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Study on Corrosion Behavior of HLE steel solicited in $(CO_2)_{\%}$ Selective Physicochemical medium

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Abstract
In petroleum industry, conventional and unconventional reservoirs have to be controlled in order to decrease the effect of hazardous components on Oil and Gas facilities, as well as equipment completion, production tubing, transport pipeline, and storage tank. Herein, the study of real state of this effect using empirical method to determine sensible parameters that have huge influence on materials degradation. Therefore, the corrosion rate is estimated by application of a theoretical calculation based on physicochemical parameters and meta-field parameters, such as medium acidity, CO_2 partial pressure, thermodynamics parameters (P, T), and mechanical proprieties of studied materials. Moreover, scenarios application permitted us to assess corrosion risk.

Keywords: Steel, Hazardous components, Oil and Gas facilities, CO_2, Corrosion risk.

Nomenclature
SEM scanning electron microscopy
EDS electron dispersed scanning
HLE high limit elasticity
K_t temperature-related constant
f(pH) factor depending on pH of the solution
fCO_2 fugacity
CO_2 carbon dioxide
S shear stress
α constant
H_2S Hydrogen sulfide
Cl- chloride ion.
R corrosion rate (mm/y)
pH hydrogen potential

1. Introduction
The presence of hazardous components such as (CO_2, H_2S, Cl- ...) in gas and oil field can provide unwanted phenomena such as worsening of materials proprieties by deterioration phenomenon. The water influx and variation of aquifer level affect directly gas or oil production by pressure depletion. Besides, the breakthrough water or conning water affects also well potential, occurs in dissolution of hazardous gas components in acid medium, and then affect resistance of completion resistance and facilities.

The interaction between CO_2 and water forms carbonate ions which results after reaction solid iron carbonate $FeCO_3$. Hence, it is good parameter for controlling corrosion phenomenon in collected network and process facilities. The gas composition impurities have an influence on carbon steel corrosion [6]. Study of the interaction between metals and fluids is one of the preventive methods to find reliable solutions for degradation phenomenon in presence of aggressive medium [1]. Several equipment in petroleum industry are basically manufactured using HLE steel (high limit elasticity) [1]. Thus, the protection of steel structure such as API 5LX60 against NS_4 Simulated Soil is proved by using polyphosphates ions as corrosion inhibitors [2]. The Sulphide molecules can decrease the corrosion rate of the API 5L X52 steel sample in a CO_2 environment [3]. The assessment of corrosion rate of three states of steel affected by thermal choc and solicited in aggressive medium using different concentrations of NaCl , which simulated corrosion phenomenon in petroleum industry, is reported in the previous study [1].
The remove general and localized corrosion of carbon steel in supercritical CO_2 phase can be accelerated by increasing ofthe amount of H_2S [7]. Calcium carbonate reduces the corrosion rate of low carbon steel corrosion in saline CO_2 at high-pressure environment [8]. The growing CO_2 pressure had animportant effect the oxidation rate [9]. The degree of turbulence of gas flow through steel pipelines plays a major role in increasing emphasis in the corrosion process associated with carbon dioxide (CO_2) [10]. The standard testing and expressions for corrosion have been reported in [10-11-12].

2. Material characterization

The Chemical composition of studied material, $C_{0.12\%}Mn_{1.02\%}Si_{0.29\%}$ Steel [1] was identified by using EDS; it is showndemonstrated in histogram given in figure 1 (a). The microstructures were carried out using SEM [1], where figure 1(b , c) shows states of texture.

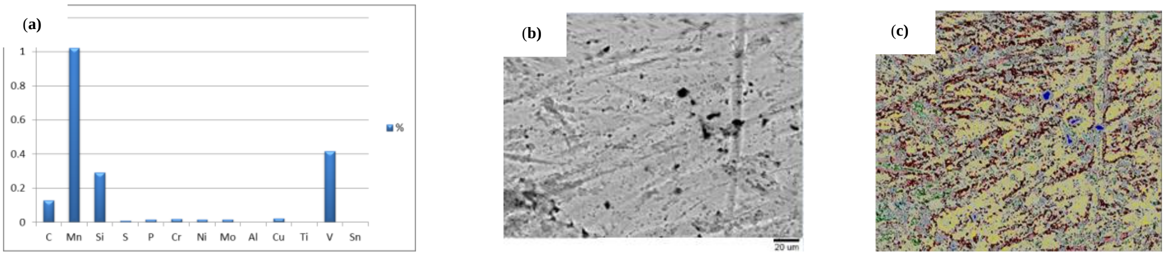

Figure 1: (a) : chemical composition of HLE steel; SEM fractographs of Steel (b): map 20um, (c): map 20um

3. Method and model

The prediction of the corrosion rate of HLE steel in (CO_2)% selective physicochemical medium is based on Norsok model. The Corrosion rate is determined by including meta-field parameters as Temperature effect, Pressure, diameter size of flow line, hydrogen potential, liquid velocity and fraction molar of CO_2.
The Norsok model is based on empirical equations (detailed in) [4,5] to predict corrosion rate in mm/year. In our case, this model is used as a proxy for multi scenario study and to determine sensitivity for each physical and chemical parameter that affect corrosion rate (given by) equation (1).

$$\mathbf{Rc_{mm/y}} = \begin{cases} k_t * fCO_2^{0.62} * (S/19)^{0.146+0.0324\log(fCO2)} * f(pH) \ , 20\ C° \leq T \leq 150C° \\ k_t * fCO_2^{0.36} * (S/19)^{0.146+0.0324\log(fCO2)} * f(pH) \ , T=15C° \\ k_t * fCO_2^{0.62} \ f(pH) \ , T=5C° \end{cases} \quad (1)$$

4. Results and discussion

The effect of medium aggressiveness on corrosion rate with different scenarios are shown in figures (2, 3, 4, 5 ,6 and 7). Figures 2 and 3 describe the variation of hydrogen potential (pH) from standard medium (pH=6) to acid (pH=3.5) at low value of CO_2%. Each value of corrosion rate is coupled by two variable parameters (Temperature and pH).

The derivation of corrosion behavior in this state starts from 293K as shown in figure 3. This phenomenon is explained by metal depletion against aggressive component; it is governed by complete reaction that can be anodic, cathodic or mixed. The general law, that can model weight loss or transfer from metal matrix, is Fick's laws of diffusion and chemical kinetic.

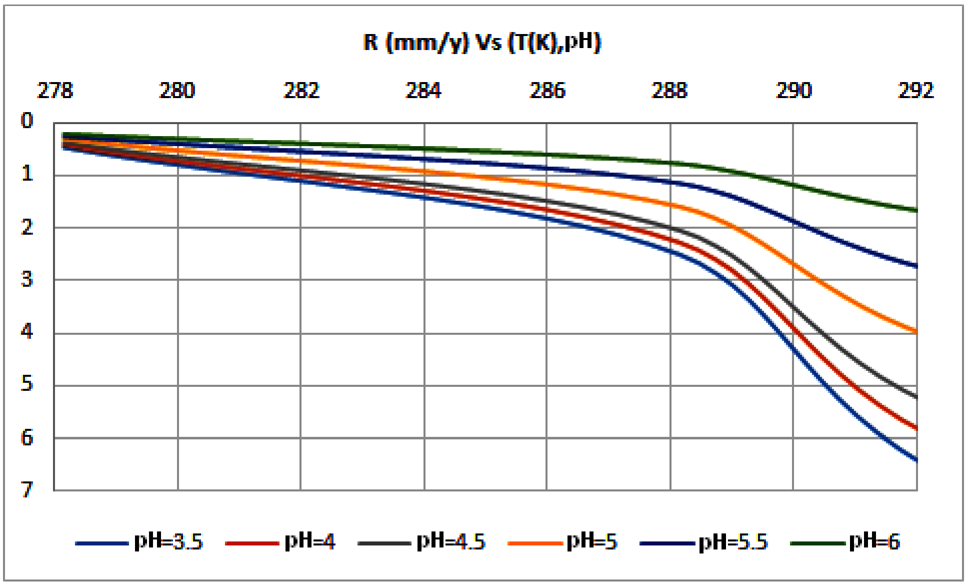

Figure 2: Effect of variation of hydrogen potential from standard medium (pH=6) to acid (pH=3.5) at low value of CO_2 % for temperature range 278K-292K.

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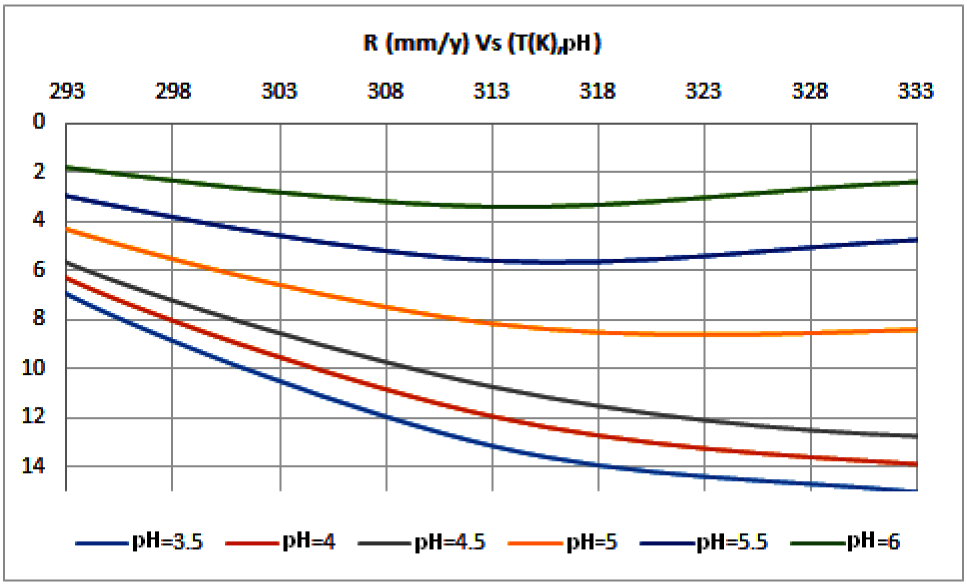

Figure 3: Effect of variation of hydrogen potential from standard medium (pH=6) to acid (pH=3.5) at low value of CO_2 % for temperatures range 293K to 333K

In Figure 3, the corrosion rate changes as a function of pH and temperature, for each temperature value at low value of CO_2 % there is increasing an increase in corrosion rate when pH decreases.
This phenomenon is explained by temperature effect and H+ concentration on chemical potential. In this case, the variation in hydrogen potential is governed by changing in thermal energy (temperature multiplied by Boltzmann constant).

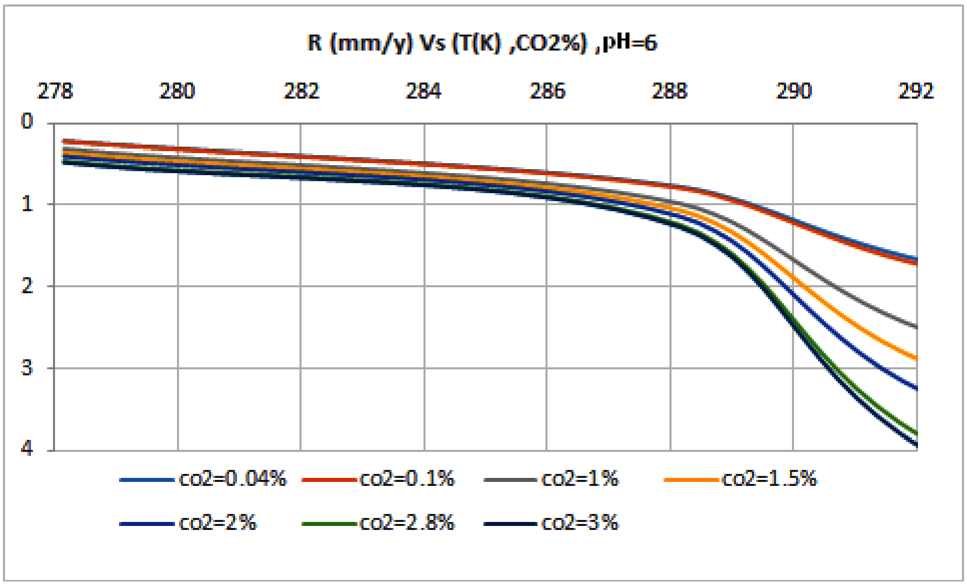

Figure 4: Effect of variation of CO_2% and temperatures at pH=6 for temperature range 278K-292K.

Figures 4, 5, 6 and 7 show corrosion rate with variation of temperature and proportion of CO_2 . This phenomenon is governed by several chemical reactions such as dissolution of Fe by evolution of hydrogen which is given by equation (2).

$$CO_2 + H_2O + Fe \longrightarrow FeCO_3 + H_2 \quad (2)$$

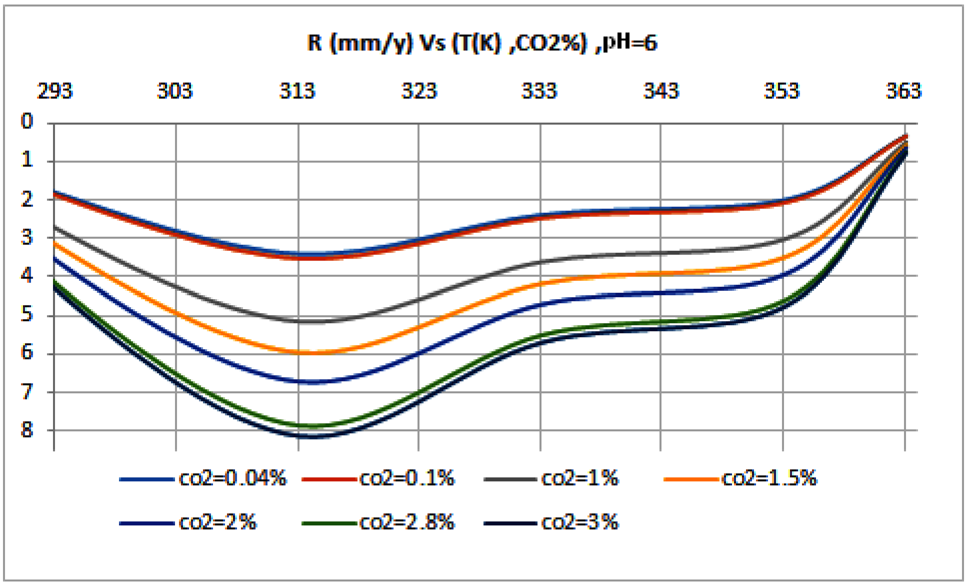

Figure 5: Effect of variation of CO_2% and temperatures at pH=6 for temperature range 293K-333K.

At normal concentration of hydrogen potential, the corrosion behavior of steel changes moderately when temperature and density of hazardous materials increases.

Hence, the decreases in potential hydrogen increase corrosion rate. Then, the temperature variation contributes directly in depletion of steel. Both parameters accelerate Weight loss or specimens transfer from base metal to aggressive medium.

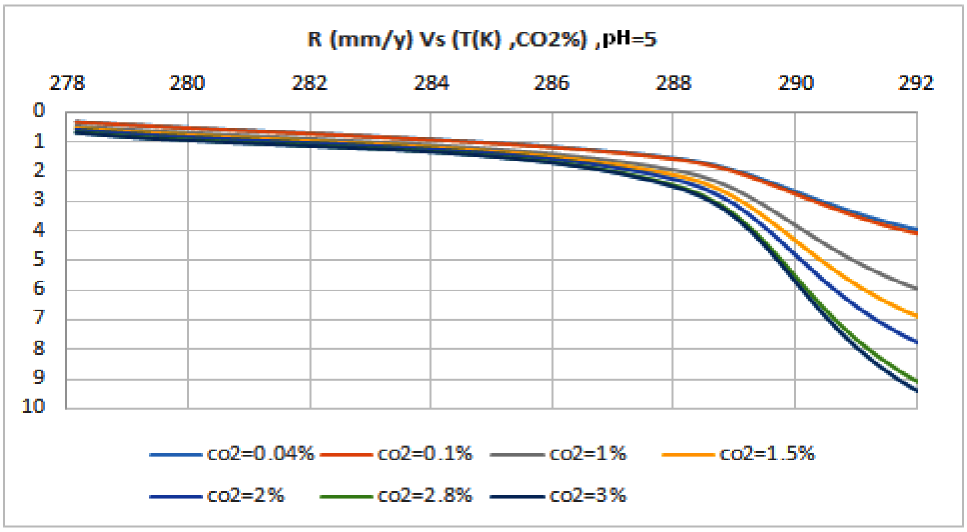

Figure 6: Effect of variation of CO_2% and temperatures at pH=5 for temperature range of 278K-292K.

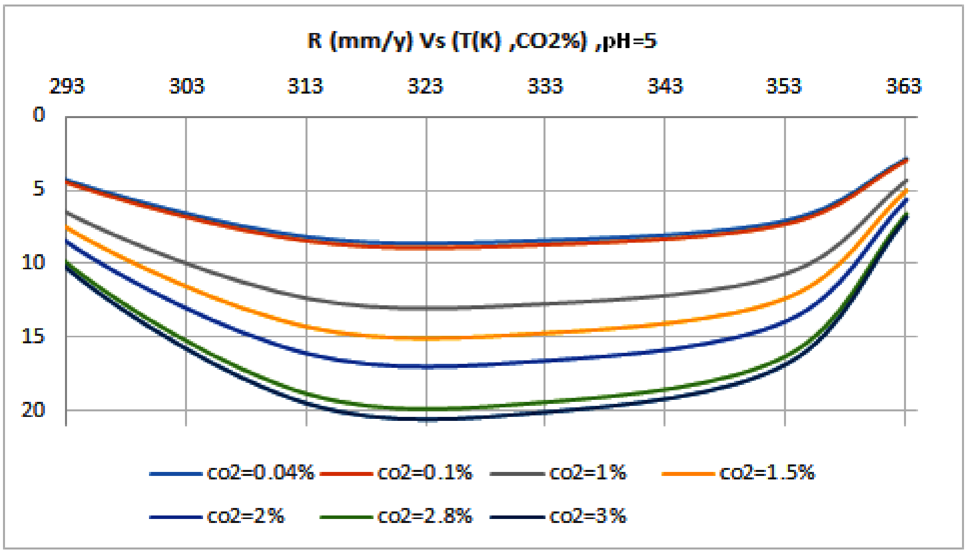

Figure 7: Effect of variation of CO2 % and temperatures at pH=5 from 293K to 373K.

This electro reduction of CO_2 and its interaction with alloys elements of steel is very important when water cut (brine water) takes place in gas canalization.

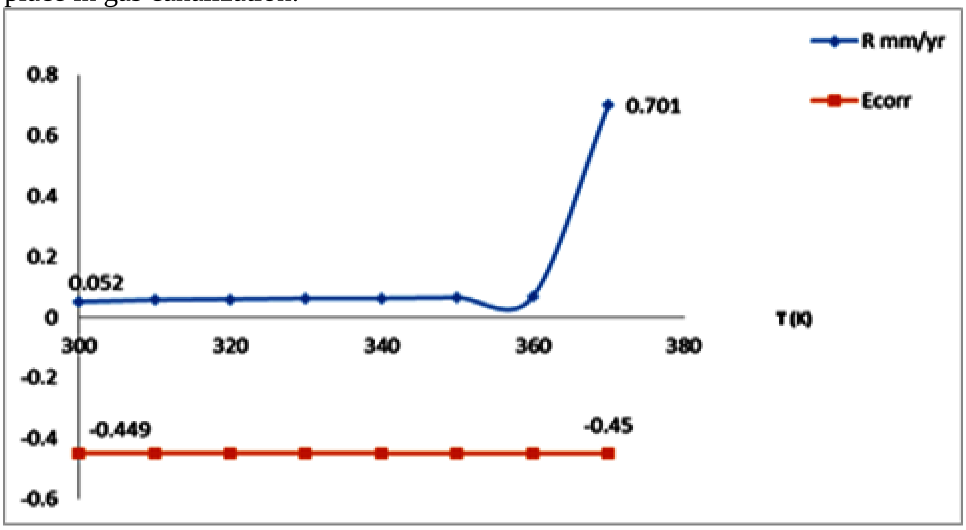

Figure 8: Corrosion rate vs temperature (NaCl medium) [1]

Figure 8 shows the influence degrees of aggressive medium based on NaCl. Wherein, the CO_2 hazardous component has a strong effect on corrosion resistance of steel compared with its behavior in NaCl medium [1].

Conclusions

- The concentration of CO_2 increases itsfugacity regarding to the total pressure and medium temperature;
- The increasing medium acidity is a result of hydrogen's potential variation, which has a direct relationship with nature of brine water and CO_2 concentration;
- The increasing potential of hydrogen at same CO_2 concentration affects corrosion rate;
- The increasing CO_2 concentration at same potential of hydrogen affects also corrosion resistance of steel;
- The increasing CO_2 concentration at various potentials of hydrogen affects strongly corrosion resistance of steel;
- The temperature has an influence on stabilization interaction of corrosion phenomenon;

It is recommended, in gas and oil industry, to control variation or influx of dioxide carbon and all hazardous materials periodically by applying sampling technics or measuring directly its partials pressure in canalization by gaging. Selection of the right type of steel in gas industry is a preventive solution against aggressive materials. In our casestudy, the corrosion resistance of steel can be achieved by transition elements that have great affinity with Fe.

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