Microelectrochemical Quantification of Drag Reducing Properties of Corrosion Inhibitors

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It has been established in recent years that above critical concentrations corrosion inhibitors can reduce the skin friction caused by turbulent flowing liquids [1]. This ‚drag' reducing effect includes the interaction of shear-induced molecular aggregate structures in near-wall turbulences with adsorbates on the solid surface. A practically important consequence is that under these conditions the initiation of flow induced localized corrosion of metallic materials can be inhibited very effectively. The impinging jet method is recommended to quantify the effect of inhibitors on critical wall shear stresses by corrosion experiments and on drag reduction by electrochemically controlled mass transport measurements [2].

The paper reports on new results on drag reducing properties of corrosion inhibitors obtained by electro-chemical measurements at microelectrode arrays incorporated flush into a jet impinged surface. The microelectrode arrays were produced i) conventionally by embedding gold wires with a diameter of 50 µm in epoxy resin and ii) with silicon planar technology on Si chips yielding gold microelectrodes with different sizes down to100 μm^2 (10x10 µm). The barrier properties of the passivation layers on the chip had been previously optimized to withstand electrolyte solutions at flow velocities up to 20 m/s [2,3]. With microelectrodes positioned in different distances (2 to 5 mm) from the center of the jet, the wall shear stress distribution on the impinged surface could be measured with high lateral resolution. In the arrangement used the highest wall shear stresses were found in a distance of 3-4 mm from the center of the jet. Data obtained at a radial distance of 3 mm were used for measuring drag reducing effects of quaternary ammonium counpounds.

It was proved for the first time that instead of the hexacyanoferrate(II/III) redox system commonly used for electrochemical wall shear stress measurements under mass transfer control, also the hydrogen evolution reaction from carbonic acid in carbon dioxide containing systems can by used under conditions of diffusion control. This finding has the great advantage that drag reduction and corrosion inhibition effects can now be measured in the same system, if necessary at the same experiment. It was shown that the drag reducing efficiency of corrosion inhibitors correlates well with the corrosion inhibition activity under comparable wall shear stress conditions. The critical inhibitor concentration to exhibit significant drag reduction corresponds well with the critical micelle concentration.

Evaluation of the diffusion current density fluctuations in the highly instationary flow system of an impinging jet showed a significant reduction of the frequency range and a high amplitude damping of the current density fluctuations. Thus, electrochemical flow noise measurements become an efficient tool in screening of drag reducing properties of appropriate additives.

References

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