Experience with Maintenance of Chlorine Dioxide Based Bleach Plant : How to Manage Corrosion

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ABSTRACT

The article describes the experience of the authors in maintaining a hard wood pulp bleach plant with various combinations of bleaching stages, chlorine dioxide being the main bleaching agent. It deals with the selection of material of construction for various items of plant and machinery, a few failures attributed to endemic corrosion, evaluating comparative performance of different materials and new strategies to deal with these problems. Case studies included are ClO_2 washing filter drum (D1 stage) failures, D1 and D2 stage prereactor linings and, C/D, D1 & D2 stage pumps and pipelines.

INTRODUCTION

In an operating pulp and paper mill, deteriorating mechanisms of corrosion are working away 24 hours, 7 day a week. They cannot be seen, heard or felt. Corrosion is like an insidious cancer constantly eating away and spreading itself throughout the tanks, piping, structures and equipment.

Changes in processes, equipment and operating techniques often show us new corrosion problems. In recent years, the environmental protection agency has brought about stringent regulations on stream pollution. Most mills have drastically reduced the amount of water used for bleaching. With fresh water usage cut back to 125 m^3 per tonne of pulp and usage of back water increase and filtrate temperatures increasing, corrosion rates have accelerated to a degree where noticeable pitting of type 317 L stainless steel was evident in only few months of service.

The effect of mill processes, production, environment and our human resources is immense during certain corrosion problems. Sharing of examples from other mills is a way for us to get a better perspective of the total impact of corrosion at the mill level.

Kraft bleaching with chlorine dioxide is well recognized as the most corrosive section of our industry. At APPM, we have seen extremely high incidence of repairing type D1 stage washer drum made out of SS 317 L material. The drum has to be replaced twice within 10 years of washing. Problems with prereactor linings, chlorine backwater pump and pipelines caused by corrosion are also discussed here. These kinds of problem create significant workload on the maintenance engineer at the mill for planning manpower, down time and keeping the existing washer repaired.

Understanding Corrosion

Corrosion studies is a science by itself and it is not the subject matter of this article. However a simple and concise description is not out of place and is attempted here. Corrosion is simply the deterioration caused when a metal reacts with its environment and it can take many forms.

Localised: This affects only small are as, but the attack may be severe. It may be caused by galvanic action, erosion, cavitations, crevices, pitting or selective leaching. Stress corrosion cracking will also cause localized corrosion.

1) **Galvanic :** Occurs when two dissimilar metals are in electric contact, both exposed to conductive solutions. It can be recognized by increased attack close to the junction of the two metals.
2) **Erosion:** Often occurs where high velocity fluid movement occurs, causing turbulence and impingement. Attack usually occurs on pump impellers, agitators and piping bends and elbows. Slurries with hard particles will also cause this type of corrosion.
3) **Cavitation :** Formation and collapse of gas bubbles at the metal surface create momentarily high impacts that tend to remove protective film from the metal.
4) **Crevice corrosion:** Usually occurs in crevices. caused by differences in oxygen and/or electrolyte concentrations. Found at gaskets, lap joints. Bolts, rivets etc may be accelerated by dirt deposits, scratches in the protective film, and changes in acidity and lack of oxygen.
5) **Pitting:** When protective films of corrosion layers

are removed, small pits begin to form in an otherwise relatively unattacked surface. This can develop into severe attack and can serve as the starting points for stress corrosion.

6) **Stress corrosion cracking:** May result from residual cold work, weloding, thermal treatment or extremely applied stress in metal. The cracks follow intergranular and/or triangular pathways within the metallic structure. The corrosion often show branched cracking.

7) **Effect of pH:** The pH of a system will bear upon the problem in a variety of ways. Generally, the acidic pH range of paper mill systems increases the corrosion possibilities. Iron and its alloys constitute a majority of the metals used in such systems, and they are very highly susceptible to corrosion at low pH levels. Low pH systems, coupled with high temperatures, high dissolved solids, fibres, organic and inorganic detritus and varied water characteristics all combine to prevent establishment of the protective film so necessary to good corrosion protection.

Once the causes of specific corrosion conditions have been identified, contributory factors must be weighed in determining the correct treatment programs to control the condition.

Corrosion cost

In 1969, K.M. Thompson of the pulp and paper research institute of Canda, in co-operation with the Mechanical Engineering Committee of the Canadian pulp and paper Association, Technical Section, serveyed the costs due to corrosion in Canadain pulp and paper mills. When a pulp or paper mill is designed, allowances must be made for the corrosive nature of the solids, liquids and gases that will come into contact with the materials of which the mill is made.

The design engineer has a certain control over this increase in cost, but it is generally true that the less spent in the initial protection against corrosion, the more must be spent in maintenance cost when the mill is in operation. It is the goal of the mill designer to minimize the sum of these two costs. To do this he requires knowledge of the materials the techniques available for corrosion protection. In order to determine the present capital cost due to corrosion, a very careful study was made and the summary of the results are as follows.

Portion of capital cost due to corrosion

Bleached kraft pulp Mills	8.0%
Unbleached kraft pulp Mills	7.0%
Newsprint Mills	6.5%

Operating cost due to corrosion will be approximately 1.5 times capital cost due to corrosion.

New bleach plant at APPM

In the Andhra Pradesh Paper Mills Limited, new bleach plant was installed and commissioned in 1994, with bleaching sequence as C-Ep-H-E-H, and for 1-1 1/2 year the plant was run with hypo bleaching. Chlorine dioxide plant was installed and commissioned by the end of 1995, but the plant Stabilization trial continued for 6 months. From the year 1996 middle, the plant is running continuously with chlorine dioxide bleaching, with the bleaching sequence C-E1-D1-E2-D2.

In the year 1999, D1 and D2 stage towers were changed into upward flow from downward flow towers by introducing two prereactors along with drop leg, M.C., pump with vacuum pump and chemical mixers. Chlorine stage was also converted to C/D stage by addition of chemical mixer. Hypo was totally eliminated and ultimate final bleaching sequence now is C/D -Ep-D1-E2-D2.

The following was the material of construction of equipment, pipes and pipe fittings selected at the time of project.

1) Washer Drums:

Cl_2, D1 & D2 stage	-- SS 317 L
E1 & E2 stage	-- SS 316 L

2) Heater Mixers:

E1 & E2 stage	-- SS 316 L
D1 & D2 stage	-- SS 317L/Ti-lined

3) Tower Agitators:

Cl_2 tower	-- SS 317 L/rubber lined
L.D. Chest, D1, D2 & H.D. Tower	-- SS 317 L
E1 & E2 towers	-- SS 316 L

4) All stock pumps & back water pumps:

All wetted parts	-- SS 316

5) Pipes and pipe fittings:

L.D. Chest, D1 & D2 stage	-- SS 317 L
E1 & E2 stage	-- SS 317 L
H.D. Tower	-- SS 304
ClO_2 lines	-- Ti
Cl_2 lines	-- M.S. for dry chlorine FRP for wet chlorine

Case history of D1 stage drum

The following is the history of corrossion attack on first stage chlorine dioxide washer drum in A.P. Paper Mills.

Year 1994: First stage chlorine dioxide washer drum was installed and comissioned in the month of September. The material of construction of drum was SS 317 L with internal supporting beams and fly rims of M.S. construction. Internal tubing is of trapezodial construction. Upto March 1996, it ran as 1st stage hypo washer. From April 1996 it started as D1 stage chlorine dioxide washer.

Year 1997: In the month of November, it was observed that the condensate water was coming through scope pipe. Plant was stopped and people were sent inside the drum for inspection. About 12 liters of water was found inside the drum. Water was squeezed out and enamel paint was applied to the inside beams and fly rims.

Year 1998: In the month of August, water started coming out of scoope pipe. Inspection cover opened and checked the drum inside. One number of trapezoidal pipe elbow developed crack near pipe weld joint. The same was tried to weld, but the pipe plate was developing cracks. Hence, it was sealed by coating with FRP.

Year 1999: Again in the month of December, two more tubes welding joints developed cracks. Those were applied with FRP putty and matting. Leak test was carried out and found no further leakage.

Year 2000: The leakage problem was referred to manufacturer, who has supplied the drum in 1994. Their representative arrived in the month of April. The washer was bypassed for 10 days for inspection. The following damages were observed on the drum inside.

- Drum inside trunion supporting beams were badly corroded. Additional "I" beam supports welded.
- Trapezoidal pipe supporting ring was badly corroded. New ring was provided.
- Drum shell supporting fly rims were badly corroded Additional fly rims were provided.
- Out of 18 nos. of trapezoidal piping, 7 nos. of piping weld joints were very badly corroded. Three tube lengths of about 600 mm long were changed. Other tubes welding joints were covered with SS 317 flats and welded. The parent metals response was poor for welding. Hence, all the weld joints were applied with FRP matting. The washer was given into operation on 26th April.
- Again in the month of December 2000, the washer was bypassed for 10 days due to peeling off its synthetic wire cloth. After removing the damaged cloth, we found most of the deck wire came out from grooves. The grooves of the division.

Strips were badly corroded and breaking. SS 317 division strips were made in local Workshop and welded adjacent to damaged strips at different place.

Year 2001: It was decided to replace the drum with a new SS 317 L drum. New drum was procured and changed in the month of July 2001. Within 2 months after installation, deck wire found damaged at several places. The damage was referred to the supplier of the drum. Their representative arrived at site along with new SS 317 L deck wire in the month of October. The washer was again bypassed for 10 days and inspected. Deck wire was completely removed and found lot of rust spots and shell longitudinal and circumferential weld joints and at grooves of division strips. Rust spots were cleaned thoroughly and new deck wire was wrapped on the drum. Washer was taken into operation on 3rd November 2001.

Test results of rust samples, collected from division strip grooves, on 12th October 2002 are as under

Moisture	----	8.03%
Ash	----	80.65%
Acid insoluble	----	14.00%
R_2O_3	----	65.40%
Calcium as $CaCO_3$	----	2.00%
Silica	----	3.40%
Iron as Fe_2O_3	----	41.80%

(all values except moisture are on OD material basis)

Drillings of drum shell was done in presence of the supplier, and the sample chips were sent to metallurgical laboratories for chemical analysis. The report confirms the material as SS 317L. The following is the presentage of elements found from sample chips.

C- 0.030	P - 0.012
Mn- 1.44	Cr - 18.09
Si 0.40	Ni - 14.71
S - 0.009	Mo - 3.83

Year 2002: In the month of October, the complete deck wire taken out as became loose and replaced with new wire. The corrosion rust spots were increased and found at several places on division strip grooves, shell -welding joints. All rust spots were passivated and new wire was fixed.

The backwaters recirculation in the bleach plant at APPM is counter current washing. The schematic hand sketch is given under below.

Due to the deteriorating condition of the drum, our management has decided to go for new drum with suitable material of construction suiting of APPM process conditions. In consultation with the manufacturer, APPM has procured new drum in material of construction High Alloyed Austenitic stainless steel 904L.

General characteristics of high-alloyed austenitic stainless steels have such high contents of chromium,

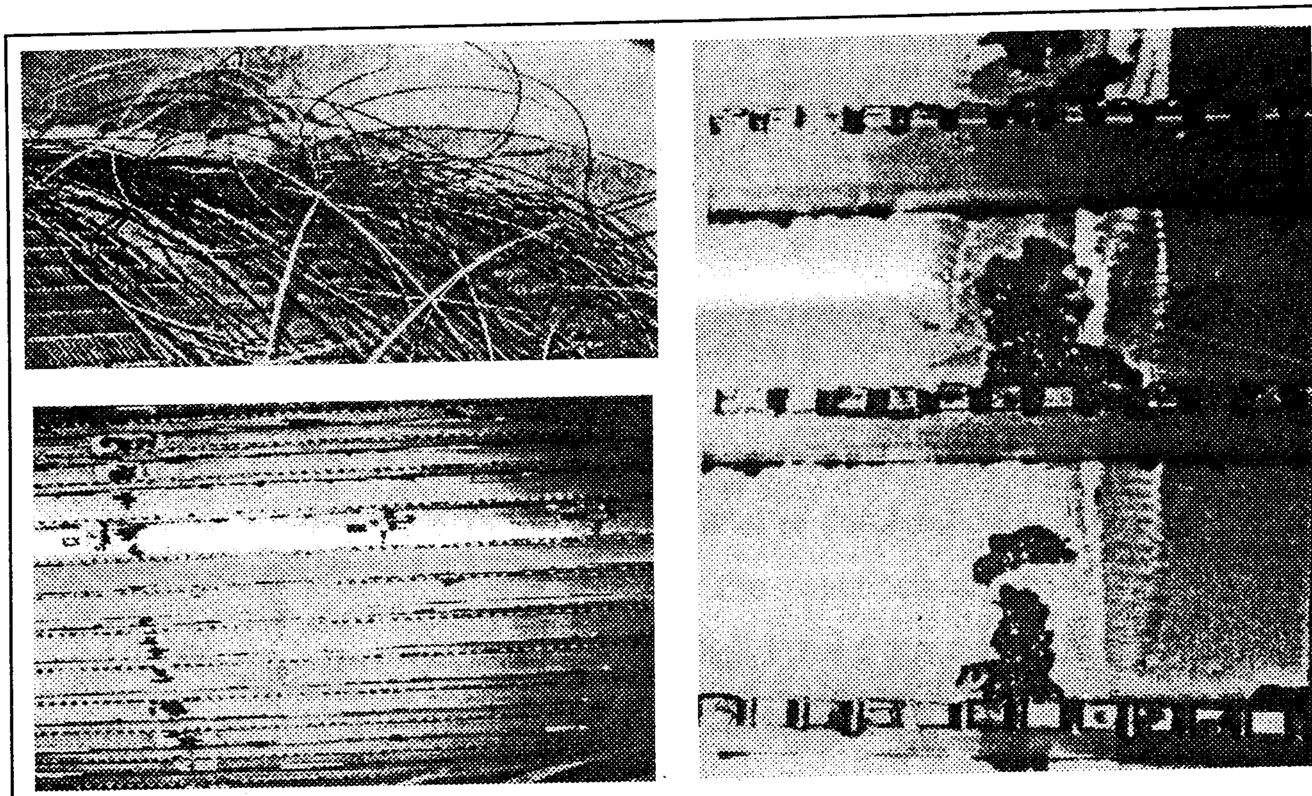

Fig. 1

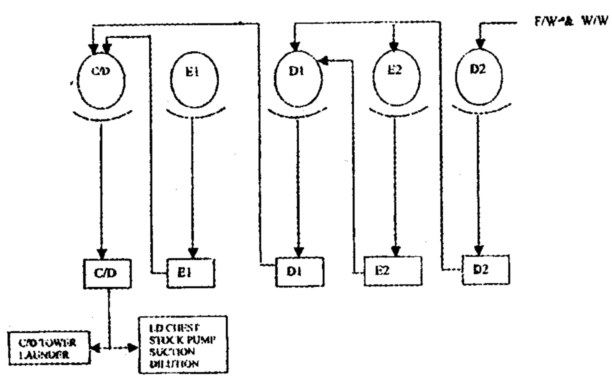

Fig. 2

nickel, molybdenum and nitrogen that they differ substantially from more conventional grades with regard to resistance to corrosion. 254 SMO and 654 SMO of Avesta group are much superior than 904 L. But they are found to be more expensive.

254 SMO & 654 SMO are more suitable for hydrochloric acid, hydrofluoric acid, chloride contaiminated sulfuric acid, phosphoric acid...etc.

The content of chromium (Cr) , Molybdenum (Mo) and Nitrogen (N) determine resistance to pitting and crevice corrosion.

Pitting resistance equivalent (PRE) = % Cr + 3.3*%Mo+16*%N

The PRE value for 904 L is 36, is slightly less as compared to 254 SMO, which is 43.

Critical pitting corrosion temperature ɩor 904 L is about 65°C But for 254 SMO is around 90°C.

We at APPM maintaining temperature of pulp at D1 stage as 65°C maximum. Hence 904 L material is selected.

D1 & D2 stage Pre-reactor lining

Bleach Plant retrofit was carried out in 1999, by

Table 1 Chemical composition

Avesta Steel Name	ASTM No	C	N	Cr	Ni	Mo	Others
904 L	N 08904	0.01	0.06	20	25	4.3	1.5 Cu
254 SMO	S 31254	0.01	0.20	20	18	6.1	Cu
654 SMO	S 32654	0.01	0.50	24	22	7.3	3.5 Mn, Cu

	C	Mn	Si	Ph	S	Cr	Ni	Mo
SS 316 (CF8M)	0.08	1.50	2.00	0.05	0.05	18-21	9-12	2-3
Alloy-20 (CN-7M)	0.07		1.00	0.04	0.04	20-21	29-30	2.0

introducing D1 & D2 stage pre-reactors in the present circuit. The pre-reactors were made out of 12 mm thick M.S. plate and lined inside by ceilcote. Foreign experts had come and carried out the lining. Lining thickness was about 2mm.

After few months of running, unknown spots were observed on paper at paper machine side. After thorough check up, lot of rust spots were observed on the surface of lining. We have bypassed the reactor and carried out spark testing. Spark test revaled that, shell got exposed. The same experts did the re-lining. But re-lining also failed within few months. Then it was decided to go for 5 to 6 mm thick FRP matting with vinyl ester resin. Ultimately, FRP lining was completed for D1 pre-reactor in the month of December 2002 and the performance is still under observation.

Chlorine back water pump

During project stage in 1994, Cl_2 backwater pump of SS 316 material was installed. The pump shaft and impeller were failed several times due to heavy corrosion. Due to cavitation the impeller vanes were getting corroded and unbalance occurred. Due to this the shaft used to break. Hence, the pump replaced with Alloy - 20 material of construction. The pump is now running continuously without any problem. The material of construction of SS 316 & Alloy-20 are as follows.

C/D, D1 & D2 Stage piping

during project stage, chlorine backwater, D1 stock pump and backwater pump suction and delivery lines were SS 317 L. After 2 years of running with ClO_2 bleaching, all welding joints of pipe lines (including longitudinal joints) developed corrosion pittings due to cavitation and started leaking. All these pipelines were replaced with FRP pipe in a phased manner. Vinyl ester resin FRP pipes were selected for this application. The replacement work was done in the year 1998. Since then the performance of these pipelines is satisfactory.

During Retrofit in 1999, D1 and D2 stage MC pump delivery lines were selected as FRP having 20mm thick. Inspite of arranging adequate clamps support, stubend joints failed in 3-4 occasions. Lot of hot pulp was gushed out resulting surrounding area polluted and plant down time. The failures may be due to high discharge pressure (8.5-10.0 kg/sq.cm) of MC pumps, and sudden stoppage and starting of MC pump depending on drop leg levels. To avoid this kind of situation, A.P.P.M. has tried with S 316 L piping. But, this piping failed within few months. Hence, it is proposed to go for Titanium piping for this application.

CONCLUSION

SS317L material is poor resistant to ClO_2 stage at first stage washing and back water applications. Cl_2 back water pump MOC alloy 20 is more resistant to corrosion. Titanium pipe lines give more life and resistant to corrosion for ClO_2 solution and first stage MC pump delivery lines. FRP pipelines are also good against corrosion at low - pressure lines. After changing Cl_2, D1 & D2 stages stock pumps suction and delivery lines to FRP, plant downtime has considerably reduced.

REFERENCES

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