Corrosion management in pulp and paper industry

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The term "Corrosion" needs no explanation to technologists, especially who are engaged in chemical process industries including pulp and paper industry. It is a natural phenomenon caused by the fact that all metals contain more energy than their corrosion products. Actually when the metal gets rusted, it gives up its contained energy. Corrosion is, perhaps, the subject above all others that possesses the widest interest among Engineers. Industrialists, Economists and Scientists alike. Corrosion is understood as the slow destruction of material by chemical or electrochemical agencies. The commenest form of corrosion is the destruction of ferrous metals through oxidation, the hydrated oxide produced being known as rust. Rapid corrosion may take place in water, the rate of corrosion is accelerated by the velocity or the acidity of water, by the motion of the metal ion, by an increase in temperature or aeratioh.

There has been an awareness about corrosion, its high cost and impacts on producitivity and safety. There is increased activity not only within pulp and paper companies but also metal producers, equipment suppliers and consulting companies.

Corrosion control has been undertaken by steel producers, equipment suppliers and National Research Institutes. Pulp and paper companies had developed their own in-house expertise. The cooperative Testing Programme for producers of various components/raw materials for paper mill equipment has led to evaluation of materials for service in pulp and paper mills. There are various areas which have been covered to combat corrosion. It was found that "welds" are prone to corrosion than the base materials. The effects of protective coating and evaluation of these coatings, use of non-destructive test which can be applied to evaluate the integrity of process equipment are some of the development areas used to combat carrosion.

Forms of Corrosion :

Corrosion taking place on metals is classified into eight categories :

1. Uniform corrosion
2. Pitting corrosion
3. Strees corrosion
4. Galvanic corrosion
5. Erosion corrosion
6. Intergranular corrosion
7. Concentration corrosion
8. Fretting corrosion

1. **Uniform Corrosion :**

   * This is caused by attack on metal by chemical or electrochemical reaction which proceeds uniformly over the entire exposed surface of the metal. This type of corrosion leads to greatest amount of damage to the metal but draws least attention since it can be well predicted and remedied in time. By choosing proper material and by providing adequate thickness of the metal for the desired life. this type of corrosion can be got over.

2. **Pitting Corrosion :**

   This is caused by the highly localised electrochemical reaction and is the most serious form of corrosion because it takes place with great rapidity and the failure of metal occurs spontaneously due to perforations of metal surface. It is difficult to predict and replacement of material, depending on the severity of pitting, is the only remedial measure.

3. **Stress Corrosion :**

   Corrosion resulting from very high tensile stress is

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known as stress corrosion and is marked by cracks. Failure of metal surface occurs due to the combination of stress and corrosion taking place simultaneously. It is another most serious form of corrosion as failure occurs suddenly. Usually the more severe the corrosion medium and higher the stress, faster cracking occurs. In some cases failure of metal occurs due to fatigue and repture of protective film as a result of combined action of corrosion and stress- Occasional check up of the metallic surface and replacement wherever necessary, is the only remedial measure.

4. **Galvanic Corrosion :**

It is the result of conduct of dissimilar metals exposed to the fluids which are electrically conducive.

An electrochemical reaction sets in at the junction of the two metal surfaces and an electric potential is established causing galvanic current to flow from the least noble metal to the more noble metal, resulting in the metal ion migration which causes failure.

This type of corrosion is found to be more serious when a large surface area of the noble metal is joined to a small area of the less noble metal.

5. **Erosion Corrosion :**

This is caused by the damage of the passive film by the turbulant flow of the fluid. It is different from abrasion caused by the mechanical damage to the metal surface by solids or solids suspended in a fluid. Cavitation and impingement caused by the formation and collapse of gas bubble in regions of fluids which are in turbulance due to localised pressure fluctuation, lead to Erosion Corrosion.

6. **Intergranular Corrosion :**

This is the preferential attack on metal at grain boundaries. All metals arc susceptible to intergranular oxidation at elevated temperature, but it is very prevalent with stainless steel and nickle alloys.

7. **Concentration Cell Corrosion :**

Many cases of failures of metal occur due to concentration cells which form on the surface of metals exposed to portions of a solution of varying composition and are electrochemical in nature. The variation in composition may be due to fluctuations in temperature and insufficient agitation.

This type of corrosion is sometimes termed as Crevice corrosion, differential aeration corrosion, or lodgement corrosion.

8. **Fretting Corrosiou :**

This is the rapid deterioration of metals at joints when their surfaces are bolted, clamped or press fitted and subjected to pressure and vibrating motion. The mechanism and the cause for this corrosion is not completely known. It may be said that this corrosion occurs because of small metal particles being torn off from the metal surface by small relative movements which are subjected to oxidation by the surrounding atmosphere.

Preventive measure to minimise corrosion :

In the design of structure and chemical process equipments, great considerations have to be given for the corrosion problem for the reason that the best design of a structure responding to all aspects of desired service may fail if resistance to corrosion is not taken care of while designing the structure Corrosion problems are to be got over by the analysis of failures and by experience. Some undesirable practices should be scrupulously avoided to reduce corrosion of metals.

1. The surface condition of a metal has enough bearing upon its corrosion resistance. Smooth surface has greater resistance to corrosion than that of rugged surface. It is because the protective surface film for corrosion resistance is readily fixed and maintained upon a smooth surface than on a rough surface.

2. Cleanlines of a surface is equally important in corrosion resistance. Corrosion is more likely to occur at inaccessible surface areas where dirt and other porous solids can accumulate than areas that are kept clean. This is because of the reason that structures and equipments that get covered with porous solids which absorb and retain moisture for longer periods of time. These moist, porous Solids create differential aeration cell corrosion

and perforate the metal beneath them unless the surfaces beneath the porous solids are properly protected by protective coatings. Such places are to be cleaned off these porous solids frequently to avoid corrosion.

3. Equipments that are exposed to moisture and aqueous solutions should not have pockets or crevice where fluids can get entrapped. All such surfaces should be provided with proper drainage arrangements.

4. Contact of metal surfaces with porous non-metallic materlal, such as wood. felt, cork paper, cloth should be avoided in wet and humid areas since these materials can become saturated with moisture and encourage localised corrosion. Where such non-metallic substances are to be used such as gaskets, they should be saturated with such compounds that prevent absorption of moisture.

5. Dry surfaces do not corrode as rapidly as wet ones. It is always a good practice to prevent or minimise the accumulation of moisture on metal surfaces. All such surfaces exposed to moisture or corrosive vapours should be provided with good drainage and ventilation to expedite removol of water and condensed liquids. Angles and channels should be placed with the open face down so that water and dirt cannot accumulate. Weep holes should be provided in the web to facilitate drainage.

6. Flat bottomed storage tanks should never be placed directly on the earth or concrete foundation. Moisture is likely to be collected beneath the tank and cause corrosion to the bottom of the tank. It is advisable to elevate the tank so that air is freely circulated to evaporate the moisture from the bottom. when it is not possible to elevate the tank, the foundation is to be made in such a way that any water which gets accumulated can be freely drained. And also it is good practice to provide wear plates as an allowance for corrosion.

7. Somestimes it is necessary to utilise dissimilar metals in the design of equipment and structure. Such usage of dissimilar metals may lead to galvanic corrosion unless special care is taken in choosing the metal in such a way that the dissimilar metals have almost similar properties. If this is not found possible the part having the smallest surface area should be fabricated out of a noble metal.

8. Another factor which needs consideration is the stress which has definite influence on corrosion of Metals. High tensile stress resulting from forming and welding are known to increase the rate of corrosion of metals in acid solution and can cause unexpected failures. Care is to be exercised to avoid stress corrosion by proper design and fabrication.

9. Metallurgical factors can be one of the reasons for corrosion. Maximum resistance to corrosion is afforded by a metal when it afforded by a metal when it is most uniform and homogenous in composition. Generally single phase metals and alloys have greater resistance to corrosion than multiphase alloys. The presence of more than one phase can establish galvanic cells between two or more phase in a metal structure and initiate corrosion. Also non-metallic inclusions can serve a discontinuation in protective metal films to cause pitting corrosion. Utmost care is to be exercised when the metals are subjected to heat treatment as there is a possibility of undesirable phases that may be formed which cause corrosion.

10. Welding is the most useful tool for fabrication when properly employed and can assist in prevention of corrosion. The most important precaution to be exercised during welding is to avoid gas pockets, laps undercutting, non-metallic inclusions and cracks which promote corrosion.

    It is necessary to have the surface adjacent to the weld, free of weld flux fume dust, since these foreign materials can initiate corrosion.

11. Impurities present in fluids or solutions accelerate corrosion. The presence of halogens especially chlorides, accelerate corrosion as the chlorides have the ability to penetrate the passive film.

    Sometimes presence of oxygen in solution greatly affects corrosion of certain metals while in some cases oxygen combines with metal and forms a a protective passive film which inhibit corrosion.

Choice of materials for corrosion resistance

The choice of materials used in the fabrication of process equipment is sometimes a difficult matter and require a complete study of all applicable service condition. The material chosen should have the desired resistance to corrosion and resistance to deterioration and should have adequate mechanical strength be adaptable to available methods of fabrication.

The best possible way to select the material of construction is to conduct corrosion tests under actual operating conditions. After a study is made, depending upon the duty the equipment and the structure it has to withstand, materials like plastics, wood, glass, refractories and rubber etc may be employed in the form of lining or coatings to resist corrosion.

Some aspects of corrosion in Paper Industry

The extensive exposure of equipment in the Pulp and Paper Industry to water, and to water dispersions and solution containing variety of materials, creates corrosion.

In the Pulp and Paper Industry as in any other industry today, to remain competitive, it is desirable to reduce maintenance and replacements costs and to aim for uninterrupted production. One of the biggest deterrents to achieve these goals is the damage to the plant and equipment caused by corrosion.

Though corrosion cannot be entirely eliminated, It can be reduced by proper selection of construction materials or by modification of the equipment design and operating proeedures and by proper selection and application of protective coatings. In many instances, corrosion difficulties occur because of unanticipated changes in operating conditions.

In order to obtain more efficient operation, plants are being operated at temperature, pressures and solution concentration which may not only increase the amount of corrosion, but have made corrosion a more complex prob'em, as the lead to different forms of corrosion.

In general, in Pulp and Paper Plant all the forms of corrosion occur. Corrosion occuring in the Paper Machine House is mostly due to environmental conditions besides stock and water system. Paper Machine area is saturated with water vapour and sometimes contaminated with chlorine which lead to corrosion. The corrosion caused due to environmental conditions can be got over by the application of protective coatings to the equipment and structure, secondly by the use of corrosion resistant material, thirdly by controlling the environment.

Digester Corrosion

The construction of pulping digester has always been complicated by corrosion phenomena. Corrosion was found to be severe in the case of sulphite pulping digester. Lead linings were used initially, but proved unsatisfactory because of creeping tendencies. Later, the digesters were provided with brick linings. These linings required constant inspection and maintenance with the disadvantage of reduced volume of digester with poor cleanliness of pulp. These disadvantages have initiated experiments with acid resistance steel. Digester of entire stainless steel construction though answers all the requirements, is found to be highly expensive.

The development in pulping methods necessitated changes in equipment and also in Material Technology. As more and more complicated systems and hardware developed, the need to quantify the reliability and safety of every critical equipment became more important. A modern tool namely Non-Destructive Testing (NDT) was introduced in 1950's to test the thickness for corrosion on batch digesters. Radiographic/Ultrasonic Testing was recommonded for testing on all field-butt welds of recovery boiler furnace tubes. NDT thus has come to stay in examination of paper mill boilers and also in preventive maintenance. By using such methods replacment of vital components are possible before their actual failure.

Corrosion is also observed in the Brown Stock Washing System. The corrosion is attributable to sulphide content in the black liquor. The cost economics do not permit usage of stainless steel and instead carbon steel of higher thickners has to be looked for.

Preventive Coatings :

After preparing the surface properly, the protective coating is applied. It is found that exterior surfaces in Paper Machine region are well protected fsom corros-

ion by the application of epoxy polyamide and amine cured paints

Use of Protective Coatings in Corrosion Control :

There are many types of protective coatings. These are coal tar paints, asphalts, oil paints, oil-modified resin paints like alkyds or epoxy esters, high polymer thermoplastics like vinyls or chlorinated rubbers, epoxy resin coatings, polyurethane coatings, silicon paints etc. These are complete ranges of quality and properties as the vehicle, solvent and pigment quality and compositional ratios vary in the formulation of each particular product. The properties that are particularly essential for successful Bleach Plant service are as follows :

1. Chemical resistance, especially to aggressive bleaching chemicals.
2. Very low moisture and gas permeability.
3. Adequate abrasion resistance.
4. Suitable temperature resistance.
5. Easy repairability

These properties are all collectively obtainable to some extent in the following coatings.

1. Chlorinated rubber.
2. Vinyl.
3. Amine-cured epoxy
4. Amide-cured epoxy.
5. Coal-tar epoxy.
6. Polyurethane.

Corrosion resistant material :

Materials of construction resistant to any form of atmospheric corrosion, are readily available, but are found to be uneconomical when compared to the materials like steel, concrete or wood painted with protective coating.

Controlling the atmosphere :

Corrosion can be controlled to a great extent by exercising some control over the environment. Good ventilation, good exhaust system and prevention of accumulation of chemicals are examples of environment control.

Recovery Plant :

Corrosion is also noted in the evaporotor bodies. Usage of stainless steel tubes has been found to be the answer. Sulphide content of white liquor is causing pitting corrosion. The corrosion due to white liquor can be avoided by using higher thickness pipes and tubes.

Corrosion due to stock and water system :

Acidity is an important factor in metallic corrosion. In order to produce special properties in the paper, stock system often operate on the acidic side with pH of 4 or even below. This low pH causes corrosion and the equipment requires protection from corrosion by the use of non-metallic materials of construction such as fibre glass or reinforced plastics.

Corrosion poses a more serious problem in the Pulp Plant specially at the digester section and bleaching system. Conditions in Pulp Mill are just similar to chemical manufacturing plant. Usage of stainless steel or alloys has improved the problem of corrosion, but is not economical to use such costly materials for all the equipment.

The exterior of pulp Mill equipment can be protected from corrosion by the use of modern coal-tar epoxy paints.

The pulp and paper industry by its nature is peculiarly vulnerable to the ravages of corrosion, its machinery operating as it does continuously engulfed in highly corrosive liquids. For a quite long time the industry reconciled to accept the huge cost of corrosion as an unavoidable production cost to be detail with. In the pulp and paper industry, corrosion control is traditionally achieved by the use of stainless steel. The stainless steel are corrosion resistants because their surfaces are protected by inherent passive film which is stable and self-healing in most environments. Bleached pulp washer drums have been constructed of 316 stainless

steel and has given reasonably good service though approaching the critical line of corrosion.

The observation revealed that due .o the more extensive reuse of water in the plant, higher temperature and especially higher chloride concentrations, 316 and 317 stainless steels are also found to be inadequate for corrosion problem. The choice of material used in the manufacture of equipment is depending on the availability of raw material in this country vis-a-vis the cost.

Thus corrosion can be minimised effectively and the life of Vital Capital Plant & Machinery can be reasonably extended by choosing proper methods of corrosion protection and prevention. It is the prime duty of the concerned Engineers to keep abreast of ltest technologies to apply to get over the problem of corrosion.