Microbiologically Influenced Corrosion (MIC) of Stainless Steel Weldments on the Pipe Line in the Sewage Treatment Plant†

Yasushi KIKUCHI* Fukuhisa MATSUDA** Kenji TOMOTO*** and Masaki NISHIMURA****

Abstract

Microbially Influenced Corrosion (MIC) of several types of stainless steel weld metal were examined by using the waste water which was extracted from sewage treating plant. An activated carbon was employed in this treatment.

Experiments were done under controlled laboratory conditions. Weld metal samples were exposed to the test solution of waste water and kept in an incubator at 40°C(104°F). The turbercles developed on the surface of samples and grew gradually as a function of time. Such developed the turbercles were not hard.The corrosion sites were observed on the samples of 316L 308N and 308 stainless steel weld metal under the turbercles. It was estimated that corrosion behavior was affected by the microstructure of the weld metal. An un-attacked ferrite dendritic skeleton structure and a pit like penetration hole were observed.

The bacteria attaching on the pits were observed by using SEM. The types of bacteria will be identified in future work.

KEY WORDS:Stainless Steel, Welds, Microbially, Corrosion

1. Introduction

In recent years, Microbially Influenced Corrosion (MIC) of stainless steel weld components has been identified as one of the serious problems in the chemical process plant, energy plant and water supply systems.

In Japan, there are many misunderstandings about MIC on the welds, and only limited amounts of information [1-2] exist on the MIC and biodeterioration of metals and their weld joints.

The present investigation was conducted to gain a better understanding of MIC by focusing one case in Japanese plant.

Leaking was found from several welded joints on a 3mm wall thickness, 304 stainless steel pipe line system. This pipe line system is one of the important components in an activated carbon waste water treatment plant. The failures in weld joints occurred with in two months from the start up of the plant.

At the beginning, crevice corrosion was considered as the main cause since field welding had been performed. In such a case, some weld defects such as incomplete bead penetration, lack of fusion ,cracking and blow holes might be introduced in the welds.

If it is the case these problems can be solved by repairing a localized corrosion portion. However, the estimated corrosion rate of weld metal was approximately 18mm/year which is too fast. Metallurgical failure analysis to examins this behavior was carried out. The following are the characteristic results obtained

(1)The formation of tubercles(brown) on the weld metal surface. (2)Tunneling pit in weld metal and haz. (3)Preferential attack of the austenitic structure (4)Absence of defects by welding

An extensive survey of the literature on this subjects was done. [3-8] Finally it was concluded that the localized corrosion on welds surface was a kind of microbially influenced corrosion(MIC). It was also found that research activity in Japan on the MIC and biodeterioration of welds joint is not widespread.

The authors propose from this fact that studies of MIC in Japan should be activated. Laboratory measurements by the use of same an environment were planned.

Residual waste water from the activated carbon sewage treatment plant pipe line was transferred to the laboratory.

† Received on July 24
* Associate Professor
** Professor,
*** Technical Assistant
**** Mitubishi Kakoki Kaisha, LTD
Transactions of JWRI is published by Welding Research Institute of Osaka University, Ibaraki, Osaka 567, Japan.

The synthetic corrosion test using this water was employed in the occaneaces laboratory.

Several types of stainless steel weld metals were tested in the same water. The susceptibility of MIC on these samples were estimated. The present paper is a preliminary report on the MIC of stainless steel weldments.

2. Experimental Procedure

Preparation of test solution

The test solution is residual water transferred from the activated carbon drainage treatment plant pipe line. Chemical analysis of the solution used is shown in **Table.1**

Bacteria in the solution were detected by cultivation. Agars(Nutrient broth 8g, agar 25g and distilled water)inoculated were kept at the room temperature. By light microscopy , several types of bacterias which have different shapes were observed. Some of examples are shown in **Figure 1.**

Table 1 Analytical result of test solution used (Six of flasks with one coupon)

PH	Fe (mg/l)	Cr (mg/l)	Ni (mg/l)	Cl^- (mg/l)	oxidation and reduction potential (mv 25℃, 78°F)	electrical conductivity (ms/cm 25℃, 78°F)
6.4	59.8	≦0.5	11.7	3100	+150	8.7

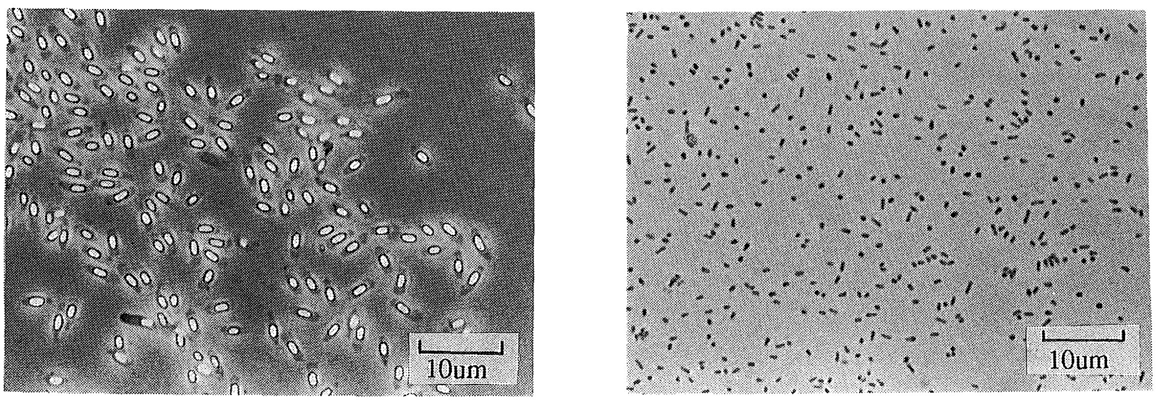


Fig. 1 Bacteria by light microscope

Corrosion test sample

Weld metal samples were made by the shielded metal arc welding (SMAW) process. Weld metals were deposited on the 304 stainless steel plate of 3mm thickness. Six different smaw electrodes (308,308N, 309, 316,316L and duplex stainless) were employed with a variations in weld metal. Welded metal samples were machined into 20mm width and 80mm length corrosion test coupons.

The test coupon was degreased and cleaned by ultrasonic methods.

Corrosion test

300ml of the test solution described above was transferred from a small tank to a conical flask.

Sterilized glass apparatus were used. The weld metal sample was exposured to test solution in the conical flask. Six conical flasks with one test coupon were kept at 40°C (104°F) by an incubator.

The formation and growth of tubercles on the coupon surface were inspected by eye periodically.

Preparation of light and SEM observation sample

The coupon was taken out of the flask after exposure of 62 to 240 days and was examined with both light and scanning electron microscopy (SEM). Tubercles were rinsed with Phosphate buffer solution and replaced with glutaraldehyde solution (25%). After fixation of 3-4hrs, the coupon was rinsed, and dried using ethyl alcohol and t-butanol, then the samples were dried under vacuum and kept in the desiccator.

3. Experimental results and discussion

Turbercles on the weld metal surface

It is known that a turbercle is sometimes observed at a local corrosion site by MIC, so turbercles and local corrosion have an intimate relationship. After about 10 days , on the surface of coupon the turbercles were developed. Their growth occurred gradually as a function of time. Under these experimental conditions , the turbercles did not change to a solid substance. It is assumed that the soft turbercles will be agglomerated into a solid substance after long time exposure.

The surface appearances of coupon after 62 days of exposure are shown in **Figure 2**. The arrow indicates to the turbercle.

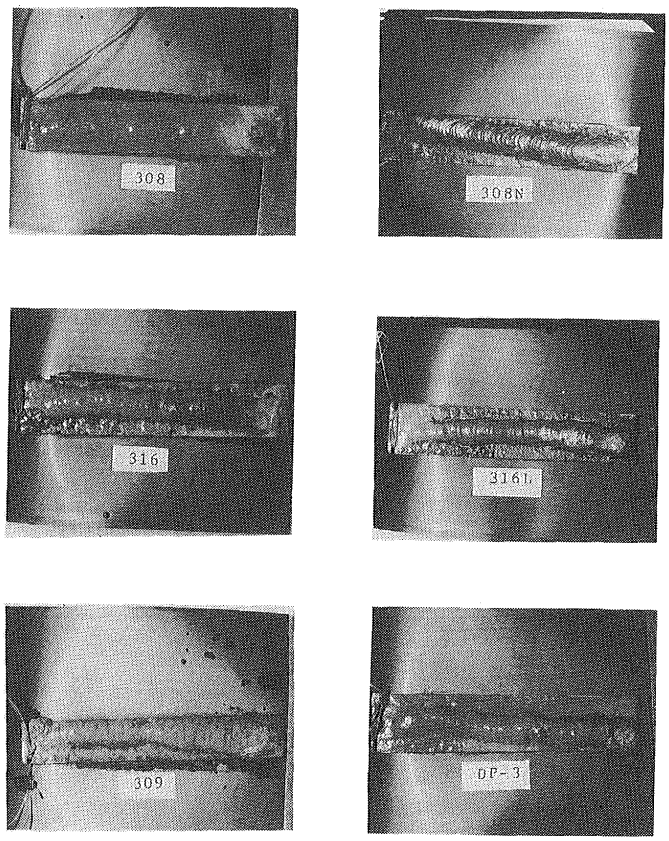


Fig. 2 Surface appearances of coupon after 62 days exposure test turbercle by arrow

MIC susceptibility of various types of stainless steel weld metal

The coupon was taken out of the flask after exposure for 62 days. Then it was washed and dried.

Surface condition was examined by SEM, particularly the sites of turbercles.

Figure 3 shows the result of 308N(nitrogen content about 0.2%) weld metal. As shown in (A) , at the crater area, a lot of corrosion sites were occurring as pitting corrosion . The circular groove observed is also corrosion site. A large corrosion site is formed as shown in (B). 308N weld metal contains about 0.2% nitrogen, but many pits developed.

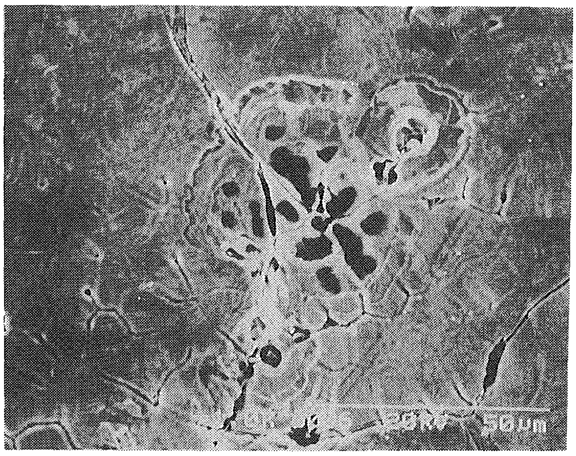
The results of 316L weld metal are shown in **Figure 4**.(A)(B) and (C) The different shape of pits can be seen as (A) and (B). (C) is a highlight of (B). As shown in (C), the morphology of the remaining structure is dendritic, and in this instance the austenitic phase in the weld metal has been preferentially corroded leaving the ferritic dendritic skeleton un -attacked [3]. The skeleton structure was analyzed by EDX.and a high Cr content in the skeleton was found. So, it is concluded that this is ferrite phase. The turbercles were also developed on the surface of weld metals for other four samples, but there was no observable pitting of MIC. The 62 days exposure test results are summarized in **Table 2**. The size variations of turbercles were grouped by eye in the three categories, as maximum (◎)moderate (○) and minimum (△). In short exposure examinations, the development of turbercles does not correlate with MIC of stainless steel weld metal. So, long exposure times were planned. The 308 and 316L weld metal samples were used. Reproducibility was checked by using 316L samples. The fixed bacteria in the corroded area were inspected by SEM.

Table 2 Summary of days exposure test results (Six of flasks witn one coupon)

weld metal type	location and number of turbercle occured			pitting
	end of weld metal	crater of weld metal	num-ber	
3 0 8	△	◎	1	no
3 0 8 N*	– – –	– – –	0	occured
3 1 6	△	○	1	no
3 1 6 L	◎	○	2	occured
3 0 9	○	○	2	no
duplex	△	○	1	no

size variations of turbercle; △:minimum ○:moderate ◎:maximum

* 0.2% nitrogen content



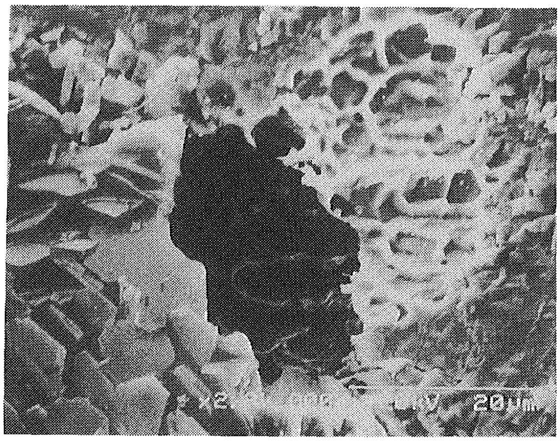
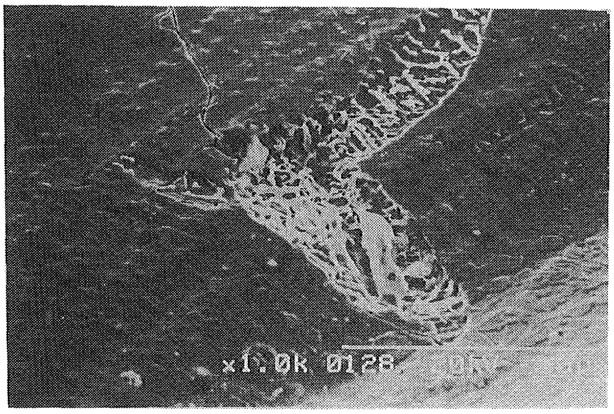
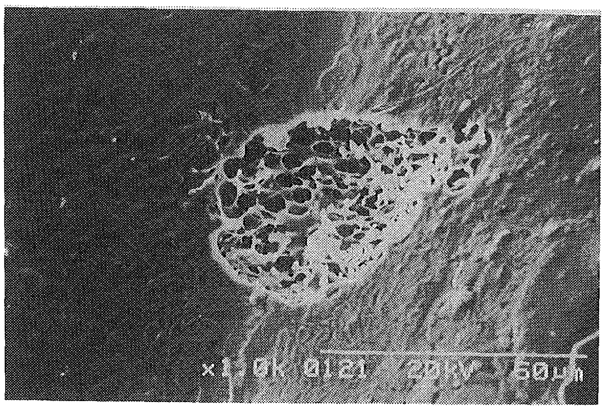


Fig. 3 Pitting Corrosion of 308N weld metal
(A) many small pit (B) large pit





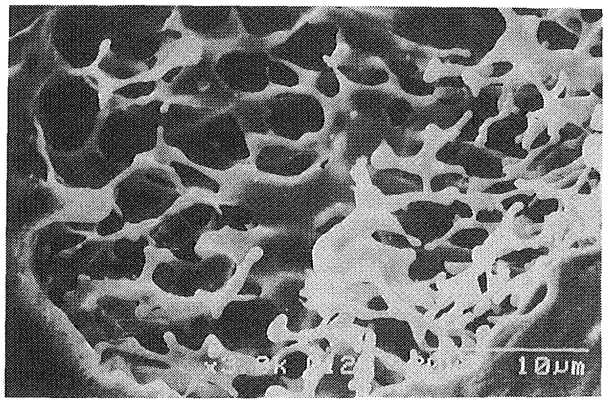


Fig. 4 Pitting corrosion of 316L weld metal
(A)early stage corrosion (B) skeleton un-attacked
(C) high magnification of (B)

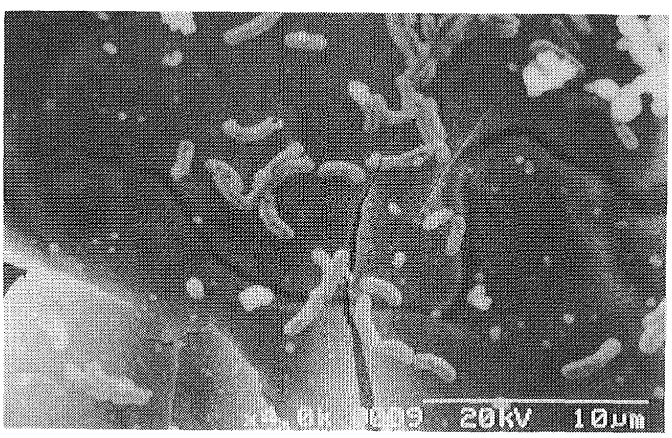


Fig. 5 Bacterial and Pit of 308 weld metal , 240 days
exposure test, (A) at Pit (B) at Crater

Long time exposure tests and observation of bacteria by SEM

308 and 316L weld metal coupons were exposed in the test solution for 240 days. Test conditions were the same as described in the 62 days exposure tests.

The test results on 308 weld metal are shown in **Figure 5**. MIC has been developed in 308 weld metal by long time exposure. As shown in (A) a dendritic skeleton structure is observed. On the other hand, bacteria are shown by an arrow in the same photograph. Bacteria are attached on the coupon surface around pits. As shown in (B) , many bacteria are attached on the crater surface. The same corroded skeleton structure was obtained in 316L sample as in the results of 62day exposure tests.

Thus the reproducibility of the experiments was confirmed,although at this moment all bacteria are not identified.

On the other hand, the development of MIC and turbercles were not observed using a sterilized test solution. The test solution was sterilized by autocleaving. So , more systematic and basic studies for the behavior of bacteria in the corrosion of stainless steel weld metal are necessary.

4. Conclusion

Main results are summarized as follows:

(1) Development of turbercles was not uniform and it depended on the type of stainless steel.

(2) MiC induced corrosion sites were developed on the coupons of 316L, 308N and 308stainless steel weld metals

(3) Two types of corrosion site were observed . One was a skeleton structure and the other was a pit. It is believed that the difference depends on the microsturcture of weld metal.

(4) Bacteria have been observed by SEM. They were attached around corrosion site but were not identified yet.

Acknowledgements

The authors wish to thank Dr. A. Yokota(Institute for Fermentation , Osaka Presently the University of Tokyo) and Dr. Y. Kaneko (Dept. of Biotechnology Osaka Univ.) for their respective advice and suggestion.

Reference

1. K. Kasahara, F. Kajiyama, Pitting corrosion of type 304 stainless steel pipe influenced by microorganisms in water for industrial use, 36th Fusyoku Bosyoku Toronkai,Paper No. D-202(1989,10) Hiroshima
2. M. Nishimura, 89th, Fusyoku-Bosyoku Toronkai (1992) ,Tokyo
3. J. Licina, Source book for Microbiologically Influenced Corrosion in Nuclear Power Plants, EPRI NP-5580, EPRI, Palo Alto, CA, 1988
4. N. J. Dowling , M. W. Mittelman and J.C. Danko, Microbially Influenced Corrosion and Biodeterioration Proceeding of International Congress on Microbially influenced Corrosion(Knoxville, TN. Oct 1990)
5. C. Lundin, Proceeding of Stainless Steel '91, 964 (Chiba , Japan :The Iron and Steel Institute of Japan, (1991).
6. G. Kobin ,A Practical Manual on Microbiologically nfluenced Corrosion, (Houston, TX: National Association of Corrosion Engineers, 1993)
7. C.F. Jenkin, D.L. Doman, Corrosion 93, Paper No. 172
8. D. Walsh, Eric Willis, T. VanDiepen, J.Sander, Corrosion 94, Paper No.612