Modeling Asphaltene Precipitation in Algerian Oilfields with the CPA EoS

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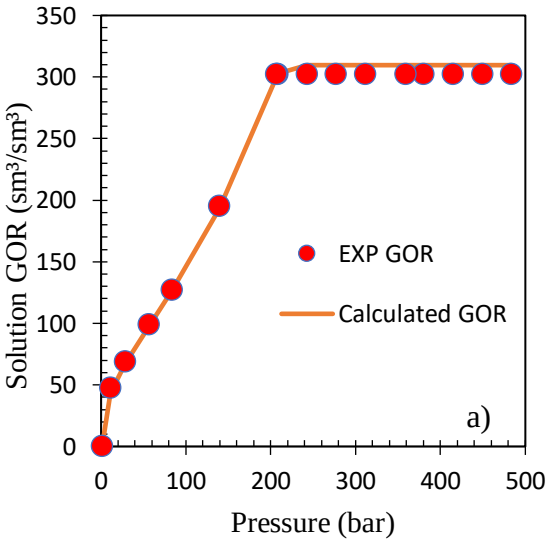
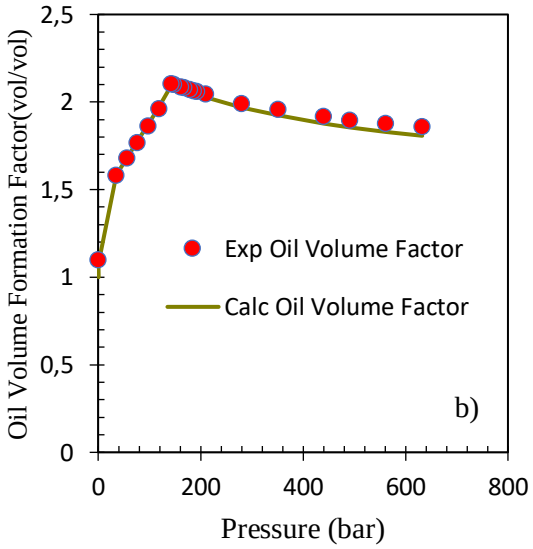
Supplementary Data

1 Prediction of PVT properties with CPA EOS





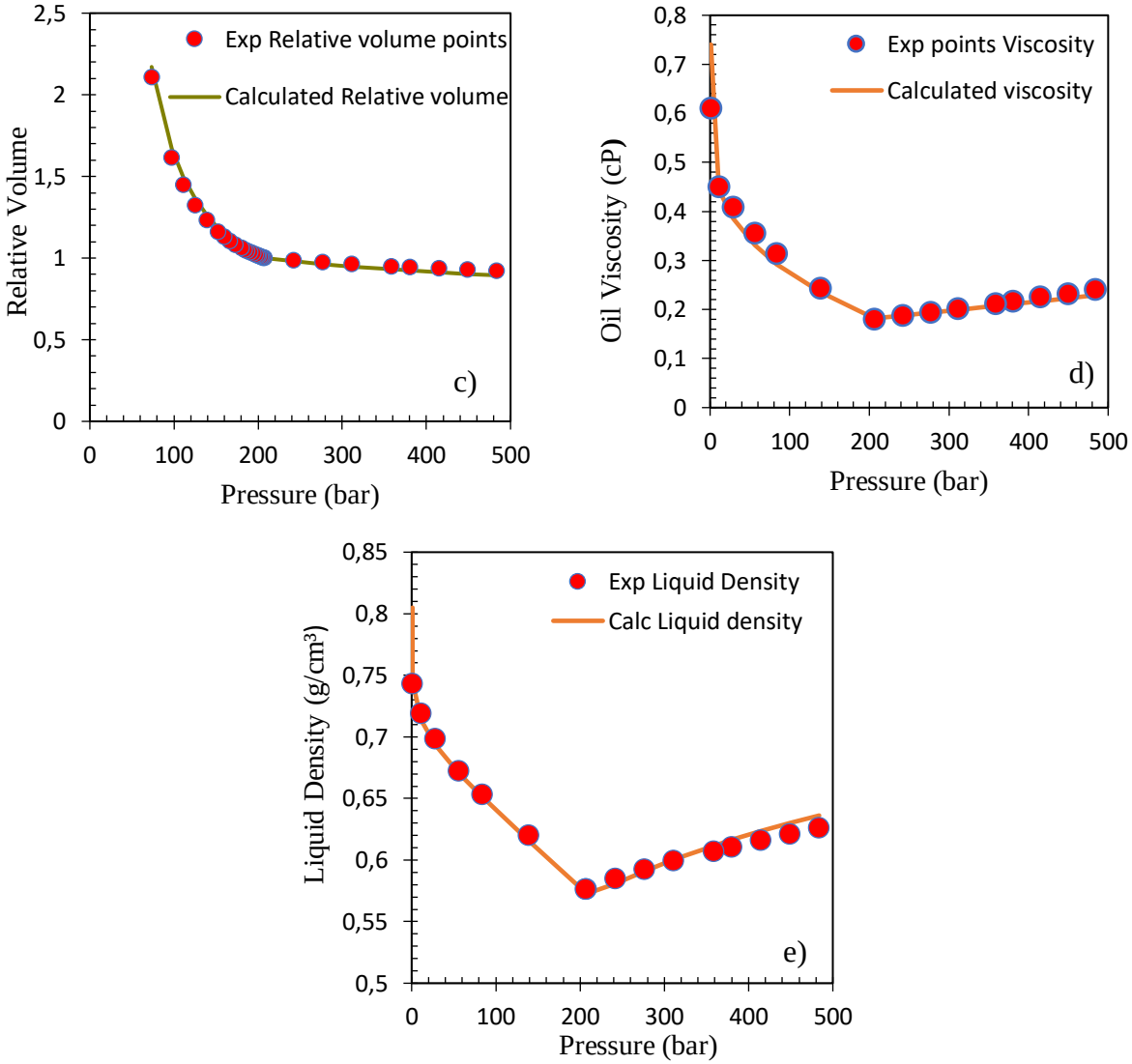


Fig. 1. a), b), c), d), e) CPA Predictions of relative volume, oil formation factor, Gas oil ratio oil viscosity and density for Oil5. Experimental data obtained from PVT report.

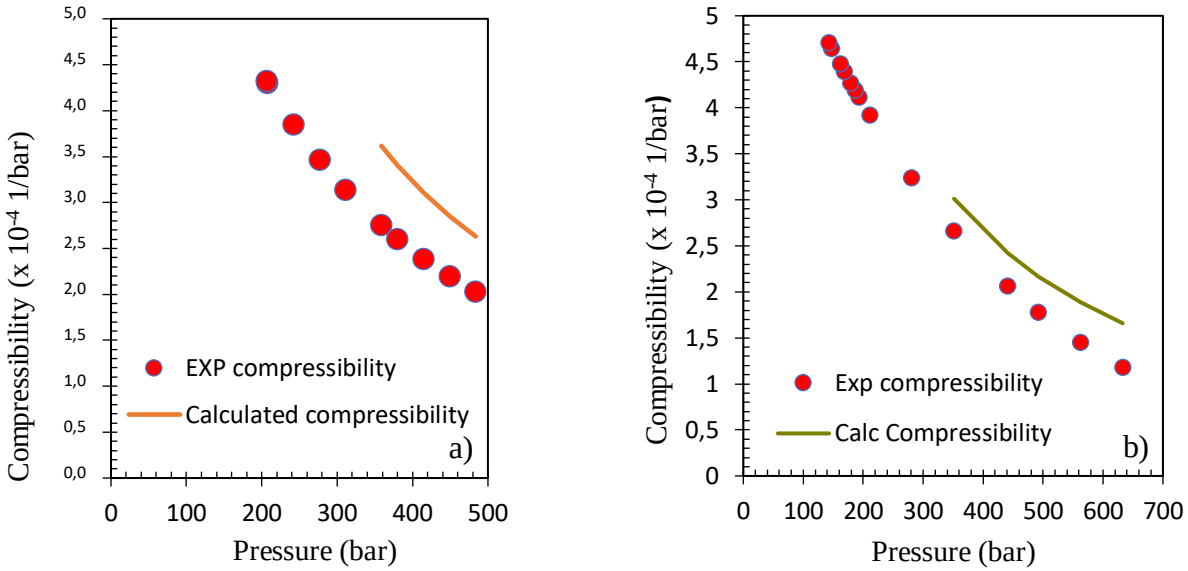


Fig. 2 a), b) CPA predictions of derivative properties (Isothermal Compressibility) for oil2 and oil5 respectively.

2. Tables for the PVT experiments (CCE, DL, Viscosity) for Oil5

Table 1

Constant composition expansion for Oil5 at Treservoir

	Pressure	% Vliq/Vtot1	% Vliq/Vsat	Relative Volume	Liquid Density	Compressibility
	psia	**%**	**%**	**Vr=V/Vsat**	**g/cc**	**10-6/psia**
	7014.7	100.00	92.07	0.921	0.6260	13.958
	6514.7	100.00	92.82	0.928	0.6210	15.120
	6014.7	100.00	93.57	0.936	0.6160	16.435
	5514.7	100.00	94.39	0.944	0.6106	17.928
Pres	**5200.0**	**100.00**	**94.94**	**0.949**	**0.6071**	**18.974**
	4514.7	100.00	96.14	0.961	0.5995	21.596
	4014.7	100.00	97.28	0.973	0.5925	23.868
	3514.7	100.00	98.55	0.986	0.5848	26.518
	3014.7	100.00	99.96	1.000	0.5766	29.635
Psat	**2994.2**	100.**00**	**100.00**	**1.000**	**0.5764**	**29.774**
	2967.7	97.97	98.30	1.003		
	2944.7	96.60	97.23	1.006		
	2914.7	95.29	96.30	1.011		
	2889.7	94.35	95.68	1.014		
	2864.7	93.52	95.18	1.018		
	2814.7	91.83	94.15	1.025		
	2764.7	90.00	92.98	1.033		
	2714.7	88.31	91.99	1.042		
	2664.7	86.81	91.19	1.050		
	2614.7	85.12	90.21	1.060		
	2514.7	82.08	88.67	1.080		
	2414.7	79.06	87.25	1.104		
	2314.7	76.09	85.95	1.130		
	2214.7	73.14	84.78	1.159		
	2014.7	66.97	82.41	1.231		
	1814.7	60.72	80.37	1.324		
	1614.7	54.04	78.30	1.449		
	1414.7	47.31	76.43	1.616		
	1064.7	34.57	72.81	2.106		

Table 2

Differential liberation for Oil5 at Treservoir

	Pressure	Solution Gas Oil Ratio1	Relative Oil Volume	Oil Density	Gas Z Factor	Gas Formaton Volume Factor	Incremental Gas Gravity	Gas Viscosity	Total FVF
		Rsd	Bod		Z	Bg			Bt
	psia	Vol/Vol	vol/vol	g/cc		vol/vol	(Air=1)	cP	vol/vo
	7014.	302.24	2.020	0.626					
	6514.	302.24	2.037	0.621					
	6014.	302.24	2.053	0.616					
	5514.	302.24	2.071	0.610					
Pres	5200.	302.24	2.083	0.607					
	4514.	302.24	2.109	0.599					
	4014.	302.24	2.135	0.592					
	3514.	302.24	2.162	0.584					
	3014.	302.24	2.193	0.576					
Psat	2994.	302.24	2.194	0.576					2.194
	2014.	195.22	1.848	0.620	0.799	0.008	0.909	0.019	2.701
	1214.	126.87	1.638	0.653	0.813	0.013	0.904	0.016	4.001
	814.7	98.67	1.543	0.672	0.832	0.021	0.935	0.014	5.725
	414.7	68.68	1.430	0.698	0.857	0.042	1.062	0.013	11.141
	164.7	47.20	1.341	0.718	0.882	0.108	1.340	0.012	28.827
Residual	14.7	0.00	1.119	0.743	0.928	1.271	2.290	0.009	385.24

Table 3

Viscosity test for Oil5 at Treservoir

	Pressure	Viscosity
	psia	cP
	7014.7	0.241
	6514.7	0.232
	6014.7	0.225
	5514.7	0.217
Pres	5200.0	0.212
	4514.7	0.201
	4014.7	0.194
	3514.7	0.187
Psat	2994.2	0.180
	2014.7	0.243
	1214.7	0.314
	814.7	0.356
	414.7	0.409
	164.7	0.450
Residual	14.7	0.610

3. Relative deviation from CPA model and other associating based models

Table 1

Relative Deviation (RD) between experimental data and calculated results for UOP from the CPA Inbuild model and other associating based models. Experimental data for fluid C1 and Fluid Y3 are from (Buenrostro-Gonzalez et al., 2004). It should be noted that experimental data are obtained by digitization of the plots from the respected references, therefore, there could be minor deviations from the actual experimental data

Fluid	Experimental		CPA						SAFT-VR	
			This work		(Arya et al., 2015)		(Li and Firoozabadi, 2010)		(Buenrostro-Gonzalez et al., 2004)	
	T (K)	UOP (bar)	UOP (bar)	RD %	UOP (bar)	RD %	UOP (bar)	RD %	UOP (bar)	RD %
C1	414.02	344.4	322.7	6.2	329.7	1.6	344.6	0.06	344.6	0.06
	393.71	361.8	378.1	4.5	378.7	1.1	355.7	1.6	355.7	1.6
	363.64	379.2	397.3	4.7	418.0	1.4	376.7	0.6	376.7	0.6
Y3	349.0	386.5	370.1	4.2	382.2	0.2	391.6	1.3	391.6	1.3
	416	366.4	351.6	4.0	400.4	2.2	374.02	2	374.02	2
	395.3	452.9	441	2.6	456.7	9.4	381.8	15.6	381.8	15.6
	357.7	474.5	554.6	16.8	540.2	9.4	474.9	0.09	474.9	0.09
	333.8	599.5	560.9	6.4	558.4	0.5	623.8	4.0	623.8	4.0

Table 2

Relative Deviation (RD) between experimental data and calculated results for UOP from the inbuilt CPA model and other associating based models. Experimental data are from (Yonebayashi et al., 2011).

Fluid	Experimental		CPA							
			This work		(Arya et al., 2015)		(Li and Firoozabadi, 2010)		(Zhang et al., 2012)	
Amount of injected gas %	T (K)	UOP (bar)	UOP (bar)	RD %	UOP (bar)	RD %	UOP (bar)	RD %	UOP (bar)	RD %
0	366.4	98.9	94.5	4.4	97.9	0.9	-	-	100.8	1.8
	337.9	141.8	146.5	3.3	126.8	10.5	-	-	147.8	4.2
	310.1	210.2	211.7	0.7	181.0	13.8	-	-	206.8	1.7
	287.7	243.4	242.9	0.2	241.0	0.9	-	-	248.0	1.9
2.9	289.7	278.7	287.6	3.2	275.6	1.0	-	-	-	-
5.4	311.3	282.8	285.5	0.9	236.5	16.3	-	-	-	-
10.7	339.8	279.1	280.8	0.6	234.7	15.8	-	-	314.0	12.5
14.1	366.2	281.3	249.8	11.1	227.1	19.2		-		
22.6	392.6	281	287.2	2.0	274.5	2.4	-	-	285.1	1.3

References

Arya, A., von Solms, N., Kontogeorgis, G.M., 2015. Determination of asphaltene onset conditions using the cubic plus association equation of state. Fluid Phase Equilib. 400, 8–19. https://doi.org/10.1016/j.fluid.2015.04.032

Buenrostro-Gonzalez, E., Lira-Galeana, C., Gil-Villegas, A., Wu, J., 2004. Asphaltene precipitation in crude oils: Theory and experiments. AIChE J. 50, 2552–2570. https://doi.org/10.1002/aic.10243

Li, Z., Firoozabadi, A., 2010. Cubic-plus-association equation of state for asphaltene precipitation in live oils. Energy and Fuels 24, 2956–2963. https://doi.org/10.1021/ef9014263

Yonebayashi, H., Masuzawa, T., Dabbouk, C., Urasaki, D., 2011. Ready for Gas Injection: Asphaltene Risk Evaluation by Mathematical Modeling of Asphaltene-Precipitation Envelope (APE) With Integration of All Laboratory Deliverables. SPE Proj. Facil. Constr. 6, 71–81. https://doi.org/10.2118/125643-pa

Zhang, X., Pedrosa, N., Moorwood, T., 2012. Modeling asphaltene phase behavior: Comparison of methods for flow assurance studies. Energy and Fuels 26, 2611–2620. https://doi.org/10.1021/ef201383r