Anti-Corrosion Effect of Curcuma Longa on Petroleum Drilling Equipment in the Presence of Different Acid Environments

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Abstract - *Corrosion is a common issue during drilling operations as it is mainly dealing with the borehole fluids which consists of acidic environments. Mainly, the challenge during drilling is the failure of drilling equipment such as drill pipe, drill string and casing pipe mostly made of mild steel that occurs due to the presence of hydrogen sulfide (H_2S) gas that leads to sulfide stress cracking and also reacts with formation water to form sulphuric acid (H_2SO_4) that eventually leads to failure or breakdown of steel drill pipes. Therefore, to prevent the drawbacks of corrosion need to be investigated through an additive via increasing the basic in nature by forming a protective layer on the metal surface. In this work, 'Curcuma longa' a botanical name of turmeric has been used as a natural additive for corrosion prevention on mild steel samples that measured in the presence of various acidic (hydrochloric acid; HCl and sulphuric acid; H_2SO_4) aqueous solutions at 0.1 M in the absence and presence of turmeric, where comparison of these experimental data is not available in the literature. The visual observation and scanning electron microscope (SEM) results show that the HCl+Turmeric and H_2SO_4+Turmeric aqueous solutions found to be reduced the corrosion rate as compared to pure acidic aqueous solutions of HCl and H_2SO_4. This work provides insight to use turmeric in drilling fluid to combat the high corrosion rate, due to the presence of H_2S gases which produces in the wellbore and shows the potential to maintain the necessary rheological properties.*

Key Words: Corrosion rate; Hydrogen sulfide; Sulphuric acid; Turmeric; Weight loss

1. INTRODUCTION

Corrosion is the disintegration of metal through an attack or chemical reaction with its surrounding condition. It is a regular problem and hard to wipe out corrosion processes that develop quickly once disruption of the protecting barrier and are in the middle of a variety of reactions that amendment the composition and properties of each metal surface and therefore the local surroundings [1-5]. Corrosion is turning into an expanding worldwide danger to the trustworthiness of petroleum industries whose significant segment is steel with its orderly financial wastages and related ecological risks [6]. Metal corrosion is a serious issue since it causes a waste in resources and reduces equipment lifetime especially in acid solutions [7]. According to the Global Relationship of Boring Contractual workers (IADC) examination records, approx. seventy-five to eighty-five percent of the drill pipe misfortune is attributable to consumption the price of replacement of a corrosion-damaged drill pipe will quantity to many hundred thousands of dollars for a single string. The cost of the drill pipe and rig time spent on the fishing process result in multiplied overall drilling prices. Some contractors estimate the cost of loss of drill pipe around $0.03 per foot on per day operating cost [8-9]. For efficient drilling operations, the drilling fluid should contain an effective corrosion inhibitor while maintain its properties and carry out the necessary functions.

The major reasons for drill pipe corrosion are sulfide (H_2S), oxygen and carbonic acid gas (CO_2). Generally, chemical element (oxygen) enters the drilling fluids within the surface portion of the current system of mud, whereas H_2S and CO_2 gas could enter the lubricating substance from formation fluid that's being drilled. Oxygen and H_2S can enter the drilling fluid or mud due to the degradation of the thermal and microorganism of organic and sulfur compounds [8-11]. The artificial corrosion inhibitors are unhealthful in nature and harmful for the atmosphere, therefore, it necessary to develop environmentally acceptable and cheap inhibitors during this term turmeric is the best inhibition product against the corrosion of a metal as a result of turmeric has tannins and terpins and different phytochemicals. Turmeric carries with it volatile and non-volatile constituents. The non-volatile constituents area unit wealthy with phenolic resin compounds like curcumin and different curcumin's derivatives. The corrosion inhibition result of turmeric is attributed to the surface assimilation of phenolic resin constituents over the metal surface [12]. The use of such inhibitors is one in every of the most effective choices for shielding metals and alloys against corrosion. The environmental toxicity of organic corrosion inhibitors has prompted the explore for inexperienced corrosion inhibitors as they're biodegradable, don't contain substantial metals or other dangerous mixes. As yet being naturally invitatory and biologically worthy, plant things square measure low-cost, promptly accessible and property [1].

2. EXPERIMENTATAL SECTION

2.1 Materials

The materials used in this present work are turmeric (T) powder, hydrochloric acid (HCl) and sulphuric acid (H_2SO_4) was prepared by using tap water. The mild steel pieces of N80 grade weighing 100 g were used with a composition in weight percentage (wt.%) of Oxygen (O): 33.01%, Manganese (Mn) 0.77% Iron (Fe) 66.21%. The two acid solutions were prepared with HCl and H2SO4using tap water with and without turmeric.

2.2 Experimental set-up

The experimental set-up is shown in Figure 1 which includes a glass chamber of eight sections consist of different four acidic environments and an air pump with a controller. The glass chamber having a total capacity of 9720 mL and each chamber consists of 1215 mL. First and second chambers consist of 1 M HCl aqueous solution; third and fourth consists of (1 M HCl + 2.57 g T) aqueous solution; fifth and sixth includes 1 M H_2SO_4 aqueous solution; seventh and eight consists of (1 M H_2SO_4 + 2.57 g T) for experimental run 1 and run 2.

Each acid aqueous solution made of 900 mL. The experimental run 1 and run 2 have done for each acid solution to get the reproducibility of results. Each number of mild steel pieces has a length of 12.7 cm (5 inches) and a width of 2.54 cm (inch) were used in this work for run1 and run2 experiments. The samples including the metal pieces for experimental run1 and run2 were dipped in the eight sections of the glass chamber consisting of different acid solutions as shown in Figure 1. Sample 1 (S1) is pure HCl aqueous solution, (S2) is (HCl + T) aqueous solution, (S3) is pure (H_2SO_4) aqueous solution and (S4) is (H_2SO_4 + T) aqueous solution. Also, air pump with the controller is provided with the glass chamber to provide and control the flow of air in the different acid solutions time to time to see the inhibition effect by turmeric (T) with air in the acid solutions.

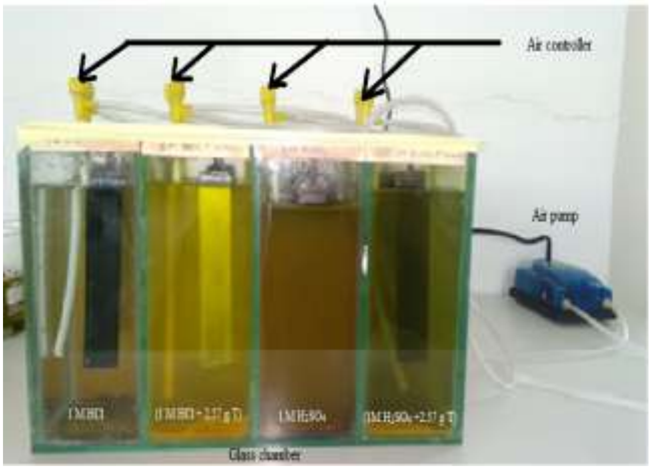


Fig -1: Experimental set-up

2.3 Experimental procedure

Refer to Figure 1, the different acid solution has been prepared in the presence and absence of turmeric powder. After the preparation and filing of the different acid solutions, the pieces of mild steel dipped in the different sections of the glass chamber. The acid solutions were made using 1M HCl (27.84 mL) with 872.16 mL of tap water and 1M H_2SO_4 (47.97 mL) with 852.03 mL of tap water. After that 2.57 g of turmeric powder in total 900 mL of the aqueous solution was added in samples 2 and 4 of the chamber. Then the same process repeated for the remaining four sections of the chamber for the run2 experiments. The final step is to seal the chamber properly with a Teflon tape to prevent the entry of any foreign particles inside the chamber on a metal cover plate, where mild steel samples attached. The air supplied by a PVC tube time to time using the air pump with the controller. The reason to supply air is to enhance the corrosion rate due to the presence of oxygen. Hence, the effectiveness of the turmeric can be checked properly as during drilling operation, oxygen can enter into a drilling fluid via borehole from oxygen rich formation water. Afterward, the different acid solutions with and without turmeric left for 1 month for the corrosion reaction.

2.3.1 Visual observation

The experiment is kept for 4 weeks (31 Days) of duration. The experiment results for samples S1, S2, S3 and S4 were analyzed daily by taking pictures for visual observation.

2.3.2 Weight Loss measurement

The corrosion rate depends on the metal pieces' weight loss, metal's surface area, and the exposure time during corrosion. The corrosion rate for the eight metal pieces used in this work has been determined in mils per year (mpy) and mm per year (mmpy), which is calculated via following equation 1 [13]:

mpy = ((Weight loss in grams) x (22300))/((Area [sq.in.])(Metal density [grams/cubic centimeter])(Time [days])) (1)

where, 1 mil = (1/1000) inch = 0.0254 mm

The overall corrosion rate determined by the weight loss value, by assuming the corrosion was uniform over the metal samples' entire surface. Hence, a complete analysis should include the visual observation of the sample to determine the type of corrosion.

2.3.3 SEM (scanning electron microscope) characterization

A SEM is a category of electron microscope that produces images of the samples via scanning its surface with electrons of a focused beam. The electrons intermingle with atoms present in the sample body and produce numerous signals that contain vital information regarding the composition of the metal pieces and surface topography [14]. The SEM images have been obtained for the metal pieces dipped in different samples used in this work.

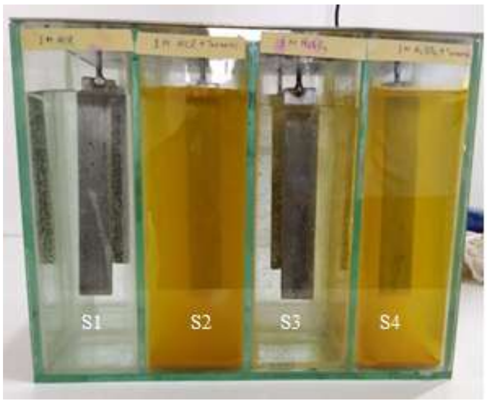
3. RESULTS AND DISCUSSION

The corrosion experiments have been conducted for one month (31 days) with four different samples (S1 to S4) containing metal pieces in each. The samples containing different acid solutions with and without turmeric (T) powder. The experimental results have been analyzed through various following methods.

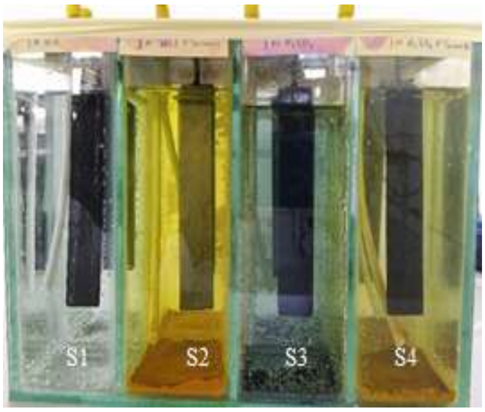
3.1 Visual observation

In this work, the visual observation has been investigated for four weeks (31 days), the observation results for the week wise have been recorded and shown in Figure 2. The different degree of corroded mild steel pieces is observed visually in

Figure 3 and the same has been determined by weight loss measurement and SEM analysis. It has been observed that the corrosion on the mild steel piece in 1 M HCl aqueous solution (S1) is more compared to (1 M HCl + 2.57 g T) aqueous solution (S2). Also, the corrosion has been observed more for 1M H_2SO_4 aqueous solution (S3) compared to (1M H_2SO_4 + 2.57 g T) aqueous solution (S4). Overall, the corrosion shows lower in S2 sample compared to the other three samples (S1, S3, and S4).



(a) Week 1



(b) Week 2

(c) Week 3

(d) Week 4

Fig -2: Metal pieces dipped in different acid solutions with and without turmeric

The reason for showing the less corrosion in HCl aqueous solution due to its less acidity compared to H_2SO_4 aqueous solution. From the visual observation results, the inhibition effect of turmeric on mild steel corrosion in 1 M HCl and 1 M H_2SO_4 with turmeric shows good abilities to be an effective inhibitor compared to non-turmeric acid aqueous solutions. The inhibition efficiencies determined by the visual observation.

Fig -3: Corroded mild steel surfaces after completion of 1 month of the experiment

The corrosion inhibition using turmeric occurs via adsorption of its constituents over the mild steel surface. The images of visual observation show that the surface of mild steel is seriously corroded in the acidic medium without inhibitor. Also, the mild steel surface is smooth in the presence of the inhibitor due to the formation of a protective film over the surface. The results show that turmeric acts as a better corrosion inhibitor with high efficiency in HCl as compared to H_2SO_4 aqueous solution at the same concentrations.

3.2 Weight loss measurements

The fresh piece of mild steel having 100 g of weight, before experiments were conducted. The comparative study of weight loss measurements in the presence of different samples have been investigated and reported in Table 1. The results show that the weight loss in the case of S4 is reduced drastically compared to S3 in the presence of H_2SO_4 aqueous solution, whereas for sample S2 is lower compared to S1 in the presence of HCl aqueous solution. Hence, turmeric helps to reduce the drastic weight loss of the metal pieces. Also, the overall corrosion rate has been determined using equation 1 and reported in Table 2 and Chart 1 has been plotted showing the error bar (standard error %) for the reproducible data obtained from run1 and run2 experiments.

Table -1: Weight Loss measurement

Sample No.	Sample	Weight loss (g) (Average from run1 and run2 experiments)
1	1 M HCl	06
2	1 M HCl + 2.57 g T	02
3	1 M H_2SO_4	46
4	1M H_2SO_4 + 2.57 g T	32

Table -2: Corrosion rate measurement

Sample. No.	Sample	Corrosion rate (mpy)	Corrosion rate (mmpy)
1	1 M HCl	16652.45	422.97
2	1 M HCl + 2.57 g T	5550.82	140.99
3	1 M H_2SO_4	127668.80	3242.79
4	1M H_2SO_4 + 2.57 g T	88813.05	2255.85

The standard error % has shown less for all the samples (S1, S2, S3, and S4) which shows the reproducibility of the data obtained in this work. The overall corrosion rate has shown lower for the sample S2 as compared to S1, S3, and S4 with a minimum standard error. Thus, the obtained results of the corrosion rate are showing satisfactory precision.

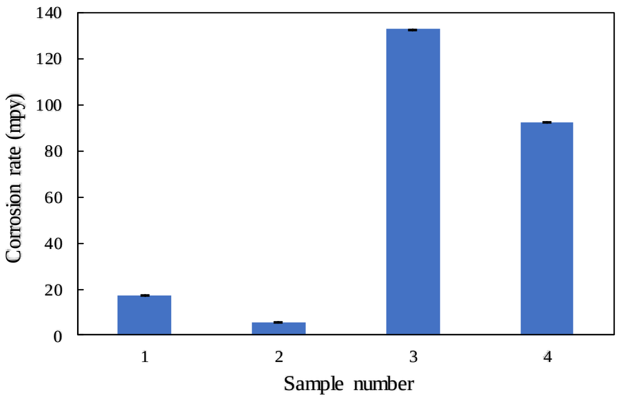
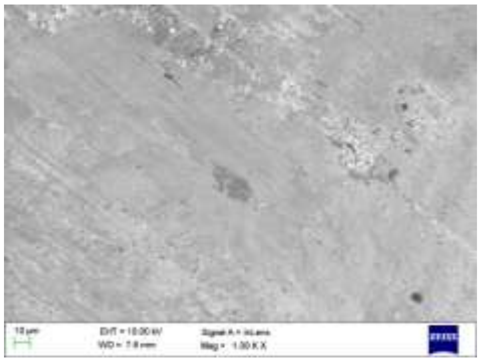


Chart -1: Corrosion rates (mpy) with standard error (%) of samples in the studied environments

3.3 Scanning electron microscope (SEM) analysis

Figure 5 (a, b) shows images of a fresh mild steel surface, before the start of the experiment for the corrosion rate analysis. All the SEM images have shown below of two-scale magnification (25 and 1 KX) i.e., one big and one small. Thus, the fresh piece of the metal shows a smooth surface before the corrosion experiment. The composition of the metal piece before the experiment was oxygen (O): 33.01%, manganese (Mn): 0.77%, iron (Fe): 66.21%.

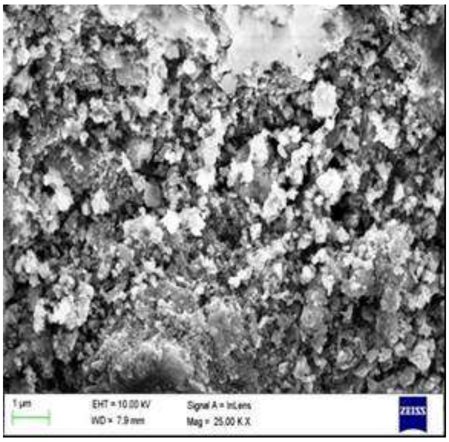
(a)



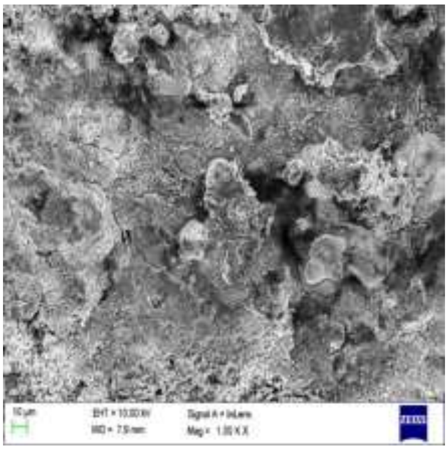
(b)

Fig -5: SEM images of a fresh piece of mild steel's surface with (a) 25.00 KX magnification and (b) 1.00 KX magnification

Figure 6 (a, b) shows the surface structure of the corroded metal piece from sample S1 where roughness or uneven surface of the metal structure observed clearly after the experiment. Figure 6 (a) shows a honeycomb-like structure on the surface of the metal in a bigger magnified scale as compared to Figure 6 (b) which shows the uneven surface in a small magnification scale. The space between the corroded particles is less and thus results in uniformity of the pattern as shown in Figure 6 (a). Pore space is created in between the corroded particles observed in the corroded metal's surface. Therefore, this shows the corrosion rate increases with the increasing acidic concentration without turmeric and shows the localized pitting type of corrosion occurred throughout the metal surface. The composition of the mild steel of sample 1 (HCl aqueous solution) after the experiment was found in (wt%) as O: 40.54%, Fluorine (F): 49.43%, Silicon (Si): 2.13%, Calcium (Ca): 3.49%, Cobalt: 4.42%.



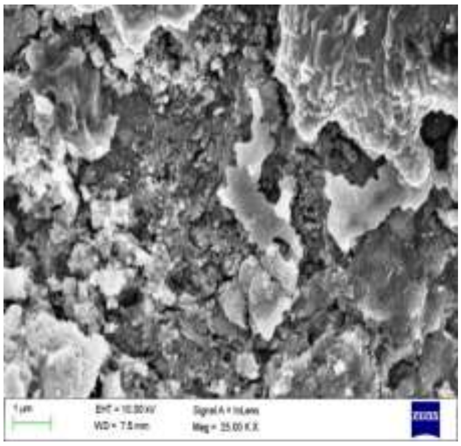
(a)



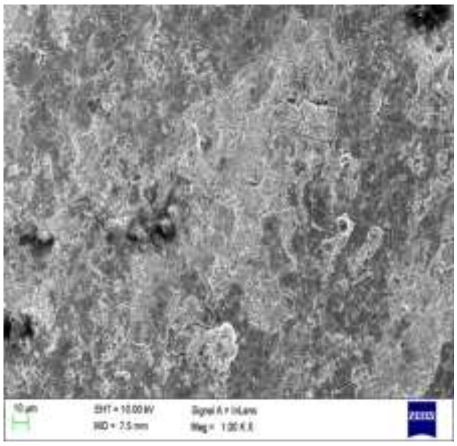
(b)

Fig -6: SEM images of mild steel surface corroded in 1M HCl solution

Figure 7 (a, b) shows a result of the metal's surface of sample 2 in the presence of turmeric. The surface of the metal is more visible compared to the pure HCl aqueous solution. The Corrosion has been taken place less as compared to S1 sample. This mild steel piece is controlled drastically in the presence of inhibitor as shown in Figure 7 (b), whereas from Figure 7 (a), it shows that the in big magnified scale also, the pore spaces between the corroded particles are less only as compared to sample S1. The adsorbed inhibitor acts to prevent the corrosion reaction of cathodic and or anodic electrochemical solution due to its phenolic constituents which helps to get adsorbed over the metal surface. The use of an inhibitor minimizes the risk of material failure by minimizing acid consumption. Therefore, this sample shows a localized type of corrosion but comparatively less than S1 sample and shows huge potential to prevent the localized pitting type of corrosion. The composition of the metal piece from sample 2 (HCl+Turmeric aqueous solution) was observed in (wt%) as O: 22.21%, F: 71.59%, Co: 6.20%.



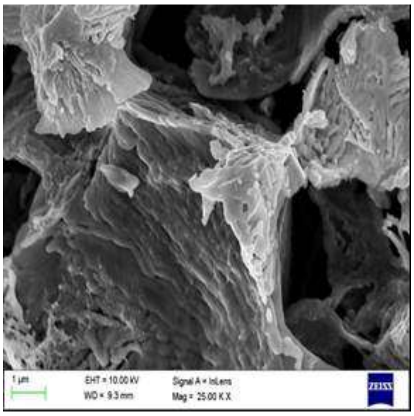
(a)



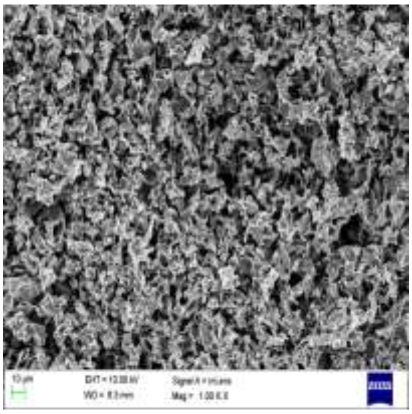
(b)

Fig -7: SEM images of mild steel surface corroded in 1M HCl+ Turmeric solution

Figure 8 (a) shows a petal-like structure with big pore spaces for the corroded metal of sample S3 in the presence of pure H_2SO_4 aqueous solution, whereas Figure 8 (b) shows the number of pore spaces between many corroded particles observed over the corroded metal surface. Among the other samples (S1, S2, and S4), this sample shows the most corrosive nature because it is too acidic in content. The surface of the metal sample is not visible due to a higher corrosion rate. The depth of the corrosion is high in the metal surface due to the chemical reaction with high chemical reactivity and thus, leads to more pores spaces between the corroded particles. Since, hydroxyl ions react with the ferrous ions produced by the anodic reaction to form ferrous hydroxide and therefore, corrosion rate increases in the absence of inhibitor in the aqueous solution. Therefore, the crevice type of corrosion has been observed in the presence of H_2SO_4 aqueous solution as it is a serious degradation of the metal and also, it can be a specific form of concentration cell corrosion (Byars, 1999). The composition of the mild steel sample S3 (H_2SO_4 aqueous solution) was found to be in (wt%) as O: 22.80%, S: 1.31%, Mn: 1.49%, Fe: 73.08%, Co: 1.32%.



(a)

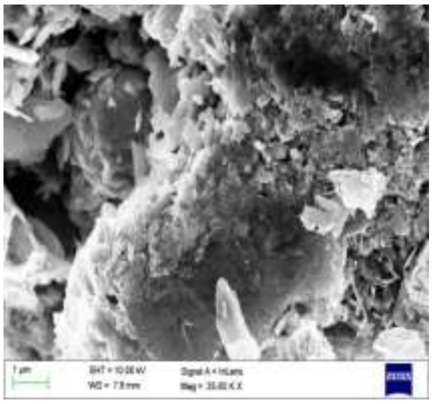


(b)

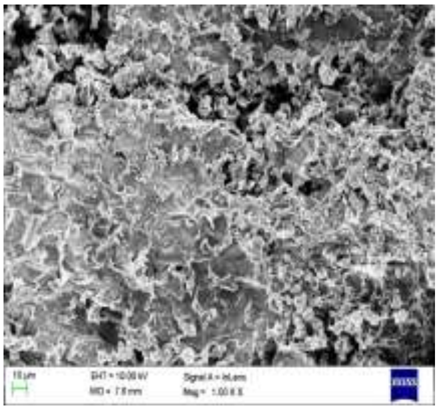
Fig -8: SEM images of mild steel surface corroded in 1 M H_2SO_4 solution

The SEM images of sample S4 (Figure 9 a, b) shows also petal-type structure but in less density. The surface of the metal sample is much visible, which means the corrosion rate is lesser due to the presence of turmeric. The depth of the corrosion with respect to pore spaces is less compared to S3 sample. The corrosion results are not in a place of uniform manner due to the chemical reaction with high chemical reactivity and hence, inhibition takes place in the anode part to resist the metal degradation compared to S3. Therefore, the corrosion rate has been controlled using turmeric in this S4 sample and can be prevented from the crevice type of corrosion as occurred in S3. The composition of the mild steel of sample 4 (H_2SO_4+Turmeric aqueous solution) was observed in (wt%) as O: 66.91%, S: 5.95%, Ca: 6.61%, Mn: 14.32%, Co: 6.21%.

Overall, the corrosion rate has been analyzed through SEM images of mild steel pieces for samples S1, S2, S3, and S4. The more corrosion rate has been observed in sample S3 compared to S1, S2, and S4. The lowest corrosion rate has been recorded in S2 sample compared to other samples. Thus, different morphological structures have been observed in the presence of different acidic solutions with and without turmeric. The mild steel surface is smooth in the presence of the inhibitors due to the formation of a protective film.



(a)



(b)

Fig -9: SEM images of mild steel surface corroded in 1M H_2SO_4 + Turmeric solution

4. CONCLUSIONS

Visual observation method, weight loss method, and SEM analysis have been conducted to study the anti-corrosion effect of turmeric (Curcuma longa) on the mild steel in 1 M HCl and 1M H_2SO_4 solutions. The corrosion rate was evaluated by weight loss measurement. The visual observation has been investigated on a per-day basis and also, SEM analysis of the metals has been done to observe the metal changes before and after the experiments in a detailed manner. The visual observation and SEM results show that the HCl+Turmeric and H_2SO_4+Turmeric aqueous solutions found to be reduced the corrosion process more as compared to pure acidic aqueous solutions of HCl and H_2SO_4. Also, from the comparative study, corrosion in mild steel pieces occurred more in H_2SO_4 aqueous solution compared to HCl aqueous solution at the same concentration of acidity, where turmeric shows an effective inhibition in both the cases. The effect of turmeric as a corrosion inhibitor occurs via adsorption of its phenolic constituents onto the mild steel surfaces. This work provides insight to use the turmeric in drilling fluid to combat the corrosion rate, due to the presence of high H_2S gases produces in the wellbore. The results show that turmeric can act as a potential inhibitor and be an important component of a drilling fluid with high efficiency when encounters with common acidic environments such as H_2S gases and chlorine content present in formation water to prevent corrosion.

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