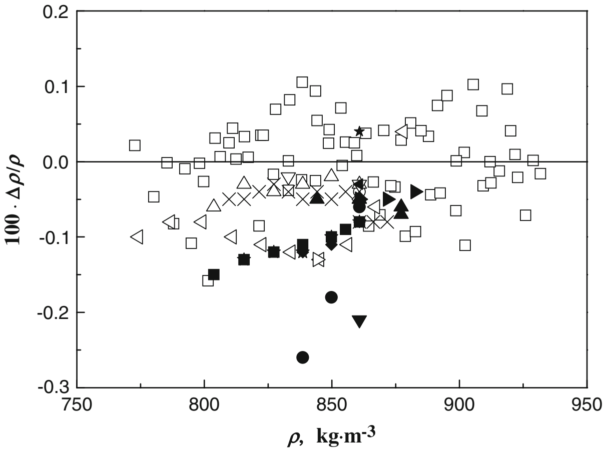

Fig. 4 Density deviations of 1,2-dimethoxyethane, $\Delta\rho/\rho = \{\rho(\text{calcd}) - \rho(\text{exptl})\}/\rho(\text{calcd})$, of this work (Table 2) and other authors, ρ (exptl), from the correlation of the present results given by Eq. 11, ρ (calcd), as a function of density, (□) this work, (○) Aizawa and Kato [21], (△) Barthel et al. [22], (▽) Burgdorf et al. [23], (◇) Comelli et al. [17], (◁) Conesa et al. [24], (▷) Deng et al. [25], (☆) George and Sastry [26], (+) Douheret et al. [27], (×) Ku and Tu [28], (■) Manfredini et al. [29], (●) Muhuri and Hazra [30], (▲) Ohji and Tamura [31], (▼) Pal and Sharma [32], (◆) Roy et al. [33], (◀) Tamura and Yamasawa [34], (▶) Tovar et al. [35], (★) Wallace and Mathews [36], and (—) Zhao et al. [37]

with an average absolute deviation of 0.09 % in density. No other measurements at elevated pressures were found. Comparisons were also made between the correlation and the densities at 0.1 MPa published by different researchers. The average absolute deviation between the literature values and calculations with the correlation is 0.07 % in density for all data available in the range between 243 K and 373 K. It was found that the present measurements are lower than the literature results, but within the uncertainty of the experiment except for results at 298.15 K published by Pal and Sharma [32] (with a deviation of −0.21 %) and Muhuri and Hazra [30] (with a deviation of −0.26 %).

The viscosity deviations for 1,2-dimethoxyethane between this work and results at atmospheric pressure from other studies are shown in Fig. 5. No measurements were found at elevated pressures for 1,2-dimethoxyethane. The average absolute deviation in viscosity is 1.15 % between the correlation and literature values from Barthel et al. [22] (298.15 K to 348.15 K), Comelli et al. [17] (298.15 K), Ku and Tu [28] (288.15 K to 343.15 K), Pal and Sharma [32] (298.15 K), Roy et al. [33] (298.15 K to 318.15 K), and Zhao et al. [37] (298.15 K). Larger deviations are observed for some data sets, with deviations from −5.17 % to −10.32 % for the data of Ramanamurti et al. [39], with a deviation of −4.94 % for the data of Wallace and Mathews [36], with deviations from −2.9 % to −4.52 % for the data of Muhuri and Hazra [30], and with deviations of −3.75 % and 3.81 % for the data of Burgdorf et al. [23]. Kinetic viscosities of 1,2-dimethoxyethane were published by Conesa et al. [24] (283.15 K to 333.15 K) and by Cocchi et al. [38] (263.15 K to 353.15 K). These dynamic viscosities were calculated with the densities of this work, and comparisons also were made with the present

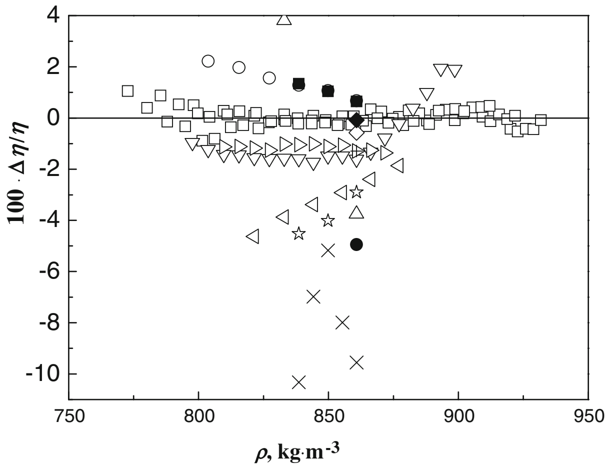

Fig. 5 Viscosity deviations of 1,2-dimethoxyethane, $\Delta\eta/\eta = \{\eta(\text{calcd}) - \eta(\text{exptl})\}/\eta$ (calcd), of this work (Table 2) and other authors, η (exptl), from the correlation of the present results given by Eqs. 12 and 13, η (calcd), as a function of density, (□) this work, (○) Barthel et al. [22], (△) Burgdorf et al. [23], (▽) Cocchi et al. [38], (◇) Comelli et al. [17], (◁) Conesa et al. [24], (▷) Ku and Tu [28], (☆) Muhuri and Hazra [30], (+) Pal and Sharma [32], (×) Ramanamurti et al. [39], (■) Roy et al. [33], (●) Wallace and Mathews [36], and (◆) Zhao et al. [37]

measurements, with a maximum deviation of 1.94 % for the data from Cocchi et al. [38] and of −4.63 % for the data from Conesa et al. [24].

4 Conclusions

Measurements of density and viscosity were performed on dimethoxymethane and 1,2-dimethoxyethane with a vibrating-wire instrument. The overall uncertainties of the present instrument in viscosity and density are 2.0 % and 0.2 %, respectively. The experiments were carried out over a temperature range from 243 K to 373 K along 14 isotherms at pressures up to 20 MPa. The experimental results were fitted successfully with a Tait-type equation for density and a correlation scheme based on a hard-sphere model for viscosity.

Acknowledgments The authors gratefully acknowledge the financial support of the Foundation for the Author of National Excellent Doctoral Dissertation (Grant 200540) and Program for New Century Excellent Talents in University (NCET-05–0836).

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