

handling different in solutions for bleaching in paper industry. So, this paper report on investigations were performed in peracetic acid solutions to said austenitic stainless steels (Table1) with chloride level 0, 500 and 1000 ppm and chelant EDTA (0.2% of pulp) , MgSO₄ (0.25% of pulp) in laboratory simulating all the conditions of bleach plant of paper industry as appropriate bleaching.

2. Experimental

2.1. Material

For Corrosion study, Test samples from plate samples of austenitic stainless steels- 6% Mo (654SMO, 254SMO), 317L, 316L and a duplex stainless steel 2205 were selected for the weight loss tests and electrochemical tests. The composition of these stainless steels is shown in Table 1. All the SS test samples were as received in the solution annealed condition as per ASTM specification A 240 [14]. Before exposure, the coupons were polished until a mirror finish surface is obtained, for achieving this state polishing machine was used. Polishing and finishing were done by abrading the specimen on emery papers with grit sequence from coarser to finer i.e. up to 800, 1000 grit size and then subjected to finishing papers 1/0, 2/0 and at last 4/0. Finally the samples were degreased using acetone solution, and weighed. For the electrochemical studies, coupons of 1 cm² were embedded in a mould of epoxy resin and an electrical connection was established via a copper wire. The polished test metals were degreased as described above. All the chemicals used during characterization of bleach solutions, were AR grade.

Table 1: Composition of stainless steels plate samples (%)

ALLOY	C	Ni	Mn	P	Cr	Mo	S	Cu	N	Si
316L	0.020	10.87	1.69	0.030	17.44	2.16	0.030	0.31	0.04	0.69
317L	0.016	13.44	1.75	0.026	18.80	3-7	0.004	0.42	0.047	0.50
2205	0.020	5.480	1.45	0.026	22.25	3.08	0.002	0.21	0.15	0.52
254SMO	0.009	18.00	0.44	0.028	20.10	6.15	0.001	0.74	0.20	0.31
654SMO	≤ 0.02	21-23	2-4	≤ 0.30	24-25	7-8	0.005	0.3-0.60	0.50	0.50

Table 2: Chemical composition of PAA bleach solutions.

Solution Name	Chemical Charges			
	Conc.(as % AO)	pH	Cl ⁻ (ppm)	Chelant
PA1	0.2 ±0.04	4.0 ±0.05	0	without
PA2	0.2 ±0.04	4.0 ±0.05	500 ±0.50	without
PA3	0.2 ±0.04	4.0 ±0.05	1000 ±0.50	without
PA1CI	0.2 ±0.04	4.0 ±0.05	0	EDTA =0.2 ±0.02%
PA1CII	0.2 ±0.04	4.0 ±0.05	0	MgSO ₄ =0.25±0.02%
PA2CI	0.2 ±0.04	4.0 ±0.05	500±0.50	EDTA =0.2 ±0.02%
PA2CII	0.2 ±0.04	4.0 ±0.05	500±0.50	MgSO ₄ =0.25±0.02%
PA3CI	0.2 ±0.04	4.0 ±0.05	1000 ±0.50	EDTA =0.2 ±0.02%
PA3CII	0.2 ±0.04	4.0 ±0.05	1000 ±0.50	MgSO ₄ =0.25±0.02%

2.2. Solutions

Table 2 shows the test conditions and composition of the solutions of PAA test media. For both the long term immersion test and the electrochemical polarization test, the stainless steel samples were exposed to three peracetic acid (PAA) solutions namely PA1, PA2 and PA3 according to desired Cl⁻ levels 0, 500 and 1000 ppm respectively. pH value of these solutions was adjusted and kept in the range 4.0 ±0.05 by adding required amount of sodium hydroxide. Six solutions were prepared on adding chelants in PAA, namely PA1CI, PA1CII, PA2CI, PA2CII and PA3CI, PA3CII here CI refer as chelant I namely EDTA while CII refer chelant II namely MgSO₄ (Table 2). All the solutions of PAA were prepared as per described Amini and Webster [1]. Accordingly, peracetic acid (CH₃COOOH) was prepared by adding glacial acetic acid to hydrogen peroxide in one molar ratio. The mixture was then warmed to 45°C and held at this temperature for two hours, and stored overnight in a refrigerator to allow the mixture to come to equilibrium. Bleach solutions (Table 2) containing Cl⁻ were prepared by adding the calculated quantity of sodium chloride needed according to desired Cl⁻ levels and adding to the solutions calculated values of both the selected chelants maintaining the reaction temperature at 30-35°C. The concentration of PAA, added chloride, pH value, concentration of chelant and other chemical charges in test media were maintained by periodic test and titration during the whole long term immersion (weight loss) and electrochemical measurements.

3. Corrosion Tests

3.1. Long term Immersion tests

For weight loss test, the prepared stainless steel coupons were exposed for six months at room temperature (27°C average) each coupon was immersed in the solutions of peracetic acid as per described in Table 2 with serrated washers to initiate crevice corrosion. During the test, the percent active oxygen (AO) and pH value of the test solutions were monitored and maintained each third day. While pH did not change much (± 0.04), decrease in percent AO was compensated to keep it within limit, as per Table 2 by adding requisite amounts of peracetic acid. After the six month exposure, the corroded coupons were cleaned mechanically as per as per ASTM G1-72 [14]. Further tested coupons were cleaned by treating them with a cold solution of concentrated hydrogen chloride with 50 g/L stannous chloride and 20 g/L antimonies chloride [17]. The coupons were then weighed to determine corrosion rate in mils per year as;

$$\text{Corrosion rate} = \frac{3.45 \times 10^6 \times W}{DAT} \text{ mpy} \quad (1)$$

Where W = weight loss [gm],
 D = density of metal in [gm/cm³]
 A = area [cm²]
 T = exposure time [hours]

To estimate the extent of localized attack the corroded samples were viewed under the microscope. The extent of pitting was estimated by measuring maximum pit depth on the surface of cleaned coupons using a stereo microscope (Olympus) and an optical microscope (Leica Q500MC).

3.2. Electrochemical tests

Electrochemical polarization tests were carried out using Radiometer “Voltalab” Electrochemical Laboratory Model PGZ301 of Radiometer France supplied with compatible corrosion measurement software (Volta Master-4). A saturated calomel electrode (SCE) was used as the reference electrode, graphite rods as the auxiliary, and the test specimen was the working electrode within corrosion cell. The tests conducted were open circuit potential (OCP), potentiodynamic (anodic) polarization, cyclic polarization and potentiostatic with the help of software Volta master 4. All the experiments were carried out at 27°C. Figure 1 shows some representative curves of different stainless steels obtained through conducted electrochemical tests. Tafel plots were used to evaluate corrosion potential (E_{corr}), I_{corr} and β_a , β_c , (anodic and cathodic Tafel slopes) and hence corrosion rate. Other polarization techniques give an idea about passivation range and possibility of pitting or crevice corrosion. Electrochemical parameters derived from these curves are presented in Table 4. All the potentials referred in paper are with respect to saturated calomel electrode. Each electrochemical test was repeated to verify the reproducibility of the results. The electrochemical tests described above were conducted in the bleach solution having conditions mentioned above; by using a potentiostat and polarization cell having five necks meant for a working electrode, two counter electrodes, a reference electrode saturated calomel electrode (SCE) as reference electrode and for gas purging. Open circuit potential (OCP), Corrosion (E_{corr}), pitting potential (E_p), and repassivation potential (E_c) were evaluated from these tests. Figure 1 shows some representative curves of different stainless steels obtained through conducted electrochemical tests.

Table 3: Long term immersion test results (corrosion rate and maximum pits' depth)

Solution → Metal ↓	Without Chelant			With Chelant					
	PA1	PA2	PA3	PA1CI	PA1CII	PA2CI	PA2CII	PA3CI	PA3CII
	Corrosion rate (mpy)								
316L	0.11	0.23	0.28	0.056	0.056	0.082	0.09	0.13	0.18
317L	0.09	0.12	0.14	0.021	0.026	0.025	0.07	0.051	0.083
2205	0.06	0.12	0.15	0.022	0.029	0.016	0.019	0.050	0.080
254SMO	0.04	0.061	0.062	NT	NT	NT	NT	NT	NT
654SMO	0.035	0.043	0.045	NT	NT	NT	NT	NT	NT
	Maximum Pit's depth(μm)								
316L	87	153	193	90	105	120	133	152	165
317L	73	142	165	60	48	88	103	130	146
2205	55	139	173	42	34	72	95	130	141
254SMO	38	37	64	NT	NT	NT	NT	NT	NT
654SMO	31	40	53	NT	NT	NT	NT	NT	NT

NT= Not tested in case of with chelant for 6% Mo SS (654SMO, 254SMO)

Table 4: Electrochemical test results (corrosion parameters, pot. in mV)

Solutions→		PA1	PA2	PA3	PA1CI	PA1CII	PA2CI	PA2CII	PA3CI	PA3CII
Metal↓	CP									
316L	OCP	260	242	138	313±17	266±21	280±11	258±21	240±15	190±11
	Ecorr	282	232	149	214±3	198±6	240±23	210±14	128±8	155±3
	Epass	761	520	367	818±15	785±9	634±21	610±09	480±23	470±22
	Ep1	1021	807	600	1060	1027	915	902	789	834
	Ep2	1005	630	505	1145	1113	801	750	595	550
	Ep3	700-750	700-750	600-650	800-850	800-850	750-800	750-800	700-750	650-700
	Ec	932	141	54	****	****	****	120	133	20
	CR (mpy)	0.31	0.38	0.46	0.18	0.21	0.30	0.38	0.40	0.44
317L	OCP	258	172	132	330±7	270±15	260±21	220±10	170±4	157±5
	Ecorr	290	250	190	256±10	204±18	230±17	250±23	130±22	132±3
	Epass	830	755	532	946±11	941±23	835±11	805±19	927±11	771±10
	Ep1	1025	997	744	1210	1221	1153	1133	958	816
	Ep2	1053	1011	980	1127	1100	1154	1098	1135	1100
	Ep3	900-1000	900-1000	700-750	1200-1250	1150-1200	1050-1100	1000-1050	1050-1100	950-1000
	Ec	1028	****	****	****	****	**	**	**	**
	CR (mpy)	0.23	0.26	0.35	0.12	0.15	0.18	0.24	0.20	0.30
2205	OCP	325	300	255	352±5	320±22	340±21	324±15	270±14	293±15
	Ecorr	291	271	210	323±06	336±10	350±16	312±21	225±21	160±15
	Epass	880	801	738	1042±1	1000±9	1012±17	980±11	997±31	869±13
	Ep1	1120	1075	967	1220	1152	1112	1076	1052	1017
	Ep2	1044	1056	1012	1131	1114	1096	1034	1047	1027
	Ep3	1100-1150	1100-1150	1000-1050	1250-1300	1200-1250	1200-1250	1150-1200	1100-1150	1100-1150
	Ec	985	993	912	****	1020	1010	990	1080	911
	CR (mpy)	0.18	0.25	0.33	0.12	0.13	0.20	0.23	0.25	0.26
254 SMO	OCP	376	338	300	NT	NT	NT	NT	NT	NT
	Ecorr	245	200	210	NT	NT	NT	NT	NT	NT
	Epass	922	836	788	NT	NT	NT	NT	NT	NT
	Ep1	1159±0	1025	998	NT	NT	NT	NT	NT	NT
	Ep2	1041±1	1076	1040	NT	NT	NT	NT	NT	NT
	Ep3	1150-1200	1050-1100	1000-1050	NT	NT	NT	NT	NT	NT
	Ec	963	1042	949	NT	NT	NT	NT	NT	NT
	CR (mpy)	0.12	0.12	0.17	NT	NT	NT	NT	NT	NT
654 SMO	OCP	445	372	360	NT	NT	NT	NT	NT	NT
	Ecorr	232	217	245	NT	NT	NT	NT	NT	NT
	Epass	962	843	814	NT	NT	NT	NT	NT	NT
	Ep1	1165±1	1095	1057	NT	NT	NT	NT	NT	NT
	Ep2	1120±2	1067	1077	NT	NT	NT	NT	NT	NT
	Ep3	1200-1250	1150-1200	1100-1150	NT	NT	NT	NT	NT	NT
	Ec	1016	1008	961	NT	NT	NT	NT	NT	NT
	CR (mpy)	0.11	0.13	0.19	NT	NT	NT	NT	NT	NT

CP (Corrosion Parameter),

CR (Corrosion rate from anodic Pol. Test in mpy),

OCP (Open circuit potential),

Epass (Passivation range) i.e. Ep1-Ecorr,

Ecorr = Corrosion Potential,

Ep1 Pitting potential from anodic polarization,

Ep2 pitting potential from cyclic polarization,

Ep3 pitting potential from potentiostatic measurements,

Ec =Repassivation potential, all the potentials in mV,

Pol = Polarization,

**** Cases in which cyclic curve does not cut at all during reverses direction (least resistance to crevice corrosion),

**Curve takes lower side but not cut the passivation curve indicate very little resistance to localized corrosion, (formation bigger loop),

NT= Not Tested for 654SMO and 654SMO in cases of measurements with chelant.

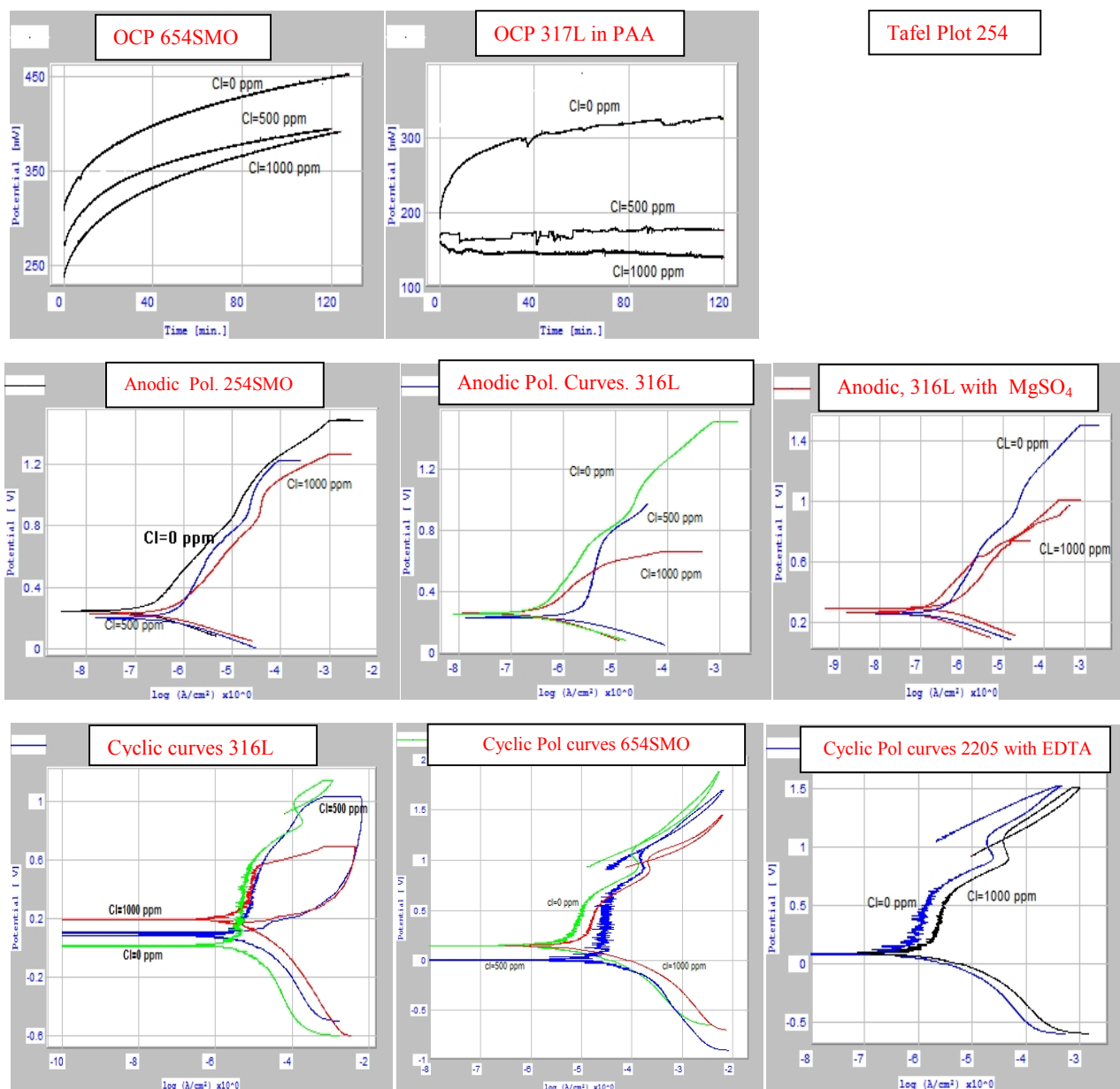


Figure 1: Electrochemical measurement (OCP, Tafel plots, anodic and cyclic polarization.) representative curves of different test metals in PAA bleach media without and with chelant, (values of Cl^- are in ppm).

4. Results

Corrosion rate was calculated by weight loss formula (1); weight loss is determined by subtracting the weight of the corroded and cleaned coupon from its original weight. The extent of pitting (evaluated by measuring the maximum depth of pits formed on freely exposed surface), and crevice corrosion on occluded surface formed by serrated washers. Values of these parameters are given in Table 3. The tests did not show any remarkable pitting attack on stainless steels containing 6% Mo. in test media without chloride.

The potentiostatic test was conducted to evaluate pitting potential E_p , which decides the vertex potential required for recording the cyclic polarization curves, The closed loop cyclic curves in Figure 1 indicate that localized corrosion has begun but was subsequently repassivated and that the downward curve therefore shows a weighted average of alloys behaviour in the solution and the localized corrosion environment. Some open loop curves (figure 1) indicate that the pits have not repassivated. Corrosion parameters E_{corr} , E_{pass} , E_p , E_c and CR are obtained from these tests are given in Table 4.

5. Discussion

5.1. Corrosivity of solutions

The corrosion rate and pits' depth of stainless steels were found greater in case of PAA solution without chelant PAA in comparison to solutions containing chelant. So, corrosivity of media reduces on adding chelant. These values are maximum for all the test metals in PA3 solutions and minimum for PA1CI i.e. in PAA solution with chelant EDTA (Table 3). No, accountable pit is observed for solutions of PAA with chelant for metals 6% Mo. On adding chloride in test solutions, corrosion rate and maximum pits depth is observed as increasing which was highest in PA3 solution and lowest in PA1 solution this behaviour of test samples indicates that corrosivity of stainless steels increases with Cl^- concentration into the test media. Similarly, comparison of these parameters (Table 3) on adding chelants in test media show PA2CII to be more corrosive than PA1CI and PA2CII is also found more corrosive than PA2CI we conclude that solutions having more chloride were more corrosive. The solutions with MgSO_4 were more corrosive than solutions with EDTA for all the three Cl^- levels. Corrosivity in peracetic media was found according to chloride concentration $\text{PA1} < \text{PA2} < \text{PA3}$ and according to chelant $\text{PACI} < \text{PACII}$.

Test results from Tafel plots (Table 4) indicate that value of E_{corr} of test metals is highest in PA1 and decreases on adding chloride while increases again when measured on adding chelant. This improvement was more in case of chelant EDTA i.e. in solution PA1CI. On increasing Cl^- , the passivation range ($E_p - E_{\text{corr}}$) decreases, this is expected due to E_p (pitting potential) decreases and E_{corr} shifts to anodic direction. The values of OCP, E_p , E_c and E_{pass} for tested SS show that solutions PA3 is more corrosive than PA2 and PA2 is more corrosive than PA1CI.

According to ascending order of corrosivity, the solution can be put as;

Without chelant: $\text{PA1} < \text{PA2} < \text{PA3}$, with chelant: $\text{PA1CI} < \text{PA1CII} < \text{PA2CI} < \text{PA2CII} < \text{PA3CI} < \text{PA3CII}$

The greater corrosivity of PAA can be explained on the basis of (i) the prevailing reduction reaction which in turn affect the corrosion of materials (ii) the nature of peracetic acid. The following reduction can be considered to be responsible for corrosion in the solutions.



According to this reduction reaction, two ions of CH_3COOO^- are responsible for consumption of 6 electrons. Thus corrosion of steels takes place when exposed to peracetic acid media, Peracetic acid is more oxidizing than hydrogen peroxide due to electrophilicity character which is greater in case of PAA is than another peracid such as Caro's acid so, at a given pH PAA is also more corrosive than Caro's acid [11]. Results (Table 4) show that the open circuit potential of different steels is higher than respective E_{corr} an increase in chloride content decrease in passivation range in both cases without and with chelant.

Margin of safety, MOS i.e. (Passivation range) was found as reduced with corrosivity of solutions for test metals this rate was found lower in PAA solutions with chelant. A reduction in E_p is observed in same manner in case of potentiostatic and cyclic tests. Values of E_p , E_c and E_{pass} is found greatest for 654SMO, 254SMO intermediate for SS-2205 and lowest for 317L and 316L while for 316L a rapid reduction is observed with chloride concentration as increasing in Cl^- makes this SS more vulnerable to localized corrosion.

No remarkable pitting was observed under microscope [20X] for 6% Mo SS in test solutions containing chelants without Cl^- . Some anodic and cyclic polarization Curves within test solutions show a kink in the curves (Fig. 1 anodic & cyclic) which indicates onset of pitting on higher potential due to O_2 evolution reaction. In some cases, cyclic polarization curve shows hysteresis behaviour when polarization scan reverses to cathodic direction on reaching vertex potential.

5.2. Material performance

5.2.1. Weight Loss Test:

In peracetic acid bleach solutions, on the basis of weight loss the metals can be put in following increasing order of observed corrosion resistance (Tables 2).

Without Cl^- : $316\text{L} < 317\text{L} < 2205 < 254\text{SMO} < 654\text{SMO}$,
With $\text{Cl}^- = 500$ ppm: $316\text{L} < 317\text{L} \leq 2205 < 254\text{SMO} < 654\text{SMO}$,
With $\text{Cl}^- = 1000$ ppm: $316\text{L} \leq 317\text{L} \approx 2205 < 254\text{SMO} < 654\text{SMO}$.

- (i) SS-316L and 317L have lowest resistance in all. It can be explained on the basis of composition i.e. its lower PRE No. ($\text{PRE No} = \% \text{Cr} + 3.3 \times \% \text{Mo} + 16 \times \% \text{N}$) 23.89 and 29.20 respectively as well as content of carbon is greater than metals having 6% Mo. Performance of metal 317L is better than 316L due to it contains more quantity

of Mo hence greater *PRE No. than 316L, as concentration of chloride increased, corrosion rate of 316L is seen highest, increased rapidly than 317L. Duplex SS-2205 exhibits intermediate performance as per its composition i.e. greater PRE. No. than 316L and 317L but its corrosion rate improved rapidly in presence of extended Cl^- . So, In case of PA3 solution 2205 does not show good performance for handling in PAA bleach media.

- (ii) The metals 654SMO & 254SMO show best resistance against all types of corrosion. CR and pits depth are lowest for these metals due to having highest PRE No. The 654SMO showed better performance than 254SMO due to larger Cr and Mo value in composition. With increasing chloride concentration CR increased by lower rate in comparison to SS-316L & 317L. So, we concluded that 654SMO & 254SMO metals can be handled in peracetic acid bleach media with extended value of chloride.

5.2.2. Electrochemical tests

- (i) On the basis of anodic polarization measured parameters OCP, E_p , E_{corr} & E_{pass} (Table 4), this is found that value of E_p is highest & of E_{corr} The metals 6% Mo SS (654SMO, 254SMO) showed higher E_p and lower E_{corr} values i.e. greater E_{pass} (passivation range) in comparison to SS-2205, 317L and 316L. In cyclic polarization curves (Fig.1), E_p can be seen very close to E_c i.e. smaller value of ($E_p - E_c$), we can say smaller cyclic loop forms for these metals, which implies highest resistance against localized corrosion of 6% Mo SS as having higher amount of Cr, Mo, Ni and N in its composition and highest PRE No., CCT, CPT values. .
- (ii) SS-316L shows very low value of above parameters due to containing lowest quantity of Cr, Mo and nitrogen in its composition. This metal contains greater value of carbon which is also responsible for its weak performance among the tested metal samples.
- (iii) Duplex SS-2205 shows intermediate behaviour by corrosion parameters in different test solutions with lower chloride or non chloride, but in case of extended chloride contained solution (PA3), the behaviour of SS-2205 tends to SS-317L and 316L. This is due to its weak resistance against chloride environmental bleach media.
- (iv) In case of corrosion measurements with chelant, however, resistance against crevice corrosion is observed to be higher in case of PA1CI, PA1CII (solutions non Cl^- , with chelant) than in solution PA1 (without chelant). Passivation range and pitting potential E_p is highest for 6% Mo SS and lowest for 316L. Results suggest higher resistance of 2205 than 317L and much higher than 316L against localized.
- (vi) Cyclic polarization curves show non passivation pits ($E_c < E_{\text{corr}}$) especially in case of 316L and 317L in chloride contained solutions and their E_c is likely to be around E_{corr} . For metal 2205, E_p and hence passivation range (E_{pass}) is measured as intermediate among the five tested metals in non chelant case. $E_c > E_{\text{corr}}$ behaviour of SS-654SMO and 254SMO showed repassivation of pits and more resistance to localized corrosion in all the PAA solutions. SS-2205 also exhibited good performance but under the condition of nil or lower quantity of chloride with chelant in PAA media.
- (v) The stainless steel 2205 in PA2, PA3 (PAA with Cl^-) solutions showed a lower value of E_p , E_c & E_{pass} which indicates smaller resistance to crevice corrosion. But on adding chelant, the values of E_p and E_{pass} improved especially in case of EDTA inhibitor. So, the performance of 2205 is still poorer with chloride. While relative performance of SS-316L, 317L is found poorer with and without chloride which improved on adding chelant.
- (vi) Metal 254SMO, 654SMO show best resistance against pitting and crevice corrosion in solutions PA2 & PA3 too. Due to having highest PRE No. , these can be suggested suitable to handle in PAA solutions with chloride. The stainless steels 317L and 316L are not appropriate to handle in PAA bleach media with extended chloride.

5.3. Effect of chloride

- (i) On adding chloride, CR increased with concentration of chloride in all the test solutions of PAA bleach media. On adding NaCl, Na^+ and Cl^- ions become free as charge carriers in solution by which conductivity of solution increases. According to penetration theory [7, 22] anodic dissolution take place by chloride i.e. Cl^- ions replace the oxygen from per acetate ion by which protective layer becomes weaker on attacking Cl^- ion on the surface of metal. So reaction rate increases, metal oxidation rate will also increase due to this is electrochemical process. So, corrosion of SS in peracetic acid bleach media accelerates by increasing concentration of NaCl.
- (ii) As concentration of chloride increases, the behaviour of SS-2205 is seen same as 317L in the solution PA3 this exhibits good performance in PA1 or PA2CI ($\text{Cl}^- = 500$ ppm with EDTA). SS-654SMO, 254SMO showed best performance (highest corrosion resistance) in all test solutions, while SS-316L is found most affected metal under each condition of solutions in all the tested stainless steels.

The results through EC measurements show a reduction in value of E_p and displacement of E_{corr} in anodic direction (anodic as well as cyclic tests), hence a reduction in E_{pass} i.e. in (margin of safety) MOS is found in

case of all the test metals in similar test conditions. An improvement in resistance against corrosion was seen in bleach media with chelant for all the stainless steels.

- (iii) The values of OCP, E_p , E_{pass} & E_c are seen least affected for 6% Mo SS, while for 2205 metal more affected than SS-317L in PA2 and PA3 solutions as this metal have higher PRE No. CCT & CPT. for SS-2205 and 316L value of these parameters (Table 4) are found more affected when concentration of chloride extended above 500 ppm. So, this metal did not show good performance in the solutions with extending limit of chloride.
- (iv) For SS 316L, Cyclic polarization measurements show lowest E_{pass} and its' E_c tends to E_{corr} when chloride concentration increased in solution. Value of E_p - E_c is bigger as a result a big loop forms which indicates lowest resistance to localised corrosion.

5.4. Effect of chelant

A surface film formed by reaction of EDTA and metal cations as complex materials at the metal solution interface considered as barrier which is responsible to inhibition,



Such reactions are possible for other metal composition of SS. The absorbed inhibitor EDTA or $MgSO_4$ used in PAA media may form a surface film that acts as a physical barrier to restrict the diffusion of ions or molecules to or from the metal surface and so retard the rate of corrosion reactions hence works as inhibitor.

The results from weight loss test were analyzed on adding chelant in test solutions as per Table 2. The values of CR as well as pits depth decreased for all the test conducted metals in every condition of chemical charges (Table 3). This is due to passive layer on metal surface becomes strong on adding chelant.

With reference to electrochemical tests, on adding chelant, the corrosivity of solutions is seen as reduced and hence value of E_{corr} decreased and corresponding value of pitting potential E_p increased in both the anodic and cyclic polarization curves; as a result the MOS value (margin of safety) increased for all the test metals without and with Cl^- . The value of OCP increases in presence of chelant EDTA or $MgSO_4$ in PAA solutions. This effect indicates that the test materials can be handled in media with EDTA having chloride (Table 4). The values of E_p & E_c for metal 2205 and 317L were found greater in solutions with chelant EDTA than 316L. This improvement was greater in case of EDTA than $MgSO_4$. SS-2205 showed best performance with chelant EDTA in case of smaller quantity of chloride in the bleach solutions. Inhibition efficiency is observed more in case of EDTA than $MgSO_4$.

5.5. EDTA versus $MgSO_4$ inhibitor

As per analyzed earlier the corrosion parameters show that bleach solutions with chelant $MgSO_4$ is more corrosive than solutions with chelant EDTA for both without and with chloride in test media. Varjonen et al [21] studied on titanium in peroxide and found that $MgSO_4$ was not found effective inhibitor.

Experimental results imply that EDTA is better inhibitor than $MgSO_4$ as SO_4^{--} ion make complex as single site but EDTA has six coordination sites free with four negative ions on its four branches on which it make complex. The reduction reaction with EDTA takes place rapidly [15]. EDTA has stronger ability to complexation. It has COOH and NH_2 functional group which form a ring structure around the metal. So, we can handle the more affective metals or with extended limit of Cl^- in the peracids with EDTA inhibitor.

5.6. Material Selection

A proposition is now given about the appropriate material for handling against adopted PAA bleach solutions considering the results and analysis of immersion test, criterion by Tuthill [20] and EC polarization measurements. With reference to material selection we concluded as follows:

- (i) The stainless steels 654SMO, 254SMO are appropriate in PA1, PA2 and PA3 solution at pH=4.0. Their suitability remains same on adding the chloride while 317L and SS-2205 are not appropriate for PA3 and PA2 solutions under the similar conditions. Their use is doubtful in view of the electrochemical measurements. Immersion test showed better performance of 2205 in PA1 and much better with chelant in same solutions. Exhibition of resistance of 254SMO & 654SMO against localized corrosion indicates that these steel to be most appropriate in PAA beach solutions.
- (ii) SS-2205 appears usable in the solutions PA1 & PA2 but with chelant on the basis of all types of tests. The 316L is not appropriate in PA2 and PA3 solutions its use is doubtful in view of the electrochemical test measurements. Immersion test showed intermediate performance of 2205 in PA1 this performance again improves in PA1CI i.e. Performance improves on adding chelant in same solutions. SS-317L shows better performance than 316L, This can be handled in presence of chelant having lower limit of chloride, this behaviour of 317L is similar to SS-2205.

- (iii) Duplex stainless steel 2205 shows even better resistance in these solutions with chelant which is acceptable for PA2CI and PA2CII too, at room temperature. It may be more appropriate in solutions with lower values (<500 ppm) of chloride but with EDTA inhibitor. The metals 654SMO and 254SMO are suitable for handling in peracetic acid solutions containing extending limit of chloride (Tables 2 & 3). Application of 2205 is more cost effective on the basis of its improved cost/strength ratio in addition to better corrosion resistance and can be considered suitable for handling with EDTA inhibitor with extended limit of chloride. This aspect of corrosion behaviour of this metal needs further investigation.

6. Conclusion

Present study reports corrosion investigation carried out on selected stainless steels (Table1) in laboratory prepared peracetic acid solutions with/without chloride and chelant at pH=4. Following conclusions can be drawn on the basis of analysis of corrosion test results.

- (i) Corrosion rate and maximum pits depth increases with test metals according to 654SMO<254SMO<2205<317L<316L. The observed increasing order of corrosivity of test solutions can be put as PA1<PA2<PA3, and with chelant: PA1CI<PA1CII<PA2CI<PA2CII< PA3CI<PA3CII i.e. corrosivity of solutions increases on adding chloride while decreases on adding chelant.
- (ii) The value of OCP of all the test material also decreases according to above manner with chloride in the above test solutions with and without chelant. The 654SMO, 254SMO show highest OCP value while SS-2205 shows intermediate value and 317L, 316L show lowest for similar conditions (Table 4).
- (iii) Electrochemical measurements were run on stainless steels in PAA solutions with Cl^- exhibit higher degree of localized corrosion whereas it is less severe in case of solutions without chloride. Corrosion parameters obtained from electrochemical tests i.e. OCP, E_p , E_c , E_{pass} etc. (Table 4) indicate that test metals can be put in following order of increasing corrosion resistance 316L<317L<2205 <254SMO<654SMO in test media. Performance of studied stainless steels with chelants EDTA & MgSO_4 is seen as improved against corrosion attack. The measured corrosion parameters imply that corrosion resistance is greater in case of solutions with EDTA than solutions with MgSO_4 under similar conditions i.e. corrosivity of media reduced on adding chelants for all the tested stainless steels in the present investigations.
- (iv) On the bases of long term immersion and electrochemical corrosion measurements in PAA, it is concluded that metal 654SMO and 254SMO show highest resistance against all types of corrosion. The comparison of performance of different test materials suggests, SS-2205 to be resistant in case of nil chloride PAA media while 316L least resistant against all types of corrosion attacks.
- (v) In PAA solutions with chelants, the suitability of test metals is fixed with extending limit of chloride. The SS-2205 can be handled in bleach media with chloride as well as with chelant MgSO_4 and found more suitable in media with EDTA. In this case this metal can be handled containing even by increased quantity of chloride in PAA solutions,
- (vi) This is also concluded that 654SMO & 254SMO are apt for handling in extended Cl^- containing PAA media. SS-2205 exhibits greater corrosion resistance than 317L in case of solutions with chelant while SS-316L shows lowest. This behavior is due to its greater PRE No. of 2205. So, this metal is appropriate for handling in bleach solutions without Cl^- or with lower concentration of chloride on the basis of degree of attack alongside comparison of cost versus strength of different stainless steels.

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