DEVELOPMENT OF A ROD GUIDE MODEL, WHICH GENERATES A MINIMUM LEVEL OF TURBULENCE, PERFORMING CFD ANALYSIS AND HYDRODYNAMIC COMPARISONS BETWEEN DIFFERENT GUIDE DESIGNS

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ABSTRACT

Computational fluid analysis (CFD) is knowingly used for solving the partial differential equations of fluid motion by discrete approximation. A hydrodynamic analysis for different rod guide designs simulating downhole fluid conditions was made using the aforementioned method. A particular turbulence kinetic energy graphic for each guide sample was generated and compared to each other. The results shows a significant difference between the samples and the new rod guide design with conclusive proof of a better hydrodynamic performance.

This paper will present the results using CFD analysis and actual field experience showing wear rate comparisons between the different rod guides geometries tested.

BACKGROUND

Guides have the function of avoid or minimize metal-to-metal contact between sucker rods and tubing. The actual tendency for the operators to increase production volumes, creates conditions of flow restriction caused by the guides and this condition generates turbulence accelerating the erosion-corrosion phenomena which in some cases may lead to premature rod failures. Using Rod Guides has proven to dramatically extend mean time between failures. Nonetheless, some operators have claimed some disadvantages when using them; flow restriction, removal of corrosion inhibitors caused by turbulence generated by the guide geometry and accelerated erosion-corrosion phenomena on rods are the most commons concerns among the users and operators.

Two of more relevant and decisive features for a guide design are their capability for handling wear and creating the less turbulence under operation. A guide without an effective erodible wear volume can lead to a premature rod or coupling failure (Figure 1) and by not having an appropriate hydrodynamic contour, once the fluid passes through, a stagnant fluid start causing corrosion and high turbulence which accelerates erosion-corrosion phenomena on the rod area at the end of the guide (Figure 2). Actual rod guides designs present only one feature of the two recently mentioned, making a guide selection criteria depending only on the less favorable condition of both.
The TenFlow design geometry was conceived for handling side loads and generate lowest fluid disruptions at the same time.

KEYWORDS

Turbulence Kinetic Energy (TKE) is the mean kinetic energy per unit mass associated with eddies in turbulent flow.

Erosion-corrosion, also known as flow-assisted corrosion. Fluid erosion occurs when liquid droplets impact metallic surface with enough force to erode either the base metal itself or the products of corrosion, that is erosion-corrosion. This phenomenon causes high rates of material loss transitioning from accelerated corrosion to a purely mechanical damage. Fontana (1986) defines erosion as the acceleration or increase in rate of deterioration or attack on a metal because of the relative movement between a corrosive fluid and the metal surface. Generally, this movement is quite rapid, and mechanical wear effects or abrasion is involved. Erosion-corrosion is characterized in appearance by grooves, gullies, waves and rounded holes and usually exhibits a directional pattern (Figure 3). The inability to maintain a protective passive film on the metal or alloy surface raises the corrosion rate.

Erodible Wear Volume is the amount of polymer from the guide outside of the coupling OD. Which is consider to wear out before to get contact between coupling and tubing (Figure 4)

To study the fluid dynamics of different flow regimes, a number of dimensionless parameters have been developed; one of the most common is the Reynolds number. In the turbulent regime, fluctuations in the mean velocity and other variables occur, and their effect needs to be incorporated into the CFD model in order to be able to provide meaningful results. This is done using a turbulence model.

It should be considered then whenever turbulence is present in a certain flow it appears to be the dominant over all other flow phenomena

Turbulence is a very complex phenomenon, which is tried to be modeled as simple as possible. In that case, a realizable k-ε model based on Reynolds Averaged Navier-Stroked (RANS), which focuses on the mechanism that affect the turbulence kinetic energy k, is used.

$$K = \tfrac{1}{2}\left(U^2 + V^2 + W^2\right)$$

$$k = \tfrac{1}{2}\left(\overline{u'^2} + \overline{v'^2} + \overline{w'^2}\right)$$

$$k(t) = K + k$$

Where,
K, is the mean kinetic energy
k, is the turbulent kinetic energy
k(t), is the instantaneous kinetic energy
u' v' and w', are the velocity fluctuations in each direction

Turbulence viscosity can be model as;

$$\nu_t \propto \vartheta \ell \propto k^{1/2}\frac{k^{3/2}}{\varepsilon} = \frac{k^2}{\varepsilon}$$

Where ε is the dissipation rate of *k*

CONSIDERATIONS AND BOUNDARY CONDITIONS

Different rod guides samples from different designs were measured; CAD models were assembled and CFD studies were performed.

For the geometric evaluation purposes same parameters and boundary conditions were considered for all samples; analysis, critic flow velocity peaks were simulated to evaluate worst conditions.

- Tubing ID: 2 7/8”
- Sucker rod diameter: 7/8”

- Strokes per minute: 7
- Stroke length: 168”
- Average velocity: 38 in/s
- Fluid: 100% liquid water + 5% initial turbulence
- Flow rate: 320 bpd
- Fluid velocity: 8.6 in/s
- Critical peak velocity: 60 in/s

As a result from modeling CFD, graphics about turbulent kinetic energy from each model were obtained (Figure 5 and Figure 6), where shows peaks of turbulence when the fluid starts contacting the guide and highest peaks at the end of the guide. This high turbulence traces may kept up to 6 inches after the guide with effects directly over the rod. These traces lead with high corrosion-erosion phenomena found in some rods (Figure 2,b/c)

Modeling of turbulence phenomena captured after guides (Figure 7), show us other effects that lead with different failures on field, and the erosion enhanced by turbulence

With the use of numerical models some others phenomena and its effects found on field and failures, were analyzed to understand them. In an interactive process of design, geometry features were improved to minimize and in some cases eliminate those effects, deriving in the improved guide TenFlow (Figure 8)

CONCLUSIONS

-Throughout the use of numerical models to solve the Navier-Strokes equations to analyze the interaction of rod guides and production fluid in beam pumping applications, we could say that an improved geometry found in the TenFlow (Figure 8) can achieve a dramatic impact in reducing flow disruption without reducing the erodible wear volume, which is the main purpose of a rod guide in order to avoid the rod / tubing contact.
-The TenFlow guide depicted unique features and outstanding performances that would extend operational running life and efficiencies during oil production. (Figure 9)
- In addition, CFD model can be used to improve another elements used in beam pumping applications where field failures are common, since such model is useful even for the simulation of the erosion phenomenon and multiphase flow

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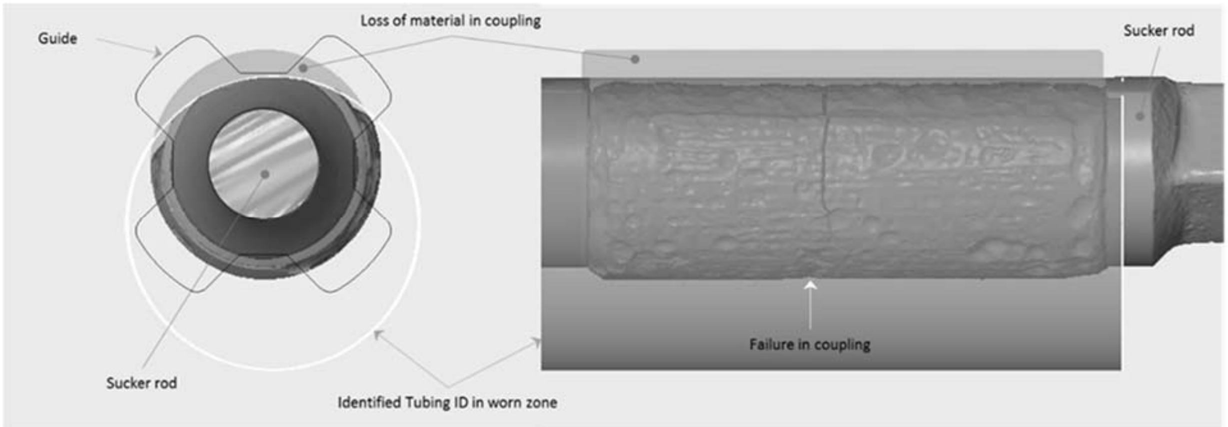

Figure 1 – Failure in worn coupling caused when EWV is worn.

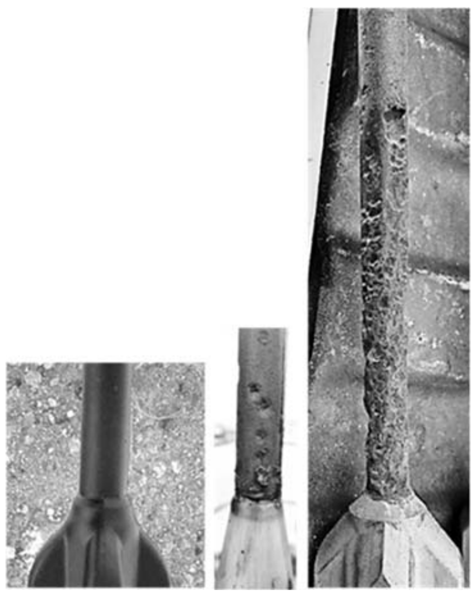

Figure 2 – Effect of turbulence after guides, a) Tenflow, b) Guide A, c) Guide B.
Guides a and b were working the same time in same well

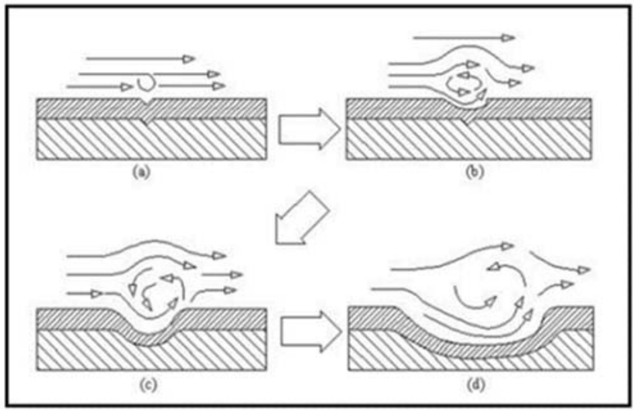

Figure 3. Erosion – corrosion process, (source: Jones, pg. 345)

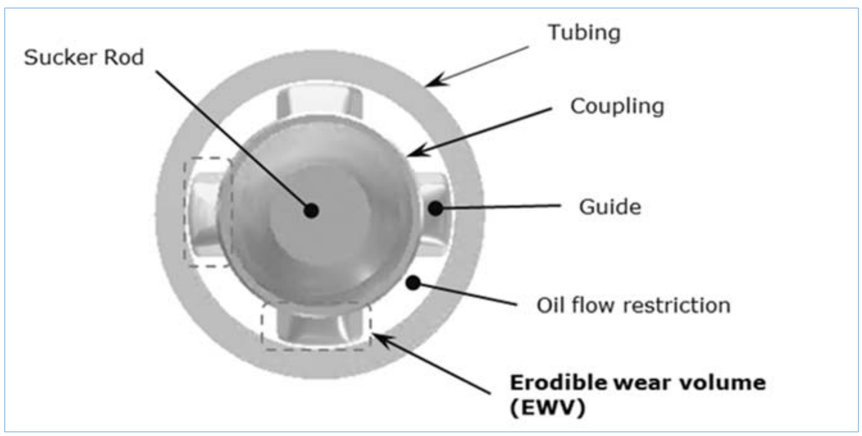

Figure 4. Erodible wear volume (EWV)

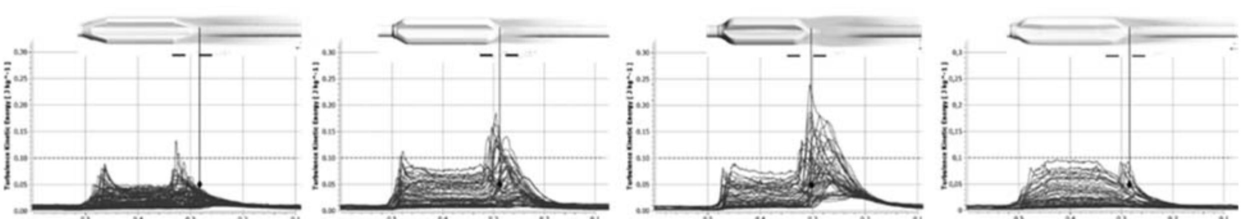

Figure 5. Turbulent kinetic energy from different guides

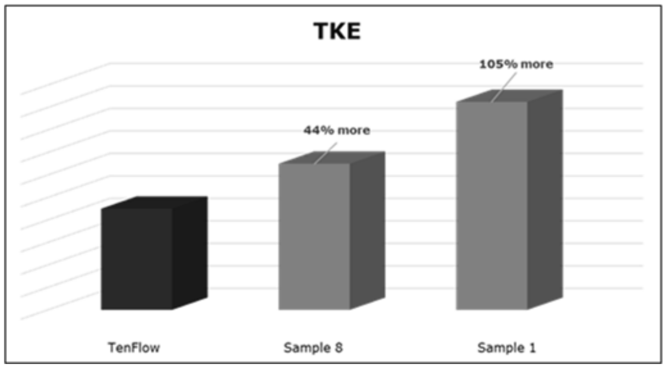

Figure 6 – TenFlow shows the less TKE for the guide tested.
All simulated samples values are between Sample 1 and Sample 8.

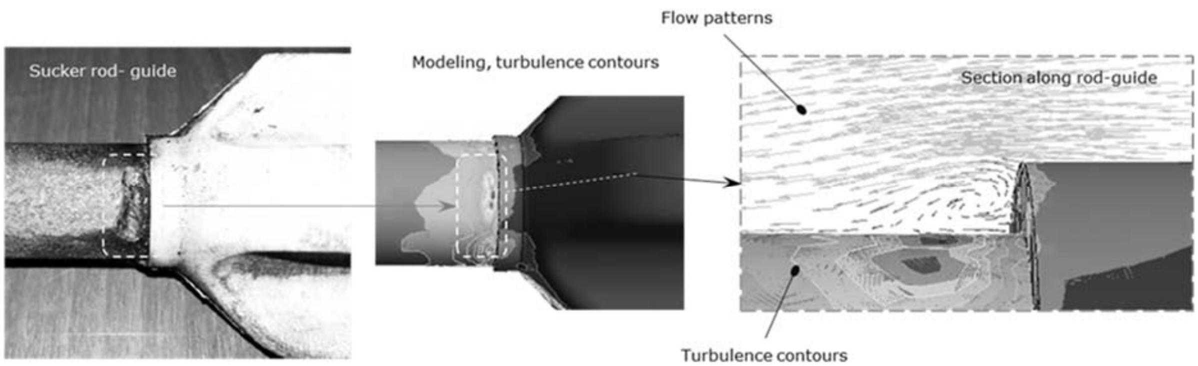

Figure 7. Turbulence contours over the rod area after guide

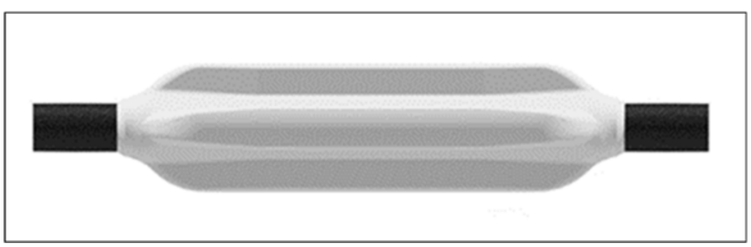

Figure 8. TenFlow rod guide design

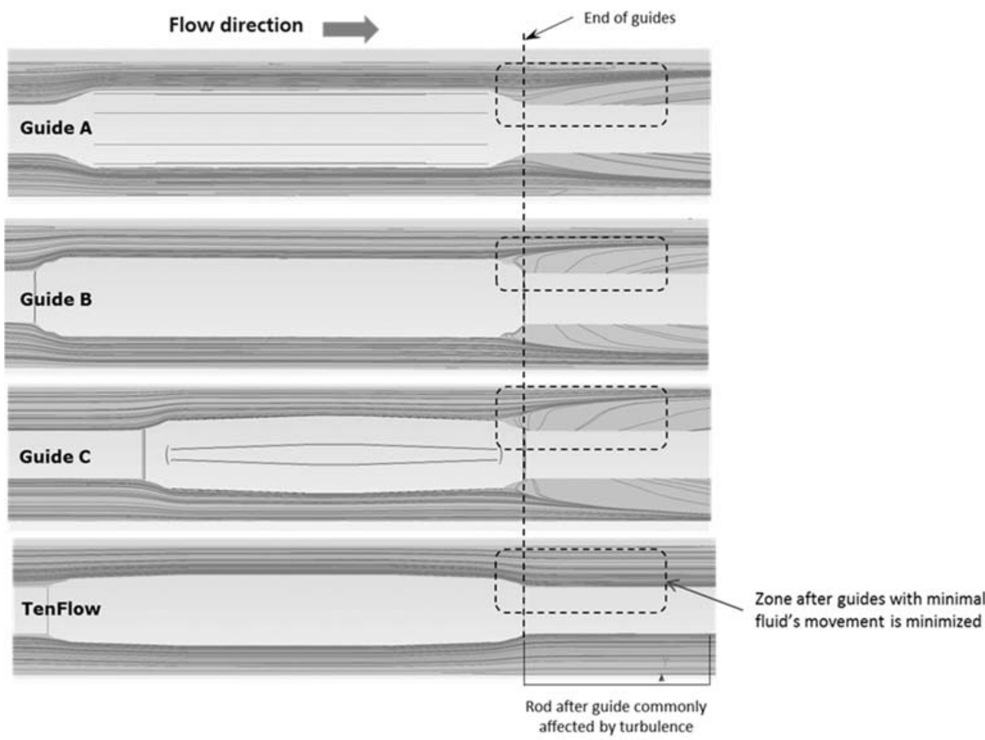

Figure 9 – TenFlow shows the less fluid disruption