Drilling Pipe Corrosion Reduction Using Natural, Biodegradable, and Environmentally Friendly Additive to the Drilling Fluid

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***Abstract*—Corrosion is one of the disasters attacking the drilling tools, particularly the drill pipes. Drilling fluid is the corrosive that increase the rate of corrosion in the pipes. In this study, it is intended to reduce the corrosivity of drilling fluid using a *Prosopis farcta* powder material. A natural, biodegradable, and environmentally friendly additive is added to the fluid in different particle sizes and amounts to obtain the lowest corrosion rate. Experiments are conducted in a well-like environment (high pressure high temperature filter press) over a wide range of parameters including pressure, temperature, and properties of the drilling fluid under dynamic conditions. The aim is to eliminate or reduce the corrosivity of the mud as well as to control the losses. The results showed a lower corrosion rate, 0.0029 mm/year, using *P. farcta* material in comparison with those obtained by researchers in the previous studies.**

***Index Terms*—Corrosion, Drilling fluid, Drilling pipe, pH, Prosopis farcta.**

I. Introduction

Drilling is one of the oldest techniques in the world (Hossain and Al-Majed, 2005), it can be used to unlock crude oil and natural gas reserves (Hossain and Islam, 2018). The drilling rig can be classified to six systems, circulating is one of the main systems used to circulate drilling fluid (mud) down through the drill string and up the annulus, carrying the cuttings from the face of the bit to surface (Heriot Watt, 2005). The drilling fluid (mud) pumped from the tanks to the drill pipe, then to the bit for the purpose of cooling, lubricating, and so on (Guo and Liu, 2011). Most of the problems that occur during drilling are related to the type and the composition of the drilling fluid, so the appropriate selection of drilling mud (type and composition) leads to the success of the drilling process. One of the technical problems that the drilling fluid cause is corrosion of the drilling pipes, Fig. 1. The types of corrosion attack the drill pipes are erosion, uniform, localized, and microbial corrosion Fig. 1. The main consequences of the corrosion in drilling pipes are drilling efficiency reduction, equipment failure, and safety hazards. The value of pH of the mud is playing an important role to control the uniform and localized corrosion. Many researchers in the field of drilling engineering were investigated different methods to obtain an optimum drilling fluid with acceptable pH value to control the corrosion in drilling pipes. Adebowale and Raji (2015) investigated the use of banana peel ash as an alternative additive to enhance pH to control corrosion. Okorie (2009) employed two local additives “Trona” powder and burnt palm powder as pH modifiers to increase the level from 7.0 to 13.0. The burnt palm head sponge powder gives a high mud pH impartation. There are some drilling fluid additives which seriously promote corrosion. The temperature and composition of make-up water can be a serious source of corrosion (Murray and Holman, 1967). This paper investigates the addition of a natural and environmentally friendly additive to the drilling fluid to reduce the corrosion in drilling pipes.

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II. Materials and Method

A. Materials

Drilling fluid

Drilling fluid refers to the circulating continuum substance use to perform a successful drilling process with lowest cost (Azar and Samuel, 2007). They are divided to two general types: Water-based drilling muds (WBMs) and oil-based drilling muds (OBMs). Water based drilling fluid is the corrosive and its widely used in drilling purposes. Liquid part of the mud can be select based on the formation type (Fink, 2015). The properties of a drilling fluid can be analyzed by its physical and chemical attributes. The major properties of the fluid should be measured and reported daily

Fig. 1. Drilling Pipes.

in the drilling daily report (Rabia, 2002). The main properties involving in corrosion of drilling pipe are the pH of the drilling fluid. The pH, or hydrogen ion concentration, is a measure of the relative acidity or alkalinity. Except for salt muds, the pH of mud is seldom below 7 (Azar and Samuel, 2007). High downhole temperature will lead to the decrease of pH value, this will make the performance of drilling fluid deteriorate. It is of importance to monitor and keep the pH high as a decrease below the value of 7 will increase the acidity of the mud thereby aiding to increase the corrosion rate of down hole equipment's (Peretomode and Peretomode, 2021). In general, the pH of mud falls between 8 and 10.5, depending on the mud type (Okorie, 2009).

Prosopis farcta (PF)

The PF is a common plant Fig. 2 germinating in wide range area. It is a below ground tree. It looks like a shrub with a height of 20–100 cm (in rare cases up to 4 m high). PF is a small, pricking flower, and is found in Algeria, Egypt, Tunisia, Iran, Iraq, and Kazakhstan (Qasem, 2007). The shrubs grow noticeably in the warm summer months. The mesquite can survive difficult weather and soil conditions (including saline soil), but dislikes shadows (Patil, 2022). The chemical composition of the PF beans has been determined by Omidi, Ansari Nik, and Ghazaghi (2012) as shown in Table I. The PF has a fibrous nature which is a type of the most common additives to drilling fluid.

Corrosion coupon

Corrosion coupons are usually used to measure the corrosion rate within a procedure in laboratories. In this study, corrosion coupons were prepared using the carbon steel API 5LX70 (Ismail, et al., 2014), the same material uses in manufacturing drilling pipes. The coupon size (30 mm × 12.5 mm × 1.25 mm) polished and cleaned with sand paper grade 60, 320, and 600 then degreased by ethanol, Fig. 3. Finally, the coupons dried, weighted, and the surface finish were recorded.

B. Methodology

The drilling fluid prepared at the laboratory according to the API standards. Additives (beans of PF) were collected from the outskirts of Koya district in Erbil province, Iraq, during the summer of 2021. The PF beans then being dried in sun light and then being powdered by gridding. Moreover, to determine the effect of PF particle size distribution, the powdered PF beans were divided into three different sizes, fine, medium, and coarse through the use of API standard mesh sieves. Devices and measuring tools used throughout the experimental work. Corrosion coupon strips were used to measure the corrosion rate for different drilling.

Fig. 2. *Prosopis farcta*.

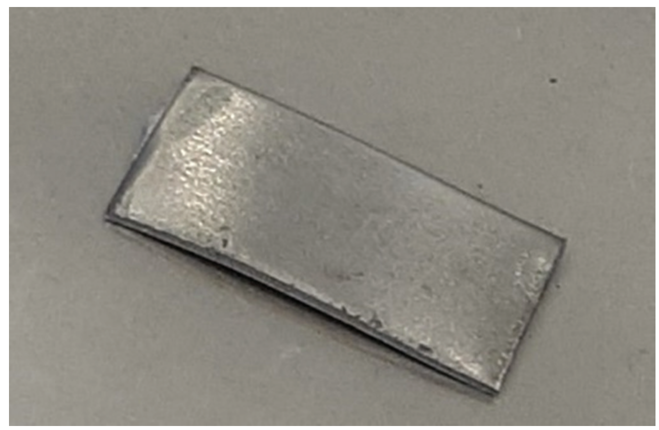

Fig. 3. Coupon Sample.

TABLE I
Chemical Composition of *Prosopis farcta* Beans (Omidi, Ansari Nik, and Ghazaghi, 2012)

Variable	Amount (%)
Dry matter	97.45±0.18
Ash	3.15±0.20
Crude protein	9.97±0.45
Neutral detergent fiber	40.37±0.36
Acid detergent fiber	34.37±0.51
Crude fat	±0.09

III. Experimental Work

A. Mud Sample Preparation

The reference mud RM with composition as shown in Table II has been prepared according to the API-SPEC-

13A-2010 standards. Once the mud is prepared, its pH and rheological properties were measured and recorded. The properties of the RM are summarized in Table III.

Different sizes (fine, medium, and coarse) of the prepared PF beans were added separately to the reference mud to find out the effect of the size distribution on drilling fluid. Moreover, for determining the effect of the PF concentration, various concentration of each size of the PF was added separately. The PF concentration was selected on the base of pounds of the PF per barrel of the drilling mud (ppb), the selected PF concentrations started from 5 ppb to 25 ppb with increment of 5 ppb. At the end, a blend of all PF sizes was added into the RM and various tests were conducted. The mud weight was conducted utilizing the mud balance.

B. Corrosion Test

pH

To determine the effect of the developed mud (with PF additive), various sizes and concentrations of the PF were added into the mud and the pH of each prepared mud has been measured using the pH meter as shown in Fig. 4. The pH of mud with most commercial additives such as $CaCO_3$ was measured also. As it is known that the best pH range for drilling mud is 8.5–10.5 (Asrar, 2010) but it was observed that the reference mud has pH of 12, higher than the recommended.

Surface morphology observation

Thermal imaging camera was used to determine any changes may occur to the surface of coupon. The property of the surface of the coupon was recorded before hanged in the mud and after. Infrared signal from the camera penetrates the surface of the coupon, any changes to the surface can be clearly observed. Fig. 5 shows the thermal and digital image of the coupon before insertion to the mud whilst Fig. 6 shows the surface images after used in the mud.

Corrosion rate measurement

Corrosion coupons are a simple yet effective tool for providing a quantitative estimation of corrosion rates occurring in an operating system. They also provide a visual indication of the type of corrosion which may be occurring in the monitored system. The drill-pipe coupons were suspended in the drilling mud at each specific temperature and high pressure set for at least 20 hours. The autoclave then after which was cooled at a rate of 2°C/min to room temperature and the samples removed. At the end of each 20-h test, the samples were collected and thoroughly cleaned in a 10% HCl solution and rinsed in deionized water, and kept in a dry and well-sealed container immediately after collection before analysis (Mohammed, et al., 2021).

Oil-well steel coupon (N-80 steel) specimen of specification 30 × 12.5 × 1.25 mm was used for the corrosion tests using the weight loss method. The weight of the coupon was

TABLE II
Composition of Reference Mud (RM)

Materials	Bentonite (gm)	Water (mL)	NaOH (gm)
Concentration	80	1400	2

TABLE III
Properties of Reference Mud (RM)

Density	8.61	ppg
Plastic viscosity	4	cp
Yield point	15.1	Ib/100 ft2
Gel strength (10 s)	9.3	Ib/100 ft2
Gel strength (10 min)	11.1	Ib/100 ft2
pH	12	---

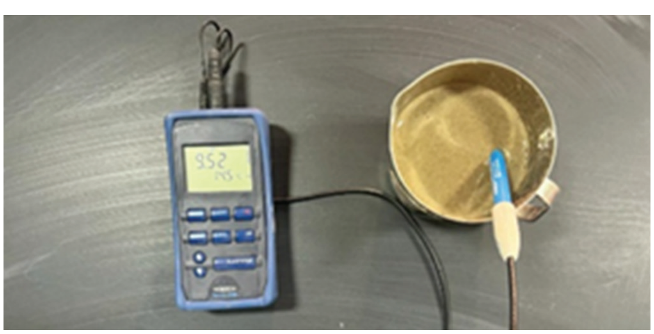

Fig. 4. pH Meter.

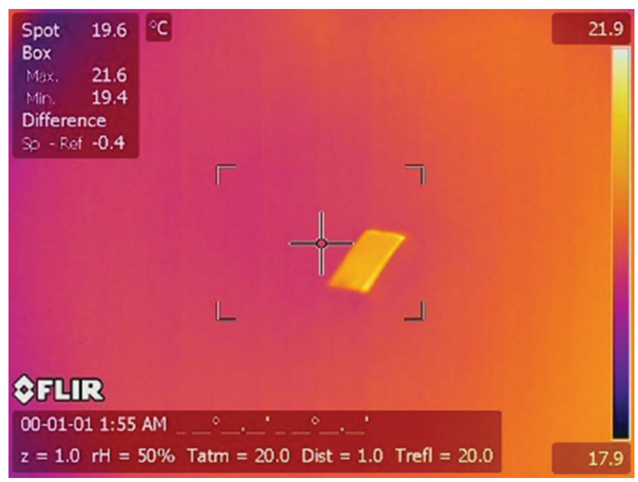

Fig. 5. Coupon surface before use in the mud.

Fig. 6. Coupon surface after use in the mud.

determined before it was subjected to the weight loss test Fig. 7a. The weight of the coupon was 3.355 g, in addition the surface of the coupon was recorded using thermal imaging camera Fig. 5. The tests were carried out using the high pressure, high temperature (HPHT) filter press machine Fig. 8. The HPHT dynamic filter press has overcome the limits of various traditional static filter presses and allows obtaining a new kind of results, much more representative of the borehole conditions. It can be used to measure the filtration property of drilling fluids and cement slurry accurately and safely under static and dynamic conditions. The usage of the instrument can provide the reliable data for realizing scientific, rapid, high quality, and safe drilling (Jaf, Razzaq and Ali, 2023). Then, an oil-well steel coupon which had been treated according to the API specifications (API RP-13 B-1) was hung in the mud (Jaf, Razzaq and Ali, 2023). When the pressure and temperature were stabilized. After 20 h from running the machine with the coupon inside, it is removed. Before the analysis, the coupons were scrubbed with a bristle brush to remove the corrosion products; and then kept in a dry and well-sealed container immediately after collection before analysis (Mohammed, et al., 2021). The corrosion products were carefully observed, the weight of the coupons was measured and recorded, the new weight of the coupon was 3.353 g, Fig. 7b.

Fig. 7. (a) Coupon on the weight scale before use. (b) Coupon on the weight scale after use.


Fig. 8. High Pressure High Temperature Filter Press.

IV. Theoretical Work

The corrosion rates were calculated for each weight loss using the relation as shown in the Eq. (1) (Aremu, et al., 2017). This correlation has been widely used in the previous similar studies.

$$CPR = \frac{87.6\ W}{\rho\, At} \quad (1)$$

Where: CPR = Corrosion penetration rate in (mm/year); W = Mass loss after the test (g); ρ = density of the specimen (g/cm^3); t = Time of exposure (h); and A = Area of exposure (cm^2). The density of iron is equal to 7.85 g/cm^3.

$$W(\%) = (W_i - W_a)*100 \quad (2)$$

Where W_i is the initial mass (g) before corrosion, W_a is the mass after corrosion.

V. Results and Discussion

The pH for the reference mud RM was 12, this value is outside the desirable range. The widely used additive $CaCO_3$ was added to RM, the reduction of pH by $CaCO_3$ addition was not enough since the pHs were still above the optimum range. The present study additive PF then added to the RM. Best pH reduction could be achieved through the addition of various sizes and concentrations of PF, particularly the addition of 15 ppb of the fine sized PF (Fig. 9), which gives a mud with 9.5 pH. As a result, all PF sizes have the potential to be used as pH reducers, especially at high concentrations, suggesting their applicability in being used as a pH control agent. Moreover, for any additive to be added as a lost control material (LCM) should keep the pH of the mud within the optimum range, the usage of 15 ppb of fine sized PF will keep the value of the pH in that range.

As for corrosion rate, the coupon weight lost was 0.002 g in 20 h, the results obtained a corrosion rate of 0.0029 mm/year in drill pipes using the PF additive. This result is compared with the corrosion rate in the previous studies Fig. 10. Only one of the studies showed a corrosion rate lower than what is obtained in the present study.


Fig. 9. Fine size of *Prosopis farcta* additive.

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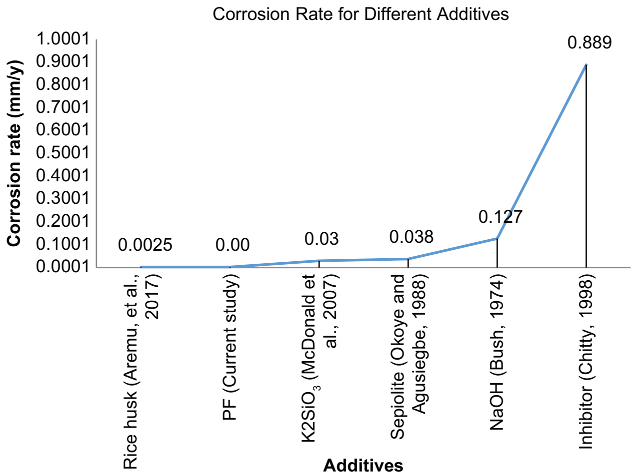

Fig. 10. Corrosion rate with *Prosopis farcta* in comparison with other additives.

VI. Conclusion

The research work is carried out to show the possibility of reducing the corrosivity of the drilling fluid and its effect on drill pipes. The additive used in this work reduced the corrosion rate in drill pipes. It is concluded that the PF is a good additive can be added to the drilling mud to reduce; it is corrosivity and the best size and concentration were fine sized and 15 ppb concentration. Furthermore, in addition to the overcome of the PF additive on the previous studies materials in term of pH control, it overcomes them in term of cost, availability, and environmentally as well. However, a blend of two or more sizes of the PF additive has not considered and recommended for future studies.

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