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Computational Fluid Dynamics (CFD) Erosion Study for Chokes

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Abstract

Because erosion is a common cause of failure in oilfield equipment, it is beneficial to approach the issue at the product design level. The areas most susceptible to erosion occur near changes in flow direction because here the particles are most likely to deviate from the flow stream and impinge on the surface geometry. While both experimentation and computer simulation are used to study erosion, experimental testing often proves difficult to perform for specific conditions. Computational fluid dynamics (CFD) simulations are used to predict erosion rates, with flow modeling and particle tracking being key tools for predicting erosion.

This paper presents a set of curves to estimate erosion of different components of the choke as a function of choke position and flow rate using CFD. Erosion results are plotted in terms of thickness loss per time in units of mils/yr as provided for each component for varying flow rates and sand volume concentrations. Results from the study show that the erosion rates increase in a quadratic fashion with respect to the flow rate. The predicted erosion rates for various scenarios are examined and compared to experimental results.

Introduction

Solid particle erosion, a concern in any application involved with the motion of solid particles in a carrier fluid, is primarily manifest in two ways. First, the particles may have enough momentum from the mean flow to cross the flow streamlines. Generally, the exchange of momentum between the fluid and the particles is more efficient when fluid is denser and more viscous. Thus, particles traveling in low-pressure gases are more likely to deviate from the fluid streamlines and impinge the wall than particles traveling in liquids. Second, the turbulence level is normally elevated in zones where the flow is changing direction. This increased turbulence level results in increased fluctuating fluid velocities that can drive particles to the wall. Here, erosion is stochastic and difficult to predict. Additionally if the erosivity is low then it may not be possible to achieve measurable erosion in a reasonable amount of time.

A multitude of factors, such as fluid properties, flow rate, sand size and rate, material type, and geometry, affect the level of erosion severity.[1] Isolating the effect of a single factor and extrapolating the findings to a wide range of conditions proves difficult; the more than 300 erosion models existent in industry literature attest to this fact. Further, consensus does not exist as to which erosion factors are most important and deserve primary consideration. The number of variables and lack of understanding of their effect makes erosion reduction extremely difficult.

Existent erosion prediction tools were used to develop a set of curves to estimate erosion of different components of the choke as a function of choke position and flow rate.

Erosion Prediction: Approach/Methodology

The most state-of-the-art erosion prediction tool uses CFD simulations and consists of four steps: geometry creation, flow simulation, particle tracking, and application of erosion equations. If experiments can not be performed for conditions of interest, it is advisable to combine experimentation and CFD techniques. First, experimental results are obtained for conditions as close as possible to those of special interest. Then CFD is used to scale the experimental results and for comparison purposes. The difference between the experimental data and predicted results provides the scaling factor to be applied to the simulations at the conditions of interest.

This study was divided into two phases. The Phase I objective was to determine the most representative way to perform the simulations and to tune the erosion equations as applied to each component, via a scaling factor, and compare predicted results to experimental results. The Phase II objective was to apply CFD erosion prediction for the operating conditions of interest and adjust the predicted results using the scaling factors. The results from Phase II are then used to develop erosion curves as a function of choke position and flow rate.

Experimentation

The test setup is shown schematically in Fig. 1. A schematic diagram of the choke is shown in Fig. 2. The choke was tested with continuous flow of sand and water-based mud (WBM). WBM slurry with entrained sand was stored in a tank, circulated by means of a centrifugal pump (the tank was mechanically agitated to maintain sand suspension inside the tank), and enhanced with small additions of an XCD polymer. Pres-