Statistical Analysis of the Relations between API, Specific Gravity and Sulfur Content in the Universal Crude Oil

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Abstract: This study was conducted on the universal crude oil samples for the purpose of understanding the relationships between some of the characteristics that control the oil quality. Data were collected from previous works, including specific gravity and weight percent of 13 crude oil samples as well as the API and S% of 138 crude oil samples belong to oil reservoirs located in the different parts of the world. The API against both of specific gravity and weight percent (kg/m³) is governed by an inverse linear regression (r² = 0.98) with a better prediction (96%) for the outcomes data. The API relies not only on sulfur content, but there are other parameters controlling the oil density, where the API° is exponentially correlated with S%.

Keywords: crude oil, statistical analyses, API, specific gravity, sulfur content

1. Introduction

Crude oil is a complex mixture doesn't a uniform material consisting of up to 200 or more different hydrocarbon organic compounds, where its quality is based on American Petroleum Institute (API) gravity, specific gravity (SG) and sulfur content (S%) (Dickson and Udoessien, 2012). The most important of commercial parameters is a specific gravity, which is used for measuring the quality of crude oils. Low specific gravity indicates good quality of crude oil having lighter fractions and vice versa. Crude oil is classified as light, medium or heavy, according to its measured API gravity. The API gravity of less than 10 defines bitumen and extra heavy oil. Asphalt on average has an API gravity of 8°, which sink in fresh water, while oil floats; API gravity less than 10° generally considered natural bitumen (Danylik and others, 1984). Generally, API from 10° to 22.3° defines heavy oil, from 22.3° to 31.1° was considered as medium oil, higher than 31.1° defines light oil (dnr.louisiana.gov, 1989). The specific gravity of the crude oil is inversely related to the API values and vice versa. The formula for API gravity can be expressed as:

\[ API = \frac{(141.5 \div SG)}{131.5} \]  

where API = Degrees API Gravity  
SG = Specific Gravity (at 60°F or 15.5°C)

The relative density is equal to the density of the substance divided by the density of water (density of water is 1000 kg/m³). So the API gravity was designed to include a wide range from 10° to 70° API (Duissenov, 2012). API is inversely proportional to the specific gravity and wt (kg/m³). At specific gravity 1, which is the density of pure water, the API value is equal 10, where the weight is 998 kg/m³ (Table 1). When investigating the increase value of API from 10 to 55 for interval 5 compared with weight; it is supposed that the weight decreases proportionally, but in fact, the proportionality has been irregular. For the purpose of follow-up those anomalies can be expressed as:

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This study was carried out on data that have been collected from international published studies regarding the oil density, where the API° is exponentially correlated with S%.

2. Results and discussion

2.1 Statistical analysis of API, SG and Wt%

Crude oil is naturally liquid consisting mainly of hydrocarbons, as well as sulfur, nitrogen and metals (Yasin et al., 2013) with a wide range of densities. Basically, crude oil was commercially ranked from very light to very heavy oil. The light oils have a high proportion of light hydrocarbon fractions characterized by less content of wax, therefore it has low viscosity and specific gravity. The high API gravity determines the grade or quality of crude oils (Dickson and Udoessien, 2012). It is an inverse measure lighter the crude, higher the API gravity, and vice versa. The formula for API gravity can be expressed as:

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2.2 Relationship between API and S%

The crude oils classified on the basis of the percentage of sulfur; the S% varies from less than 0.1% to greater than 5%. Crude oils with less than 1% S are called low-sulfur or sweet crude, and those with more than 1% S are called high-sulfur or sour crude (Chang et al., 2012), but this ratio is not constant, where other studies have considered the sweet oil as that with sulfur value of 0.5%, while the sour oil is that oil defined by having more than 0.5% S. API gravity has been reported to have an inverse relationship with S% of crude oil blends (Ekwere, 1991) and confirmed by Madu et al. (2011), Odubumni and Adeniyi (2007) and Awadh and Hussien (2015) whom they had mentioned that, API gravity varies inversely with both of specific gravity and the S%. Sulfur is relatively a heavier than C and H element; it has 2.07 gm/cm³ density. Thus, it is evident that its presence in crude oil causes an increase in the specific gravity. This also explains why crude oil with low S% has a low specific gravity and vice versa. A total of 138 crude oil samples was investigated for the determination the how affect S% on the API°. Accordingly, The Data are listed in Table 2 and plotted (Figure 2). The best relationship that links S% to API value was concluded as an exponential equation as follows:

\[ y = 11.903 \times e^{-0.102x} \]  

Where y is S%; x is API°.

The correlation coefficient (r) displays a medium positive relationship (0.54) and the coefficient of determination (R²) (0.3) reflects that only 30% of the samples have correlated well. Ideally, for significant relations, the variables must be linearly correlated, but in the present study, the correlation between API and S% tend to be exponential rather than linear. Consequently, it is certainly the existence of other factors rather that S% plays an important role in the API gravity. A graph of Figure 3 is useful to visualize the relationship which exists between API and S%.

Figure 1: Statistical analysis of the API versus both of the specific gravity (SG) and Wt% of the crude oil

Figure 3 is useful to visualize the relationship which exists between API and S%.
Cumulative frequency analysis shows that nearly 70% of the API° values are located within the interval 30 to 70 indicating light oil, and the remnant API (30%) is heterogeneously distributed within the interval varies from 10 to 30 (Figure 4) indicating medium to heavy oil. But about 57% of crude oil samples contained S% less than 0.5 defining sweet oils, while the other samples (43%) represent sour oil (Figure 5). It is clear that the API° is inversely affected by S%, and this conclusion confirms the notice reported by Komine and Tomoike (1997) as sulfides are fairly evenly distributed over medium and heavy factions of crude oils.
3. Conclusions

The findings of this study are drawn as follows:

1) The linear regression between API versus both of SG and Wt% is stronger than it is for S%, where all are inversely proportional.

2) The perfect linear correlation between API and both of SG ($y=1.43x^{0.17}$) and Wt% ($y=1428x^{0.15}$) with a large set of data ($r=98$) represented the degree of linear regression association which was inversely correlated with high probable prediction ($R^2=0.96$) for the parameter outcomes.

3) The API versus S% has an exponential correlation ($y = 11.903 * e^{-0.102x}$) that reflects the existence of other parameters that affect the crude oil density, such as heavy metals (Ni and V), NSO compounds asphaltene, whereas some studies, for example: Akpan (2005) emphasized that the light crude oil usually contains relatively low trace metal contents compared to the heavy crude. Thereby, a rough estimation can be predicted for API from data of S% and vice versa.

Table 2: Data of API gravity and sulfur content in the universal crude oil (Data Referenced by Teugels and Tillbert, 2012; Lillis and Peter et al., 2003; Kenny, 2009; API, 2011).

<table>
<thead>
<tr>
<th>Oil field/Country</th>
<th>API°</th>
<th>S %</th>
<th>*CS %</th>
<th>**DF %</th>
<th>Oil field/Country</th>
<th>API°</th>
<th>S %</th>
<th>*CS %</th>
<th>**DF %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Doman oil</td>
<td>32.6</td>
<td>1.14</td>
<td>0.89</td>
<td>0.25</td>
<td>Dukhan/(Qatar)</td>
<td>41.1</td>
<td>1.22</td>
<td>0.41</td>
<td>-0.54</td>
</tr>
<tr>
<td>Dubai oil</td>
<td>30.4</td>
<td>2.13</td>
<td>1.03</td>
<td>1.10</td>
<td>Dulang/(Malaysia)</td>
<td>37.6</td>
<td>0.05</td>
<td>0.59</td>
<td>-1.61</td>
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<tr>
<td>Print oil</td>
<td>37.5</td>
<td>0.46</td>
<td>0.60</td>
<td>-0.14</td>
<td>Durri/(Indonesia)</td>
<td>20.8</td>
<td>0.2</td>
<td>1.81</td>
<td>-0.65</td>
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<tr>
<td>ESPO oil</td>
<td>34.8</td>
<td>0.62</td>
<td>0.75</td>
<td>-0.13</td>
<td>EA(Crude)/Nigeria</td>
<td>35.1</td>
<td>0.08</td>
<td>0.73</td>
<td>1.10</td>
</tr>
<tr>
<td>Abu/Bukhosi/Abu Dhabi</td>
<td>31.6</td>
<td>2</td>
<td>0.95</td>
<td>1.05</td>
<td>East MS Mix/(US)</td>
<td>30.9</td>
<td>2.1</td>
<td>1.00</td>
<td>-0.28</td>
</tr>
<tr>
<td>Agharni/Nigeria</td>
<td>47.2</td>
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<td>0.13</td>
<td>-0.08</td>
<td>Ekofisk Blend/(UK)</td>
<td>37.5</td>
<td>0.32</td>
<td>0.60</td>
<td>-0.24</td>
</tr>
<tr>
<td>Akettive/Khazakhstan</td>
<td>41.6</td>
<td>0.73</td>
<td>0.39</td>
<td>0.34</td>
<td>ElSharai/ Libya(India)</td>
<td>43.1</td>
<td>0.07</td>
<td>0.31</td>
<td>-1.39</td>
</tr>
<tr>
<td>Alshahen/Qatar</td>
<td>26.5</td>
<td>2.49</td>
<td>1.31</td>
<td>1.18</td>
<td>Eastfield/(Australia)</td>
<td>21.7</td>
<td>0.13</td>
<td>1.72</td>
<td>-1.32</td>
</tr>
<tr>
<td>Akjurf/Libya</td>
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<td>1.9</td>
<td>1.06</td>
<td>0.84</td>
<td>Escalante(Argentina)</td>
<td>24.1</td>
<td>0.19</td>
<td>1.51</td>
<td>-0.13</td>
</tr>
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<td>Alaska/North slope</td>
<td>31.9</td>
<td>0.93</td>
<td>0.93</td>
<td>0.00</td>
<td>Espo-Blend/(Russia)</td>
<td>34.8</td>
<td>0.62</td>
<td>0.75</td>
<td>1.10</td>
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<tr>
<td>Alba/Guinea</td>
<td>53</td>
<td>0.02</td>
<td>-0.11</td>
<td>0.13</td>
<td>Fateh(Dubai)</td>
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<td>1.24</td>
<td>1.95</td>
<td>-0.71</td>
<td>Flotta(UK)</td>
<td>35.4</td>
<td>1.22</td>
<td>0.72</td>
<td>1.26</td>
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<td>Albion/Heavy/Canada</td>
<td>19.6</td>
<td>2.1</td>
<td>1.93</td>
<td>0.17</td>
<td>Foroosan-Blend/Iran</td>
<td>29.7</td>
<td>2.34</td>
<td>1.08</td>
<td>0.00</td>
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<td>Algerian/Condensate</td>
<td>68.7</td>
<td>0.001</td>
<td>-0.64</td>
<td>0.64</td>
<td>Furrial/(Venezuela)</td>
<td>30</td>
<td>1.06</td>
<td>1.06</td>
<td>-0.74</td>
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<tr>
<td>Amenam-Blend/Nigeria</td>
<td>38.2</td>
<td>0.12</td>
<td>0.56</td>
<td>-0.44</td>
<td>Girassol(Argentina)</td>
<td>29.9</td>
<td>0.32</td>
<td>1.06</td>
<td>-1.65</td>
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<td>Amenam-Mars/Nigeria</td>
<td>33.5</td>
<td>0.94</td>
<td>0.83</td>
<td>0.11</td>
<td>Grane(Norway)</td>
<td>18.7</td>
<td>0.38</td>
<td>2.03</td>
<td>-0.23</td>
</tr>
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<td>Ameriven-HamacaVenezuela</td>
<td>26</td>
<td>1.55</td>
<td>1.35</td>
<td>0.20</td>
<td>Handil mix/(Indonesia)</td>
<td>43.9</td>
<td>0.05</td>
<td>0.28</td>
<td>-1.23</td>
</tr>
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<td>Amna-Libya</td>
<td>36</td>
<td>0.17</td>
<td>0.68</td>
<td>-0.51</td>
<td>Hardings(UK)</td>
<td>20.7</td>
<td>0.59</td>
<td>1.82</td>
<td>-0.91</td>
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<td>39.4</td>
<td>1.09</td>
<td>0.50</td>
<td>0.59</td>
<td>Hedrun(Norway)</td>
<td>25</td>
<td>0.52</td>
<td>1.43</td>
<td>-0.37</td>
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<td>Arab/Heavy/Saudi Arabia</td>
<td>27.7</td>
<td>2.87</td>
<td>1.22</td>
<td>1.65</td>
<td>Hibernia/(Canada)</td>
<td>34.4</td>
<td>0.41</td>
<td>0.78</td>
<td>0.73</td>
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<td>1.97</td>
<td>0.87</td>
<td>1.10</td>
<td>Iran/Heavy</td>
<td>30.2</td>
<td>1.77</td>
<td>1.04</td>
<td>-0.54</td>
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<td>Arab medium/Libya</td>
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<td>1.04</td>
<td>1.55</td>
<td>Iran/Light</td>
<td>33.1</td>
<td>1.5</td>
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<td>0.00</td>
<td>0.09</td>
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<td>33.4</td>
<td>1.25</td>
<td>0.84</td>
<td>0.41</td>
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<td>Asgard-Blend/Norway</td>
<td>50.5</td>
<td>0.07</td>
<td>-0.01</td>
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<td>Kirkuk/(Iraq)</td>
<td>33.9</td>
<td>2.26</td>
<td>0.81</td>
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<td>36.1</td>
<td>0.14</td>
<td>0.68</td>
<td>-0.54</td>
<td>Kuitna/(Congo)</td>
<td>36.4</td>
<td>0.11</td>
<td>0.66</td>
<td>-0.55</td>
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<td>Azeri light/Azerbaijan</td>
<td>34.8</td>
<td>0.15</td>
<td>0.75</td>
<td>-0.60</td>
<td>sole/(Camer)</td>
<td>32.1</td>
<td>0.33</td>
<td>0.92</td>
<td>-0.59</td>
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<td>BCF-T/7/Venezuela</td>
<td>16.5</td>
<td>2.53</td>
<td>2.28</td>
<td>0.25</td>
<td>Kuwait-Blend/Kuwait</td>
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<td>2.72</td>
<td>1.04</td>
<td>1.68</td>
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<td>Balder/Norway</td>
<td>30.1</td>
<td>0.48</td>
<td>1.05</td>
<td>-0.57</td>
<td>Lagonu/Malaysia</td>
<td>10.9</td>
<td>5.4</td>
<td>3.13</td>
<td>2.27</td>
</tr>
</tbody>
</table>
BaoBab/Ivory Coast 23 0.46 1.60 -1.14 Lavan-Blend(Iran) 34.2 1.93 0.79 1.14
Barrow(Australia) 36.1 0.05 0.68 -0.63 Liverpool Bay(UK) 45 0.21 0.22 -0.01
Basrah Light/Iraq 30.5 2.9 1.02 1.88 Lower Zakum/(Abu Dhabi) 39.8 1.02 0.48 0.54
Bayou Chactow(sour)/US 32.2 1.43 0.91 0.52 Loreto(Pero) 18.1 1.3 2.09 -0.79
Bayou Chactow(sweet)/US 36 0.36 0.68 -0.32 Lufeng(China) 33.3 0.06 0.84 -0.78
Bayuundan(Australia) 55.9 0.07 -0.22 0.29 Marib light(Yemen) 48.9 0.07 0.05 0.02
Belanak(Indonesia) 47.8 0.02 0.10 -0.08 Marlim(Brazil) 19.6 0.67 1.93 -1.26
Belayim Blend (Egypt) 27.5 2.4 1.24 1.16 Mayal(Mexico) 21.8 3.33 1.71 1.62
Beryl/UK 37.5 0.42 0.60 0.18 Mayna(Peru) 21.5 0.5 1.74 -1.24
Bintulu condensate(Malaysia) 69.3 0.03 -0.66 0.69 Medanatio(Argentina) 34.9 0.48 0.75 -0.27
Bonga(Nigeria) 35.5 0.99 0.71 0.28 NFC H /Qatar 57.95 0.23 -0.29 0.52
Bonny light(Nigeria) 33.4 0.16 0.84 -0.68 Napo(Ecuador) 19 2 1.99 0.01
Boscan(Venezuela) 10.1 5.7 3.29 2.41 Nome/(Norway) 30.8 0.22 1.00 -0.78
Bouri/Libya 26.3 1.91 1.33 0.58 Oman-Blend 34 2 0.80 1.20
Bow river(canada) 24.7 2.1 1.46 0.64 Oso-Nigeria 45.7 0.06 0.19 -0.13
Brega/Libya 39.8 0.2 0.48 -0.28 Pang Lai(China) 21.8 0.29 1.71 -1.42
Brent Blend/(UK) 38.3 0.37 0.56 -0.19 Plutonio/Angola 32.6 0.39 0.89 -0.50
CPC Blend(Kazakhstan) 45.3 0.56 0.21 0.35 Port Hudson(US) 45 0.05 0.22 -0.17
Cajina(Indonesia) 32.4 0.13 0.90 -0.77 Premium-Albian(Canada) 35.5 0.04 0.71 -0.67
Cam Linom(CON/Colombia) 29.2 0.5 1.11 -0.61 Qatari marine 35.8 1.47 0.69 0.78
Capitan(UK) 19.2 0.7 1.97 -1.27 Kabi light/Gabon 37.7 0.15 0.59 -0.44
Cebia(Guinea) 29.9 0.57 1.06 -0.49 Kincon/Argentina 35.8 0.39 0.69 -0.30
Cepa(Indonesia) 32 0.15 0.92 -0.77 Sahran blend/Africa 45 0.09 0.22 0.13
Cerro Negroso(Venezuela) 16 3.34 2.35 0.99 Santa/Barbana/Venezuela 39.5 0.49 0.49 0.00
Champion(Brunel) 28.7 0.13 1.15 -1.02 Senipah/Indonesia 51.9 0.03 -0.07 0.10
Chim Sao(Vietnam) 40.1 0.03 0.46 -0.43 Siberian light/Russian 35.1 0.57 0.73 -0.16
Chingoretlo(Mauritania) 28.3 0.49 1.18 -0.69 Siri/Denmark 38.1 0.22 0.57 -0.35
Cinta(Indonesia) 31.1 0.09 0.98 -0.89 Sirit/Iran 33.4 1.81 0.84 0.97
Clair(UK) 23.7 0.44 1.54 -1.10 Sleipner/Norway 62 0.02 -0.43 0.45
Cold lake(Canada) 21.2 3.7 1.77 1.93 Soudich/Syria 24.1 3.9 1.51 2.39
Cooper(UK) 45.2 0.03 0.22 -0.19 South armen/Denmark 37.71 0.21 0.59 -0.38
Cossak(Australia) 47.7 0.05 0.11 -0.06 Fabs blend/Malaysia 50.2 0.03 0.00 0.03
Cusiana(Chile) 43.1 0.14 0.31 -0.17 Friton/UK 37.5 0.32 0.60 -0.28
DUC/Denmark 33.6 0.26 0.82 -0.56 Upper Zamuk/Abu Dhabi 32.9 1.78 0.87 0.91
Dalia(Angola) 23.6 0.51 1.55 -1.04 Urucu/Brazil 42.1 0.09 0.36 -0.27
Daqing(China) 32.2 0.11 0.91 -0.35 Xarco/Norway 37.9 0.23 0.58 -0.35
Dar-Blend(Sudan) 36.42 0.12 0.66 -0.54 Vasconia/Colombia 24.5 1.01 1.47 -0.46
Djenot(Congo) 27 0.47 1.27 -0.80 Vityaz/Russia 34.6 0.22 0.76 -0.54
Dobal(Chad) 21.1 0.1 1.78 -1.68 West seno/Indonesia 38 0.12 0.57 -0.45
Doroud(Iran) 34 2.5 0.80 1.70 White rose/Canada 29.8 0.32 1.07 -0.75
Draagant(Norway) 39.9 0.15 0.47 -0.32 Zarzatine/Algeria 42.8 0.06 0.33 -0.27

*CS% is a computed sulfur content%
**DF% = % - CS%

References

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