Density Correlation of Some Pure Hydrocarbons and Crude Oil Samples with the Speed of Sound

Mohammad Vakilinejad, Jiali Xia, Rashid S. A-Maamari, Nabeel Al-Rawahi, and Gholamreza Vakili-Nezhaad

***Abstract*---** Density and speed of sound have been accurately measured at atmospheric pressure and different temperatures for n-decane, n-hexadecane, and three different types of Omani crude oil samples. These crude samples cover the light, medium and heavy oils from different oil fields. A general correlation has been developed to correlate density and speed of sound for the mentioned samples. Statistical analysis on the obtained correlations has shown accurate predictions using the proposed correlations.

***Keywords*—** Crude Oil, Density, Hydrocarbons, Speed of Sound, Thermodynamic Properties.

I. Introduction

AMONG thermodynamic properties, PVT behavior of different fluids is crucial for design and operation of process equipments. There are plenty of equation of states (EOS) proposed for this task in which cubic equation of states are the most versatile and effective tools for predicting the PVT behavior and other thermodynamic properties of fluids. Although their success in phase equilibrium calculations and PVT behavior of the vapor phase is quite promising but they fail in the density prediction of the liquid phase. To overcome this difficulty speed of sound has been used for fine tuning of the EOSs parameters. The most commonly used EOSs where tuned so far by this approach are Peng-Robinson (PR), Redlich-Kwong (RK), and Soave-Redlich-Kwong (SRK) [1]. Although this approach could be readily applied for pure fluids but its application for the liquid mixtures and complex hydrocarbon fluids mixture is a quite challenging problem. Therefore other methods such as accurate correlations have been followed by some researchers [2]. In the present work the latter approach has been used to come up with reliable correlation for density calculation of some pure hydrocarbons and crude oils based on the sound speed measurements.

Mohammad Vakilinejad is with the Mechanical Engineering Department, Faculty of Engineering, University of Tehran, Tehran, Iran. He was with the Petroleum & Chemical Engineering Department, Sultan Qaboos University, Muscat, Oman during summer 2013.

Jiali Xia is with the School of Chemical Engineering, Ningbo University of Technology, China.

Rashid S. Al-Maamari is with the Petroleum & Chemical Engineering Department, Sultan Qaboos University, Muscat, Oman.

Nabeel Al-Rawahi is with the Mechanical & Industrial Engineering Department, Sultan Qaboos University, Muscat, Oman.

Gholamreza Vakili-Nezhaad is with the Petroleum & Chemical Engineering Department, Sultan Qaboos University, Muscat, Oman (corresponding author, Email: Vakili@squ.edu.om).

II. Material and Methods

Two pure liquid samples were n-decane and n-hexadecane with high purity and three samples of crude oils supplied by Petroleum Development Oman (PDO) from different oil fields (Samples M, N and Z) which are light, medium, and heavy crude oils were used in this work.

The instrument used to measure velocity of sound in these liquids was Multifrequency Ultrasonic Interferometer Model M-81 H made by Mittal Enterprises. The density for each sample was measured by density meter (DMA-5400M; Anton Paar).

III. Results And Discussion

Density and speed of sound have been measured at different temperatures for n-decane and n-hexadecane and three crude oil samples M, N and Z. The results have been shown in Tables I to V. The experimental data have been correlated using the following simple equation:

$$\rho = aV^n$$

where ρ is the sample density, a and n are two constants and V is the speed of sound in the samples. After doing regression process the values of a and n were calculated for the samples and given in Table VI.

TABLE I
DENSITY AND SPEED OF SOUND FOR N-DECANE AT DIFFERENT TEMPERATURES.

Temperature K	*Density (kg/m^3)*	*Exp velocity (m/s)*
293.15	729.9	1255
298.15	726.2	1235
303.15	722.4	1215

TABLE II
DENSITY AND SPEED OF SOUND FOR N-HEXADECANE AT DIFFERENT TEMPERATURES.

Temperature K	*Density (kg/m^3)*	*Exp velocity (m/s)*
293.15	769.8	1338.8
303.15	766.4	1320.2
313.15	759.4	1283.4
323.15	752.5	1247.4
333.15	745.6	1212.3

TABLE III

DENSITY AND SPEED OF SOUND FOR CRUDE OIL SAMPLE M

Temperature K	*Density (kg/m^3)*	*Exp velocity (m/s)*
293.15	854	1378.5
303.15	850	1342.5
313.15	843	1318
323.15	836	1279
333.15	833	1223.5

TABLE IV

DENSITY AND SPEED OF SOUND FOR CRUDE OIL SAMPLE N

Temperature K	*Density (kg/m^3)*	*Exp velocity (m/s)*
293.15	940	1492
303.15	934	1452
313.15	927	1388.5
323.15	920	1396.7
333.15	912	1334.1

TABLE V

DENSITY AND SPEED OF SOUND FOR CRUDE OIL SAMPLE Z

Temperature K	*Density (kg/m^3)*	*Exp velocity (m/s)*
293.15	834	1326
303.15	828	1312.5
313.15	821	1273
323.15	814	1255.5
333.15	807	1222

TABLE VI

VALUES OF A AND N FOR PURE HYDROCARBONS AND THREE CRUDE OIL SAMPLES.

Particular	*No. of pts*	*Cons. n*	*Cons. a*	*AAD**
n-decane	3	3.1360	1.3166e-006	0.0056
n-hexadecane	5	3.1049	1.4614e-006	0.0075
Sample M	5	4.1953	6.9365e-010	0.9207
Sample N	5	3.4652	7.3924e-008	0.7946
Sample Z	5	2.5122	6.1000e-005	0.3471

* ADD= (1/no. of data pts.)∑ 100 |(calc. value – exp. value)|/exp. value

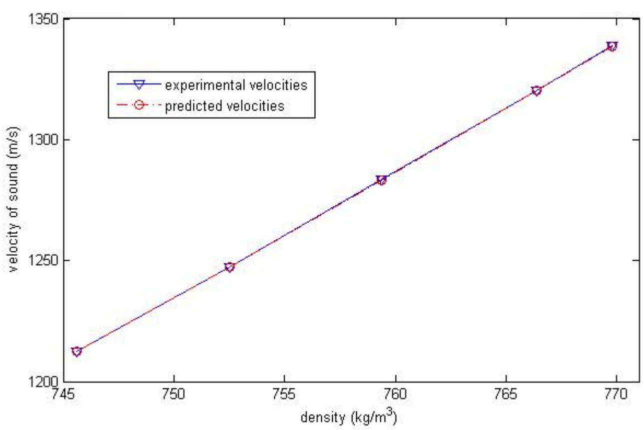

Fig. 1 Correlation between the experimental and calculated velocity using the proposed equation in this work for n-hexadecane

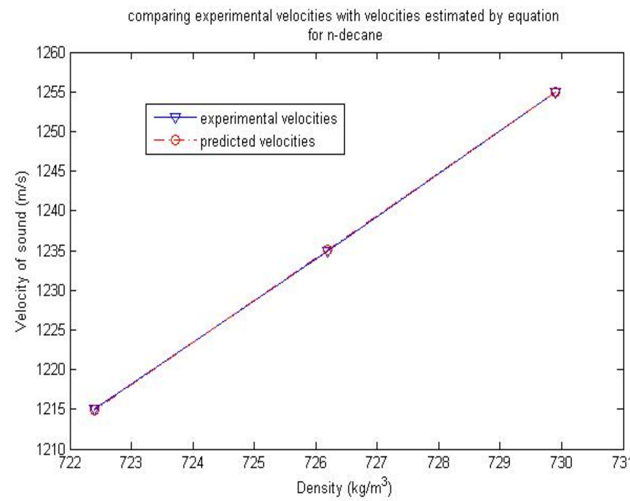

Fig. 2 Correlation between the experimental and calculated velocity using the proposed equation in this work for n-decane.

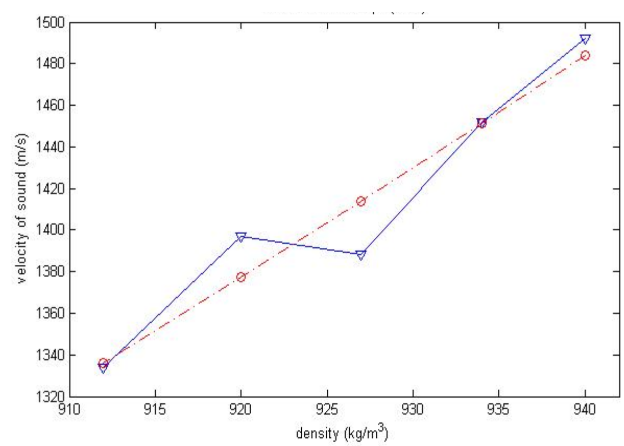

Fig. 3 Correlation between the experimental and calculated velocity using the proposed equation in this work for crude oil sample N.

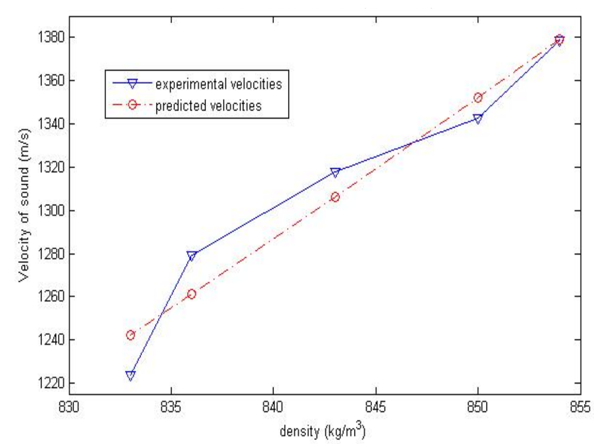

Fig. 4 Correlation between the experimental and calculated velocity using the proposed equation in this work for crude oil sample M.

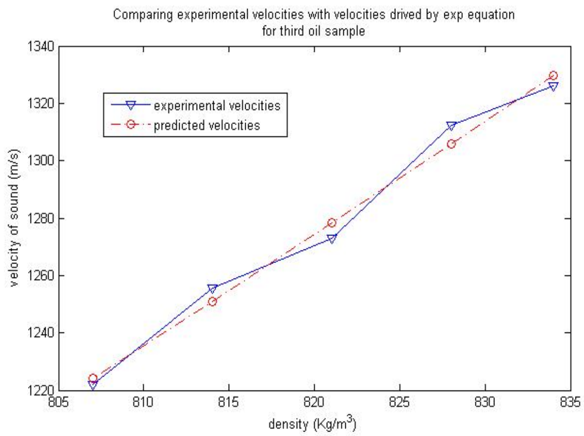

Fig. 5 Correlation between the experimental and calculated velocity using the proposed equation in this work for crude oil sample Z.

IV. Conclusion

This study showed that the speed of sound as a thermodynamic property which can be measured accurately in the liquid phase systems, can be used for density prediction of these systems through simple power law correlations.

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