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Corrosion Monitoring and Detection Techniques in Petrochemical Refineries

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Abstract: *Corrosion is defined as an attack on a material as a result of chemical, frequently electrochemical reaction, with the surrounding medium. Corrosion monitoring and detection provides comprising monitoring and detecting of all critical components of petrochemical refineries objects, assets, facilities and plants for signs of corrosion. Monitoring and detection of corrosion is useful for plant engineers and maintenance personals to replace the corroded parts of pipeline in petrochemical industries only after when damage has occurred. On basis of recorded data, observer can predict at how much rate the corrosion should occur. This paper provides information about different types of corrosion and detection methods. Common methods used for corrosion monitoring and detection are destructive and non–destructive. In non-destructive method ultrasonic guided wave, radiographic and electromagnetic and in destructive methods corrosion coupons, electrical resistance and linear polarization resistance are included.*

Keywords: *Corrosion detection and monitoring, destructive method, Non-destructive methods.*

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I. Introduction

There are significant incentives to monitor corrosion in petrochemical refineries. The corrosion measurement helps us to predict the life of the assets in refineries, petrochemical, water areas where there is likely chance of corrosion. To measure internal corrosion quickly and accurately one can control the level of damage that internal corrosion inflicts on company's production system. Inside the pipelines corrosion is difficult to detect and monitor [1], [2] and [3]. Corrosion monitoring is generally performed for the following reasons: (a) To get the information about the state of equipment at specific location and to ease the inspection during shutdowns, (b) To obtain information on the corrosion rates and operating process variables, (c) On the basis of data recorded should apply predictive control schemes and/or modified plants and processes [4] and [5].There is small difference between monitoring and inspection. In monitoring methods, there are use of electrical resistance and linear polarization method and in inspection or detection weight loss coupon is use [6] and [7].Corrosion monitoring requirements because of (a) For proper schedule of inspection, (b) Identification of component alloy composition, (c) To identify the location at where defect of pipelines is occur, (d) Prediction of remaining life of assets, (e) Determination of service condition, (f) Optimize to process conditions to achieve maximum throughput without sacrificing the integrity of the equipment, (g) Remedy and correction of problems in industries.

II. Type of Corrosion

1. Uniform Corrosion:

Uniform corrosion also refers to the corrosion that proceeds at approximately the same rate over the exposed metal surface. It is relatively easily measured and predicted, making disastrous failures relatively rare. It can be practically led control by cathodic protection, use of coatings or paints. This type of corrosion can be detected by acoustic emission method [8].

2. Localized corrosion:

Localized corrosion is same as general attack corrosion, localized corrosion specifically target on one place of the metal surface. Localized corrosion is accelerated attack of a passive metal in corrosive environment. General types of localized corrosion include pitting, inter-granular corrosion of an alloy with a susceptible grain boundary region and predictive modeling of localized corrosion. There are number of applications where localized corrosion of metals under atmospheric corrosion conditions might play a role. Localized corrosion takes place when works with other destructive processes such as stress fatigue, corrosion and other forms of chemical attack [9] and [10].

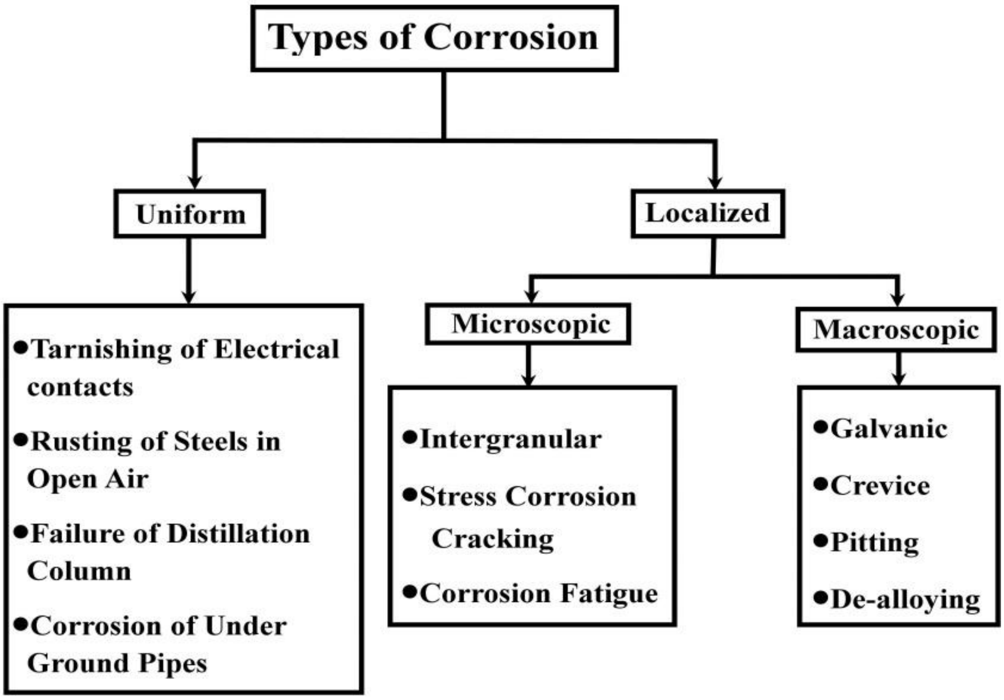

Fig.1. Types of Corrosion.

Types of localized corrosion:

a. Galvanic Corrosion:

Galvanic corrosion is also called bimetallic corrosion. Galvanic corrosion takes place when one metal is in electrical contact with another in the presence of an electrolyte. Two dissimilar metals are in the electrolyte, one metal acts as anode and another metal as cathode. The electro potential difference between the reactions at two electrodes is the driving force for an accelerated attack on the anode metal, which dissolves into the electrolyte. This leads to the metal at the anode corroding more quickly than it otherwise would and corrosion at the cathode being inhibited [11]. A common example of galvanic corrosion such as corrugated iron, a sheet of iron or steel covered with a zinc coating. There are several ways of reducing and preventing this form of corrosion such as, (a) two different metals electrically from each other so that no galvanic coupling will occur between metals. Two metals are isolated by made of plastic material or made of material internally coated or lined, (b) Choose both metal materials that have similar electro potentials. As the lowest difference between electro potential less the galvanic current, and less the galvanic corrosion, (c) For reduces the galvanic corrosion use cathodic protection. It is applied by connecting direct current (DC) electrical power supply to oppose the galvanic current [12] and [13].

b. Crevice Corrosion:

It is initiated by a difference in concentration of some chemical constitutes, usually oxygen, which setup an electrochemical cell. The major factors influencing crevice corrosion are: (1) Crevice type.(2) Crevice geometry.(3) Material.(4) Environment. It is prevented through welded but joints instead of riveted or bolted joints in new equipment, eliminate Crevices in existing lap joints by continuous welding or soldering use solid and non-absorbent gaskets such as Teflon [10].

c. Pitting Corrosion:

It is one of the most destructive types of corrosion, as it can be hard to predict, detect and characterize. When it is occur it grows into a hole or cavity that takes on one of a variety of different shapes. Typically pits penetrate from the surface downward in a vertical direction. It can cause by non-uniformities in the metal structure itself. Pitting corrosion is localized accelerated dissolution of metal that occurs as a result of a breakdown of the otherwise protective passive film on the metal surface [14]. Statistical variation of pitting potential and induction time for pit generation has been studied based on a stochastic theory which had been developed for the fracture of solid materials caused by applied stress [15].

d. Intergranular Corrosion (IGC):

Chemical or electrochemical attack on the grain boundaries of metal called intergranular corrosion. Higher contents of effects near to the grain boundaries occur due to impurities in the metal. It is also called intercrystalline corrosion or interdendritic corrosion. The anodic behaviour of pure Al and some specially prepared Al-Cu alloys has been studied to check the mechanism of intergranular corrosion of aged Al-4%Cu. The conditions of heat treatment, solution composition, and potential, at which intergranular corrosion appears, have been established [16]. Eddy Current Testing (ECT) technique to assess, quantify sensitization and intergranular corrosion (IGC) in thermally aged AISI type 316 stainless steel [17].IGC can be prevented through use low carbon grade of stainless steels, use stabilized grades alloyed with titanium or niobium, use post weld heat treatment.

e. Corrosion Fatigue:

Pitting was found to be associated with constituent particles in the hole and pit growth often involved coalescence of individual particle-nucleated pits. Fatigue cracks typically nucleated from one or two of the larger pits, and the size of the pit at which the fatigue crack nucleates is a function of stress level and load frequency [18],[19], and [20]. Corrosion fatigue is the mechanical degradation of a material under the joint action of corrosion and cyclic loading. The environment plays a significant role in the fatigue of high strength structural materials like steel, aluminum alloy and titanium alloys. It is dependent on the interactions among loading, environmental and metallurgical factors. It is prevented through minimizing vibration and pressure fluctuations, reducing corrosion fatigue using corrosion coating and inhibitors.

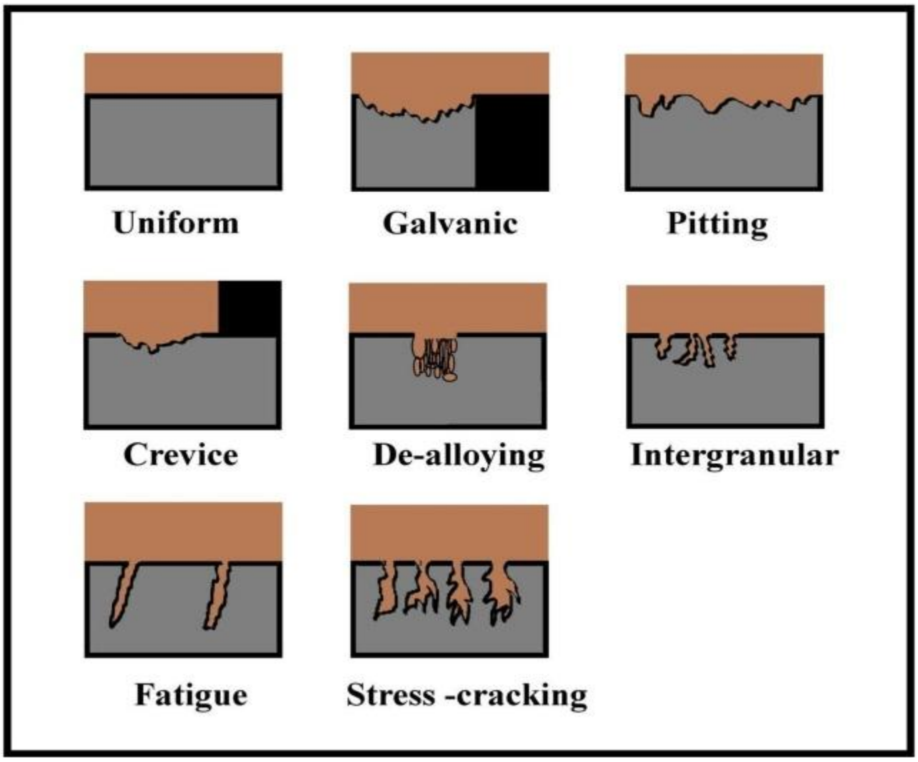

Fig.2. Different Types of Corrosion.

III. Methods

1. Non-Destructive Method:

Non-Destructive Testing (NDT) is a wide group of analysis techniques used in science and technology industry to evaluate the properties of a material, component or system without causing damage.

Types of non-destructive method:

a. Ultrasonic and Acoustic Method:

The main principle of ultrasonic testing method is two probes are connected with the testing material and on the basis of transmitting and receiving pulse it is measures the thickness of the material and calculate the corrosion rate. Acoustic wave devices design in such way that they can measure the atmospheric corrosion of thin plat. Very short ultrasonic pulse –waves are transmitted through the material to detect the internal flaws or to characterize the material. In most of cases the center frequency is in the range of MHz [21],[22] and [23].AE

(Acoustic Emission) sensors are generally piezoceramic transducers; the basic principle is convert physical displacement into voltage. According to change in voltage we can calculate stress-corrosion cracks and ductile fracture of the materials. The main advantage is high penetrating power means we can detect the deep internal flaws. It is capable to estimating the size and orientation of defects. Manual operation is required so the percentage of error is increase [24],[25] and [26].

b. Electromagnetic Method:

The main principle of method is inducing electric currents or magnetic fields or both into the test object and observe the electromagnetic response of the object there are many types of electromagnetic method like:

i. Magnetometer and di-electrometers:

Hidden corrosion under paint and to measure the depth of moisture within barrier paint coatings are detect by Meandering Winding Magnetometers (MWM) [27], [28], [29] and [30] and interdigital Electrometers (IDED) because of the reducing the conductivity near a metal surface there may be chance of oxygen diffusion layer on the metal surface, it is early stage of corrosion. MWM uses magnetic fields and inductive coupling to measure property profiles of the material. The IDED uses electric fields and capacitive coupling to measure the properties of multi-layered insulating media, such as paint on metal oxides formed during corrosion.

ii. Magnetic flux leakage (MFL):

Basic principle of MFL technology is saturating magnetic field is applied to the test material through large magnet and sensing local change in the applied field. Basically MFL is use in larger diameter pipes over a long distance. MFL tools consist of total two parts (1) magnetizer with magnet and sensor,(2) electronics and batteries. The magnets are mounted between the brushes and tool body to create the magnetic circuit along with the pipe wall. As the tool travels along the pipe, the sensors detect interruptions in the magnetic circuit. Interruptions are typically caused by metal loss and which in most cases are corrosion and the dimensions of the potential metal loss is denoted previously as "feature." Other features may be manufacturing defects and not actual corrosion [31].

iii. Eddy current testing (ECT):

Given an Alternating Current (AC) to a wire coil, this wire coil produces alternating magnetic field around itself. Frequency of current and magnetic field is same. When the coil approaches a conductive material, currents opposed to the ones in the coil are induced in the material this called eddy current. It is basic principle of eddy current testing. There two major applications of ECT (1) Surface inspection: used in aerospace industries and petrochemical industries. Surface inspection can be applied to both ferromagnetic and non-ferromagnetic material, (2) Tubing inspection: It is only applicable to non-ferromagnetic material. An inversion algorithm for the reconstruction of cracks from eddy current signals is developed in this study and applied to the profile evaluation of natural stress corrosion cracks that were found in steam generator tubes of a nuclear power plant [32],[33] and [34].Using ECT testing cracks, laminar defects and assess wall thickness types of flaws can be detected. Merits of ECT are Non-contact test, No residual effects, MFL induced currents can be detected by ECT sensor. There are some more techniques used in electromagnetic testing like (1) Remote field testing, (2) Wire rope testing,(3) Magnetic particle inspection (MT OR MPI), (4) Alternating current field measurement (ACFM) and (5) Pulsed eddy current.

c. Radiographic Method:

A radiographic method is use of high frequency gamma radiation and x-ray, are employed to produce images of physically inaccessible metallic components obstructing the radiation path. This radiation method of corrosion monitoring has low sensitivity and requires radiation safety. In the chemical and petroleum industries radiography is extensively used in measure pipe thickness. Applications of radiographic method are (1) Internal deposits: radiography has been proven to be very useful in detecting different kinds of internal deposit

(2) Pitting corrosion: Radiography can detect pits very easily. The depth of pit can be determined by measuring the densities of the pitted and sound areas,(3) Thickness loss: This can be determined by the measuring the radiographic densities or by tangential radiography [35],[36]and [37].

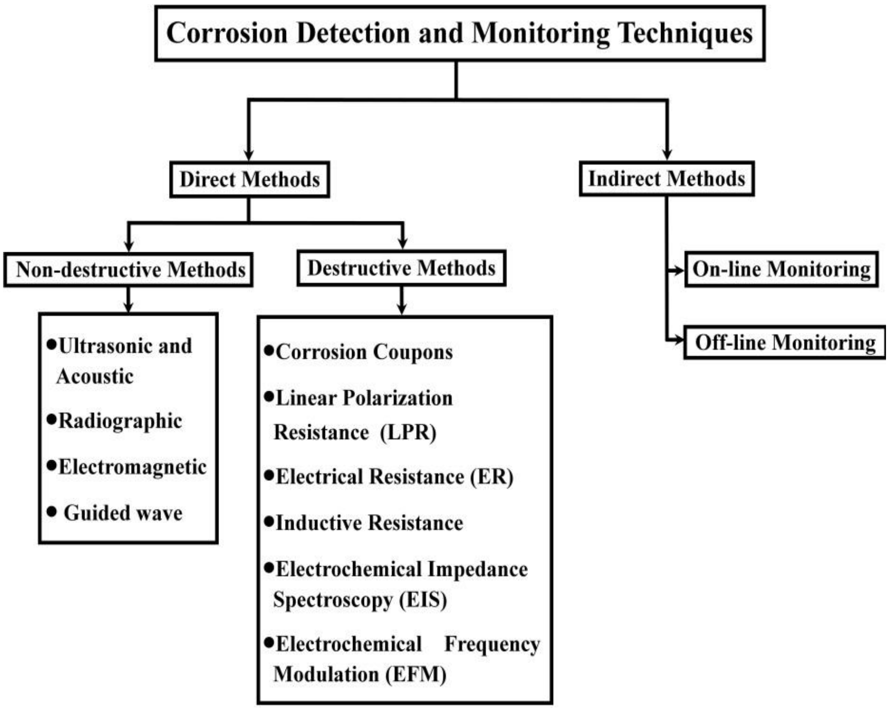

Fig.3. Corrosion monitoring and detection methods.

2. Destructive Method:

Destructive Physical Analysis, (DPA) test is carried out to the specimen's failure, in order to understand a specimen's performance or material behavior under different loads. These tests are generally much easier to carry out, yield more information, and are easier to interpret than non-destructive testing.

Types of Destructive Method:

a) Corrosion coupons:

Corrosion coupons are inexpensive, effective method for monitoring the corrosion rate in any system or structure. Though accurate, meaningful results from these test is not always as simple as measuring the weight loss and calculating meaningful corrosion rate [38].Corrosion coupons are placed directly in the process stream and extracted for measurement. This monitoring technique provides direct measurement of metal loss that allows calculating general corrosion rate. Various forms of corrosion can be examined with these coupons like Galvanic corrosion, Pitting, Crevice corrosion, Susceptibility to stress corrosion cracking etc. Types of corrosion coupon are (1) Strip coupon, (2) Disc coupon, (3) Weld coupon, (4) Stressed coupon, (5) Scale coupon. Merits of corrosion coupon testing are Principle is easy to understand, Provides specimens for post- test examinations, Comparison between different alloys and inhibitors can be done, Inexpensive.

Equation for measuring corrosion rate (CR) from weight loss coupon:

$$\mathrm{CR\ (mpy)} = \frac{22300 \times \mathrm{WL}}{\rho \times \mathrm{A} \times \mathrm{T}} \qquad (1)$$

Where,
CR denotes corrosion rate in "mils per year"(mpy),
WL denotes by weight loss (gm),
ρ denotes metal density (gm/cm^3),
A denotes coupon area (in^2),
T denotes by time (days).

Table no 1: Substitute value for 22300 in equation.

Units of measure	Substitute for value of 22300
Corrosion rate(mm/year), Coupon area (in2)	566
Corrosion rate(mpy), Coupon area (cm2)	143700
Corrosion rate (mm/year), Coupon area (cm2)	3650

Limitations of corrosion coupon testing are Measures only the average corrosion rate during the time of exposure, Corrosion rate only calculated after coupon removal from pipeline, Short exposure period can yield unrepresentative corrosion rates andCoupon surfaces are smooth and polished. These surface are may differ from the surface of older piping system which might be worn or pitted. The difference could create a source of error.

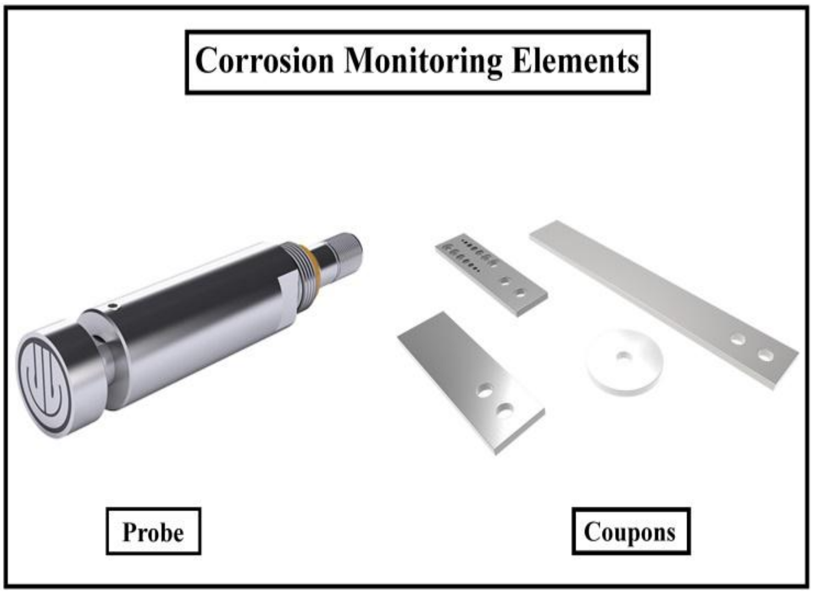

Fig.4. Corrosion monitoring elements.

b) Linear Polarization Resistance (LPR) method:

It is an electrochemical method of corrosion. Electrochemical potential and current generated between electrically charged electrodes in process stream monitoring relationship between these two allows the calculation of corrosion rate. LPR is a continuous monitoring system. Here the solution resistance (Rs) is the resistance between the corroding interface and the reference electrode and polarization resistance (Rp) is related to corrosion rate. In a making direct current, or a low frequency, corrosion rate measurements. The Rs and Rpbecomes series resistor which adds in the measurement [39],[40],[41] and [42]. The effect of the high solution resistance between the reference and working electrodes is eliminated by chemically modifying the dielectric surface between the electrodes to make it ironically conductive [43], [44], and [45]. During corrosion discrete points on the surface of the corroding metal will be at different electrochemical potentials. So, current will flow through mass of metal until the both are at the same compromise potentials, the corrosion potential. It is online corrosion monitoring using LPR probes.

LPR resistance defined as:

$$\mathrm{Rp} = \frac{\Delta \mathrm{E}}{\Delta \mathrm{i}} \qquad (2)$$

Where,
Rp denotes LPR resistance,
ΔE denotes potential difference,
Δi denotes current passing through metal.

$$\mathrm{CR(mpy)} = \frac{\mathrm{Icorr} \times \mathrm{E} \times 123.67}{\mathrm{A} \times \mathrm{D}} \qquad (3)$$

Where,
CR denotes Corrosion rate in "mils per year" (mpy),
E denotes Equivalent weight of the corroding metal (gm),
A denotes Area of corroding electrode (cm^2),
d denotes Density of corroding metal (gm/cm^3).

LPR application is used in Cooling water system, Secondary recovery system, Potable water treatment and distribution system, Amine sweetening, Waste water treatment system, Pickling and mineral extraction processes, Pulp and paper manufacturing, Hydrocarbon production with free water. Merits of LPR technique are that it can provide a measurement of the changes in the corrosion rate can typically be detected in minutes, it can provide qualitative pitting tendency measurement such as whether the tendency for pitting we be shallow and in frequent or deep and abundant, LPR electrodes are replaceable, which extends probe life and offers options in electrode material types for different monitoring objectives.

c) Electrical resistance method:

There are several techniques for online corrosion monitoring the most commonly techniques used is electrical resistance technique. The ER technique measures the effects of both the electrochemical and the mechanical components of corrosion such as erosion or cavitation. It is the only on-line, instrumented technique applicable to virtually all types of corrosive environments. The electrical resistance of this probe is compared with that of an identical reference probe that is shielded from corroding. As the exposed probe corrodes, its electrical resistance increases depending upon the extent of corrosion [46].

Principle of operation:

$R = \frac{\rho L}{A}$(4)

Where;

L denotes Element length,

A denotes Cross sectional area,

r denotes Specific resistance.

Reduction means metal loss in the element cross sectional area due to corrosion will be accompanied by a proportional increase in the element's electrical resistance.

Corrosion rate (C) is derived by:

$C = \frac{P \times 365 \times \Delta S}{\Delta T \times 1000}$(5)

Where,

P denotes probe life,

ΔS=S2-S1,

T being the lapse time in days between instrument readings S1 and S2.

Applications of ER probes are Feed water system, Flue gas stacks, Architectural structures, Oil/gas production and transmission system, Refineries and petrochemical process streams. Merits of electrical resistance technique are Corrosion monitoring can be made without seeing or removing the sample, response is quick and can be monitor continuously, permitting detection of any sudden increase in corrosion rate, and immediate remedial action. Demerits of electrical resistance technique are when a solid corrosion product is formed, meaningful results can only be obtain on a new element after a conditioning period which is difficult to ascertain if scale on the probe and equipment surface is identical, When localized pitting or crevice corrosion occur, local thinning puts a high resistance in series with the rest of element giving an inflated corrosion rate reading.

d) Electrochemical Impedance Spectroscopy (EIS):

The influence of surface in homogeneities on corrosion processes is demonstrated by EIS [46]. EIS is another more recently developed technique that is continuous measurement of corrosion rate. In this method measurement of polarization resistance (Rp) is directly measure of corrosion rate. To make an EIS measurement, a small amplitude signal, usually a voltage between 5 to 50 mV is applied to a specimen over a range of frequencies of 0.001 Hz to 100,000 Hz.The EIS instrument records the real (resistance) and imaginary (capacitance) components of the impedance response of the system. Depending upon the shape of the EIS spectrum, a circuit model or circuit description code and initial circuit parameters are assumed and input by the operator. Applications of EIS Analysis of corrosion on metal surfaces, Characterization of the hardening process of cement paste, Determination of state of charge (SoC) and state of health (SoH) in batteries [47] and [48].

IV. Conclusion

Corrosion is a common problem encountered in the petrochemical industry and at oil & gas refinery. Oil and gas pipelines, petrochemical plants and process lines have serious corrosion problems. Corrosion is occurring due to the metal deterioration and chemical reactions with the pipes. Corrosion problem consider an economic loss in these industry at extremely high. Different types of corrosion take at different location. Types of corrosion basically are uniform corrosion, localized corrosion. Monitoring and detection is necessary in petrochemical refineries to reduce the economic loss. Corrosion monitoring and detection techniques commonly are destructive and non-destructive methods. Corrosion coupons and probes like electrical resistance and linear polarized resistance are monitoring and detection techniques in the pipelines. Hence corrosion control is not possible but can only a monitoring and based on the data, can replace the pipelines in the industry**References**

References

[1] Y. Zeng, “Comparative online monitoring system in the application of distillation unit”, Journal of Petroleum Chemical Corrosion and Protection, 2011.
[2] X. Gu, T. Gu, J. Li , Y. Huang, Y. Wang, “ A variety of corrosion monitoring system in the application of the peak stood”, Journal of Petroleum and Natural Gas Chemical Industry,2011.
[3] L. Zheng, Z. Wan, N. Gao, C. Zhang, “Refining corrosion monitoring technology application and device progress”, Journal of Petroleum Chemical Corrosion and Protection, 2012.
[4] Z. Yu, X. Meng, “Corrosion monitoring technology and its application in oil and gas field”, Pipeline Technology and Equipment, 2012.
[5] X. Yang, J. Rao, Y. Wang,“Application of online monitoring technology in petrochemical industry”, Journal of Petroleum Chemical Corrosion and Protection, 2011.
[6] J. Rose and J. Barshinger, “Using ultrasonic guided wave mode cutoff for corrosion detection and classification”, in Proc. IEEE UltrasonicsSymp, vol. 1, pp. 851–854, 1998.
[7] J. Pei, M. Yousuf, F. Degertekin, B. Honein and B. Khuri-Yakub, (2012, Dec.) “Lamb wave tomography and its application in pipe erosion/corrosion monitoring”, Res. Nondestruct. Eval., vol. 8, pp. 189–197,1996. [Online]. Available: http://dx.doi.org/10.1007/ BF02433949.
[8] C. Jirarungsatian, A. Prateepasen, “Pitting and uniform corrosion source recognition using acoustic emission parameters”, Corrosion ScienceVol. 52, no. 1, pp. 187-197,Jan. 2010.
[9] C. Jomdecha, A. Prateepasen, P. Kaewtrakulpong, "Study on source location using an acoustic emission system for various corrosion types”, NDT & E International, Vol. 40, no. 8, pp. 584-593, Dec. 2007.
[10] V. Guillaumin1,G.Mankowski1, “ Localized corrosion aluminium alloy in chloride media of 2024 T351”, Corrosion Science, Vol. 41, no. 3, pp. 421-438, Mar. 1998.
[11] G. Songa, B.Johannessonb, S. Hapugodaa, D. StJohna, “Galvanic corrosion of magnesium alloy AZ91D in contact with an aluminium alloy, steel and zinc”, Corrosion Science, Vol. 46, no. 4, pp. 955-977, Apr. 2004.
[12] Rothwell, A. N. & Eden, D. A, “Electrochemical noise techniques for determining corrosion rates and mechanisms”, NACE, Corrosion 92, paper no. 223, Apr. 1992.
[13] Bertocci, U, “Electrochemicalnoise analysis and its application to corrosion”, NACE, Corrosion 89, paper no.24, Apr. 1989.
[14] G. S. Frankel, “ Pitting Corrosion of Metals A Review of the Critical Factors”, J. Electrochem. Soc. Vol. 145, no. 6, 1998.
[15] Khian-Hooi Chew, R. Kuwahara and K. Ohno, “First-principles study on the atomistic corrosion processes of iron”, Physical Chemistry Chemical Physics 20:3, pp. 1653-1663,Jan. 2018.
[16] J.R.Galvele, S.M.de De Micheli, “Mechanism of intergranular corrosion of Al-Cu alloys”, Corrosion ScienceVol. 10, no. 11, pp. 795-807, 1970.
[17] H.Shaikha, N.Sivaibharasia, B.Sasib, T.Anitaa, R.Amirthalingamc, B.P.C.Raob, T.Jayakumarb, H.S.Khataka,BaldevRajd, “Use of eddy current testing method in detection and evaluation of sensitisation and intergranular corrosion in austenitic stainless steels”, Corrosion Science, Vol. 48, no. 6, pp. 1462-1482, June 2006.
[18] G.S.Chena, K.C.Wana, M.Gaoa, R.P.Weia, T.H.Flournoyb, “Transition from pitting to fatigue crack growth—modeling of corrosion fatigue crack nucleation in a 2024-T3 aluminum alloy”, Materials Science and Engineering, Vol. 219, no. 1–2, pp. 126-132, Nov. 1996.
[19] Ishihara, S. SAKA, Z.Y. NAN, T. GOSHIMA, S. SUNADA, “ Prediction of corrosion fatigue lives of aluminium alloy on the basis of corrosion pit growth laws”,FFEMS, Vol. 29, no. 6, pp. 472–480, June 2006.
[20] C.Kuang, L.Sheng-TsengYanga, “ Corrosion fatigue behavior of 7050 aluminum alloys in different tempers”, Engineering Fracture Mechanics, Vol. 59, no. 6, pp. 779-795, Apr. 1998.
[21] J.L. Rose, D. Jiao, S.P. Pelts, J.N. Barshinger, and M.J. Quarry, "Hidden Corrosion Detection with Guided Waves", Department of Engineering Science and Mechanics, Pennsylvania State University, 1998.
[22] W. Yeiha, R. Huanga, “Detection of the corrosion damage in reinforced concrete members by ultrasonic testing”, Cement and Concrete Research, Vol. 28, pp. 1071-1083,July 1998.
[23] Kenneth, R. Lohra, Joseph, L.Roseb, “Ultrasonic guided wave and acoustic impact methods for pipe fouling detection”, Journal of Food Engineering, Vol. 56, no. 4, pp. 315-324, Mar 2003.
[24] N.R. Sorenson, A.J. Ricco, and S.J. Martin, "Metallic Materials", NASA Technical Reports, ID:19890013357N (89N22728), Sandia National Laboratories, Albuquerque, NM, Jan. 1989.
[25] L. Veleva, S.A. Tomas, and E. Marin, "On the Use of the Photoacoustic Technique for Corrosion Monitoring of Metals: Cu and Zn Oxides Formed in Tropical Environments", Corrosion Science, Vol.39, pp. 1641-655, Sept. 1997.
[26] R. Mah, R. L. Kochen, and J. M. Macki, NASA Technical Reports, ID: 19760018289 N (76N25377), Atomic International Division, Golden, CO, Dec. 1975.
[27] N. Goldfine and N.A. Greig, "Using Electromagnetic Sensors (Magnetometers and Dielectrometers) to Detect Corrosion Beneath and Moisture Within Paint Coatings on Aircraft", Corrosion/94, NACE International, Paper No. 353,1998.
[28] P.A. von Guggenberg and J.R. Melcher, "A Three-Wavelength Flexible Sensor for Monitoring the Moisture Content of Transformer Pressboard", Proceedings of the 3r d International Conference on Properties and Applications of Dielectric Materials, Tokyo, Japan, July 1991.
[29] A. P. Washabaugh, P. A. von Guggenberg, M. Zahn, J. R. Melcher, "Temperature and Moisture Transient Flow Electrification Measurements of Transformer Pressboard/Oil Insulation Using a Couette Facility", Third International Conference on Properties and Applications of Dielectric Materials, *July 1991.*
[30] M. C. Zaretsky, L. Mouayad, J. R. Melcher, "Continuum Properties from InterdigitalDielectrometry", *IEEE Transactions on Electrical Insulation*, vol. EI-23, no. 6, pp. 897-917, Dec. 1988.
[31] L. Atherton, P. Laursen, and M.A. Siebert, "Small-Diameter MFL Detector Overcoming Technical Hurdles", Pipeline Industry, pp. 69-73,1993.
[32] N. Yusaa, Z. Chena, K.Miyaa, T. Uchimotob, T. Takagib, “Large-scale parallel computation for the reconstruction of natural stress corrosion cracks from eddy current testing signals”, NDT & E InternationalVol. 36, no. 7, pp. 449-459, Oct. 2003.
[33] D. Kima, L. Udpab, S. Udpab, “ Remote field eddy current testing for detection of stress corrosion cracks in gas transmission pipelines”, Materials LettersVol. 58, no. 15, pp. 2102-2104, June 2004.
[34] Kim, Dae-Won, “ Remote Field Eddy Current Testing for Detection of Stress Corrosion Cracks in Gas Transmission Pipelines”, Journal of the Korean Magnetics Society , Vol. 16, no. 6, pp.305-308, 2006.
[35] M. Twomey, "Inspection Techniques for Detecting Corrosion under Insulation", Materials Evaluation, pp. 129-32, 1997.

[36] J. Asher, J.W. Webb, N.J.M. Wilkins, and P.F. Lawrence, NASA Technical Reports, ID: 19830007191 N (83N15462), Atomic Energy Research Establishment, Harwell, UK.

[37] J. Asher, T.W. Conlon, B.C. Tofield, and N.J.M. Wilkins, "Thin Layer Activation: A New Plant Corrosion- Monitoring", NASA Technical Reports, ID: [9830027947 N (83N36218), Mar. 1983.

[38] S.W. Dean, "In-Service Monitoring", ASM Handbook, ASM International, Vol. 13, pp. 197, 1987.

[39] N.G. Thompson and K.M. Lawson, "Development and Use of Polarization Resistance Measurements for Measuring Corrosion Rate in Soil and Concrete", Corrosion Asia/92, Singapore, NACE, 1992.

[40] F. Ansuni, "Dual Mode Corrosion Monitors", CORROSION/91, NACE International, Paper No. 327,1991.

[41] R. Jasinski and K.D. Efird, "Electrochemical Corrosion Probe for High Resistivity Hydrocarbon/Water Mixtures", Corrosion 44, pp. 658, 1988.

[42] S.K. Chawla, T. Anguish, and J.H. Payer, "Microsensors for Corrosion Control", Materials Performance 29, pp. 68,1990.

[43] Z. Ming Wang and J. Zhang. (2016), " Corrosion of multiphase flow pipelines: the impact of crude oil", Corrosion Reviews, Jan. 2016.

[44] M. STERN, " A Method For Determining Corrosion Rates From Linear Polarization Data", Vol. 14, no. 9, pp. 60-64, Sept. 1958.

[45] Keith B. Oldham, F. Mansfeld, "On the So-Called Linear Polarization Method for Measurement of Corrosion Rates", Vol. 27, no. 10, pp. 634-635,Oct. 1971.

[46] S.W. Dean, "Electrochemical Methods for Corrosion Testing in the Process Industries", in Electrochemical Corrosion Testing with Special Consideration of Practical Applications, E. Heintz, J.C. Rowlands, and F. Mansfield, Ed., Proceedings of International Workshop, Ferrara, Italy, DECHEMA, pp. 1-15, 1986.

[47] K.Jüttner, " Electrochemical impedance spectroscopy (EIS) of corrosion processes on inhomogeneous surfaces", ElectrochimicaActaVol. 35, no. 10, pp. 1501-1508, Oct. 1990.

[48] F. Mansfeld, "Electrochemical impedance spectroscopy (EIS) as a new tool for investigating methods of corrosion protection", ElectrochimicaActaVol. 35, no. 10, pp. 1533-1544,Oct. 1990.

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