Corrosion in Pulp and Paper Industry

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ABSTRACT

The paper highlights various forms of corrosion and factors affecting corrosion in pulp and paper industry. Corrosion problems at various stages of pulp and paper making and corrosion prevention methods has been discussed.

INTRODUCTION

Corrosion is one of the worst enemies of an industry. Like a cancer cell it often slowly develops for many years and remains undetected. When observed, it is too late to eliminate it and mend the damages caused by it. It affects the ecooomy directly, in the form of replacement costs of equipment and corroded structures and indirectly, as maintenance and operating costs due to failures and shut downs of equipment, structures, pipe lines and through contaminating the product and affecting the safety and reliability. The loss in production and the maintenance and replacement costs due to corrosion in Indian industry arc estimated into thousands of crores of rupees annually ([1]).

Corrosion problem in pulp and paper industry is more serious as it is using a wide variety of corrosive chemicals like chlorine, chlorine dioxide, sulphides, alum, sulphuric acid, hydrochloric acid, sulphamic acid, hypochlorite and generating several other similar corrosive substances as reaction products at various stages. The severity of corrosion has increased considerably during the recent years due to pollution control requirements and resultant increased recycling of back-water, and waste paper contaminated with foreign materials and use of other nonconventional raw materials like rice straw, wheat straw and bagasse. In India corrosion has been reported to cost about Rs. 100,00 per tonne of paper.

A Knowledge of the factors causing corrosion and variables affecting it as well as compatibility of the conditions of environment by paper choice of material of construction and good design for the greater protection will be of great help in reducing the problems. In the present paper an attempt has been made to highlight various forms of corrosion, factors affecting corrosion and corrosion problem at various stages of pulp and paper manufacture and its prevention with special reference to kraft pulp and paper industry.

FORMS OF CORROSION AND FACTORS AFFECTING CORROSION

Corrosion is destruction or deterioration of materials by environmental agencies through chemical or electrochemical reaction, or by wear and tear. Corrosion is a result of recombination with other materials through which metals revert to a non-refined state i. e. reversion to the state in which the metal existed in nature with corsesponding release of free energy which is the driving force in corrosion reaction. The rate of change in free energy determines whether or not a corrosion reaction will start spontaneously.

Uniform corrosion, galvanic corrosion, pitting and crevice corrosion, intergranular corrosion, wear corrosion cracking corrosion, stress, fatigue, hydrogen embritlement, caustic embritlement, high temperature corrosion and biological corrosion are the various forms of corrosion which commonly occur at various stages of pulp and paper manufacture. Details of various forms of corrosion and their prevention methods are given in Table I.

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TABLE—I. FORMS OF CORROSION AND PREVENTION (2–10)

Forms of Corrosion		Prevention
1. Uniform Corrosion	Charaterised by a chemical or electorochemical reaction which proceeds uniformly over the entire exposed surface. Caused due to heterogeneity in metal.	Selection of proper materials, application of coatings, use of inhibitors, cathodic protection, avoid surface water collection.
2. Galvanic Corrosion	Occurs when two dissimilar metals are in electrical contact while immersed in an electrolyte. Extent or severity depends on difference in potential of metal and relative surface.	Selection of metals as close together as possible in galvanic series, avoiding large cathode and a small anode area, insulation of dissimilar metals, use inhibitors and application of coatings, use of readily replacceable anodic parts.
3. Pitting Corrosion	Localised form of corrosion due to formation of an electrolytic cell to initiate anodic/cathodic corrosion, associated with stagnant conditions, factors promoting pitting – surface roughness, scratches, differential strain, heterogeneous structure, differential metalurgical or thermal treatments, differential conceentration of solution, aeration, heating, agitation.	Selection of pitting resistant material e g. addition of 2% molybdenum in SS304 increases pitting resistance. Nickel alloys and titanium have good resistance to pitting, solids deposits to be remove proper drainage agitation and washing, reduce internal condensation.
4. Crevice Corrosion	Intense localised attack frequently takes place within crevices or other shielded areas, associated with small volumes of stagnant solution caused by holes, gasket surfaces lap joints, surface deposites, crevice under bolts and rivet hood.	Proper design, to avoid crevices e g. welded butt joints instead of rivette or w bolted joint, close crevices in lap joints by welding or soldering, designing vessel for proper drainage, romove solid in suspension, remove wet packing materials, used of Teflon garkets.
5. Inter Granular Corrosion	Localised attack at and adjacent grain boundaries without appreciable attack on the grain is called inter granular properties of metal.	Lowering carbon content, use of solution heat treatment use of titanium, columbium, addition of tantalum to stabilise carbides.
6. Stress Corrosion	Craeking resulting from combined effects of residual or applied stress and chemical action. Influenced by stress level, corrosive agent, time and temperature of exposure, structure of metal.	Elimination of high stresses, minimising marked composition differences between grains and grain boundaries, use of stress corrosion resistant material e. g. use of alloys containing more than 30% nickel, lowering nitrogen content.
7. Wear Corrosion	Results from erosion of the surface caused by turbulent flow, cavitation, solids present in fluids, wear due to adhesion wear, surface fatigue fretting. Wear corrosion is a serious problem in mills empioying noncon-vention raw material like, bagasse, rice straw, wheat straw.	Selection of erosion resistance material, proper design alteration of environment, coating, better lubrication, cladding, surface treatment, thermal hardening.

Forms of Corrosion		Prevention
8. High Temperature corrosion	Corrosion is due to oxidation where metal oxides are formed by reaction with the products of fuel combustion accelerated by alternate heating and cooling.	Addition of chromium, silicon and aluminium to improve resistance to high temperature oxidation
9 Biological Corrosion	Corrosion occurs due to activity of bacteria, fungi and alge which may be aerobic or anaeropbic.	Coating cleaning and effective house keeping, biological treatment.
10. Hydrogen Embrittlement	Carcking on exposure to corrosive environment due hydrogen entering the metal through corrosion reaction.	Using clean steels, using coatings impervious to hydrogen penetration, using inhibitors.
11. Caustic Embrittlement	When steel is stressed and exposed to alkaline solutions at high temperature it cracks. Cracking in digester boiler is due to caustic embrittlement Succeptibiiity of caustic cracking dependent on the potential that spontaneously develops at steel surface by pulping liquors.	Use of high alloy steel, plasma sprays, shot pecning.
12. Stray Current Corrosion	Corrosion occurs whed the installation is located to storay electrical currents and there is no insulatson.	Proper insulation.

Various factors affecting corrosion are temperature, velocity, pH, oxidizing and reducing conditions, concentration, dissolved gases, differential acration, presence of colloids, bacteria, existence of stresses, place of metals in emf series, purity of metal, physical state of metal oxide or surface behaviour of metal, solubility of salts of metals, dissolve oxygen, carbondioxide and iron impuritles, sulphidity of cookiug liquor, cleanness of surface and deposits, etc.

CORROSION IN PULP AND PAPER INDUSTRY

The corrosion problem in pulp and paper industry is very serious and various forms of corrosion in some or other way are experienced in almost all sections, starting from chipper house, digester house, pulp mill-washing, screening and bleaching, evaparator, recovery boiler and causticizing section, stock preparation, paper machines to power generation plant. The corrosion problems of these sections are briefly described below.

Chipper House—In chipper house wear and erosion/corrosion occur in log handling system due to wear and tear of chain conveyors, feed chutes, cyclones, chips blow line etc. However the corrosion is not of very serious nature, minor repair, proper selection of material of construction, proper preventive maintenance of equipment to minimise wear and tear, and incorporation of impact boxes in chips blow line have helped in reducing erosion.

Digester House—Digesters, preheater, circulation pump, white liquor storage tank, liquor feeding line, digester blow line, blow pits are the various units which are affected by corrosion. Various causes of corrosion[11] in digesters are hot plate boiling on the digester surface during liquor charging circulation and impingement, direct steaming, temperature differential, galvanic effect, and violent agitation of pulp during blow causing erosion of passive films. The digester is actively corroded during the temperature raising period,and it spontaneously self passivates near the operating temperature and remains passive throughout the remainder of tha cook [12].

Carbon steel is the traditional material of construction for digesters, however, new trend is to have clad plate with lining of SS304 [10]. In batch digester severe corrosion has been observed in the digester cone, corrosion in the other parts of digester is comparatively low. Shell wall thickness of digester cone was found to be reduced to 18 mm from original 25 mm thickness after 10 years of service [3]. Corrosion at cone shell has been experienced by other mills also. The normal rate of corrosion in digester shell is 0.5—0.6 mm per thousand cooks (less than 1 mm per year) but rates as high as 1-3 mm per 1000 cooks or upto 7 mm per year have been also reported [13].

Corrosion problem in continuous digester is a severe problem. Castrophic failure of digester due to wide spread cracking was found in welds in upper zone of continuous digester [14,15]. Problem of stress cracking due to corrosion of continuous digester was studied by various workers [16,17,18]. Succeptibility of caustic cracking is strongly dependent on the potential that spontaneously develops at a steel surface wetted by pulping liquors [16]. Stress corrosion cracking of digester shells and weldment was found to occur in solution simulating make-up, impregnation and cooking zone liquor in kraft continuous digester [17]. Cracking in digester occurs as a result of stress corrosion which is caused by the action of tensile stress during exposure to a specific corrosive environment [17].

In order to improve yield and pulp quality tendency has been to use higher sulphidity. It is a well known fact that higher the sulphidity greater the incidence of corrosion. Some mills dissolve sulphur in white liquor to maintain sulphidity which accelerates the corrosion. Sodium thiosulphate which is usually present in fresh liquor, considerably accelerates corrosion. Thiosulphate is corrosive to SS304 as well as bronze and thiosulphate should be kept to a 5 ppm maximum to zero if possible for materials made of SS304. Greater resistance of thiosulphate pitting has been in SS316, 317L, Ferralium 225 and cast duplex steels KCR-A171 and Alloy 75.

Welding procedure are of greatest importance in the control of cracking in digester steels. Welds made on cold steel can have high residual stressesand produce brittle zones which are very succeptible to stress corrosion cracking [7]. Overlay welding is a satisfactory method for prevention of corrosion in kraft and soda process digesters [18,19]. Recent advancement is to do plasma spraying to protect carbon steel in kraft cooking liquor rather than the traditional weld overlay [17]. Operation modification to reduce corrosion consist of reducing time to cooking pressure, installation of liquor deflectors, change in location of nozzles and opening, change in method of liquor charging and steam introduction. Anodic protection of carbon steel digester at all temperature in alkailne sulfide liquor has been found effective in controlling corrosion [12].

Digester blow bends, blow tanks at top are also getting corroded very rapidly and rate of erosion has increased substantially with the use of more and more hard woods and poor chip size having higher percentage of oversize chips and knots and may cause fatal accident especially if heavy leakage occurs during blowing of digester. Digester blow line problem has been overcome by some of the mills by incorporating impact boxes in all bends providing cushion effect [20].

Brown Stock Washer—Although black liquor in its usual form of concentration temperature and nature does not pose serious problems with standard material of construction. However corrosion of washer backing plates and vacuum pipes especially at grouting places due to pitting has been experienced. Carry over of sand and other foreign materials causes erosion of wire mesh, repulpers and washer vat. These problems can be overcome with proper material of construction and proper design. Wire mesh of washer also get damaged sometime due to presence of foreign material in vat and faulty operations.

Screening—Erosion and corrosion have been a serious problem in screening section especially in centricleaners when higher percentage of sand and foreign materials are present due to poor washing of bamboo and poor performance of sand table and vortrap. Effective bamboo washing, timely cleaning of vortrap, sand table and proper material of construction help in minimising the erosion and corrosion. Ceramic cone in centricleaner have been found very effective in comparison to stainless steel cone.

Bleach Plant—Corrosion is a wide spread phenomenon in bleaching plant and accounts for nearly 50% of total mill corrosion. The process involves a wide variety of corrosive chemicals like chlorine, chlorie dioxide, hypochlorite, peroxide, sulphuric acid etc. Residual oxidant such as chlorine and chlorinodioxide are the primary cause of corrosion in bieach plant and at concentrations above 25 ppm, corrosion reaction proceeds [21] The free corrosion potential of a 317L SS bleach plant washer is strongly influenced by the concentration of residual chlorine in washer vat [22]. Recycling of the filterate in closed system has compounded the corrosion problems due to increase in chloride ion concentration temperature, pH, etc.

Corrossion is most serious In chlorine dioxide generator, chlorine and chlorine dioxide tower mixer, washer, pipe line and other units handling filterate of chlorination and chlorine dioxide stage, chlorine gasifier chlorine gas line andcontrol system. These equipments and ancilliary units are to be protected to achieve optimum bleach plant reliability and productivity.

Corrosion of equipment and pipe lines especially at the grouting position has been also observed and sometimes it is very severe if proper care is not taken. In one mill corrosion of rubber lined chlorine tower was so severe that heavy leakge started and whole segment had to be repaired and changed later. Intensity of corrosion was highter at places of grouting.

Corrosion of non-wetted components such shower pipe metal vats above the stock level, supports, hood and vent pipe, process control equipments, cable trays, chemical preparation and handling equipment also pose a major problem. Vapour phase corrosion of non-wetted components is caused by excessive chlorination where gaseous chlorine from tne filterate makes small droplets of condensation highly corrosive. Filterate of chlorination and chlorine dioxide stage is also very corrosive and care is to be taken in discharging and using back-water in the system. In one mill chlorination stage back-water was used along with back-water of unbleached pulp in washing and screening, however, due to severe corrosion of screening section equipments and pipe line, use of chlorine stage back water had to be discontinued. Sulphamlc acid consumption has increased considerably during recent years to improve pulp quality however, it is very corrosive and systems using sulphamic acid are exposed to severe corrosion. Concrete floor screw conveyor vat and conveyor shaft have been found to be corroded due to sulphamic acid.

During hypochloride, oxygen and peroxide bleaching the corrosion is much less in comparison to that with chlorine and chlorine dioxide as bleaching is carried out under alkaline condltions and various parts are much less subjected to pitting and crevice corrosion. Stainless steel washers often fail because of weld related corrosion, the principal cause, of which are (i) welding with no filler, (ii) welding with under alloyed filler (iii) microfissures in weld metal create sites for crevice corrosion (iv) lack of penetration (v) entraped welding flux (vi) precipitation of carbides during welding and (vii) unmixed zone formed at fusion line [24,24,55].

Common corrosion preventing methods in these sections are (i) use of proper material of construction (ii) control and modification of environment (iii) use of antichlor (iv) use of eleetrochemical protection and (v) proper selection and application of protective coatings. Apart from this good house keeping, proper drainage control of spills and leakage also help in corrosion control and long life of equipment.

Material of Construction for Bleach Plant—In bleaching equipment are exposed to variety of corrosive chemicals in each stage and proper material of construction to combat corrosion is very important. A wide variety of alloys are available for bleach plant application. Table II shows the typical chemical composition of some of the alloys used in fabricating equipment for bleach plant [3,26,27]. Traditionally used 316L and 317L SS alloys are no longer adequate for long term service in chlorination and chlorine dioxide stage bleaching. 6% Mo stainless Avesta 254 SMO-1, Nickel based alloys Hastelloys G and C-276 and titanium have been found to be very effective in highly corrosive washer environment. Rubber lined equipment have been found satisfactory for chlorine environment, however, rubber is unsuitable for chlorine dioxide service as it is highly explosive in contact with rubber, In case of hypochlorite washer SS 316L and rubber line M.S. washer has been found to be satisfactory. Thick wall seamless MS pipe, lead pipe, and saran lined pipes are suitable for chlorine gas line.

Rebuiiding of old washer with fibre glass reinforced plastic (FRP) or covering the washer with synthetic materials in order to protect in closed system is one of

TABLE–II. CHMEICAL COMPSITION OF SOME IMPORTANT ALLOY USED IN BLEACH PLANT (3,26,7)2

Alloy	Cr	Ni	Mo	C	Si	Mn	Fe	Others
SS 304	18–20	8–10.5	—	- 0.08	1.0	2.0	Bal	
304L	18–20	8–12		0.03	1,0	2 0	Bal	
316	16–18	10–14	2–3	0 08	1 0	2.0	Bal	
316L	16–18	10–14	2–3	0.03	1.0	2.0	Bal	
317	18–20	11–15	3–4	0.08	1.0	2.0	Bal	
317L	18–20	11–15	3–4	0.03	1.0	2.0	Bal	
Hastelloy G	21–23	Bal	5.5–7.5	0.05	0.4	1–2.0	18–20	(Cb+Tc) 2.18, Co–2.07 W-O.79
Hastelloy C–276	14.5.16.5	Bal	15–17	0.021	0.1	0.5	4–7	Co-1.13, V–0.2, W–3.49
Incoloy 825	19.5–23.5	Bal	2.5–3.5	0.05	0.3	0.3	28–29	
Aresta 254 SMO	20	18	6.1	0.02	0.5	0.5	Ball	Cu 1.5–3 0, Ti 0 6–1.2
Carpenter 20 Cb-3	19–21	32-38	2.0-3.0	0.07	1.0	2 0	Ball	Cu 3 4, Cb+Ta 0-83
Carpenter 20 Mo 6	24	Ball	5.6	0.02	0.3	0.3	31	Cu 3 3, Cb+Ta 0.05

the most recent developments in corrosion prevention ([28]). FRP has beeu successfully used for pipe line, washer sprays, tanks, tower lining, washerhood, ducts and fans lining. Materials of construction for bleach plant equipment and aecessories is given in Table III.

Control and Modification of Environment–Vapour phase corrosion is severe due to high chlorine dioxide rcsiduals, low pH and excess of $S0_2$ used as antichlor (if not properly controlled). Various options to keep residual oxidants below 25 ppm are automatic chlorine and chlorinc dioxide senser controls, use of $S0_2$ and Na0H as antichlor. $S0_2$ doses should be properly controlled as excess $S0_2$ will lead to corrosion.

Evaporators—Corrosion of black liquor handling equipment is not very serious. However due to presence of sodium sulphide and organic sulphides, sulphuric acid derivatives, organic acids, corrosion of steel equment is accelerated. The corrosion is accelerated by rise of temperaturc, high velocity and presence of undissolved solids. Stainless steel 304 or 304L is preferred to carbon steel. Stainless steel impellers, and fittings are recommendcd. Barometric condenser shell and barometric legs of M.S. construclion are also reported to be getting corroded.

Recovery Boiler—Corrosion in recovery boiler is due to black liquor and different gases present in the recovery boiler system. The elemental sulphur formed by the reaction of furnace gases with the frozen smelt on water wall tube surface corrodes the tubes forming FeS. The chemical compositions of the corrosion deposit is FeS. Following reactions take place during corrosion ([32,33])

$$Na_2S + 2C0_2 \rightarrow Na_2CO_3 + S + CO$$
$$H_2S + 1/2O_2 \rightarrow H_2O + S$$
$$Na_2S_2O_3 + heat \rightarrow Na_2SO_3 + S$$
$$2Na_2S + 2O_2 \rightarrow Na_2S_2O_3 + Na_2O$$
$$Fe + S \rightarrow FeS$$

The corrosion in recovery furnace is more serious in reduction zone and various factors affecting corrosion are (i) composition of gases—SO_2, H_2, CO, CO_2 and H_2S/O_2 ratio (ii) smelt composition—sulphidity, melting point and NaCl concentration (iii) physical state of deposits (iv) metal surface temerature ([33]). Highest corrosion rates are encountered when H_2S and oxygen ratio is nearly one ([34]). the rate of corrosion increases above 300°C especially at low oxygen content. Most of the recovery boiler corrosion is occurred in the lower part of the furnace before the full amount of combustion air has been supplied,

TABLE-III. MATERIAL OF CONSTRUCTION FOR BLEACH PLANT EQUIPMENT AND ACCESSORIES (10,20,24,20.31)

Equipment & Accessories	BLEACHING STAGES				
	CHLORINATION	CAUSTIC EXTRACTION	HYPOCPLORITE	CHLORITE	PEROXIDE
1. Chlorine Disperser	PVC, FRP				
2. Chemical Mixer Cassing	M.S. rubber lined FRP	Cast iron, SS304	M.S. rubber lined, SS316L	Titanium or Titanium lined	Cast iron or SS 316
Impeller	SS317L, Hastelly C	Cast iron, M.S. rubber lined SS304	SS316L	Hastelloy C Titanium	Cast iron or
3. Tower Shell	Concrete, M.S.	Concrete, Mild Steel	Concrete, M.S.	Concrete, Mild Steel	Mild Steel
Lining	Rubber, Tile	Tile	Rubber lined, Tile	Tile lined, Polyster pointing SS317L	Tlle
Nozzles	Rubber lined, FRP	SS304 SS316	SS316L	FRP, Tantalum	SS316
4. Washer Vat	Concrete or M.S. rubber or Tile lined, FRP	Concreate or M.S., Tile	Cocrete, M.S. Tile or rubber lined	SS317L or Tile	SS304, Concrete Tile lined
Drum	M.S. Rubber lined SS316L SS317L, Synthetic material, FRP lining	SS304 SS316	SS316 or 317 Rubber or Sarn lining FRP lining	SS317L, Titanium Avesta 254 SMO Hastelloy G, C-276	SS304L
5. Piping Before Tower	M.S.rubber lined, SS304	SS304	M.S. rubber lined SS316L FRP	SS316L	SS304L SS304L
After Tower	M.S. rubber lined, SS316L 317L or FRP	Cast iron, SS304	SS316L	SS316L,	Cast iron or SS316
6. Tower agitators Casing	M.S. rubber linod, SS316L, 317L	Cast ion, SS304	SS316L	SS316L, 317L	Cast iron or SS316
Impeller	SS310L or 317L	Cast iron or SS304	SS316 or 317	SS317L	Cast iron or SS316
7. Heater Mixer Casing	—	SS304	SS304	SS304	SS304
Impeller		Cast iron or SS304	SS304	SS304	SS304
8. Pump Pulp	Rubber lined, SS316 317L	Cast iron. SS304	SS316	SS316	SS316
Filterate	SS316 or 317	Cast iron, SS304	SS316	SS316	SS316
9. Piping for Filterate	Rubber lineed, SS316 or 317 FRP	Cast iron or SS304	SS316	SS316	SS316
10. Seal Tank	M.S ruber lined, Tile FRP	SS304, Tile, FRP	Tile or FRP	Tile or FRP	Tile, FRP
11. Pipe Liners for Chemical	Carbon, Steel, Lead Rubber lired, Saran lined, Glass lined	Carbon Steel	Rigid PVC or FRP	FRP, Titanium, Saran lined or glass linod steel Storage-Glass, Brick, Tile lines FRP	Aluminium Storge—Aluminum

* No rubber lined equipments to be used when chlorine dioxide is used in chiorination stage.

The corrosion in superheater is due to molten deposit at the tube metal surface, which are due to carryover of black liquor particle and condensation of material vaporised in the lower part of the furnance. Metal wastage is higher on the windward side due to local reducing atmosphere which facilitates sulfidation corrosion ([35]).

In the economiser, when temperature is below dew point of gases, acid will condense on the tube and will cause corrosion. To avoid this temperature of feed water should be kept over 121°C and preferable near 149°C with high sulphidity,

In the electrostatic precipitator corrosion occurs due to low temperature of flue gases and the uneven distribution of flue gas in the chamber and the presence of oxides of sulphur at lower temprature aggravate the rate of corrosion ([36]). Temperature of gasses entering ESP is to be maintained around 163°C at 100% MCR. Low temperature of flue gasses also accelerate the corrosion in ID fan blades.

Smelt spout corrosion causes serious problem as molten smelt reacts very 'rapidly' with iron and steel, a protective layer of frozen smelts by cooling metal reduces corrosion considerably. Particular care has to be taken of hardness of cooling water due to presence of calcium bicarbonate. Use of warm condensate to cool the smelt spout results in increased spout life ([37]).

Closely studded tubes covered by plastic chrome ore for hearth portion diffusion coating, clad welding, multi-coating metallizing of nickel aluminide, stainless steel and aluminium, weld spray, or composite tube are the various corrosion protection measures taken in recovery furnace ([33,34]).

Causticizing Section—In the causticizing section corrosion is severe with concentrated liquor and green liquor. The sulphidity, concentration and temperature are the important factors affecting corrosion. Corrosion is aggravated with strong high local velocities, presence of lime sludge and by aeration. The presence of chlorides in the closed system also increase the corrosion rate. Corrosion is not so serious in the unit handling weak liquor. The selection of proper material of construction is of prime importance in ensuring satisfactory life of various equipment and pipe lines.

Power Plant—Corrosion in the boiler is primarily due to dissoloved gases such as oxygen, CO_2 either naturaily present or due to break down of carbonates and presence of bicarbonates and iron oxide primarlly from condenesate sysiem. Control of pH, temperature, removal of dissolved gases by use of aerator, oxygen scavenger, volatile oxygen scavenger ([38,39]) for reducing oxygen to 0 2 ppm, elimination of iron oxide are various measures taken for prevention of corrosion.

Stock Preparation—In stock preparation refiner casing segment, refiner inlet impeller, disk refiner segments are subjected to erosion corrosion due to turbulent flow of the pulp slurry, entrained foreign materials and sand. The life of refining blade or disk depends on material of construction, hardness of material, design of disk pattern, stock consistency and the entrained foreign material, sand additives, filler, alum, etc. The pulp containing higher percentage of sand results in serious corrosion and reduced life of disk segment. It has been experienced that by effective bamboo washing, timely cleaning of vortrap and sand tables and better centricleaner efficiencies results in marked increase in life of disks.

Paper Machine—In the paper machine corrosion of headbox, suction rolls and other equipment are due to low pH (in case of acid paper making where alum and rosin are used for sizing) chloride, sulphate, thiosulphate bacteria, fungi, dissimilar metal, stray electrical current, unretained sizing materials. Both alkaline and acid paper making are succeptable to biological corrosion([40]) Various deposits of microbiological or nonmicrobiological nature–micro-organism, pitch, foam. scale, dirt, alumina gel, starch additives, fillers, unretained size result in decrarsed life or wet felt, headbox and suction roll([31]). Micro-organism, slime and fungi growths thrive in neutral pH environments and adhere to SS piping and equipments.

In acid sizing much higher concentration of sulfate causes formation of hydrogen sulphide and CO_2 due to formation of sulfate reducing bacteria in stagnant and anaerobic location resulting in severe corrosion.

Thiosulphate ion contamination and residual sodium hydrosulphite which is used as brightening agents causes severe corrosion and are ten times more corrosive to bronze than sodium sulphide, sodium metabisulphide, sodium chloride and alum([41]).

The problem of suction rolleorrosion and cracking in both bronze and stainless steel rolls continue to be serious due to increased corrosivity of white water, increased stresses and residual stresses in suction roll([42])

Life of head-box, suction roll and other equipment and accessories can be maximised by taking following steps ([40,41,43,44,45,46]).

— Minimising contamination of white water with sulphur compounds, and sodium chloride.

— Use of inhibitors such as sodium mercaptobenzotriazo'e.

— Mininimising the presence of sulphate reducing bacteria.

— Frequent cleaning and biological treatment.

— Avoiding deposits by good cleaning and house keeping.

— Prevention of stray current entering the head-box,

— Cathodic protection.

— Proper selection of material.

— Suction roll holes must be kept open to avoid build up of fibres and eventual plugging to avoid crevice corrosion.

— Protective coating,

— Avoiding contamination with pulping liquor in case of unbleached paper making.

— Using of fresh water shower.

— Controlling of CO_2 content, chlorides, unretained size, alum concentration, thiosulphate econcentration.

Corrosion of Building Structure—Corrosive environment due to presence of various gases, fumes, and moisture causes the corrosion of concrete and steel structures. In almost all bleach plant environmental deterioration occurs in all concrete structures-floor, walls, roof or other steel structures. Various corrosive fumes like HCL and chlorine, react with calcium oxide in concerete and flakes of concrete are detached and further accelerate corrosion. Steel structure over the various storage tanks have been found erroded due to presence of water vapour.

Controlling permeability temperature during curing ([46]), protective routine coating of steel structure, suitable barriors for entry of moisture into steel structure, precoating of steel before embedding, proper drainage, effective house keeping, control of leakage, providing hoods over brown stock washer and chlorine washer, better ventilation aud exhaust are some of the measures taken to minimise corrosion of concrete and steel structures.

Corrosion of the Control Equipment—The presence of corrosive gases such as chlorine H_2S, SO_2, HCl and sulfuric acid fumes, moisture in mill environment causes corrosion of various control equipment, compressor and pipe line and instruments using air, motor, transformer room, cable structure, roof of control rooms etc Various measures taken for corrosion control are to limit the concentration of corrosive vapours, using non-reactive metals for fabrication, physical rupture of film formed due to chemical reaction, and high efficiency gas phase filtration.

CONCLUSIONS

Corrosion problem in pulp and papar industries is chronic and it is incurring huge losses in terms of repair and replaccment. Proper selection of material of construction is very important and serious considerations will have to be given in selecting the materials. Initially the cost may be high, however, it will compensate the recurring losses. In addition to upgradation of materials of construetion good house keeping, better ventilation and proper drainage system, routine protective coatings of ctructure, pipe lines, equipments is very essential in order to have longer serviceability. Monitoring and assessment of corrosion losses and setting of separate corrosion cell. is essential in order to have better control of the problem.

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