Local Wall Shear Stress Gradients in Slug Flow from Current Noise Data at Microelectrodes

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The protectivity of corrosion inhibitors in flowing media is not only related to their adsorption properties on the solid surface but also to their effect on the hydrodynamic properties of the flowing medium. Thus, the effective inhibitor concentration needed to prevent flow induced localized corrosion (FILC) correlates with the flow intensity. A FILC-safe increase of the flow intensity (production rate) has to be payed with an increase of the inhibitor concentration. Thus, the performance of corrosion inhibitors under high shear conditions must be taken as the leading parameter to optimize FILC-safe flow/production rate in a given technical system under given flow regimes.

According to our model on FILC initiation [1,2], protective scales are cracked via fatiguing by repeated burst impacts of near-wall turbulence elements which are critical in size, frequency and energy. As the size of these turbulence elements ranges in the order of 50 to 1000 µm (depending on the wall shear stress and the corrosion medium) appropriate measuring tools have to be chosen to quantify the momentum exchange and wall shear stress gradients encountered during these bursts. We have developed different designs of microelectrode arrays and used them successfully to investigate and quantify electrochemically local wall shear stress gradients in different flow regimes: e.g. submerged jet impingement up to 20 m/s liquid flow velocity; moving and stationary slug flow up to Froude numbers of 14 (pipe diameter: 100 mm; superficial gas velocity: 8 m/s; superficial liquid velocity: 1.5 m/s).

The paper reports on the electrochemical quantification of local wall shear stresses under slug flow conditions. For these investigations a special data aquisition system for measuring current fluctuations down to the nanoamp range with a measuring frequency up to 200 kHz and a user friendly software for data evaluation in the time/amplitude/frequency domaines were developed. With an accuracy never obtained before it was possible to generate detailed information on mean and instantaneous wall shear stresses as well as Froude number-dependent burst frequencies in moving and stationary slugs of aqueous and 9:1 mixtures of aqueous and hydrocarbon liquids in 6:00, 3:00 and 12:00 o'clock position of the pipe at Froude numbers up to 14. It was proved with quat type model inhibitors that the burst frequencies during the slugs are significantly reduced and the amplitudes of the current fluctuations are highly damped in the presence of such inhibitors above critical concentrations. Based on this knowledge a new generation of corrosion inhibitors for application in highly turbulent and instationary flow systems can be developed.

References

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[2] G. Schmitt, C. Bosch, M. Müller, „Modelling the probability of flow induced localized corrosion from critical hydrodynamic data and fracture mechanics data of scales from CO_2 corrosion of steel", EFC-Publication No. 26, ‚Advances in Corrosion Control and Materials in Oil and Gas Production', The Institute of Materials, London, 1999, Chapter 2, pp. 24-51.