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Effect of Corrosion on Hydrocarbon Pipelines

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***Abstract*—**The demand of hydrocarbons has increased the construction of pipelines and the protection of the physical and mechanical integrity of the already existing infrastructure. Corrosion is the main reason of failures in the pipeline and it is mostly produced by acid ($HCOOCH_3$). In this basis, a CFD code was used, in order to study the corrosion of internal wall of hydrocarbons pipeline. In this situation, the corrosion phenomenon shows a growing deposit, which causes defect damages (welding or fabrication) at diverse positions along the pipeline. The solution of the pipeline corrosion is based on the diminution of the Naphthenic acid.

***Keywords*—**Pipeline, corrosion, Naphthenic acid (NA), CFD.

I. INTRODUCTION

THE universal demand of energy has increased the hydrocarbon production in the world. Consequently, it is essential to construct new infrastructure. Corrosion is generally the common reason of damages in the hydrocarbon industry [1]. In the industry, the use of pipelines to transport hydrocarbon exceeding long distances has been extensive. Many of the difficulties are related to the paraffin crystals and construction gel corresponding to the structure of the crude oil rheological features [2]. Pipeline corrosion is a more difficult phenomenon that happens due to the instantaneous actions of some rheogical behavior of the crude oil. Some of these mechanisms occurring in exchangers of crude distillation units are deposition of FeCOOH, and corrosion products, chemical reaction fouling and sedimentation [3]. The complex rheological models are hypothetical more perfect in predicting the behavior of drilling fluids than the two factor models that are infinitely accepted [4]. The difficulty of corrosion based to naphthenic acids is motionless a demand mark in the material science program. The corrosion by the naphthenic acid occurs by the chemical reaction with sulfur limits corrosion done formation of a surface film [5]. Crude oil is best of the important raw sources for the production of energy and crude oil tankers play a strategic role in its transportation with pipeline. In this work, the naphthenic and Sulfur acids corrosion mechanism present in the oil production pipelines was studied.

The results of this study provide insight how to control the corrosion of naphthenic acid and sulfur for oil refinery enterprises [6].

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II. MATERIALS

A. Pipeline Configuration

The pipeline configuration used in this study is shown in Fig. 1, the Pipeline and restriction geometry are made of steel. The crude oil flow is generated using a pressure from a pump, which is connected to the pipeline inlet via a Station.

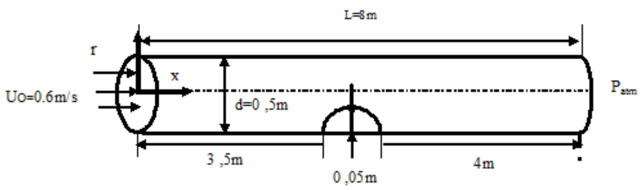

Fig. 1 The pipeline

B. Naphthenic Acid

The naphthenic acid corrosion involves the presence of hydrogen sulfide as follows [3, 4],

$$Fe + 2RCOOH \longrightarrow Fe(RCOO)2+H2 \quad (1)$$

$$Fe + H2S \longrightarrow FeS + H2 \quad (2)$$

Reaction (1) produces the oil-dissolved iron; reaction (2) inhibits dissolved iron production. Since the dissolved iron quantity will be affected by all three reactions, the Iron Powder Test can be used to verify this mechanism.

According to the sulfur compound functionality, they may: (1) inhibit, (2) assist, the naphthenic acid corrosion. In the first case, the amount of oil-dissolved iron will diminish with respect to the control experiment. The amount of sulfur in a crude oil (total sulfur) says nothing about its reactivity. For example, H_2S is very reactive toward iron, producing a FeS protective layer.

III. NUMERICAL MODELING

The Hydrocarbon was supposed to be composed of oil and Naphthenic Acids. Globally, chemical and thermo-physical properties of different crude oils vary vastly. Moreover, their temperature reliance and chemical reaction, determined by their composition, can vary remarkably.

Rheological parameters, viscosity, Density and thermal conductivity of the other constituents have a secondary role in crude oil impurity behavior. Consequently, they were considered as typical values for impurity precursors and reaction products. Though, as a part of the developed CFD code, the viscosity values of Naphthenic acids were given to be varied in a vast variety [7].

A. Model Development

A 2D calculation area was used for numerical simulation. The symmetric flow domain composed with the boundary conditions is shown in Fig. 1. The pipeline length and diameter are considered 80cm, 25cm respectively. However, the geometry was discretized using 8010 to 40058 quadrilateral cells. The selection of a very thin mesh grid in the whole radial direction was aimed at considering the capacity to predict a very thick impurity layers occurring in the very long industrial procedure times. [7] The CFD has been used for the simulation. Finite volume technique is used to discretize the controlling equations with convenient discretization structures for the case. In this one, a 3D CFD model using volume of fluid (VOF) approach to study the development of non-Newtonian fluid modeling [8].

B. Numerical Simulation

1. Meshing of the Model

The discretization of the model has been done by a GAMBIT. Density mesh is taken near nozzle inlet area, exit and near the wall of pipeline. Fig. 2 shows the meshed shape. The mesh based of 8010 to 40058 elements quadrilateral. To ensure, the result dependence on the density of the mesh, grid independence has been performed. It has been shown that the results are independent of the grids for the present set of nodes.

2. Initial Conditions

In all the simulations, the flow has been initiated from oil inlet and the pipe is initially filled with oil.

3. Inlet Boundary Condition

The oil velocity is specified at the nozzle. Thus considering uniform velocity distribution, the initial conditions are:

Length (L)= 8m, radius (r) = 0.25m, velocity (U):Ur = 0 and Uz = Uoil=0.6m/s

4. Computational fluid Dynamics

Computational fluid dynamics (CFD) solves the partial differential equations of fluidic flow, e.g., the Navier–Stokes equation which, only in special cases, has exact solutions. Numerical methods are applied such as Finite Elements Method (FEM). At the first step of the pre-processing, the geometry boundaries of the system are defined. The CFD simulations for this work were performed using the Ansys Fluent in assumption of laminar flow conditions and an incompressible liquid [7].

C. Velocity Profile

The velocity profile of the crude oil flow in the pipeline is shown in Figs. 3, 4 and 5. As it can be seen from Fig. 2, the velocity profile is almost parabolic with a mean velocity which increases with the pipeline length because of continuous fluid saturation. After a short distance from the inlet, the velocity profile is fully developed (Fig. 2). [8] We observe the maximum velocity at the center-point is 7.5 at end of the pipeline.

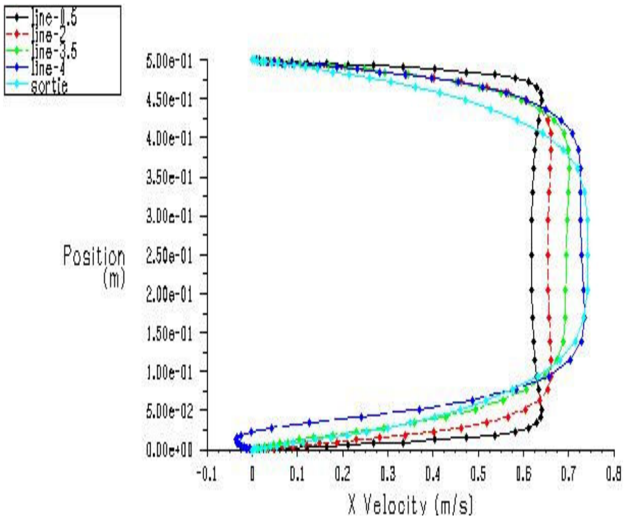

Fig. 2 Speed profile for different areas of the pipeline

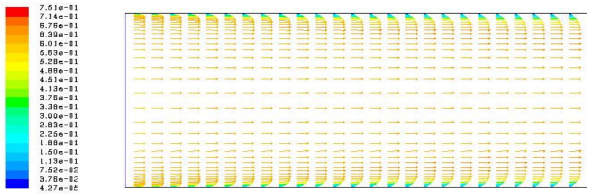

Fig. 3 distribution of velocity vectors at the entrance

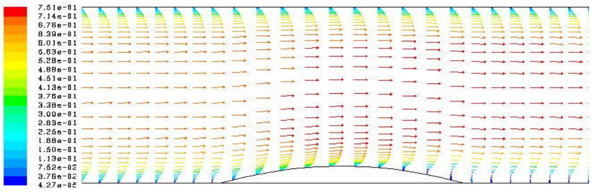

Fig. 4 Distribution of velocity vectors in the middle to (r = 0)

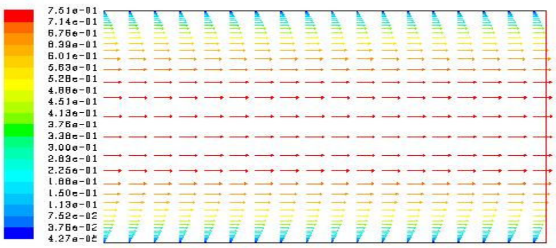

Fig. 5 Distribution of velocity vectors at the output

The simulation results exposed that decreasing feed velocity and increasing solvent velocity increase solute removal.

D. Deposit Solid of $FeCH_3COO$

Fig. 6 shows $FeCH_3COO$ deposit in core as a function of position. The deposition rate slows considerably at a later stage. However, the generally solid deposit continues to reduction monotonously of $FeCH_3COO$ by several meshes at lower wall defect pipeline. Solid deposits are measured in the non- pluggable pathways in order to observe the effect of change in flow rates during the fluid.

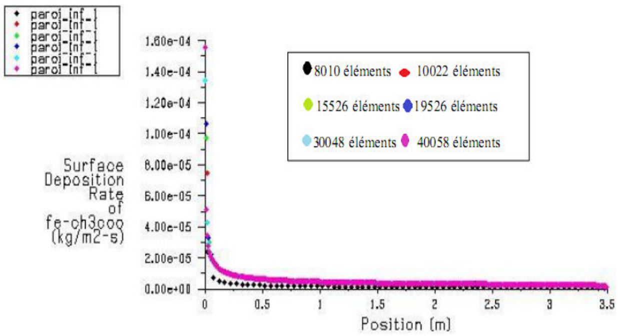

Fig. 6 Variation of the deposition rate on the surface of FeCH3COO by several meshes at lower wall

The adherence of chemical reaction products to the wall was taken into account by applying a high viscosity (Non Newtonian fluid) for the products in corrosion with the deposit solid of $FeCOOCH_3$ on the wall. The CFD model could be used to novel effective situations to examine the corrosion of the pipeline.

IV. Conclusion

The CFD model has been developed to predict crude oil corrosion behavior. Constituents of the crude oil were assumed to be oil and acid naphthenic characterized by their chemical and physical properties. The influence of compositing factor was considered to determine the probability of adhesion of reaction products to the tube wall. This factor includes the deposit metal on the wall. Simulation results indicated that the CFD model is capable of predicting corrosion in the pipeline. Hence, the developed CFD model is expected to be advantageous for evaluating crude oil corrosion under new functioning conditions.

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