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Effect of Cr content on flow accelerated corrosion rate of carbon steels and its correlation with oxide layer characteristics

ABSTRACT

Combined effects of Cr content (~1 wt %) and environmental factors, pH and dissolved oxygen concentration, on removal rate of carbon steels due to flow accelerated corrosion have been examined by experiments. Cr content holds a strong impact on the FAC rate regardless of pH values from 6.84 to 10.4. Addition of 1% Cr to a carbon steel reduces the FAC rate by one order of magnitude under the environmental conditions, where magnetite forms. Detailed characterizations of oxide layer formed on the specimens have been carried out by using SEM and TEM. It has been suggested that characteristics of oxide layer were obviously different between low and high Cr content steels, and their correlation to the FAC rate has been discussed. Porous oxide monolayer has been observed on the low Cr content steels; in contrast dense oxide inner layer and outer layer which contains chromium much higher than base metal have been formed on the high Cr steels.

INTRODUCTION

Flow accelerated corrosion (FAC)

Chemical or electrochemical dissolution of metal under very fast mass transportation between pipe wall and bulk water, where a number of influencing parameters are involved.

Removal rate is controlled by...

-Temperature
-Flow dynamics factors
-Water chemistry (pH, oxygen and hydrogen concentrations)
-Materials factors (compositions and microstructure)

OBJECTIVE

-A small amount of Cr addition is very effective to suppress FAC.
- Available knowledge on effect of steel composition is limited to a particular water chemistry condition.
-The mechanism of [Cr effect] is not altogether understood.

In this study,

Combined effects of Cr content and environmental factors, pH and dissolved oxygen concentration, on removal rate of carbon steels due to FAC have been examined by experiments and their relation to oxide layer characteristics have been discussed.

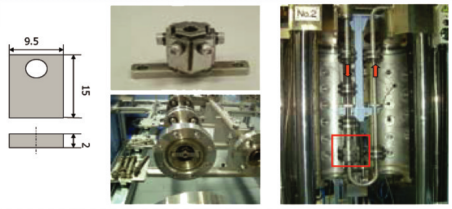
EXPERIMENTALS

Chemical compositions of carbon steels (wt%)

	Fe	C	Si	Mn	P	S	Cr
CS0	Bal.	0.16	0.23	0.7	0.024	0.17	0.003
CS01	Bal.	0.15	0.23	0.69	0.024	0.17	0.014
CS04	Bal.	0.15	0.23	0.69	0.023	0.17	0.043
CS1	Bal.	0.15	0.24	0.69	0.023	0.17	0.1
CS4	Bal.	0.15	0.23	0.68	0.024	0.17	0.42
CS10	Bal.	0.15	0.23	0.7	0.023	0.16	1.01

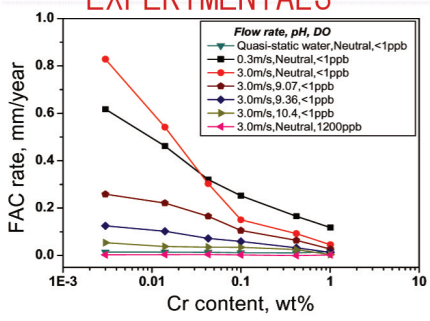
FAC experiments conditions

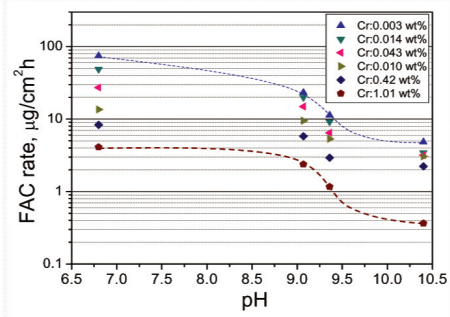
pH / Flow rate	Neutral(6.83)	9.07	9.36	10.4
Quasi-static	(1)DO<1ppb	/	/	/
0.3 m/s	(2)DO<1ppb	/	/	/
3.0 m/s	(3)DO<1ppb (4)DO=1200ppb	(5)DO<1ppb	(6)DO<1ppb	(7)DO<1ppb



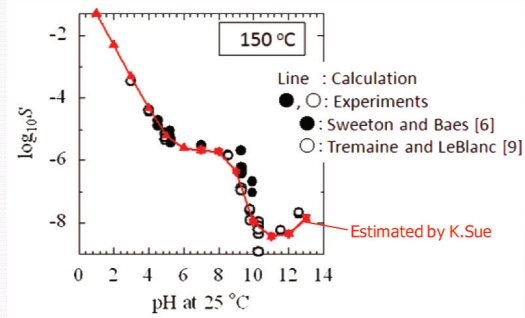
Specimen, specimen holder, and test section for FAC experiments

EXPERIMENTALS



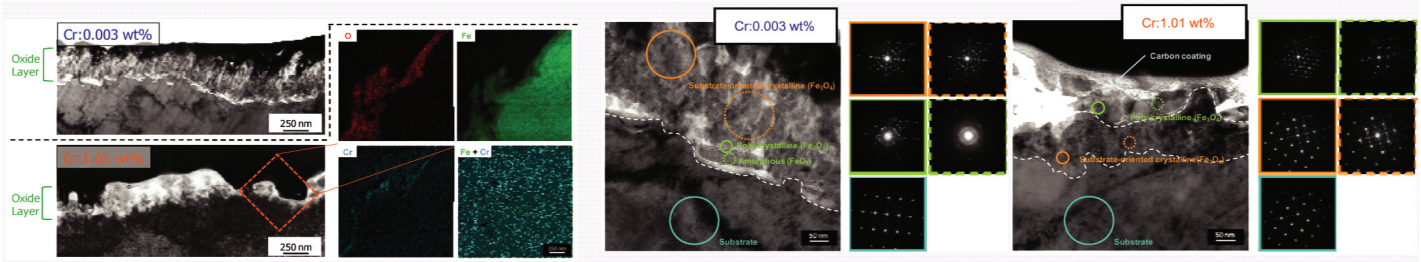


Metal removal rate due to flow accelerated corrosion plotted as a function of Cr content of carbon steels. The figure also indicating the effect of pH and oxygen concentration of water and flow rate.

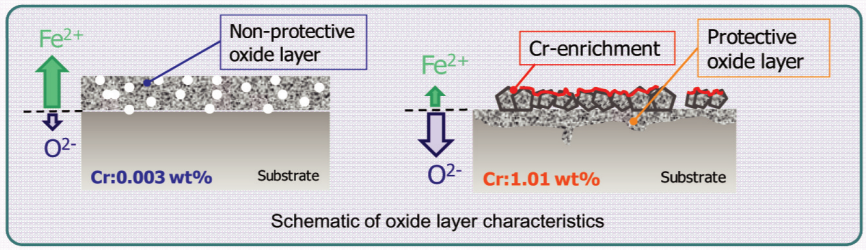


Estimated solubility of magnetite at 150C plotted as a function of pH.

CHARACTERISTICS OF OXIDE LAYERS AND ITS RELATION TO FAC BEHAVIORS



Cross-sectional analysis of oxide layer by using TEM (Flow rate:3.0m/s, pH:6.83, DO:<1ppb)



Schematic of oxide layer characteristics