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Innovative monitoring tool for anaerobic Microbiologically Influenced Corrosion (MIC)

Main Author

Martin de Wacht[#1],

The Netherlands

Co-*authors*
Mirjam van Burgel[1], Jan Gerritse[2], Stefan Jansen[2], Bas van der Zaan[2].

1) KEMA Nederland B.V., P.O. Box 2029, 9704 CA Groningen, The Netherlands, www.kema.com
2) Deltares, P.O. Box 85467, 3508 AL Utrecht, The Netherlands, www.deltares.nl

Abstract

Microbiologically Influenced Corrosion (MIC) is a degradation process which occurs very locally and at high corrosion rates. The major part of the microbiological activity takes place behind a biofilm which often makes remedial actions ineffective. As a consequence the process is difficult to detect, predict and mitigate.

Another handicap is the absence of a facility which is capable of measuring the entire degradation process. This makes the MIC process, as well as factors affecting the process, difficult to monitor. Setups to monitor the individual processes such as bacterial counts are available, however the inability to cover the entire process make the results from these tests difficult to implement in industrial applications. This means that effective implementation of corrosion management solutions like RBI or ECDA is difficult once MIC is found. In the end this means that, to ensure safe operation, conservative assumptions have to be made which lead to high costs in the oil and gas industry.

In an attempt to obtain a monitoring facility for MIC, a research and development effort has been made with the intention to realize a setup which is capable to initiate, maintain and measure the entire anaerobe MIC process. In this paper the development of a monitoring tool to assess corrosion rates associated with MIC will be addressed.

The tool is a corrosion monitoring system based on the principle of an electrical resistance (ER) probe. It has been found that a probe, in which the MIC process has been artificially initiated, could maintain itself within the original environment (e.g. ground or process water) without the addition of any supplements. In this setup the metal loss of the MIC degradation process is monitored continuously and so the effects of sulphate reduction on the corrosion rate can be monitored continuously. The system has been tested in cultures of *Desulfovibrio sp.* strain G11 and groundwater samples. Microbiological activity has been linked directly to corrosion and effects of water flow and cathodic protection have been demonstrated. Currently, the system is being tested on a field location to simulate the MIC behaviour on underground pipelines.

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Introduction

Processes related to anaerobic MIC (Microbiologically Influences Corrosion) are very complex. It is present locally and corrosion rates can reach values up to millimeters per annum. The MIC process takes place behind a biofilm which effectively shields the MIC process from the mitigating factors from the environment. This combination of facts makes it difficult to combat the consequences of MIC.

Various methods are available to study the behaviour of MIC. Usually these methods are based on bacterial count or analysis and can only assess the consequences of MIC process indirectly. Several laboratory studies by coupon measurement are available as well.

For the effective implementation of corrosion management systems (e.g. RBI and ECDA) reliable monitoring methods are necessary. Numerous cases have been presented of successful implementation of these management systems, however all based on reliable data of the degradation processes which take place. For a.o. MIC these data are not available which makes the degredation process difficult to predict. MIC is considered as a process which is not-trending and therefore effective implementation of management systems is difficult.

Setup for measurement of MIC process

Based on the above mentioned arguments, it was concluded that a device was necessary which simulates the behaviour of MIC. In brief the requirements for this setup are:

1. Create corrosion by MIC
2. Maintain corrosion by MIC in the actual process medium
3. Measure the corrosion by MIC.

Ad. 1: A MIC process is initiated in a start-up procedure under laboratory conditions. The end of this start-up is when corrosion takes place in a sample of the eventual media.

Ad. 2: Corrosion needs to be confirmed in the actual industrial situation. To ascertain the distinctive influence of mitigating measures it is considered necessary to simulate the condition before and after mitigating measures have taken place.

Ad. 3: The results of the measurements have to be convincing. Discussions of results are often safety and reliability related and therefore it is a requirement that the results need to be well understood and persuasive.

Simulation of corrosion can be effectively achieved by coupon measurements. Online versions of coupons measurements are commercially available as ER-probes (electrical resistance probes). These probes measure actual metal thickness of a steel coupon sheet. Basic principle behind these probes is that thinning of a steel sheet is measured by increase of electrical resistance related to the reduction of the effective cross-section of that sheet. From the measurements the corrosion rate is calculated. Several reliable versions of ER-probes are available on the commercial market. The ER-probe used for the setup is presented in figure 1.

MIC-processes are initiated on the ER-probe in a laboratory situation. A start-up procedure is developed which ends when corrosion is measured on a specimen in an environment which closely simulates the actual industrial environment. From this situation the probe is placed in the actual industrial environment. In general corrosion by MIC continues after placement in this environment. To check that the setup is still active, the mitigating measures in the media through the probe need to be switched off at regular intervals. During these periods the setup needs to confirm metal loss by corrosion.
This method measures the thickness reduction by MIC online and the effectiveness of mitigating measures can be monitored online. Another advantage of this method is that this probe is capable the instantaneous detect the effects of incidents.

Results of the probe measurements

The above mentioned setup has been tested in a laboratory situation. Primary objective was to assess whether the setup was capable to discriminate on purely microbiological factors. For this purpose MIC was initiated during a start-up process. After this start-up was completed, the setup corroded by MIC in plain groundwater specimens. Molybdate is a medium which is well known to stop the activity of Sulphate Reducing Bacteria. When molybdate was added to the groundwater, the setup immediately reacted by a lower corrosion rate (figure 2). When the addition of molybdate stopped, the setup started corroding again within a few days. This is the proof that the corrosion rate in this setup reacts on the changes in microbiological activity.

Conclusions

During the R&D effort a setup has been realised which is capable to simulate metal loss by MIC. It is exposed to a fully developed MIC situation including the effect of biofilms. It has been proven to be capable to online measure the influence of mitigating factors from which it known that it affects microbiological activity.

In fact a MIC-probe has been realised by modification of an existing ER-probe which is capable to online monitor the effectiveness of mitigating measures against MIC in realistic industrial environments. Reliable versions of ER-probes are readily available on the commercial market and for application as a MIC-probe these ER-probes do not need further development.

This online method reacts within days which makes it capable to monitor for incidents as well.

Future work

Current R&D efforts are focussed on further perfection of this setup and realisation of a mature MIC-probe which can be applied to monitor MIC in industrial applications. One of the issues to deal with is to prove that relevant MIC-species are present on the MIC-probe. At present the MIC-probe is successfully applied in an underground field setup up with the objective to assess the factors which affect corrosion of underground objects. The first versions of MIC-probes have been installed in industrial environments as well. It is expected that more projects will commence soon and that the MIC-probe can count on confidence to be applied in industrial installations as a reliable method for monitoring the effectiveness of MIC mitigating measures.

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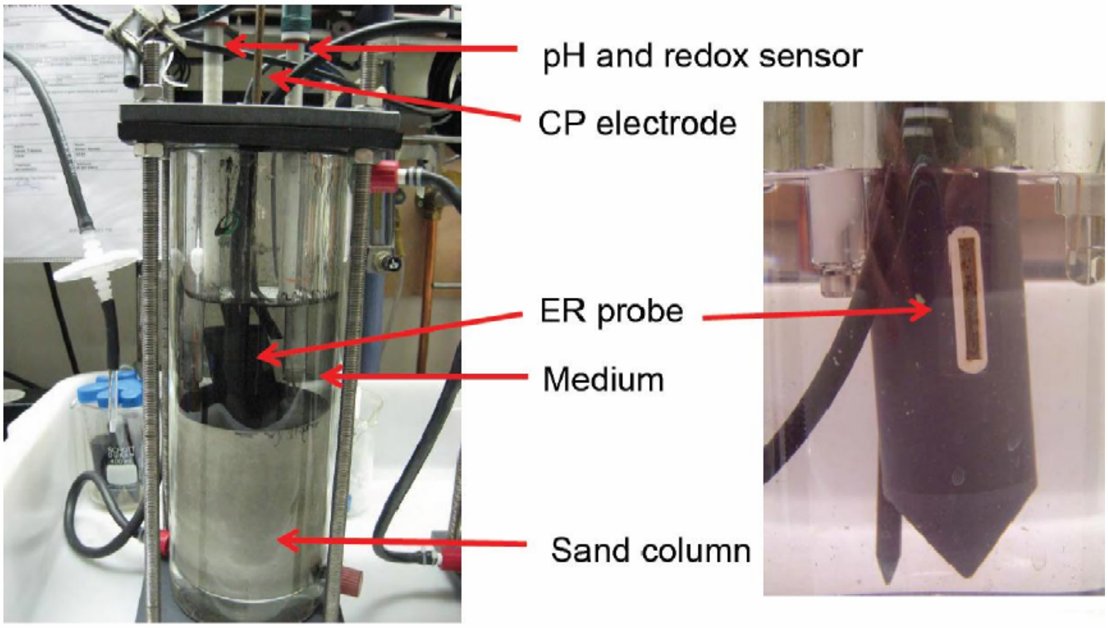

Figure 1 Overview of the setup for measurement of metal loss by MIC.

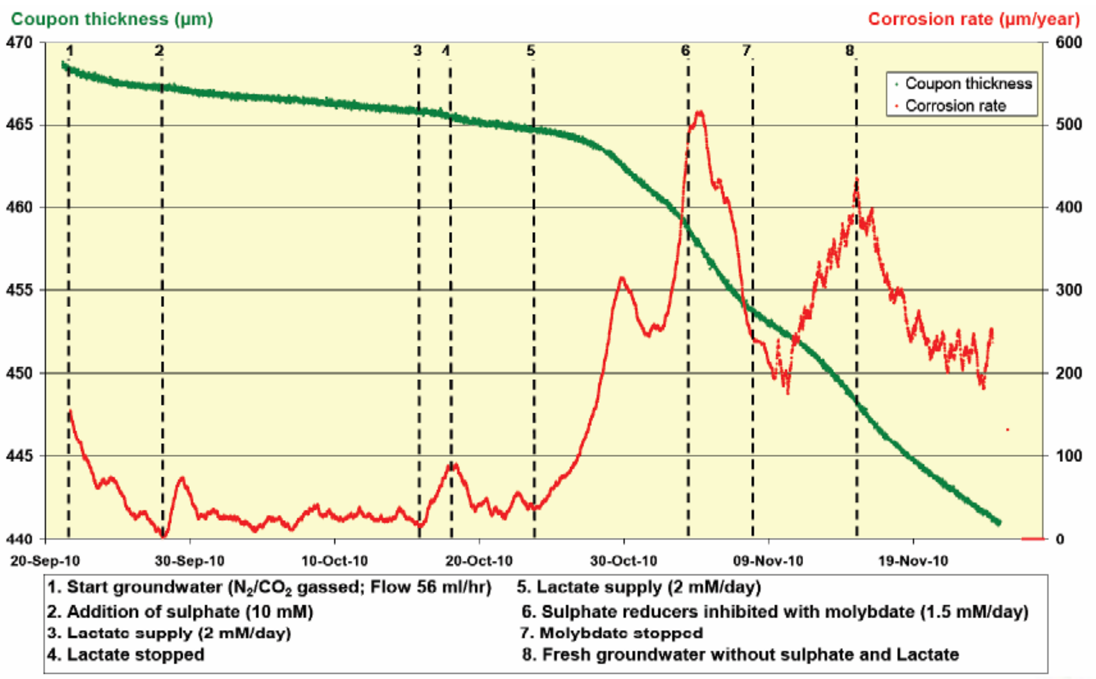

Figure 2 A graph representing the measured metal loss of a coupon and the calculated corrosion rate. The effect of addition of molybdate (point 6) and subsequently stopping of it (point 7) is evident.