Research Article

Chemical Review and Letters

journal homepage: www.chemrevlett.com

ISSN (online): 2645-4947 (print) 2676-7279

An Experimental Study of the Corrosion Process of Metals in Virtue of Crude Oils and the Characteristics

Suresh Aluvihara[a,] ∗, Jagath K. Premachandra[b]

[a]*Department of Chemical and Process Engineering, University of Peradeniya, Peradeniya, Sri Lanka*
[b]*Department of Chemical and Process Engineering, University of Moratuwa, Katubedda, Sri Lanka*

ARTICLE INFO

Article history:
Received 20 April 2019
Received in revised form 17 May 2019
Accepted 22 May 2019
Available online 22 May 2019

Keywords:
Crude oils
Corrosive composites
Ferrous metals
Decay
Weight loss
Corrosion

ABSTRACT

Crude oils are dominant earth resources since composed with large number of hydrocarbons and some of trace compounds especially with corrosive compounds such as sulfur compounds, naphthenic acids and salts. In the current research the major scope was the investigations of the impact of such corrosive compounds on the corrosion of seven different types of ferrous metals in both qualitatively and quantitatively. According to the methodology such corrosive properties of two different types of selected crude oils were analyzed and the chemical compositions of seven different types of selected ferrous metals were detected by the standard methodologies and recommended instruments. The corrosion rates of such metals were determined by the relative weight loss method after certain immersion time periods in both crude oil samples while analyzing the corroded metal surfaces through a microscope. In addition that the decays of metallic elements from metals into crude oil samples were measured and the variations of the initial hardness of metals after the corrosion were measured by Vicker's hardness tester. Basically there were observed the lower corrosion rates from stainless steels mainly with at least 12% of chromium and sufficient amount of nickel, higher progress of salts on the metallic corrosion at the normal temperatures while comparing with other corrosive compounds, formations of FeS, Fe_2O_3, corrosion cracks and cavities on the metal surfaces, decay of ferrous and copper from most metals while the immersion into crude oils and small and some insignificantly deductions of the initial hardness of metals due to the effects of the corrosion.

1. Introduction

Crude oils are some essential resources for the various industrial applications mostly composed large amounts of hydrocarbons and some amount of trace compounds since the occurrences in the interior pert of the earth. Among the trace compounds of the crude oils corrosive properties may have much significance because the corrosion is a severe impact on the metals. According to the working schedules of the crude oils refining plants the major devices and the essential units have been manufactured by the various types of metals ~~because~~ of the much suitability and the aided properties to fulfill the required tasks in the crude oil refining units. In the material engineering explanations of the term of corrosion it is possible to be happened through either chemical or electrochemical process between the metal and the corrosive aided surrounding environment which is composed either strong oxidizing agent or some combination of both water and oxygen [1-6].

Basically the nature of corrosion process depends upon the exposed oxidizing agent and conditions of the surrounded environment of the relevant metals.

According to the classifications of the types of corrosion mainly there were categorized as general corrosion, pitting corrosion, thermal corrosion and

∗ Corresponding author: e-mail: sureshaluvihare@gmail.com

galvanic corrosion also the relevant features and the chemical compositions of such corrosion compounds may be differ with each other [4,5,6].

In the case of the chemistry of crude oils that predominantly composed with large amounts of hydrocarbons although there may be composed some various trace compounds in such crude oils foremost of the corrosive compounds [2-15].

Among the corrosiveness of crude oils the sulfur compounds play a severe role regarding various corrosion types because of the presence of large number of various sulfur compounds in the crude oils and the reactivity of relevant functional groups of such sulfur compounds when having required conditions for those chemical reactions [2, 4, 6].

In addition that there were found some corrosive effects from organic acids, salts and some microbiological organisms basically from bacteria. Apart from that it is possible to be composed some trace amount of water in crude oils also with a little amounts of dissolved oxygen in crude oils. In the existing research there were expected to investigate a few of objectives and aims as given in the below.

- Comparison of the corrosion rates of seven different types of ferrous metals which are applicable in the industry of crude oil refining industry with respect to two different types of crude oils
- Investigation of the corrosive impacts of different corrosive compounds presence in crude oils such as the elemental sulfur, Mercaptans, organic acids and salts
- Analysis of the formed corrosion compounds on the metal surfaces qualitatively by the microscope

In the existing research especially the experiments were scheduled to analyze both qualitative and quantitative characterizations of the corroded metals and the corrosive causing compounds that presence in the crude oils. In the most of previous researches the corrosion phenomenon has been discussed vastly based on some particular cases although in this research it was taken effort to link these concepts at once and tally with the most recently investigated theoretical concepts.

2. Materials and Experimental Procedures

By considering the aims and objectives there were selected two different types of crude oils that different in their chemical compositions including most useful corrosive compounds for the existing investigation. The two selected crude oils are namely as Murban and Das Blend which are slightly different in their chemical compositions. Usually Das Blend crude oils is categorized as a "sour" crude oil because of the relatively higher sulfur content of that crude oil and Murban crude oil also may be composed with some corrosive properties. According to the necessity of the existing research the elemental sulfur contents, Mercaptans contents, organic acid contents and the salt contents of both crude oils were measured by following standard methodologies and recognized instruments as explained in the Table 1.

Table 1. Analysis of the corrosive properties of both crude oils

Property	Method	Readings
Sulfur content	Directly used the crude oil samples to the XRF analyzer.	Direct reading
Acidity	Each sample was dissolved in a mixture of toluene and isopropyl and titrated with potassium hydroxide.	End point
Mercaptans content	Each sample was dissolved in sodium acetate and titrated with silver nitrate.	End point
Salt content	Each sample was dissolved in organic solvent and exposed to the cell of analyzer.	Direct reading

In the selections of the metals for the relevant works there were considered the applicability of such metals in the industry of crude oils refining for various tasks such as the manufacturing of some essential devices in that industry. The selected ferrous metals their general applications in the industry of crude oils refining have been given in the below.

- Carbon Steel (High) – Transportation tubes, heat exchangers
- Carbon Steel (Medium)- Storage tanks, pre heaters
- Carbon Steel (Mild Steel)- Storage tanks, transportation tubes
- 410-MN: 1.8 420-MN: 2.8 (Stainless Steel)- Heat exchangers
- 410-MN: 1.7 420-MN: 1.7 (Stainless Steel)- Crude distillation columns
- 321-MN:1.4 304-MN:1.9 (Stainless Steel)- Crude distillation columns
- Monel 400- Pre heaters, de- salting unit

The chemical compositions of selected ferrous metals were detected by the X-ray fluorescence detector as the percentages of composed metals and most of non metals excluding carbon. The X-ray fluorescence detector is a digital instrument and it gives direct readings. As the sample preparations only it is required to be exposed cleaned metal surface to the detector of that instrument. A batch of metal coupons was prepared from such metals as six metal coupons from each type of metals and altogether as forty two metal coupons from all metal types while following the precautions given in the below because of the further requirements for the calculations.

- Similar dimensions such as width, length and thickness
- Similar surface areas

The typical carbon percentages of the selected ferrous metals have been given in the Table 2 [1, 3, 5, 6].

Table 2. Typical classification of metals according to the amount of carbon

Metal Name	Carbon (wt %)
Carbon Steel(High)	0.80-1.50
Carbon Steel(Medium)	0.30-0.80
Carbon Steel (Mild Steel)	0.20- 0.30
410-MN: 1.8 420-MN: 2.8 (Stainless Steel)	0.15-0.40
410-MN: 1.7 420- MN: 1.7 (Stainless Steel)	0.15-0.40
321-MN:1.4 304- MN:1.9 (Stainless Steel)	0.08
Monel 400	0.13

The surfaces of prepared metal coupons were cleansed by the isooctane and sand papers and also simultaneously measured both initial weight and dimensions of each metal coupon by in order of analytical balance and micrometer. The prepared metal coupons were shown in the Figure 1.

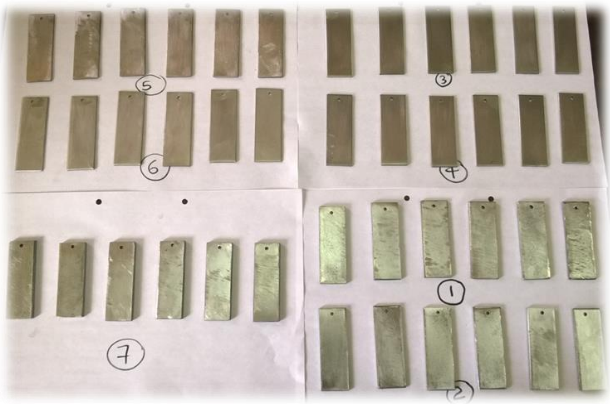


Fig.1. Prepared metal coupons for the experiment

The prepared metal coupons were immersed in crude oil containers as three homogeneous metal coupons per each crude oil container that altogether fourteen crude oil containers as seven Murban crude oils containers and seven Das Blend crude oils containers as shown in the Figure 2.

(a)

(b)

Fig.2. (**a**) Apparatus and (b) Preparation of the experimental setup

After 15 days from the immersion, a metal coupon was taken out from each crude oil container as a batch of fourteen heterogeneous metal coupons. The corroded surfaces of such metal coupons were observed by 400X lens of an optical microscope and the corroded particle were removed by the isooctane and sand papers. The final weight of each cleaned metal coupon was measured by the analytical balance and ultimately the corrosion rate of each metal coupon was determined by the relative weight loss method which is explained descriptively in the section of theory and calculation [9, 10]. By following the same methodology the corrosion rates of another two similar batches of metal coupons were determined in order of thirty days and forty five days immersion time periods.

According to the unexpected observations that obtained some invisible weight losses from some metal coupons while the determining the corrosion rates of metal coupons that the decayed concentrations of ferrous and copper were measured by the atomicabsorption spectroscopy (AAS). Regarding the sample preparations for the atomic absorption spectroscopy (AAS) 1 ml of each crude oil sample was diluted with 9 ml of 2-propanol and filtered.

As the investigations of the corrosive impact on the mechanical properties of metals the variations of the initial hardness of metal coupons were tested by the Vicker's hardness tester. As the essential measurements for such calculations the initial hardness and the hardness after the corrosion were tested in each metal coupon. The working principles and relevant determinations have been discussed in the section of theory and calculation.

2.1. Theory/Calculation

The weight loss method is a mechanical method which is used in the determinations of the corrosion rates of metals. Under this method it is better to choose some regular shape in the preparations of metal coupons because these determinations are always correlated with dimensions and surface areas of metal coupons. The mathematical derivation and its terms have been given in the Scheme 1 [9, 10].

$$\mathbf{CR = W * k/(D * A * t)}$$

Scheme 1. Mathematical expression of weight loss method

Where;
W = weight loss due to the corrosion in grams
k = constant (22,300)
D = metal density in g/cm^3
A = area of metal piece (inch^2)
t = time (days)
CR= Corrosion rate of metal piece

The Vicker's hardness tester is an instrument which is used to measure the hardness of some particular point on a surface of some material. The working principle and the nature of the indenter are shown in the Figure 3.

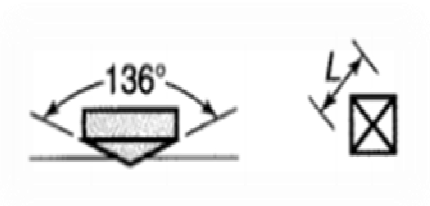


Fig.3. Indenter of the Vicker's hardness tester

The determination of the hardness of relevant particular location is done by the following equation which is depended on the load of applied on the relevant surface by the indenter.

$$\mathbf{HV = 1.854 * P^2/L^2}$$

Scheme 2. Hardness calculation formula of the Vicker's hardness tester

Where;
P= Applied Load on the surface of metal
L= Diagonal length of square
HV= Hardness

In the existing experiments it was used a digital Vicker's hardness tester. Therefore, the direct readings were recorded.

3. Results and Discussion

According to the analysis of the chemical compositions of selected ferrous metals by the X-ray fluorescence detector the obtained results have been interpreted in the Table 3.

Table 3. The metallic compositions of the elected ferrous metals

Metal	Fe (%)	Ni (%)	Cr (%)	Cu (%)
(1)Carbon Steel (High)	98.60	0.17	0.14	1. 0.37
(2)Carbon Steel (Medium)	99.36	-	-	-
(3) Carbon Steel (Mild Steel)	99.46	-	<0.07	-
(4) 410-MN: 1.8 420-MN: 2.8 (Stainless Steel)	88.25	0.18	10.92	0.10
(5) 410-MN: 1.7 420-MN: 1.7 (Stainless Steel)	87.44	-	11.99	-
(6) 321-MN:1.4 304-MN:1.9 (Stainless Steel)	72.47	8.65	17.14	-
(7)Monel 400	1.40	64.36	<0.04	33.29

Basically the obtained results showed the relatively higher ferrous concentrations in carbon steels, intermediate ferrous concentrations in stainless steels and trace amount of ferrous in Monel while having elatively higher amounts of bath copper and nickel as the majority. In addition of that basically the stainless steels were composed with some trace amounts of d-block elements such as nickel and chromium. The doping of such elements with the ferrous as the stainless steels is based upon a few of expectations of the quality of such metals and some sort of improvement [1, 3, 4, 5, 6].

- Enhancement of the strength and hardness of such metals
- Reductions of the corrosive tendency and enhancing the corrosive protection ability

According to the reductions of the corrosion rates of metals the important theory that the combination of both nickel and chromium tends to be formed a self corrosive protection film on the metal relevant metal surfaces when having at least 12% of chromium with sufficient amount if nickel that composed in a metal [1,3,4,5,17].

The obtained results for the analysis of the corrosive compounds in both crude oils have been interpreted in the Table 4.

Table 4. Corrosive compounds in both crude oils

Property	Murban	Das Blend
Sulfur content (Wt. %)	0.758	1.135
Salt content (ptb)	4.4	3.6
Acidity (mg KOH/g)	0.01	0.02
Mercaptans content (ppm)	25	56

According to the outcomes of the analysis of the corrosive properties of both crude oils it can be observed the higher elemental sulfur content, higher Mercaptans content, higher organic acid contents and lower salt content in Das Blend when comparing the such parameters of Murban. The impact of the corrosive compounds should be analyzed with the relevant concentrations and the required conditions as well because the supportive environmental conditions play a dominant role in the progresses of the relevant chemical or electrochemical reactions.

In addition each crude oil may be contained with some little amount of water which is depending on the occurrences of such crude oil. Usually the formations of the crude oils is occurring beneath of the earth surface as a mixture of hydrocarbons nearby the sedimentary basins while having high pressure and temperature with the aid of bacteria in the decomposition of such buried sediment organic matter. It is possible to seep the water into that sedimentary basins along the cracked layers of the adjacent sedimentary rocks although they are permanently immiscible solutions because of the varieties of their densities [19, 20, 21]. A simple experiment to practice the separation of an emulsion of both crude oils and water has been shown in the Figure 4.

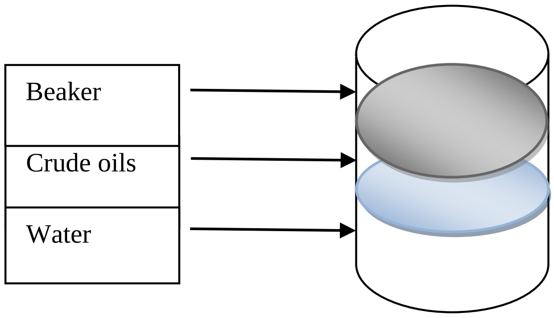


Fig.4. Separation of mixed crude oils (emulsion) and water

Usually the crude oils are lighter than water and also the density of some particular crude oil may be varied with the occurring conditions. Therefore, while separating the emulsion of crude oils and water the bottom part of the beaker will be occupied by the water. The partially dissolved water play some major roles while befalling the corrosion processes since it is completely immiscible in water as discussed in the below.

Organic acids are the foremost corrosive compounds that found from crude oils since the occurrences which are also known as the “naphthenic acids” that having a chemical formula of “RCOOH”. Such organic acids may have the ability of metal oxidizing and also oxidizing of some metallic compounds such as the metallic sulfides [2, 4, 8, 12, 14, 15]. Therefore, such organic acids tend to cause the corrosion of metals when presence of the raw metallic element as it is or after converting into some compounds. Also it is able to enhance the corrosion processes that occurred with other corrosive agents while remaining as the initial forms after happenings of the relevant chemical reactions by showing the properties of catalysts. The general chemical reactions of the corrosion between the metals and such organic acids have been given in the Scheme 3.

$$Fe + 2RCOOH \rightarrow Fe(RCOO)2 + H2$$

$$FeS + 2RCOOH \rightarrow Fe(COOR)2 + H2S$$

$$Fe(COOR)2 + H2S \rightarrow FeS + 2RCOOH$$

Scheme 3. General chemical reaction of the corrosion between metals and organic acids

Salts are the trace chemical compounds that found in crude oils since the occurrences because of the abundance of such compounds in the interior part of the earth which are mainly found in the forms of NaCl, $MgCl_2$ and $CaCl_2$. Usually at the higher temperatures such salt molecules tend to be broken into HCl molecules while having inert conditions. When reducing the temperature of the system such HCl molecules are reacted with water or even the moisture presence in crude oils and ultimately formed hydrochloric acids which are known as highly corrosive compounds [2, 7, 14, 15].

Such hydrochloric acids may have the strong oxidizing ability because that is a string acid. Further chemical reactions are linked with the contributions of the elemental sulfur that presence in crude oils for the formation of hydrogen sulfides also known as the corrosive compound. In the existing series of chemical reactions also HCl play a role of the catalyst as shown in the Scheme 4 [2, 4, 7].

$$CaCl_2 + H_2O \rightarrow CaO + 2HCl$$
$$HCl + Fe \rightarrow FeCl_2 + H_2$$
$$H_2 + S \rightarrow H_2S$$
$$FeCl_2 + H_2S \rightarrow FeS + 2HCl$$

Scheme 4. General chemical reactions between salts and metals

Sulfur is a trace compound that fund in crude oils since the occurrences because of the relatively higher abundance of sulfur in the mantle and crust of the earth where the most of crude oils deposited are located. Those sulfur compounds are found in various forms including elemental sulfur, Mercaptans, hydrogen sulfides, thiophenes and sulfoxides and also most them have been identified as highly corrosive compounds because of the reactivity of the functional groups of relevant compounds. The corrosion process also possible to be varied with the type of sulfur compounds and required conditions relevant with such corrosion processes foremost of the requirements of the temperature [2, 4, 7, 8, 13, 14, 18].

The corrosion process due to the effect of elemental sulfur is known as the "localized corrosion" that usually happened at about 80^0C properly.

Mercaptans are the active sulfur compounds that having the chemical formula of "RSH" which is highly reactive functional group and chemical reaction related with the Mercaptans is known as the "sulfidation" usually willing to be happened in the range of 230^0C-460^0C in proper manner. The general chemical reactions regarding the initiation of such processes have been given in the Scheme 5 [2, 4, 9, 12, 15, 18].

$$S_8(s) + 8\ H_2O\ (l) \rightarrow 6\ H_2S\ (aq) + 2\ H_2SO_4\ (aq)$$
$$8\ Fe + S_8 \rightarrow 8\ FeS$$

Scheme 5. Initiation chemical reactions for the sulfidation and localized corrosion

Therefore, according the obtained results for the existing investigations and the chemical concepts behind that it is mandatory to analyze the obtained results with the supporting environmental conditions that required for the occurrences of relevant chemical reactions.

The obtained results for the determinations of the corrosion rates of metal coupons with respect to both crude oils after certain immersion periods have been interpreted in the Tables 5 and 6.

According to the above interpretations mainly there were identified some higher corrosion rates from carbon steels, intermediate corrosion rates from Monel metal and usually lower corrosion rates from stainless steels. When comparing the corrosion rates of stainless steels mainly the least corrosion rates were found from 321-MN: 1.4 304-MN: 1.9 (Stainless Steel) in both crude oils among other stainless steels since it is having a chemical compositions of 18% of chromium and ~8.5% nickel which is a good enough combination for the formations of the self corrosion protection film on the metal surfaces because this is satisfied the minimum required contents of both nickel and chromium as 12% of chromium and sufficient amounts of nickel.

Therefore, it is possible to conclude that the performances of such self corrosive protection layer are becoming high at the relatively higher chromium contents with sufficient amount of nickel as well [1, 3, 4, 5, 6].

In the considerations of the impact of corrosive properties on the corrosion rates of metals four types of metals showed their higher corrosion rates in Murban crude oil while other three types of metals were showing their higher corrosion rates in Das Blend crude oil. When comparing the concentrations of the corrosive properties of two types of crude oils Murban crude oils was composed with higher amount of salts while Das Blend crude oils was composing with higher amounts of organic acids, elemental sulfur and Mercaptans contents. By considering such results it is possible to emphasize that there is a higher corrosive impact is occurred especially at the lower temperatures although with the asymmetric distributions of the corrosion rates it is better to recommend some further analysis of the corrosion rates of metals as explained in the below.

The above results have been shortlisted and interpreted as a descriptive graphical representation in Figure 5.

The average corrosion rates of each metal type with respect to both crude oils have been interpreted in the Figure 6.

- Investigation of the more corrosive compounds from different types of crude oils in addition to the discussed compounds in the existing research.
- Perform a few of experiments in various temperatures and investigate the real impacts of various corrosive compounds at those different temperatures.
- Also simultaneously use some advanced analytical technique for the determination of the corrosionrates of metals in addition to the weight loss method.

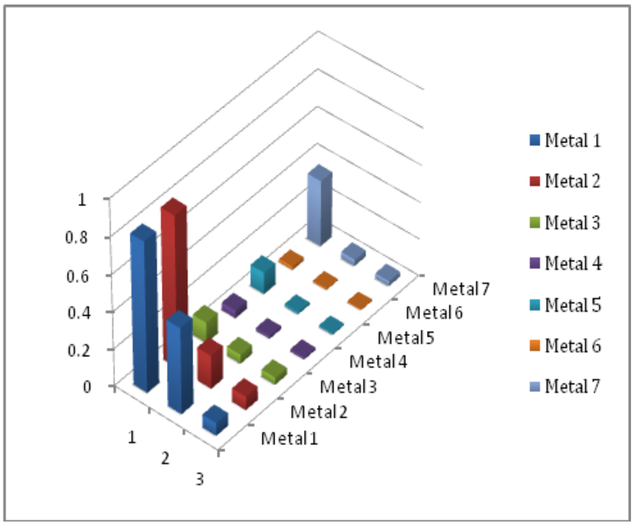
Table 5. Corrosion rates of metals after particular immersion periods in Murban

Metal	Corrosion Rate after 15 Days (cm^3 $inch^{-1}day^{-1}$)	Corrosion Rate after 30 Days (cm^3 $inch^{-1}$ day^{-1})	Corrosion Rate after 45 Days (cm^3 $inch^{-1}$ day^{-1})	Average Corrosion Rate (cm^3 $inch^{-1}$ day^{-1})
(1)Carbon Steel (High)	0.811971	0.466425	0.068794	0.4490632
(2)Carbon Steel (Medium)	0.817791	0.180339	0.073358	0.3571623
(3) Carbon Steel (Mild Steel)	0.10973	0.048244	0.038592	0.0655217
(4) 410-MN: 1.8 420-MN: 2.8 (Stainless Steel)	0.041784	0.016075	0.011801	0.02322
(5) 410-MN: 1.7 420-MN: 1.7 (Stainless Steel)	0.11626	0.011968	0.007574	0.0452676
(6) 321-N:1.4 304-MN:1.9 (Stainless Steel)	0.016612	0.007453	0.005599	0.009888
(7)Monel 400	0.356263	0.034877	0.026729	0.13929

Table 6. Corrosion rates of metals after particular immersion periods in Das Blend

Metal	Corrosion Rate after 15 Days (cm^3 $inch^{-1}$ day^{-1})	Corrosion Rate after 30 Days (cm^3 $inch^{-1}$ day^{-1})	Corrosion Rate after 45 Days (cm^3 $inch^{-1}$ day^{-1})	Average Corrosion Rate (cm^3 $inch^{-1}$ day^{-1})
(1)Carbon Steel (High)	0.350249	0.224901	0.024738	0.1999627
(2)Carbon Steel (Medium)	0.481055	0.140654	0.05911	0.2269396
(3) Carbon Steel (Mild Steel)	0.162883	0.141093	0.100635	0.1348702
(4) 410-MN: 1.8 420-MN: 2.8 (Stainless Steel)	0.044146	0.034035	0.006149	0.0281102
(5) 410-MN: 1.7 420-MN: 1.7 (Stainless Steel)	0.053701	0.034841	0.016363	0.0349681
(6) 321-MN:1.4 304-MN:1.9 (Stainless Steel)	0.022894	0.006503	0.002825	0.0107404
(7)Monel 400	0.061554	0.037655	0.016067	0.0384254

(a)



(b)

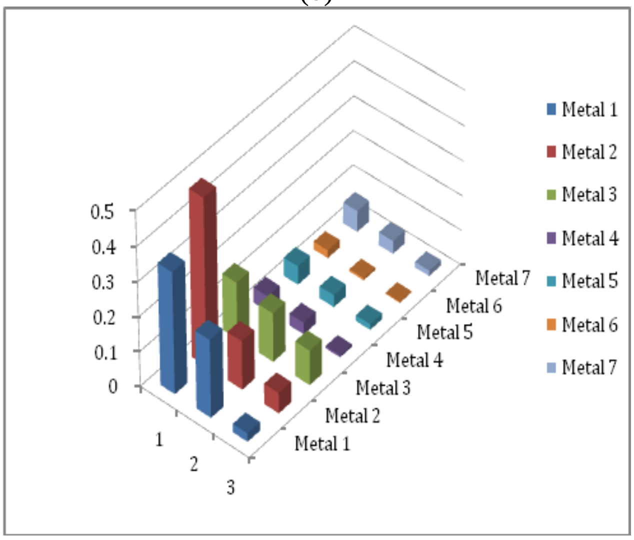


Fig.5. Corrosion rates of metals after certain immersion periods in (a) Murban and (b) Das Blend crude oils

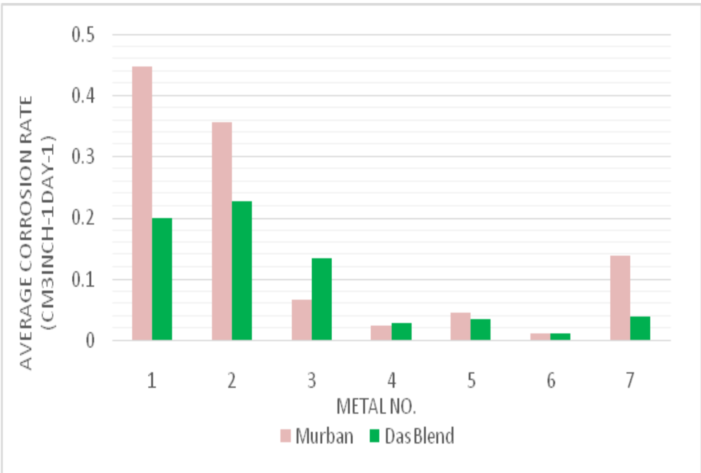


Fig. 6. Average corrosion rates of metals

The variations of the above corrosion rates with the exposure time in both crude oils have been interpreted in the Figure 7 and Figure 8.

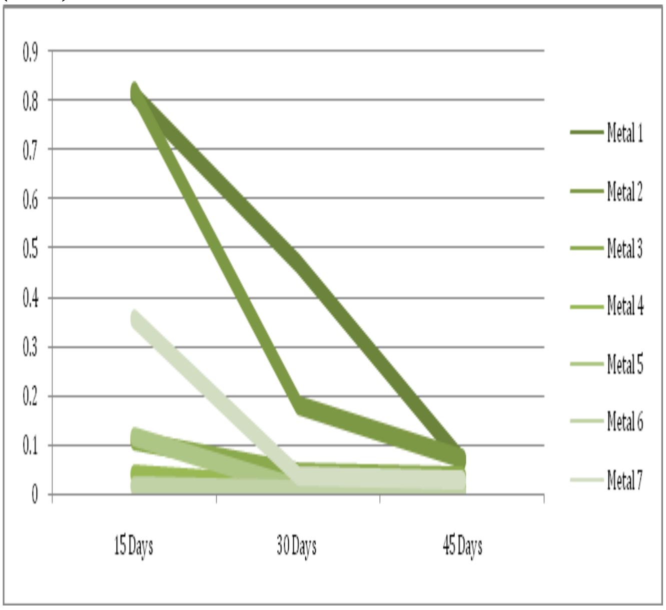


Fig.7. Variances of the corrosion rates of metals with the exposure time in Murban

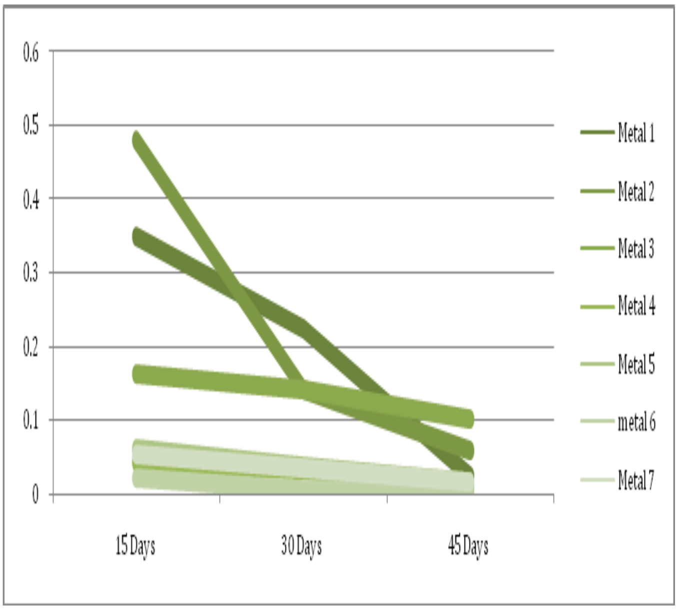


Fig. 8. Variances of the corrosion rates of metals with the exposure time in Das Blend

Both variations showed some similar variations of the corrosion rates of metals with the exposure time that varied the corrosion rates in approximately inversely proportional way with the immersion period as defined in the weight loss method. Therefore, it is possible to emphasize the applicability of weight loss method for various types of metals [9, 10].

According to the microscopic analysis of the corroded metal surfaces through 400X lens of the laboratory optical microscopic the specific observations have been shown in the Figure 9.

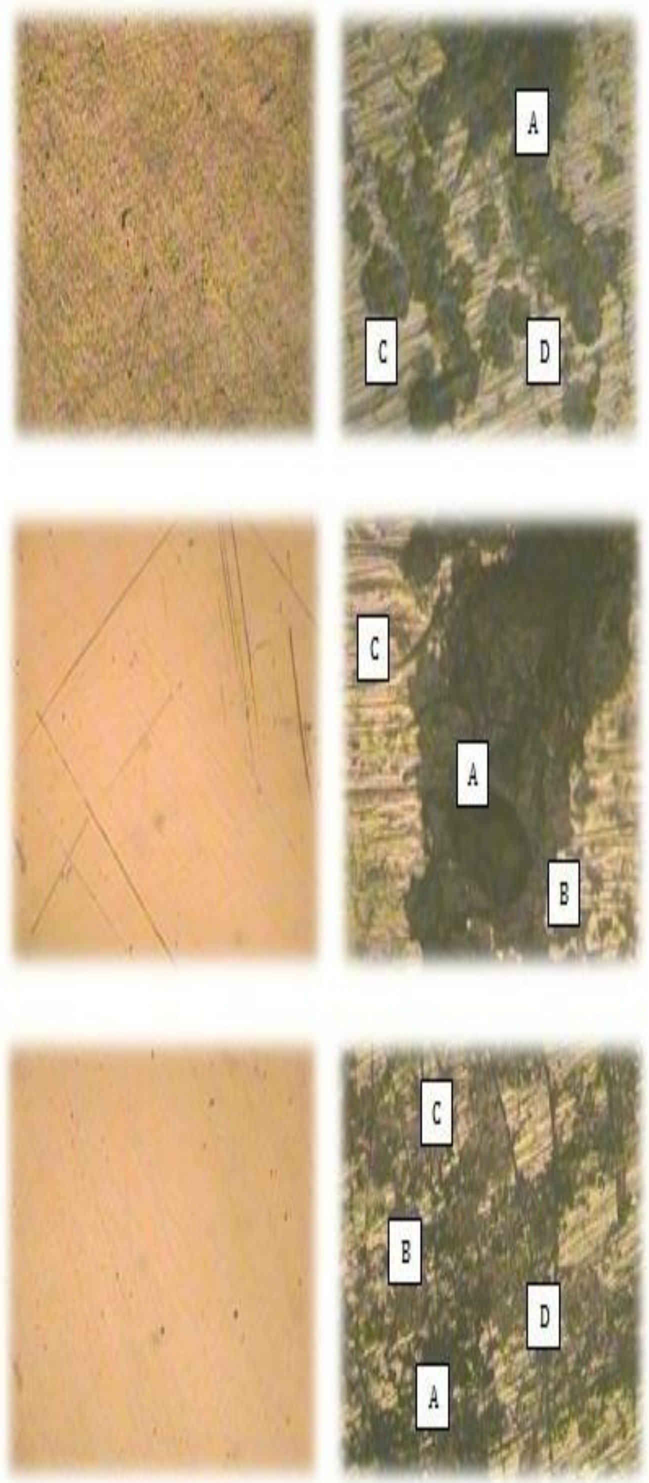


Fig.9. Corroded surfaces of metal coupons

By considering the above appearances basically there were identified some distinguish corrosion compounds based upon the visible features foremost of the color as discussed and compared in the Table 7 [1, 3, 4, 5, 6, 17].

A- Ferrous Sulfide (FeS)
B- Ferrous Oxides (Fe_2O_3)
C- Corrosion Cracks
D- Cavities/ pits

Table 7. Visible appearances of the corrosion compounds

Compound	Appearances	Observations
FeS	Black, brownish black, property of powder, pitting, cracks	Observed most of features in each metal piece.
Fe_2O_3	Rusty color	Observed rarely.
CuS	Dark indigo/ dark blue, property of powder	Unable to specify.

According to the theoretical explanations and observed results that it is possible to distinguish the corrosion compounds of ferrous sulfides (FeS), ferrous oxides (Fe_2O_3), corrosion cracks asymmetrically and cavities on some of places on the corroded metal surfaces with their visible appearances . In addition that it was observed some similar compound with ferrous oxides that having approximately having similar visible features on Monel metal surfaces and it is impossible to conclude that compounds as copper sulfide (CuS) by distinguishing from ferrous sulfides (FeS) only considering the visible features.
Therefore, it is better to recommend some compositional analysis of the corrosion compounds such as the X-ray diffraction (XRD) for better analysis.

Regarding the analysis of the decayed metallic elemental concentrations from some of metals during the immersion in crude oils by the atomic absorption spectroscopy (AAS) the obtained results have been presented in the Table 8. The concluded interpretations of the decayed ferrous and copper concentrations from metals into crude oils during the immersion have been shown in the Figure 10 and Figure 11. According to the above results mainly there were found the higher decay concentrations of ferrous from carbon steels also found higher corrosion rates, significant decay of copper from Monel metal that found intermediate corrosion rates in both crude oils and there was not found any metallic decay from any stainless steels that found least corrosion rates among other metals.

Table 8. Decayed metallic concentration from metals into crude oils

Metal	Crude Oil	Fe Concentration/pp	Cu Concentration/pp
Carbon Steel (High)	Murban	0.47	-
	Das Blend	1.10	-
Carbon Steel (Medium)	Murban	0.54	-
	Das Blend	0.02	-
Carbon Steel (Mild Steel)	Murban	- 0.08	-
	Das Blend	-0.48	-
410-MN: 1.8 420- MN: 2.8 (Stainless Steel)	Murban	-0.65	-
	Das Blend	-0.78	-
410-MN: 1.7 420-MN: 1.7 (Stainless Steel)	Murban	-0.71	-
	Das Blend	-0.79	-
321-MN:1.4 304-MN:1.9 (Stainless Steel)	Murban	-0.44	-
	Das Blend	-0.17	-
Monel 400	Murban	-	10.47
	Das Blend	-	9.49

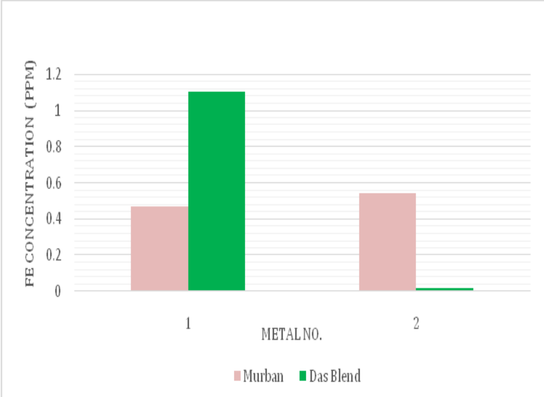


Fig.10. Decayed ferrous concentrations from metals into crude oils

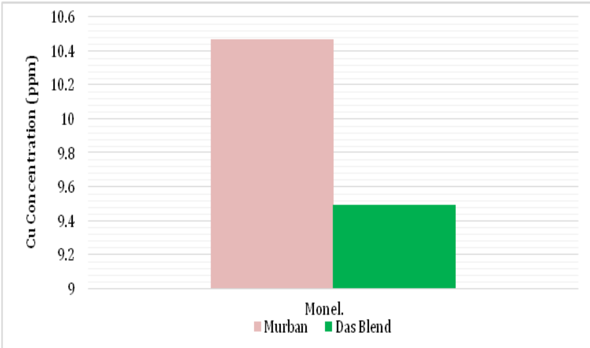


Fig.11. Decayed copper concentrations from metals into crude oils

When combining such observations with the theoretical concepts that it is possible to discuss with the theory of electron repulsive. Because after the formations of the corrosion compounds on the metal surface such corrosion compounds tend to be removed from the metal surfaces because of the repulsive and attractive forces between the successive electrons and protons of relevant compounds [1, 3, 4, 5, 6]. Therefore, it is possible to conclude some higher weight losses from highly corroded metals and relatively lower weight losses from lower corroded metals.

The obtained results for the analysis of the variations of the initial hardness of the metals by the Vicker's hardness tester have been shown on the Figure 12 and figure 13.

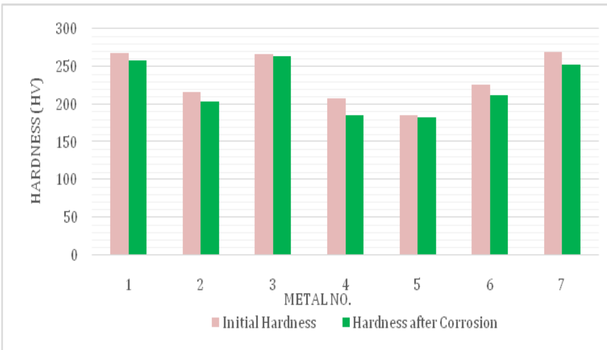


Fig.12. Variance of the initial hardness of metals after corrosion in Murban

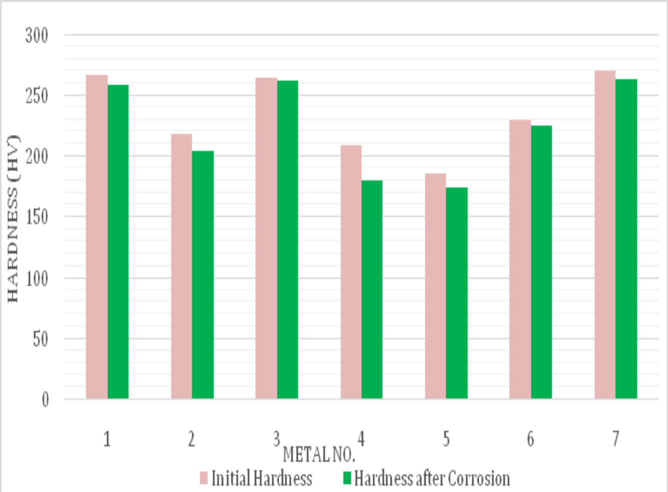


Fig.13. Variance of the initial hardness of metals after corrosion in Das Blend

By referring the above results that it is possible to find some slight reductions of the initial hardness of most of metals after formations of the corrosion on the metal surfaces. At this stage the possible mechanism for the explanations of the relevant incident is also the electron repulsive theory. After formations of the corrosion compounds on the relevant metal surfaces it is tend to create some sort of uncertainty on the metallic surfaces based upon the repulsive and attractive forces between the successive electrons and protons and also the heterogeneity on the metallic surfaces because of the removal of such corrosion compounds either completely or partially [1, 3, 4, 5]. Therefore, these observations confirmed that the formations of the corrosion on the metal coupons while the immersion in crude oils.

4. Conclusion

At the end of the research basically investigated some important observations such as the lower corrosion rates from stainless steels among other metals at least with 12% of chromium and sufficient amounts of nickel because of the stability of the corrosive protection film that formed with the combination of both chromium and nickel, relatively higher corrosive impact from organic acids and salts on the metallic corrosion among other compounds such as the sulfur compounds especially at the lower temperatures, formations of FeS/CuS frequently, Fe_2O_3 rarely, corrosion cracks and cavities on the metal surfaces similarly as discussed under the theories of the corrosion due to the such corrosive compounds, some amount of the decay of ferrous from carbon steels that having higher corrosion rates, significant copper decay from Monel metal and lack of any metallic decay from any stainless steels into crude oils and small reductions of the initial hardness of metals due to the formations of the corrosion on the metal surfaces while providing sufficient evidences for the corrosion.

Acknowledgements

The special thank goes to the laboratory staff members on behalf their arrangements of facilities to perform the existing research as expected.

References

[1] O. P. Khana, *Materials Science and Metallurgy*, New Delhi: Dhanpet Rai and Sons publication, 2009.

[2] T.A. Alsahhaf, A. Elkilani and M.A. Fahim, *Fundamentals of Petroleum Refining*, Amsterdam: Radarweg Press, 2010.

[3] W. D. Calister, *An Introduction of Materials Science and Engineering*, NewYork: John Wiley and Sons, Inc, 2003.

[4] M.E. Davis and R.J. Davis, Eds., *Fundamentals of Chemical Reaction Engineering*, New York: McGraw-Hill, 2003.

[5] R. Singh, *Introduction to Basic Manufacturing Process and Engineering Workshop*, New Delhi: New Age International Publication, 2006.

[6] W. Bolton, Eds., *Engineering Materials Technology*, London: B. H Newnes Limited, 1994.

[7] H. A. Ajimotokan, A. Y. Badmos and E. O. Emmanuel, Corrosion in Petroleum Pipelines. *NY. Sci. J.*, 2 (2009) 36-40.

[8] J.G. Speight, Eds., *The Chemistry and Technology of Petroleum*, New York: Marcel Dekker, 1999.

[9] G. A. Afaf, Corrosion Treatment of High TAN Crude. PhD. Thesis, University of Khartoum, Khartoum, Sudan, 2007.

[10] G. C. Okpokwasili and K. O. Oparaodu, Comparison of Percentage Weight Loss and Corrosion Rate Trends in Different Metal Coupons from two Soil Environments. *Int. J. Environ. Bioremediat. Biodegrad.*, 2 (2014) 243-249.

[11] A.D. Usman and L.N. Okoro, Mild Steel Corrosion in Different Oil Types. *Int. J. Sci. Res. Innov. Technol.*, 2 (2015) 9-13.

[12] I. M. Ahmed, M. M. Elnour and M. T. Ibrahim, Study the Effects of Naphthenic Acid in Crude Oil Equipment Corrosion, *J. Appl. Indust. Sci.*, 2 (2014) 255-260.

[13] G. W. Luther and D. Rickard, Chemistry of Iron Sulfides. *Chem. Rev.*, 107 (2007) 514-562.

[14] H. Fang, S. Nesic, D. Young, Corrosion of Mild Steel in the Presence of Elemental Sulfur *Int. Corros. Conference. Expo.*, (2008).

[15] G. M. Bota, S. Nesic, D. Qu and H.A. Wolf, Naphthenic Acid Corrosion of Mild Steel in the Presence of Sulfide Scales Formed in Crude Oil Fractions at High Temperature, *Int. Corros. Conference. Expo.*, (2010).

[16] M. Muller, Theoretical Considerations on Corrosion Fatigue Crack Initiation. *Metal. Trans. A.*, 13 (1982) 649-655.

[17] W.F. Smith, and J. Hashemi, *Foundations of Material Science and Engineering*, 4th Ed. New York: McGraw-Hill, 2006.

[18] N. S. Hassan, The Effect of Different Operating Parameters on the Corrosion Rate of Carbon Steel in Petroleum Fractions. *Eng. Technol. J.*, 31A (2013) 1182- 1193.

[19] M. Schoell, Stable isotopes in petroleum research. In Advances in Petroleum Geochemistry, 1st Ed. J. Brooks and D. Welte. pp. 215-245. London: Academic Press, 1984.

[20] Royal Dutch Shell, The Petroleum Handbook. Amsterdam: Elsevier, 1983.

[21] M. Engel, and S. A. Macko, Organic Geochemistry: Principles and Applications, Plenum Press, NewYork, pp. 861, 1993.

How to Cite This Article

Suresh Aluvihara; Jagath K. Premachandra. "An experimental study of the corrosion Process of metals in virtue of crude oils and the characteristics". Chemical Review and Letters, 2, 1, 2019, 21-32. doi: 10.22034/crl.2019.87897