A method of selection of bioreactor material based on microbial influenced corrosion

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Summary

In this present study the Microbiologically influenced Corrosion study has been done for different types steel metals samples like 0.6% carbon steel, 0.4% carbon steel, 18/8 steel, high speed steel, st 301, st 401, st304, ASLN 1 and ASLN 4 with experimental set (with microbe) and proper control set (with out microbial activity) was maintained. For the metal sample 0.6% carbon steel, the microbes (T. Ferroxidans) is involved in direct corrosion of the metal. In case of 0.4% carbon steel and plain 18/8 steel it is observed weight loss is very low comparing to control set. high speed steel initially little corrosion was observed and that may be due to the dissolution of loosely bonded materials and then gradually the corrosion rate has decreased. In St 301 little corrosion was observed in the experimental set. For the metal sample St 401 initially the rate of material lost is very high, which indicates that the microbial influenced corrosion (MIC) is the main cause for this high dissolution rate. In case of ASLN 1, ASLN 4 and St 304 the initial reaction rate is slow but later on it is increasing i.e the first peak (SEM) is lower than the second peak. The study also reveals that MIC is influenced with pitting type of corrosion, the structure of the metals, the crystal orientation and the molecular arrangement. Images of metal sample were taken using Scanning Electron Microscope (SEM) and these pictures support the above experimental results. The enzymes rusticianin and cytochrome C are the key enzyme, which plays the key role for the electron transfer process or oxidation of the metals.

Key Words: MIC, SEM,

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Introduction:

Microbiologically influenced Corrosion (MIC) refers to corrosion that is influenced by the presence and activities of micro-organism and / or their metabolites[1-4].MIC occur as a consequence of biofilm formation on the metal surface as a result an increase of the open circuit is observed. Potential values of approx 300-350 mv (SCE) have been measured after 10-20 days of exposure independent of geological locations[5]. Organism are commonly associated with MIC, including sulphate reducing bacteria(SRB) sulphur and sulphide oxidising bacteria, iron and manganese oxidising bacteria, aerobic slime formers and acid producing bacteria and fungi[4]. MIC also create problem in fluid flow changing friction factor due to microbial fouling. It also effect heat transfer offering extra resistance due to scale formation and biofouling[1-6] (forming biofilm).The role of microorganisms in the corrosion of metals and alloys has received increased attention recent years. Their corrosive effects on metal and alloy can be attributed to Direct Chemical action of metabolic products[4]. Different control mechanism is suggested and tested for MIC are coating, using biocides, change of environmental condition, Brushing, Irradiation ultraism energy etc. It is reported that the responsible microbes for MIC are SRB, Iron/manganese oxidising bacteria, & sulfer/sulfide oxidising bacteria etc. and they are capable to deteriorate all the common metal and alloy, only copper shows good resistance against some micro-organisms but it is also attached by MIC in certain condition. On the other hand Titanium and its alloy appear to be uniquely resistant to MIC.

Thiobacillus Ferroxidans has made a significant stride in the development of commercial viable technology to processing/recovery copper, gold, Uranium etc. This microbes has been utilised for the waste water treatment using its oxidising capability. In its life process it took energy from oxidation of ferrous sulphate to ferric sulphate One the other hand ferric sulphate act as a good coagulant and helps to waste degradation.

In this present study resistance of steel materials has been investigated against MIC specially *Thiobacillus Ferroxidans.* And it is searched to select a suitable material for construction of bioreactor where *Thiobacillus Ferroxidans* is used as biocatalyst.

Materials and Methods:

Materials: Bacterial Culture of *T.Ferrooxidans*, $FeSo_4$, Potassium Chloride, Ammonium by Phosphate, Potassium di chromate, Sulfuric Acid and other analytical grade Chemicals. Steel materials

Bacterial Strain and culture Medium: T.Ferrooxidans strain were used in this work. This strain were originally collected from Deptt. Of Microbiology, University of Helsinki, Finland and Strain were subculture regularly in 9k medium.

Steel materials: Sample set-1

1.0.6% carbon steel:(Composition: C 0.582%-0. 6%, Si-0.327%, Mn-1.00%, S0.0269%, Ph-0.042%, Cr-0.0609%, Ni-0.0673%.)

2.0.4% carbon steel:(Composition: C-0.38%-4.0%, Si-.15%, Mn-0.7%)

3. Plain 18/8 steel:(Composition: Cr-15%, Ni-6-11%, C- 0.05-0.15%)

4. High-speed steel:(Composition: Tn-14-18%, Cr-3-5%, C-0.6%, S-0.9%),

5. St-301:(Composition: Fe, Cr, C, and Ni)

Sample set 2:

1. St-401:

Composition: C-0.025%, Mn-0.83%-0. 93%, Ph-0.03%, S-0.015%, Si-0.45-0.55%, Cr-11.6- 11.8%, Mo-0.2%, Ni-0.35%-0. 55%, Cu-0.25%.

2.ASLN-4:

Composition: C-0.6%-0. 8%, Mn-7.0%-7.5%, Ph-0.05%, S-0.015%, Si-0.4%-0.5%, Cr-16.0%-16.2%, Ni-4.0%-4.2%

3.St-304:

Composition: C-0.67%, Mn-0/35%, Ph-0.028%, S-0.013%, Si-0.13%, Cr-16.48%, Mo-0.17%, Al-0.009%

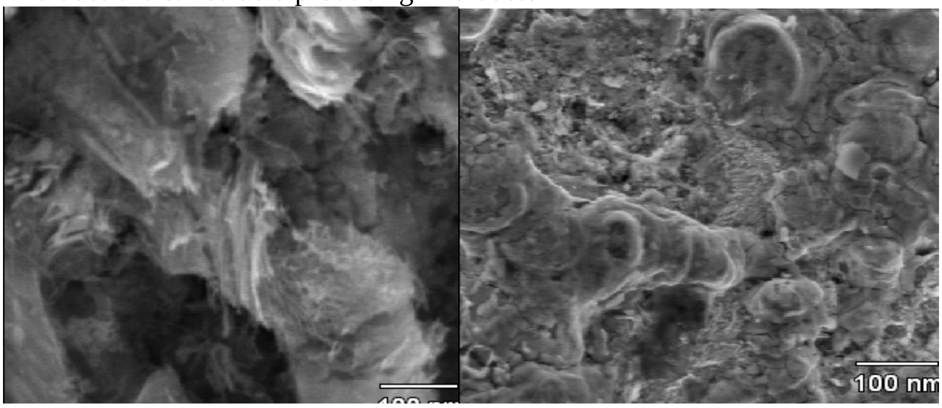
4. ASLN-1:

Composition: C-0.08-0.1%, Mn-9.0%-9.5%, Ph-0.05%, S-0.015%, Si-0.4%-0. 5%, Cr-15.0-15.2%, Ni-1.0%-1.10%, Cu-1.6%-1.7%.

RESULT AND DISCUSSION:

The corrosion study was investigated for the said steel metal samples in experimental set (with microbe) and in proper control set (with out microbial activity).The weight loss due to MIC with time was studied (gm/cm^2) and Scanning Electron Microscope (SEM) were taken before and after the treatment, to study the change of morphology and crystal structure/orientation in the metal surfaces due to MIC.

For the metal sample 0.6% carbon steel, form the table and graph it is clear that the microbes (T. Ferroxidans) is involved in direct corrosion of the metal. Different study suggests that T.Ferroxidans is a ferrous oxidising bacterium as well as it is effective in dissolution of metals from its ore (Cu, Zn, Au etc). In the present case the dissolution rate of the carbon steel is very high from 0 to 5 days comparing with the control set. In this time period microbes were in their viable condition with the proper nutrient and other conditions were suitable for microbial growth and activity. But after these days probably microbes were presenting their stationary and decay phase as a result the oxidation rate is lower. From the graph (not shown) it is observed that another two peak is observed in weight loss Vs time curve, which is probably due to the presence of organic acid. These microbes produces organic acid . So these microbes are called acid producing microbes.

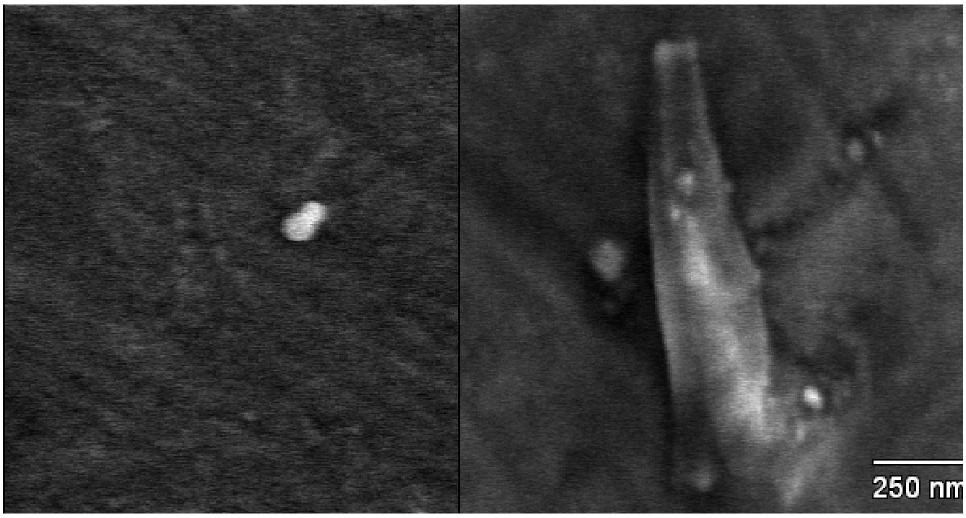


SEM of 0.6%Carbon steel (MIC-treated & Control)

On the second set the corrosion study was done for different types metal samples with experimental set (with microbe) and proper control set (with out microbial activity) was maintained. The results observed on the periodic intervals for different types of stainless steel samples are studied (not shown).
The weight loss in gram/cm^2 with time (days) was investigated. Images of metal sample were taken using Scanning Electron Microscope (SEM) before and after the treatment. Some morphological changes were observed. This is due to corrosion in the metal surfaces

For the metal sample St 401 (from corresponding table and graph, not shown) it is observed that initially the rate of material lost is very high, which indicates that the microbial influenced corrosion (MIC) is the main cause for this high dissolution rate. After the initial phase, probably the nutrient of the microbe are not sufficient and the microbes not viable enough due to presence of by product into the reaction medium, another cause may be the atomic structure and crystal structure of materials. Any one of the cause or may be more than one can play a rocking role in the restriction of degradation of the material. On the other hand the above said microbe has the capability to produce organic acid in the reaction system, which may corrode or increase the rate of corrosion of the exposed material. As a result several peak has been observed from the graph.

In case of ASLN 1 and St 304 (tables and graphs not shown) it is observed that. the initial reaction rate i.e the first peak is lower than the second peak, which normally happens due to presence of acid. Probably in the first stage pitting type of corrosion may have occurred and due to that more surface area has been produced. As a result in second stage corrosion, material lost will be more due to more surface area that is available for corrosion.



SEM of ALSN4 (MIC-treated & Control)

For the metal sample ASLN 4 (from corresponding table and graph, not shown) it is observed that the initial reaction rate i.e the first peak is lower than the second peak, which is normally obtained due to extra acid produce by the bacterium. Probably in the first stage pitting type of corrosion may have occurred and due to that more surface area has been produced. As a result in second stage corrosion, material lost will be more due to more surface area that is available for corrosion. But the corrosion observed here is very less (among the second set of samples) and may be due to loosely bonded materials as said earlier.

Images of metal sample were taken using Scanning Electron Microscope (SEM) and these pictures support the above discussion.

Total Dissolved Solid (TDS):

This parameter was studied through out the reaction both for experimental and control set .From the corresponding table and graph it is clear that the value of TDS is increased both for experimental and control set. Already from our previous discussion it was mentioned that the bacteria *T.Ferroxidans* has the capability to dissolve the metal from the concentrated material through oxidation.

From the experimental set data it is already proved that MIC has occurred and as well as some other by product may be formed in this reaction process. As a result corrosion product with the other by product helping to increase the total dissolved solid into the solution. In the control set also TDS has increased due to the presence of corrosion product and byproduct material. In this case no MIC has observed but due to acid environment of nutrient solution corrosion may occur as well as some by product may also have formed.

And coming to the discussion of pH, normally the microbial activity is very much pH dependent. All microbes has the tendency to show better activity in a certain range of pH. In the present case T.Ferroxidans normally grow in the pH range of 2.4.but it can work better in lower pH if it is adjusted to the survival of lower pH. This bacterium is an acid (organic) producing bacterium. So with the reaction time proceeds the ph of the system decreases too. For dissolution of the metal from ore is enhanced due to lowering pH, but microbes may die reaching a certain range .so as a result productivity may drop in certain range and may also fall to zero. pH control in this type of reaction system will be helpful for better productivity.

On experimental data (, not shown) and the corresponding graph also support that the bacteria is an acid producing one as the pH of the system drops gradually. On the other hand the pH of the control set does not fall at all.

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