CHAPTER IV

Result and Discussion

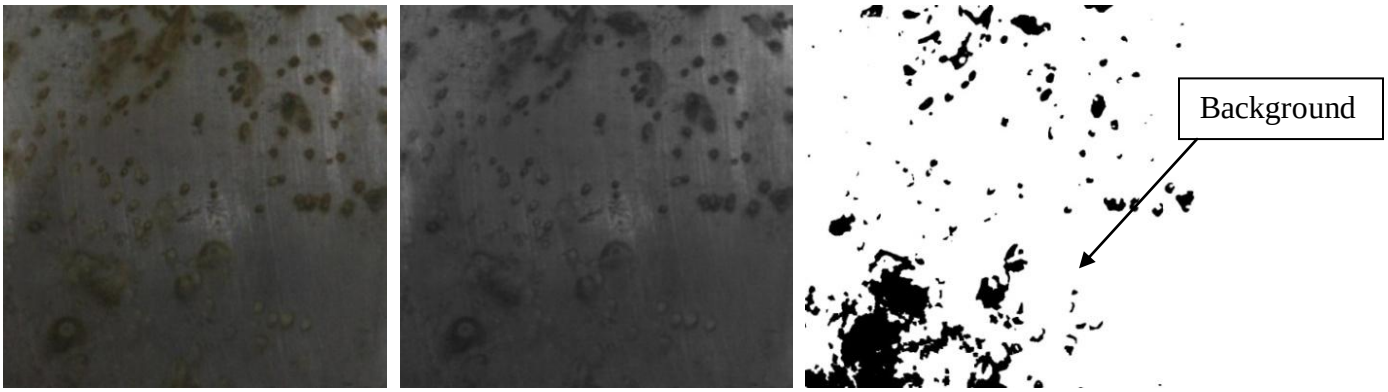
This chapter is divided into the sections. Analysis of the carbon steel corrosion surface of steel exposed under water is presented in 4.1, which estimate sample with a set five images were obtained using ImageJ image analysis software. Section 4.2 shows empirical calculation of fractal dimensions, Graphs show Log N (L) (MF) magnification factor versus Log L similar-self corrosion particles (SSCP) Estimate sample exposed to **2 nd** hour, **8 th** hour,13 **th** hour, **th** hour, and **24 th** hour of surface corrosion of steel using box count method.

4.1 Surface morphology of corrosion steel surface membrane

Showing that the surface roughness surface height variation increased with time difference of corroded carbon steel surfaces particles. The graphs also show the microstructure of the surface corrosion of steel membranes to be homogeneous. The surface morphology of corrosion of surface steel can be influenced by its internal change in microstructure. The color images are converted to gray-level images and homogenized for light illumination. The gray-level images are then converted to black and white binary images for fractal box counting analysis. At each observation (image capture) time, a set of five images were obtained, and the procedures were repeated for all five observation times. These images are presented in Figures (4.1, 4.2, 4.3, 4.4, and 4.5).

Image pre processing at Time = 2nd hour

In this image we analyze the corrosion on surface of steel after exposed to mineral water under room temperature. Picture (a) Shows corrosion in color photo picture (b) Shows corrosion in gray photo picture (c) Shows spots result from corrosion after analyzing the photo using ImageJ image analysis software.

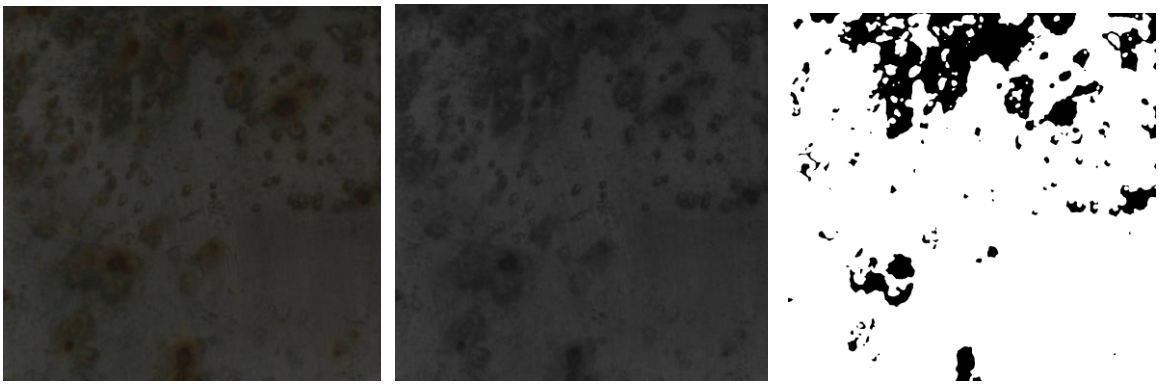


(a) Color image (b) Grayscale image (c) Black white image

Figure 4.1 Surface corrosion of carbon steel

Image pre processing at Time = 8th hour

In this image we analyze the corrosion on surface of steel after exposed to mineral water under room temperature and after 6 hours of image 2nd hour exposure. Picture Shows corrosion in color photo. Picture (b) Shows corrosion in gray photo. Picture (c) Shows spots result from corrosion after analyze the photo using ImageJ image analysis software.

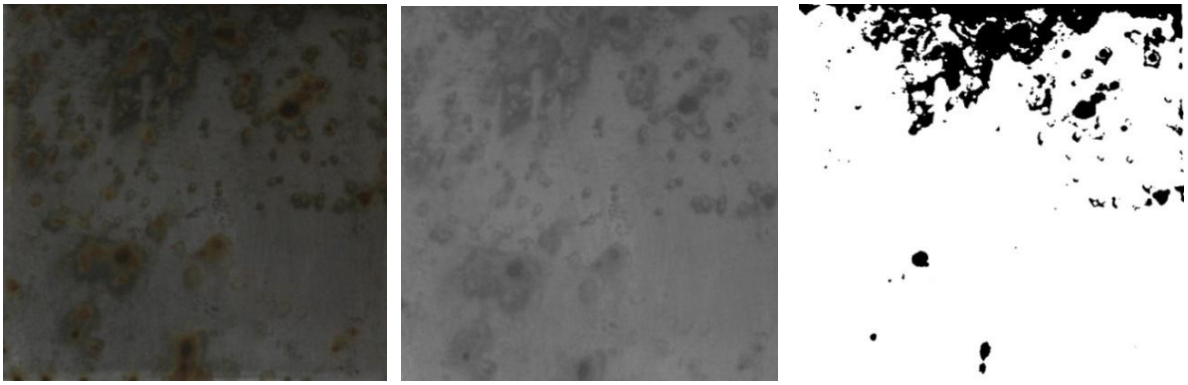


(a) Color image (b) Grayscale image (c) Black white image

Figure 4.2 Surface corrosion of carbon steel to figure 4.1 after 6 hours

Image pre processing at Time = 13th hour

In this image we used analyze the corrosion on surface of steel after exposed to mineral water under room temperature and after 5 hours of image 8th hour exposure. Picture (a) Shows corrosion in color photo .picture (b) Shows corrosion in gray photo picture (c) Shows spots result from corrosion after analyze the photo using ImageJ image analysis software.

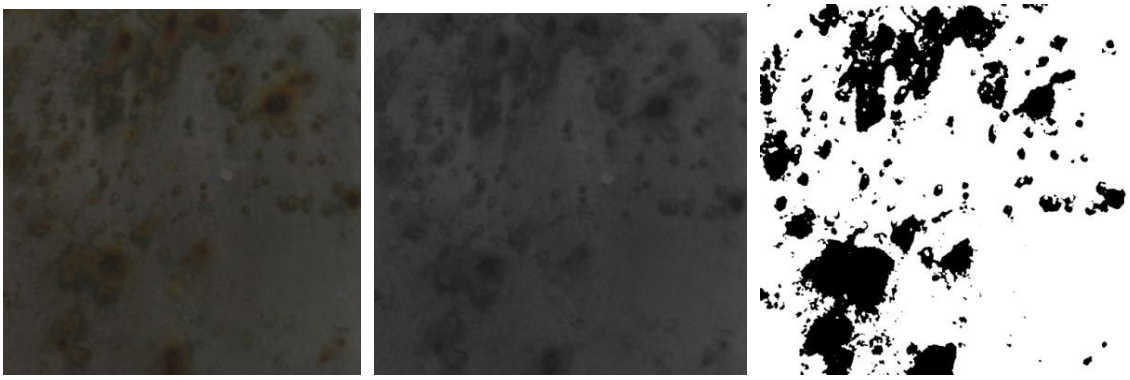


(a) Color image (b) Grayscale image (c) Black white image

Figure 4.3 Surface corrosion of carbon steel to figure 4.2 after 5 hours

Image pre processing at Time = 20 th hour

In this image we analyze the corrosion on surface of steel after exposed to mineral water under room temperature and after 7 hours of image 13th hour exposure. Picture (a) Shows corrosion in color photo .picture (b) Shows corrosion in gray photo. Picture (c) Shows spots result from corrosion after analyze the photo using ImageJ image analysis software.

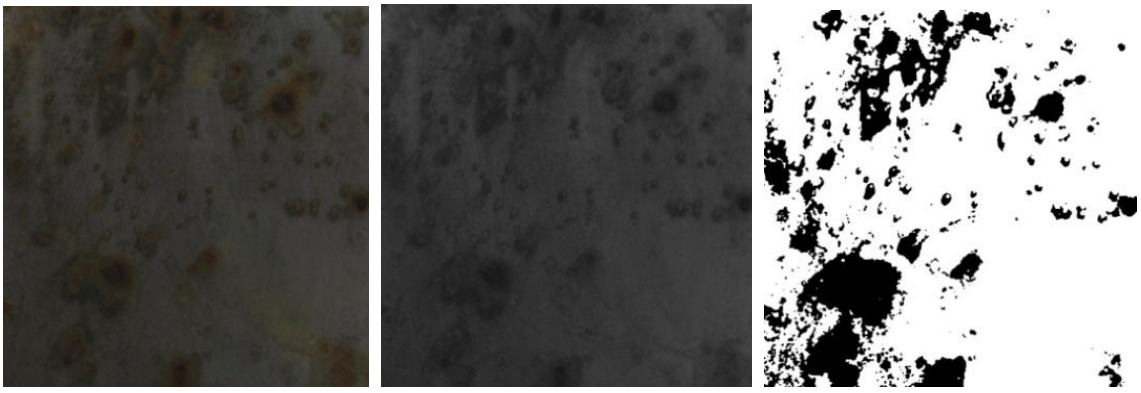


(a) Color image (b) Grayscale image (c) Black white image

Figure 4.4 Surface corrosion of carbon steel to figure 4.3 after 7 hour

Image pre processing at Time =24 th hour

In this image we analyze the corrosion on surface of steel after exposed to mineral water under room temperature and after 4 hours of image 20 **th** hour exposure. Picture (a) Shows corrosion in color photo picture (b) Shows corrosion in gray photo picture (c) Shows spots result from corrosion after analyze the photo using ImageJ image analysis software.



(a) Color image (b) Grayscale image (c) Black white image

Figure 4.5 Surface corrosion of carbon steel to figure 4.4 after 4 hours

4.2 Fractal dimension of corroded carbon steel surfaces

The fractal dimensions of corrosion were estimated by equation (Chapter 3). Using ImageJ image analysis software. The relationship are linear with their slope giving the fractal dimension (*D*) of corrosion the values of d varied from 1.46 to 1.69 for these a set five time difference. Thus, increasing the corrosion particles size enhanced the fractal dimension of the surface corroded steel surface membrane. Show Log N (L) (MF) magnification factor versus Log L (SSCP) similar- self corrosion particles Estimate sample from 2nd hour, 8 th hour, 13 th hour, 20 th hour, and 24 th hour of carbon corrosion steel **surface are** represent in Figures 4.6, 4.7, 4.8, 4.9 and 4.10.

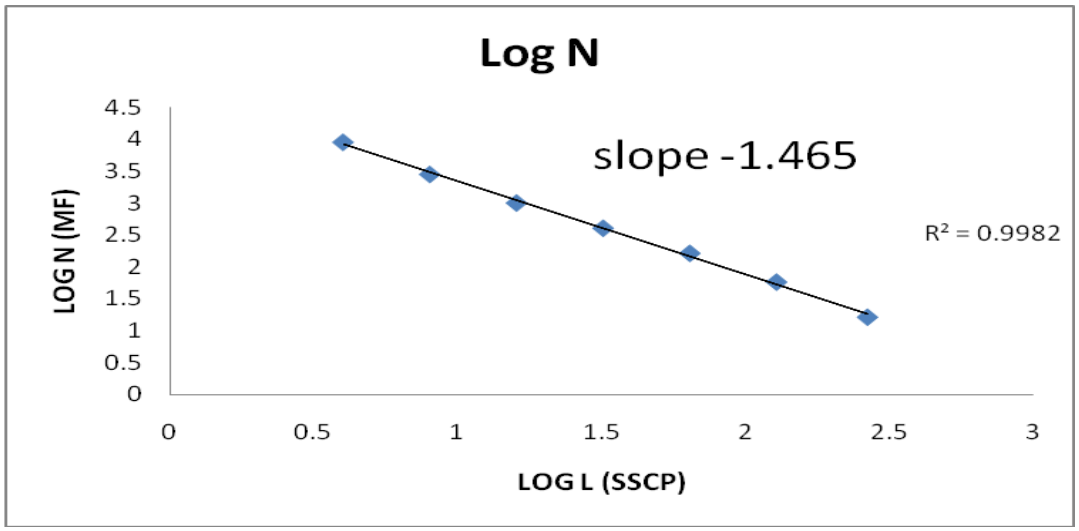


Figure 4.6 Log (*N*(*L*)) (MF) versus log(*L*) (SSCP) at t = 2 ^{hour}

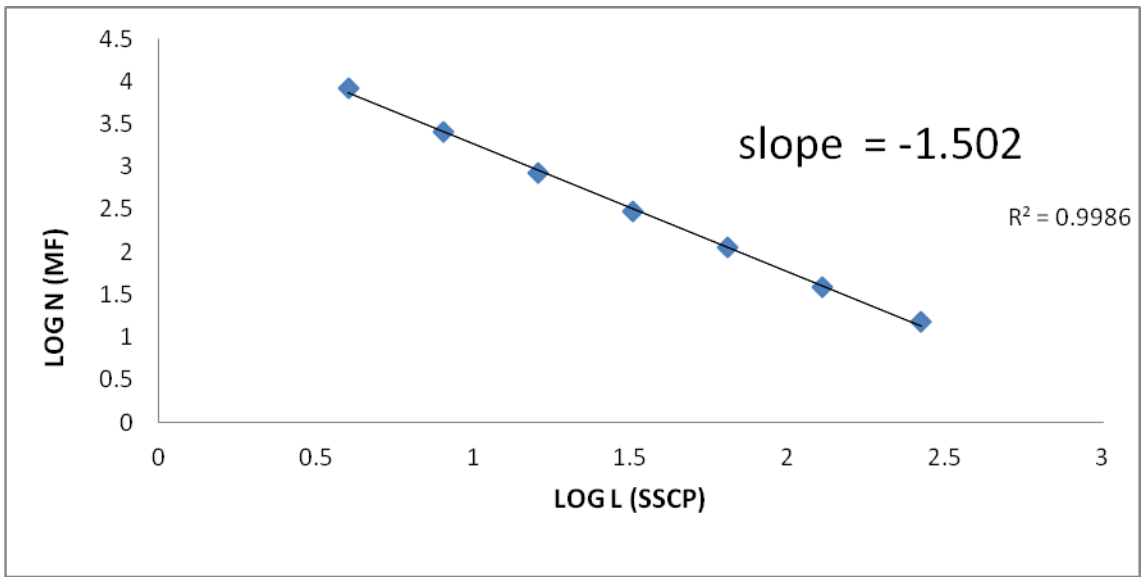


Figure 4.7 Log ($N(L)$) (MF) versus log(L) (SSCP) at t = 8 hour

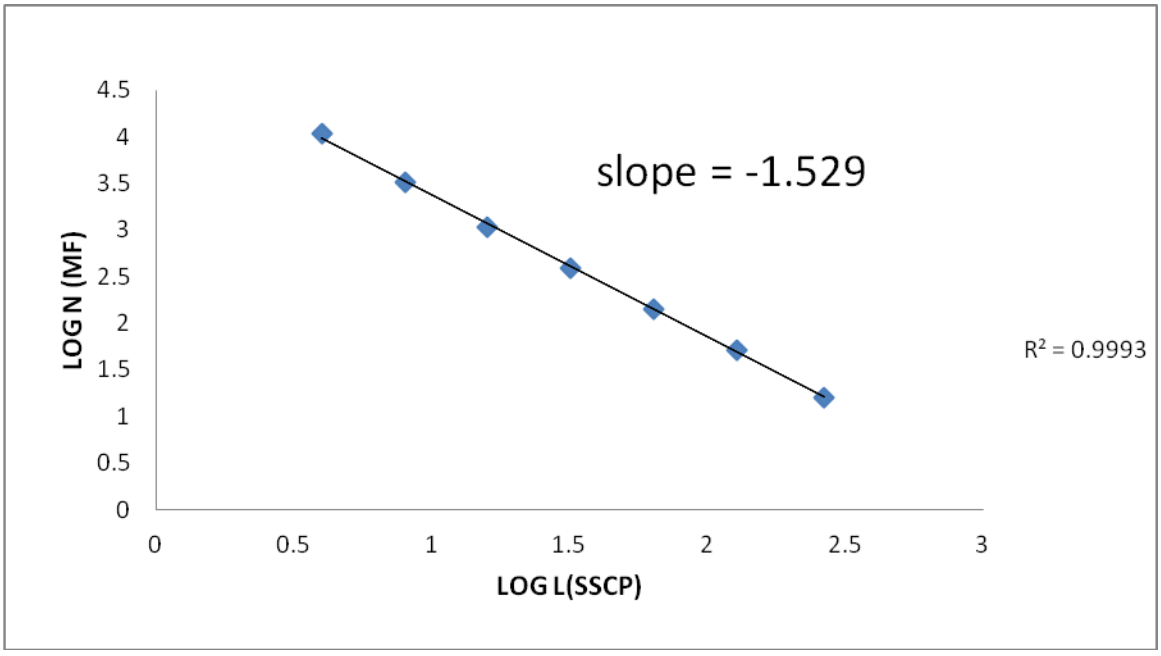


Figure 4.8 Log ($N(L)$) (MF) versus log(L) (SSCP) at t = 13 hour

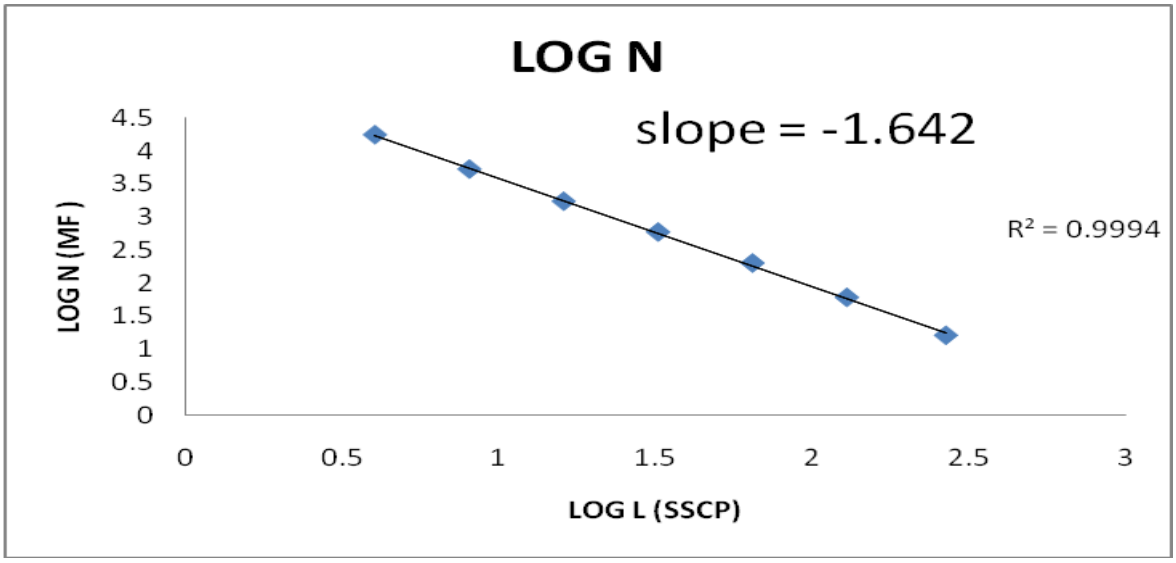


Figure 4.9 Log ($N(L)$) (MF) versus log(L) (SSCP) at t = 20 hour

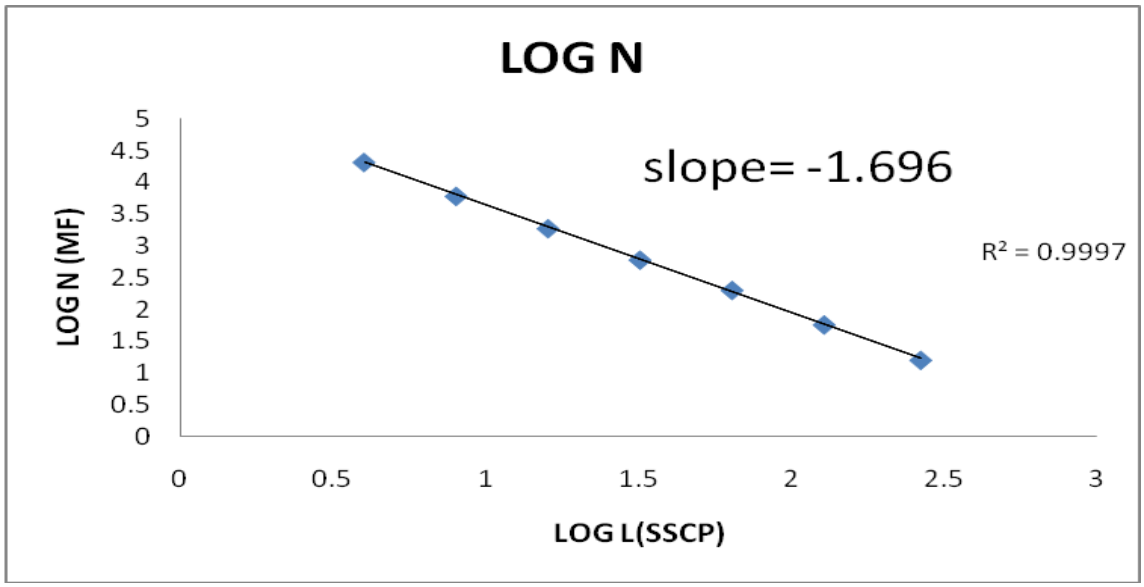


Figure 4.10 Log ($N(L)$) (MF) versus log(L) (SSCP) at t = 24 hour

The Tables 4.1, 4.2, 4.3, 4.4, 4.5 shown the calculation of fractal dimensions of that explains different calculation results at different times using ImageJ image analysis software. The number of self- similar corrosion particles log L SSCP versus the logarithm of the magnification factor log N(L) (MF) . We can use Microsoft excel for calculation empirical. The color to binary images using image j image analysis software program. Each image was subdivided into five images using box accounting method (see chapter 3). The subdivided images for all carbon corrosion steel surface membrane, particles size which were taken as squire size pixels for each image. Box Counting Method Count number of boxes $N(L)$ of different side length L to cover the object , Plot log N versus log l since fractal curve follows $N \sim L - D$, Slope gives the fractal dimension D (see Chapter 3). The fractal dimension of the estimated by equation (Chapter 3, 3.3).

Table 4.1Calculation of fractal dimensions L is SSCP, (N (L) is MF at t = 2nd hour

Box Accounting L	**What is N(L) (MF)**	**Log L(SSCP)**	**Log N (MF)**
4	**8958**	**0.60206**	**3.952211**
8	**2796**	**0.90309**	**3.446537**
16	**997**	**1.20412**	**2.998695**
32	**399**	**1.50515**	**2.600973**
64	**161**	**1.80618**	**2.206826**
128	**57**	**2.10721**	**1.755875**
256	**16**	**2.423246**	**1.20412**

Table 4.2 Calculations of fractal dimensions L is SSCP, N (L) is MF at t = 8 th hour

Box Accounting L	What is N(L) (MF)	Log L(SSCP)	Log N (MF)
4	**8318**	**0.60206**	**4.02914**
8	**2534**	**0.90309**	**3.511349**
16	**841**	**1.20412**	**3.034227**
32	**295**	**1.50515**	**2.587711**
64	**112**	**1.80618**	**2.152288**
128	**39**	**2.10721**	**1.70757**
256	**15**	**2.423246**	**1.20412**

Table 4.3 Calculation of fractal dimensions L is SSCP, (N (L) is MF at t = 13 th hour

Box Accounting L	What is N(L) (MF)	Log L(SSCP)	Log N (MF)
4	**8318**	**0.60206**	**3.920019**
8	**2534**	**0.90309**	**3.403807**
16	**841**	**1.20412**	**2.924796**
32	**295**	**1.50515**	**2.469822**
64	**112**	**1.80618**	**2.049218**
128	**39**	**2.10721**	**1.591065**
256	**15**	**2.423246**	**1.176091**

Table 4.4 Calculation of fractal dimensions L is SSCP, (N (L) is MF at t = 20 th hour

Box Accounting L	What is N(L) (MF)	Log L(SSCP)	Log N (MF)
4	17270	0.60206	4.237292
8	5223	0.90309	3.71792
16	1706	1.20412	3.231979
32	583	1.50515	2.765669
64	198	1.80618	2.296665
128	60	2.10721	1.778151
256	16	2.423246	1.20412

Table 4.5 Calculation of fractal dimensions L is SSCP, (N (L) is MF at t = 24 th hour

Box size L	Box accounting N(L)	Box size Log L	Box accounting Log N
4	20938	0.60206	4.320935
8	6129	0.90309	3.78739
16	1900	1.20412	3.278754
32	606	1.50515	2.782473
64	202	1.80618	2.305351
128	58	2.10721	1.763428
256	16	2.423246	1.20412

Table 4.6 Summary of F.D exposure time in water, Variation of fractal dimension, *D* with corrosion time with error ratio

Time (^{hour})	**Fractal dimension (*D*)**	**Error ratio**
2	**1.465**	**0**
8	**1.502**	**- 0.2**
13	**1.529**	**0.0208**
20	**1.624**	**-0.02**
24	**1.696**	**0.0279**

The variation of average fractal dimension as the surface corrosion progresses is determined. It is found that the fractal dimension increases as the corrosion evolves in time. So, the relationship are a set of five images of different time to fractal dimension.

Sample for a set five images was subdivided into five digital images of 1024 x1024 pixels sample with five time difference 2nd, 8th, 13th, 20th, and 24^{th}. So, the average of this sample will represent the exposed variation of fractal dimension of the surface corrosion particles distribution in each time, Table 4.6 we have error ratio for a set five images.

However ; in this study we have implemented a statically method for surface corrosion of steel membrane surface morphology characterization using fractal analysis method, which can be obtained from calculating the average of each subdivided corrosion particles microstructure images sample at different part of the whole microstructure images sample as calculated at Table 4.7 ,and Figure 4.11 presented.

Table 4.7 Summary of F.D exposure time in water, Variation of fractal dimension, *D* with corrosion time

Time (hr)	**Fractal dimension (*D*)**
2	**1.465**
8	**1.502**
13	**1.529**
20	**1.624**
24	**1.696**

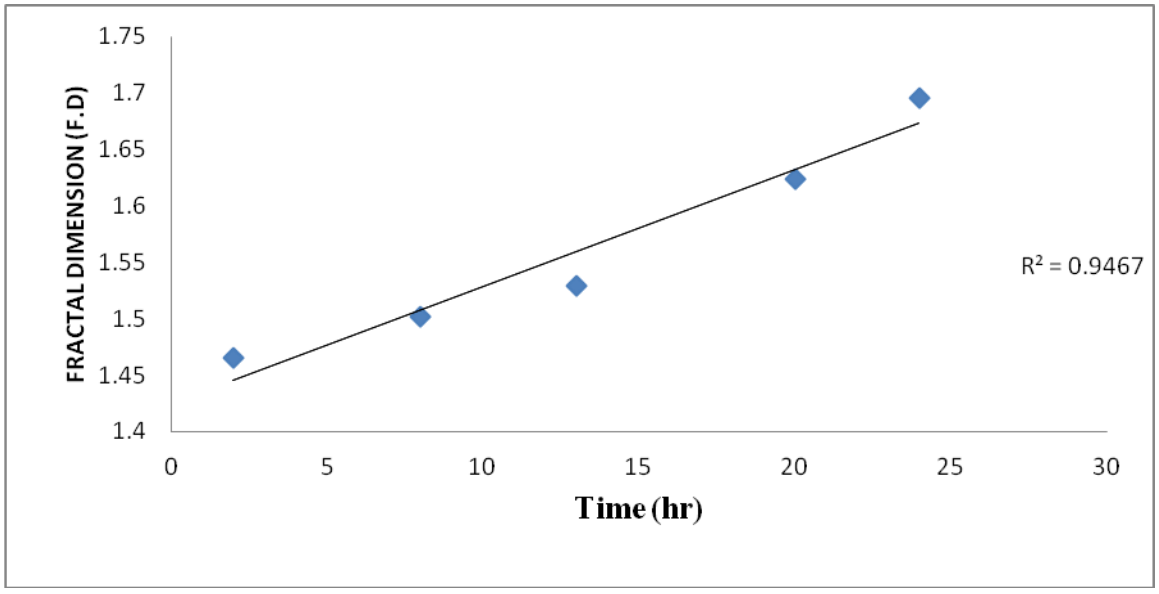


Figure 4.11 Variation of fractal dimension, *D* with corrosion time

In this study, we have investigated the morphologies of corroded carbon steel surfaces using image analysis and fractal methods. We used the standard threshold technique based on visual inspection of information retention upon binary conversion. Despite being subjective, the technique is reasonably accurate provided there exists clear distinction between the corrodes areas in the gray-level images.

The spot corrosion related to initial pitting mechanism has lower fractal dimension and as the corrosion progresses around these spots, larger areas are affected thus the fractal dimension increases. The fractal dimension can be interpreted as an index of surface damage. As the fractal dimension approaches the topological dimension 2, the whole areas would have been corroded.