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Electrochemical Evaluation and Characterization of Stainless Steel 304

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Abstract: ***Stainless Steel has found wide applications in industry and machinery because of its cost and potential properties. Grade 304 stainless steel is generally regarded as the most common austenitic stainless steel. The Corrosion behavior of 304 Stainless Steel was studied in the chloride environment (in 4% NaCl Sol.) using electrochemical testing techniques with the help of Gamry Instruments. Corrosion rate and Corrosion resistance were determined using polarization & EIS techniques. After that the surface characterization was carried out using Scanning electron Microscopy (SEM), Energy Dispersive X-Ray spectroscopy (EDS) and X- Ray Diffraction (XRD) techniques. It has been found that the electrochemical stability of 304 Stainless Steel in NaCl solution is quite good.***

I. INTRODUCTION

A. Corrosion- Historical Background

The word corrosion is as old as the earth, but it has been known by different names. Corrosion is known commonly as rust, an undesirable phenomena which destroys the luster and beauty of objects and shortens their life. Corrosion since ancient times has affected not only the quality of daily lives of people, but also their technical progress. There is a historical record of observation of corrosion by several writers, philosophers and scientists, but there was little curiosity regarding the causes and his 'Mechanical Origin of Corrosiveness'. The most important contributions were later made by Faraday (1791-1867) [1] who established a quantitative relationship between chemical action and electric current. Ideas on corrosion control started to be generated at the beginning of nineteenth century. It was left to Evans to provide a modern understanding of the causes and control of corrosion based on his classical electrochemical theory in 1923. Considerable progress towards the modern understanding of corrosion was made by the contributions of Evans [2], Uhlig [3] and Fontana [4].

1) Corrosion- Definition

Several definitions of corrosion have been given and some of them are below:

a) Corrosion is the surface wastage that occurs when metals are exposed to reactive environments.
b) Corrosion is the result of interaction between a metal and environments which results in its gradual destruction.
c) Corrosion is an aspect of the decay of materials by chemical or biological agents.
d) Corrosion is an extractive metallurgy in reverse. For instance, iron is made from hematite by heating with carbon. Iron corrodes and reverts to rust, thus completing its life cycle.
e) Corrosion is the destructive attack of a metal by chemical or electrochemical reaction with the environment.
f) Corrosion is the deterioration of materials as a result of reaction with its environment.

Despite different definitions, it can be observed that corrosion is basically the result of interaction between materials and their environment.

Pitting corrosion also occurs much faster in areas where micro structural changes have occurred due to welding operations [6].

2) Consequences of Corrosion

Some important consequences of corrosion are summarized below:

a) *Plant Shutdowns:* Shutdown of nuclear plants, process plants, power plants and refineries may cause severe problems to industry and consumers.
b) *Loss of Products:* Leaking containers, storage tanks, water and oil transportation lines and fuel tanks cause significant loss of product and may generate severe accidents and hazards. It is well-known that at least 25% of water is lost by leakage.
c) *Loss of Efficiency:* Insulation of heat exchanger tubing and pipelines by corrosion products reduces heat transfer and piping capacity.

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d) *Contamination:* Corrosion products may contaminate chemicals, pharmaceuticals, dyes, packaged goods, etc. with dire consequences to the consumers.
e) *Nuclear Hazards:* The Chernobyl disaster is a continuing example of transport of radioactive corrosion products in water, fatal to human, animal and biological life.

The magnitude of corrosion would depend upon the sensitivity of a particular metal or alloy to a specific environment. Environmental conditioning offers one method of controlling corrosion, such as the use of inhibitors and oil transmission pipelines.

B. Issues In Corrosion And Engineering

Corrosion may be inevitable; however, there are ways to retard its kinetics and greatly reduce the economic burden on society. In broad terms (and in the eyes of the committee), the issues in corrosion science and engineering can be subdivided into four main categories of design, mitigation, detection, and prediction, which comprise key areas for research and development. The categories encompass the different approaches to solve the problems created by corrosion, which will enable improvements in our quality of life and reduce the cost of corrosion on society.

Design is the development of new materials that retard or inhibit corrosion, and includes the use of computational modelling to help increase the rate of discovery and the performance of desired material properties. Mitigation, the most widely applied method, pertains to the protection and maintenance methodologies (e.g., painting) applied through the development and implementation of corrosion modelling tools, databases, design rules, and lessons learned. Detection assesses corrosion damage and develops prognoses of the state and rate of material degradation (ideally using sensors and remote monitoring) to reduce maintenance costs and prevent sudden catastrophic failure.

Prediction models the life and performance of materials under multiple environmental and mechanical stresses, and can incorporate data from accelerated testing and other real-world sources.

Research on many aspects of corrosion over the past century led to mitigation techniques that enable our current standards of living. Better materials (slower corrosion rates), better protection (coatings), increased awareness (detection of the early stages of corrosion), and better organized and executed plans for combating corrosion or replacing corroded parts lead to dramatic improvements not possible without such research.

C. Importance Of Electrochemical Corrosion

The most common kinds of corrosion result from electrochemical reactions. General corrosion occurs when most or all of the atoms on the same metal surface are oxidized, damaging the entire surface. Most metals are easily oxidized: they tend to lose electrons to oxygen (and other substances) in the air or in water. As oxygen is reduced (gains electrons), it forms an oxide with the metal.

When reduction and oxidation take place on different kinds of metal in contact with one another, the process is called galvanic corrosion.

In electrolytic corrosion, which occurs most commonly in electronic equipment, water or other moisture becomes trapped between two electrical contacts that have an electrical voltage applied between them. The result is an unintended electrolytic cell.

Take a metal structure such as the Statue of Liberty.

It looks strong and permanent. Like nearly all metal objects, however, it can become unstable as it reacts with substances in its environment and deteriorates.

Sometimes this corrosion is harmless or even beneficial: the greenish patina that covers the statue's copper skin protected the metal beneath from weather damage. Inside the statue, however, corrosion caused serious harm over the years. Its iron frame and copper skin acted like the electrodes of a huge galvanic cell, so that nearly half of the frame had rusted away by 1986, the statue's one hundredth anniversary.

II. LITERATURE SURVEY

A. Background

M K Punith Kumar *et al.*[25] has chosen TiO_2 nanoparticles as second-phase particles to generate anticorrosive Zn composite coatings.

The TiO_2 nanoparticles were dispersed in a Zn plating solution to co-deposit them with Zn. This study highlights the use of TiO_2 nanoparticles in generating a Zn-TiO_2 coating that imparts good corrosion resistance to a Zn deposit.

Juliana Sarango de Souza *et al.*[26] aimed to study the passive film stability and pitting corrosion behavior of the AISI 409 stainless steel.

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The electrochemical tests were carried out in 0.1 M NaCl solution at room temperature. The general electrochemical behavior was assessed using electrochemical impedance spectroscopy (EIS) measurements whereas the semiconducting properties of the passive film were evaluated by the Mott-Schottky approach.

Praveen B M *et al.* [27] carried out research on Zn-TiO_2 composite coatings were electrodeposited on mild steel using an electrolyte containing dispersed nanosized TiO_2.

The corrosion resistance of the coating was studied in (3.5 wt.%) NaCl solution by electrochemical and weight loss measurements. The study revealed higher resistance of composite coating to corrosion.

M. Azizi *et al.* [28] studied particles of silicate and mica were co-deposited with zinc from a weakly acid zinc electrolyte.The co-deposition became possible after 3 h of milling of the particles. A pH of 4.5, a rotation speed of 600 rpm and a particle concentration of 50 g/l were the optimal conditions.

Adriana Vlasa *et al.*[29] aims to investigate the electrodeposition on steel substrate and the corrosion behavior of Zn–TiO_2 nanocomposite coatings. Zn–TiO_2 composite coatings were electrodeposited on OL 37 steel from an electrolyte containing $ZnCl_2$, KCl, HBO_3 (pH 5.7) brightening agents and dispersed nanosized TiO_2. The results of electrochemical measurements were corroborated with those obtained by using non-electrochemical methods (X-ray diffraction, atomic force microscopy and scanning electron microscopy).

J. Fustes *et al.*[30] focused on Zn–TiO_2nanocomposite films which were prepared by pulsed electrodeposition from acidic zinc sulphate solutions on a Ti support.

The influence on the composite structural and morphological characteristics of Zn^{2+} and TiO_2 concentrations in the deposition bath has been investigated.

Yong-Jia Wei *et al.[*31] analysed the stress corrosion crack (SCC) of 304 nuclear grade (NG) stainless steel (SS) in 0.5 mol/L NaCl+1.5 mol/L H_2SO_4 was monitored using electrochemical noise (EN) based on chaos theory, statistics and wavelet analysis. The results indicated that the SCC process was divided into three stages according to the transient features in the EN.

Woonggi Hwang *et al.*[32] studied the acoustic emission (AE)which is one of the promising methods for detecting the formation of stress corrosion cracks (SCCs) in laboratory tests.

This method has the advantage of online inspection. Some studies have been conducted to investigate the characteristics of AE parameters during SCC propagation

Dahai XIA *et al.*[33] studied the mechanical properties and corrosion resistance of SA508-4Ni-Cr-Mo low carbon alloy steel are elucidated using tensile testing, Charpy impact testing, fracture surface analysis and in-situ electrochemical noise (EN) technique.

P. Kučera *et al.* [34] observed the he corrosion behavior of pressurized water reactor (PWR) steam generator tube material (08CH18N10T steel) was studied by electrochemical noise (EN) measurements and electrochemical impedance spectroscopy in high□temperature water at 280 °C and 8 MPa.

Long□term measurements were performed in two electrolytes: (i) de-ionised water alkalized to pH_{25} = 9.5 by KOH; (ii) the same electrolyte with 200 ppm of chlorides added (as KCl

III. OBJECTIVES

A. Objectives Of Present Work

The study of the evaluation of electrochemical corrosion of 304 Stainless and its characterization was undertaken with the following objectives:

1) To determine the corrosion rate using Electrochemical Corrosion measurement techniques.
2) To perform EIS to find out the corrosion resistance offered by material to working environment (Electrolyte).
3) To perform EDS in order to find the elemental composition.
4) To perform SEM in order to confirm the presence of corrosive layer.
5) To perform XRD in order to find the composition of corrosive layer.

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IV. MATERIALS AND METHODS

A. *Experimental Planning*

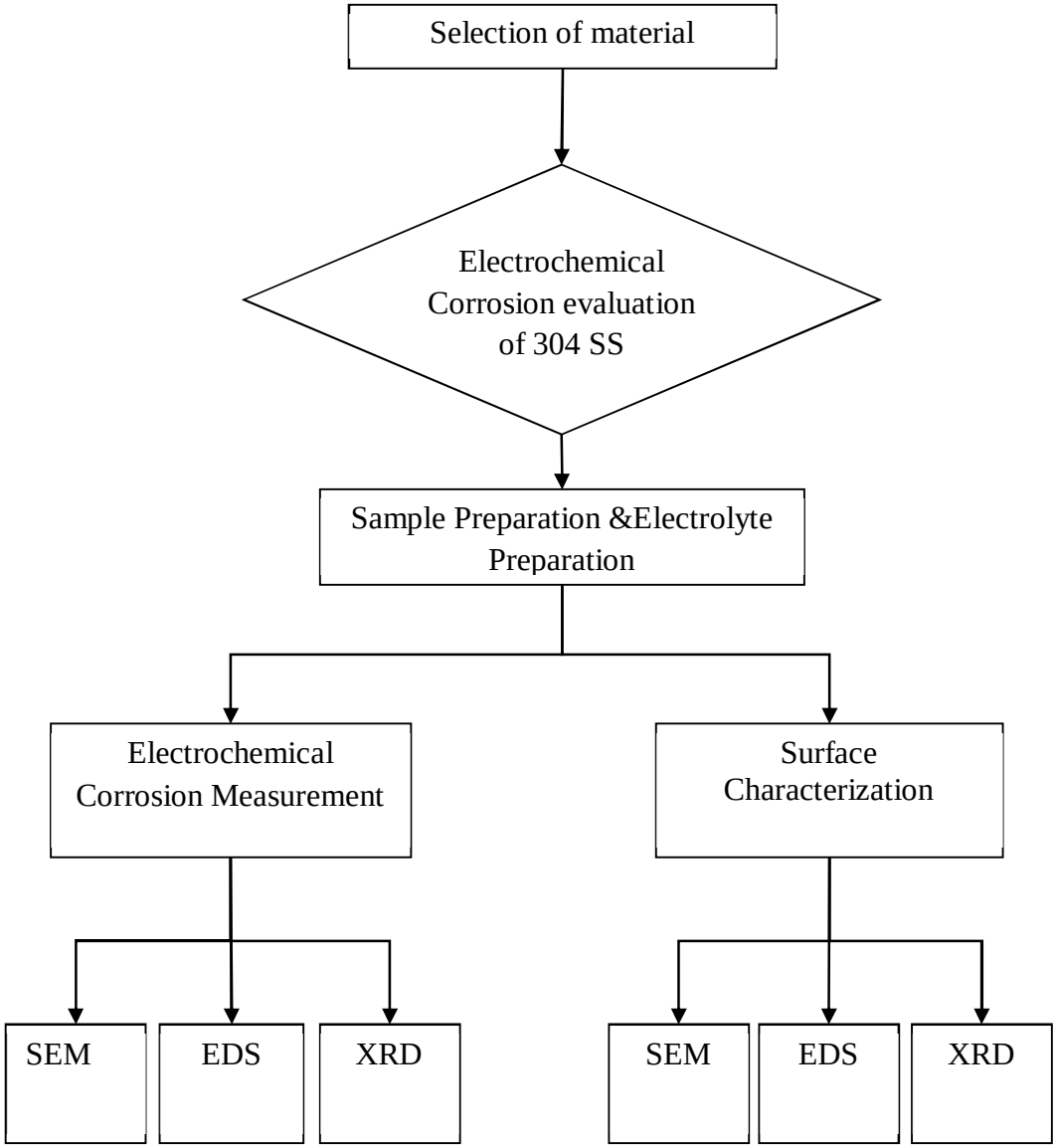

Figure 4.1 Experimental Planning

B. *Material Used*

304 Stainless Steel is the most commonly used type of stainless steel. Essentially, It is an austenitic chromium alloy which is also known as an 18/8 stainless as the make-up of the steel is 18% chromium and 8% nickel. The chromium content promotes the material's considerable resistance to the effects of corrosion and oxidation. The stainless steel alloy resists most oxidizing acids and will withstand ordinary rusting though this does not mean that the steel will not tarnish over time. The steel needs to be cold worked to generate higher tensile strength. For stainless steel sections which are welded heavily, post-weld annealing may be necessary to provide maximum corrosive resistance. Type 304 Stainless Steel has excellent welding and deep drawing characteristics and it is easy to fabricate and easy to clean.

Table 4.1 Chemical Composition of 304 Stainless Steel

Element	C	Mn	Si	P	S	Cr	Fe	Ni
%age by wt	0.08 Max	2	0.75	0.045	0.03	18	Rest	8

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Table 4.2 Physical Properties of 304 Stainless Steel

Property	Metric	English
Density	8 g/cc	0.289 lb/in^3

Table 4.3Electrical Properties of 304 Stainless Steel

Property	Metric	English
Electrical Resistivity	7.2e-005 ohm-cm	7.2e-005 ohm-cm
Magnetic Permeability	1.008	1.008

Table 4.4 Mechanical Properties of 304 Stainless Steel

Property	Metric	English
Brinell Hardness	123	123
Rockwell Hardness	70	70
Vickers Hardness	129	129
Ultimate Tensile Strength	505 Mpa	73200 psi
Yield Strength	215 Mpa	31200 psi
Elongation at break	70%	70%
Modulus of Elasticity	193-200 Gpa	28000-29000 Ksi
Poisson Ratio	0.29	0.29
Charpy Impact	325 J	240 ft-lb
Shear Modulus	86 Gpa	12500 Ksi

*C. Working **Environment***

4% NaCl Solution in water is used as electrolyte.

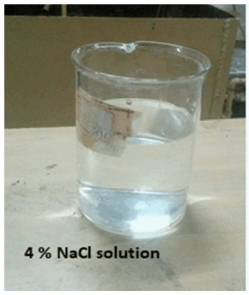

Fig.4.2 Electrolyte Used

D. Gamry Instrument

For performing Electrochemical Corrosion test with Gamry Instrument, main component is Potentiostat. A Potentiostat is an electronic instrument that controls the voltage difference between a working Electrode and a reference electrode. Both electrodes are contained in an electrochemical cell. The Potentiostat implements this control by injecting current into the cell through an Auxiliary, or Counter, electrode. Basically, the potentiostat measures the current flow between the Working and Counter electrodes. The controlled variable in a potentiostat is the cell potential and the measured variable is the cell current.

A potentiostat requires an electrochemical cell with three electrodes. These three electrodes are namely Working electrode, Reference electrode and Counter (Auxiliary) electrode.

1) *Working Electrode:* The Working Electrode is the electrode where the potential is controlled and where the current is measured. For many physical electrochemistry experiments, the Working Electrode is an “inert” material such as gold, platinum, or glassy carbon. In these cases, the Working Electrode serves as a surface on which the electrochemical reaction takes place. In corrosion testing, the Working Electrode is a sample of the corroding metal. Generally, the Working Electrode is not the actual metal structure being studied. Instead, a small sample is used to represent the structure. This is analogous to testing using weight-loss coupons. The Working Electrode can be bare metal or coated. For batteries, the potentiostat is connected directly to the anode or cathode of the battery.

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2) *Reference* ***Electrode:*** The Reference Electrode is used to measure the Working Electrode potential. A Reference Electrode should have a constant electrochemical potential as long as no current flows through it. The most common lab Reference Electrodes are the saturated calomel electrode (SCE) and the silver/silver chloride (Ag/AgCl) electrodes. In field probes, a pseudo-reference (a piece of the Working Electrode material) is often used.
3) *Counter (Auxiliary) Electrode:* The Counter, or Auxiliary, Electrode is a conductor that completes the cell circuit. The Counter Electrode in lab cells is generally an inert conductor like platinum or graphite. In field probes, it is generally another piece of the Working Electrode material. The current that flows into the solution via the Working Electrode leaves the solution via the Counter Electrode. The electrodes are immersed in an electrolyte (an electrically conductive solution). The collection of the electrodes, the solution, and the container holding the solution are referred to as an electrochemical cell.

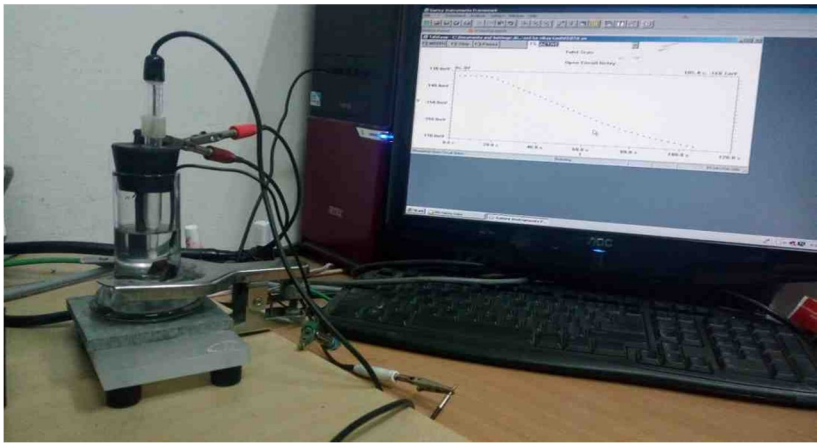

Fig.4.3 Experimental Set-up

E. Operating Parameters

1) Initial Voltage: 0.25 V
2) Final Voltage: -0.25 V
3) Scan Rate: 0.1 mV/s
4) Density: 7.999 g/cm^3
5) Weight: 25.27 g
6) Frequency: 1- 100000 Hz
7) Initial Delay: 2400 s
8) Immersion Time in Electrolyte: 1 week
9) Temperature: 27°C
10) Area: 1 cm^2

F. Surface Characterization

Surface characterization involves the Study of surface texture before and after the corrosion test by using SEM (Scanning Electron Microscope), elemental composition by EDX (Energy Dispersive X-ray) and XRD (X-ray Diffraction) for phase analysis.

1) Sample Preparation for different Studies

a) In the present work, for electrochemical corrosion test, Stainless Steel 304 is taken as the test specimen. It consists of a block of dimension 1cm x 1cm x 1cm. Also a hole of 1.5 mm diameter has been made at the corner of the sample to pass current through it with the help of CNC machine.
b) Specimen was cut down to desire shape and polishing operation followed by ASTME3 standards. The specimen was first polished by using emery papers of grit sizes starting from 80 and proceeding to 220 then 320, 500, 800, 1200 and finally on 2000.
c) The specimens were polished for mirror finish on two different velvet cloths with diamond paste of size 3µ and 1µ respectively and thoroughly cleaned with soap solution for etching.
d) After that 5 faces of the specimens were painted with the help of nail polish in order to make it highly corrosion resistant and the entire study was performed on one face which was left uncovered.

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Fig.4.4 Test Specimen

Fig.4.5 Polishing Machine

G. Applications Of 304 Stainless Steel

Bellows, chemical equipment, coal hopper linings, cooking equipment, cooling coils, cryogenic vessels, dairy equipment, evaporators, flatware utensils, feed water tubing, flexible metal hose, food processing equipment, hospital surgical equipment, hypodermic needles, kitchen sinks, marine equipment and fasteners, nuclear vessels, 0oil well filter screens, refrigeration equipment, paper industry, pots and pans, pressure vessels, sanitary fittings, valves, shipping drums, spinning, still tubes, textile dyeing equipment, tubing.

V. RESULTS AND DISCUSSIONS

A. Electrochemical Corrosion Measurement Results

1) OCV vs Time Graph

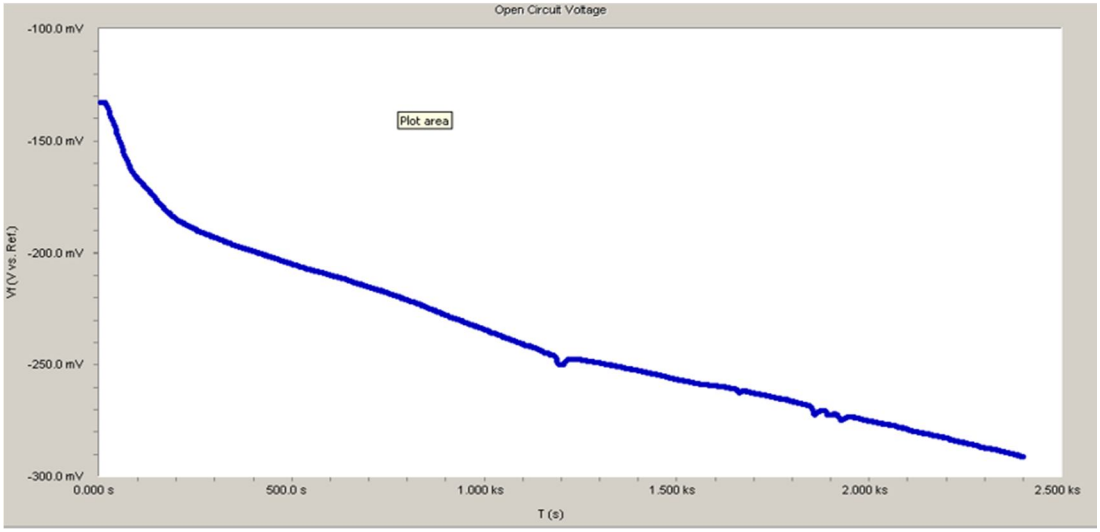

Fig.5.1 OCV vs Time Curve

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a) The equilibrium potential assumed by the metal in the absence of electrical connections to the metal is called the Open Circuit Voltage, E_{oc}. In most electrochemical corrosion experiments, the first step is the measurement of E_{oc}. The terms E_{oc} (Open Circuit Potential) and E_{corr} (Corrosion Potential) are usually interchangeable, but E_{oc} is preferred.

b) Voltage above OCP means corrosion resistance gets reduced and rate of corrosion gets increased.

c) A stable E_{oc} is taken to indicate that the system being studied has reached "steady state", i.e., the various corrosion reactions have assumed a constant rate. Some corrosion reactions reach steady state in a few minutes, while others may need several hours. Regardless of the time required, a computer-controlled system can monitor the E_{oc} and begin the experiment after it has stabilized.

d) After performing test it gives the steady state value of OCV which is equal to -0.286 V in our test.

2) Polarization Curve

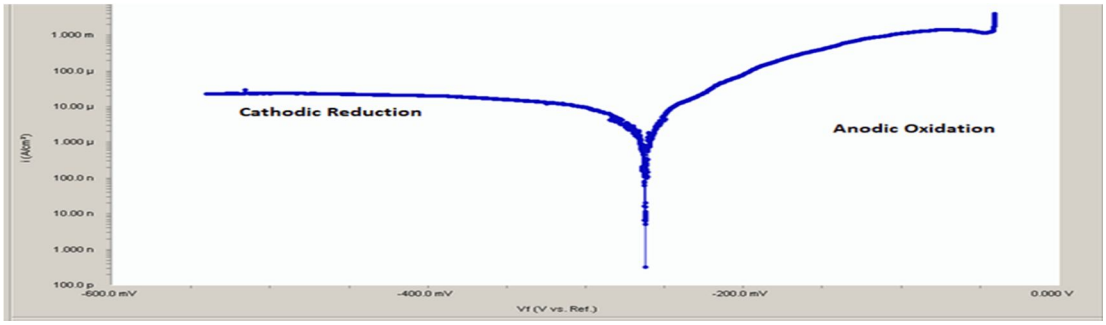

Fig.5.2 Polarization Curve

- A polarization curve is a plot of current density (I) versus electrode potential (E) for a specific electrode-electrolyte combination. The polarization curve is the basic kinetic law for any electrochemical reaction.
- Polarization curves are valuable in quantifying the behaviours of metals under various conditions. Polarization curves for passive systems may show active/passive and/or passive/trans-passive transitions.
- Helps to get corrosion rate through polarization resistance (R_P) with the help of anodic and cathodic slopes.
- Also helps to get E_{corr} and I_{corr} by crossing over the anodic and cathodic slopes.

a) Calculation of Polarization Resistance

- Polarization resistance (R_p) is the transition resistance between the electrodes and the electrolyte. In other words, an increased resistance to the flow of current in a voltaic cell is caused by chemical reactions at the electrodes. Polarization results in a reduction of the electric potential across the voltaic cell.
- An electrode is polarized when its potential is forced away from its value at open circuit or corrosion potential. Polarization of an electrode causes current to flow due to electrochemical reactions that it induces at the electrode surface.
- High R_p of a metal implies high corrosion resistance and low $R_p$implies low corrosion resistance. Thus, polarization resistance is the ratio of the applied potential and the resulting current response. This "resistance" is inversely related to the uniform corrosion rate.

Table 5.1 Polarization Resistance & Corrosion Rate Determination

β_a	β_c	E_{cor} (V)	I_{corr}(µA/cm^2)	Corrosion Rate (mm/yr)
0.010	0.0126	-0.262	0.277	0.112

$$B = \frac{\beta_a \beta_c}{2.3\,(\beta_a+\beta_c)} \quad (5.1)$$

$$R_p = \frac{B}{I_{corr}} = 8.75\ K\Omega\text{- cm}^2 \quad (5.2)$$

Where,

β_a is anodic slope and β_c is cathodic slope,

$R_p$is Polarization Resistance which is the barrier between cathodic and anodic current flow, B is a constant.

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3) EIS (Nyquist Plot) Results

a) Electrochemical impedance is the response of an electrochemical system (cell) to an applied potential.

b) The frequency dependence of this impedance can reveal underlying chemical processes.

c) The response of electrochemical systems is verynonlinear. The complex response of the system is usually displayed in Nyquist Plot, with the reactance inverted (since such systems are inherently capacitive).

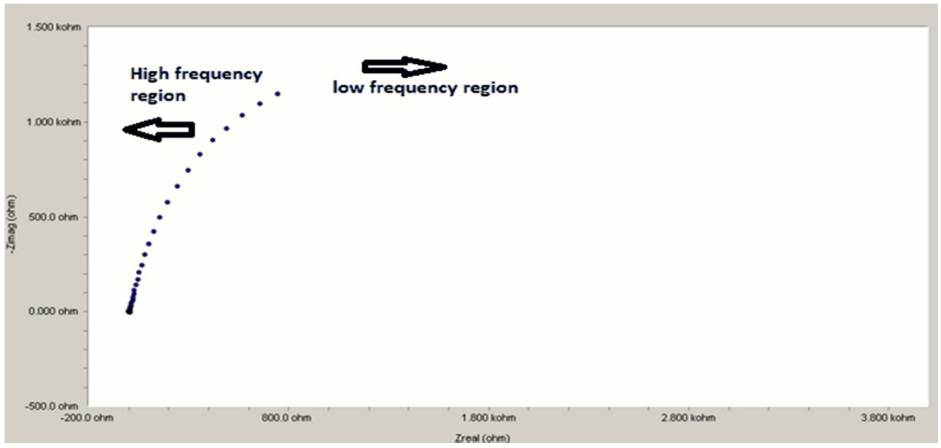

Fig.5.3 Nyquist Plot

d) R_{ct} (charge transfer resistance) is the resistance between the electrode and the electrolyte.

e) Also Capacitor value can be calculated by using $C=1/\omega Z_{im}$

$Z = Z R_e + Z_{im}$

$Z= R + iX$

$C = \frac{1}{\omega X}$

$R_{ct} = 0.8\ K\Omega\text{- } cm^2$

4) EIS Results (Bode diagram)

a) This curve gives the shift in phase angle (between voltage and current) as well as modulus of absolute impedance with respect to frequency.

b) Max shift in phase angle = -83.48 degree at 25 Hz.

c) Large impedance at low frequency means high corrosion resistance

d) At high frequency, shift in phase angle remains closer to zero degree which signifies that the effect of capacitor at high frequency is significantly low.

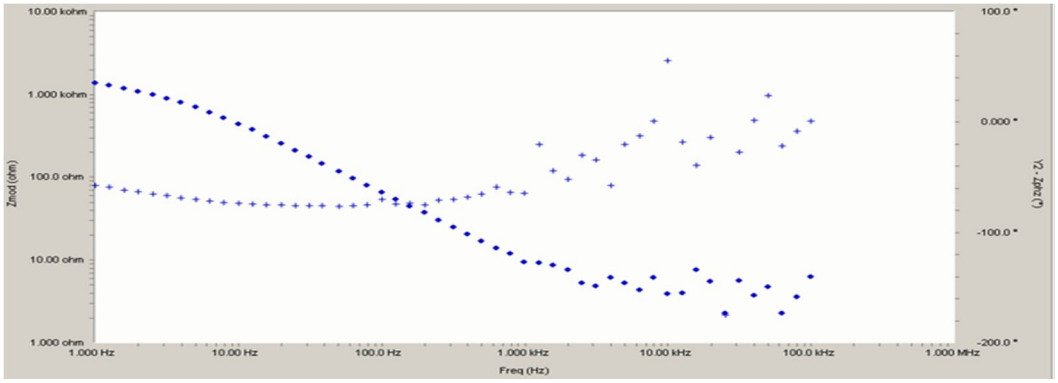

Fig.5.4 Bode Plot

$V = V_o \cos\omega t$

$I = I_o \cos(\omega t - \phi) \phi = \tan^{-1} \frac{Z_{im}}{Z_{Re}}$

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B. Surface Charcterization

1) SEM Results (Before Corrosion)

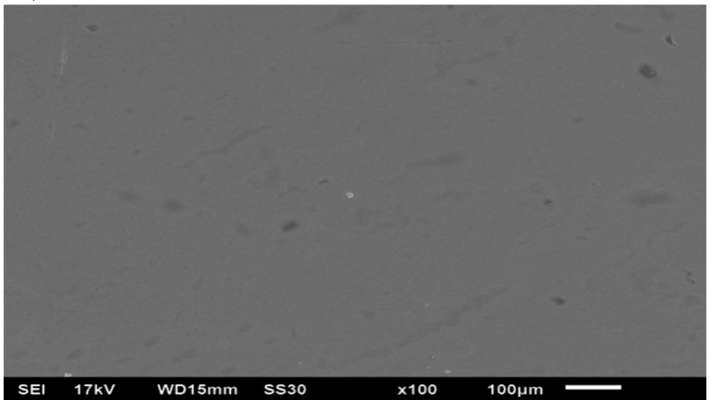

Fig.5.5 SEM Results (Before Corrosion)

2) SEM Results (After Corrosion)

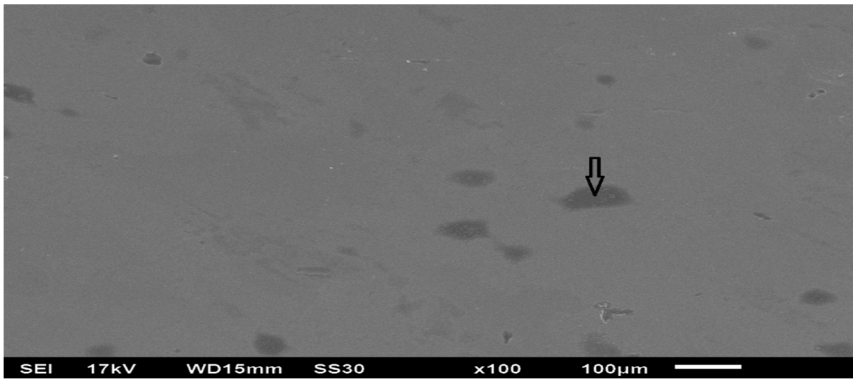

Fig.5.6 SEM Results (After Corrosion)

a) In the above fig. are the spots of corrosive layer on the surface of the metal also known as pitting corrosion.
b) In our case these spots may be of ferric chloride, ferrous hydroxide or some other chloride, oxide etc.
c) These spots are maybe because of least resistance on the surface at these places. Resistance depends on surface roughness or the geometry of the anodic sample surface.

3) EDS Results (Before Corrosion)

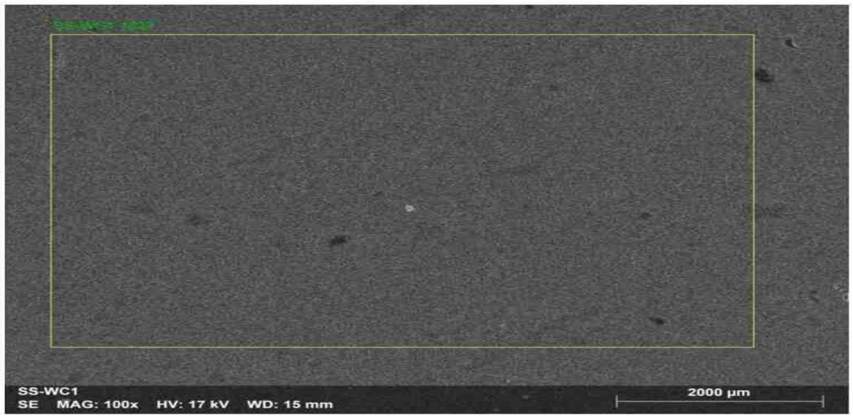

Fig.5.7(a) EDS(Before Corrosion)

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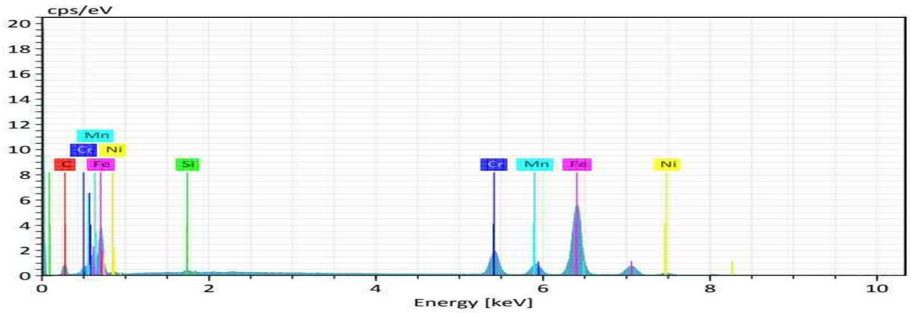

Fig.5.7(b) EDS (Before Corrosion)

SS-WC1 1827

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Carbon	6	3211	9.32	8.92	31.02	1.62	17.33
Silicon	14	907	0.30	0.28	0.42	0.04	14.52
Chromium	24	20907	13.13	12.57	10.09	0.40	3.07
Manganese	25	8174	6.90	6.60	5.02	0.23	3.40
Iron	26	66980	71.91	68.82	51.46	2.04	2.84
Nickel	28	1768	2.92	2.80	1.99	0.14	4.79
		Sum	**104.49**	**100.00**	**100.00**		

Fig.5.8 Elemental Composition by EDS (Before Corrosion)

a) Fig 25 shows the elements present in the sample before doing corrosion test.
b) Now depending upon the electrolytic solution, sample after reacting with electrolyte will form corrosive layer or spots.

4) EDS Results (After Corrosion)

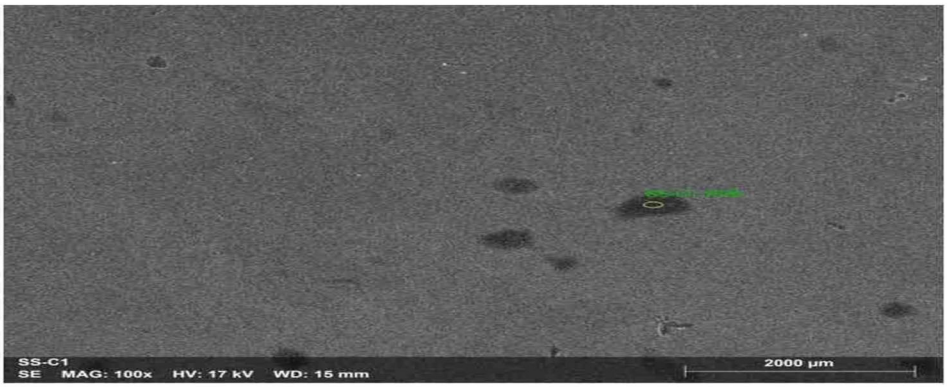

Fig. 5.9(a) EDS (After Corrosion)

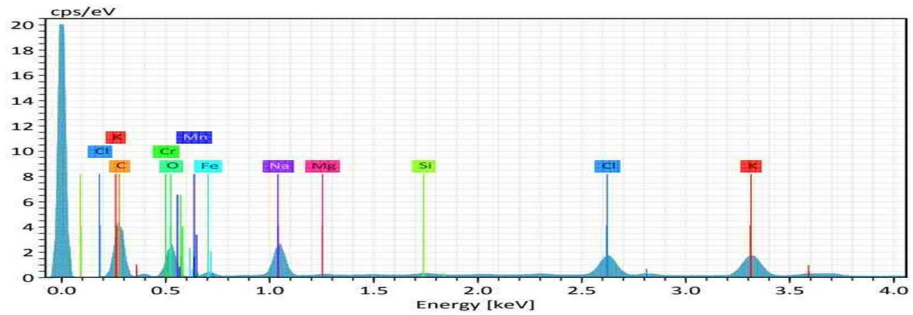

Fig. 5.9(b) EDS (After Corrosion)

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SS-C1 1833

Element	At. No.	Netto	Mass [%]	Mass Norm. [%]	Atom [%]	abs. error [%] (1 sigma)	rel. error [%] (1 sigma)
Carbon	6	20577	34.75	35.41	58.01	4.47	12.86
Oxygen	8	13723	15.53	15.83	19.47	2.11	13.58
Sodium	11	16278	7.29	7.43	6.36	0.49	6.77
Magnesium	12	519	0.17	0.17	0.14	0.04	22.87
Silicon	14	1081	0.22	0.22	0.15	0.04	17.40
Chlorine	17	15312	3.01	3.07	1.70	0.13	4.31
Potassium	19	18589	4.31	4.39	2.21	0.16	3.74
Chromium	24	10807	5.18	5.28	2.00	0.18	3.46
Manganese	25	4002	2.47	2.51	0.90	0.11	4.32
Iron	26	32291	25.21	25.69	9.05	0.74	2.94
		Sum	**98.13**	**100.00**	**100.00**		

Fig. 5.10 Elemental Composition by EDS (After Corrosion)

a) After performing electrochemical corrosion testing some more elements were there in which oxygen, potassium chlorine and sodium.
b) So there is a chance of oxide, chloride or hydroxide on the surface of the sample.
c) Hydrogen may or may not present here.
d) The energy of k_{α} electron for hydrogen is very less that is why hydrogen peak is not there in EDS chart.

5) XRD Results (Before corrosion)

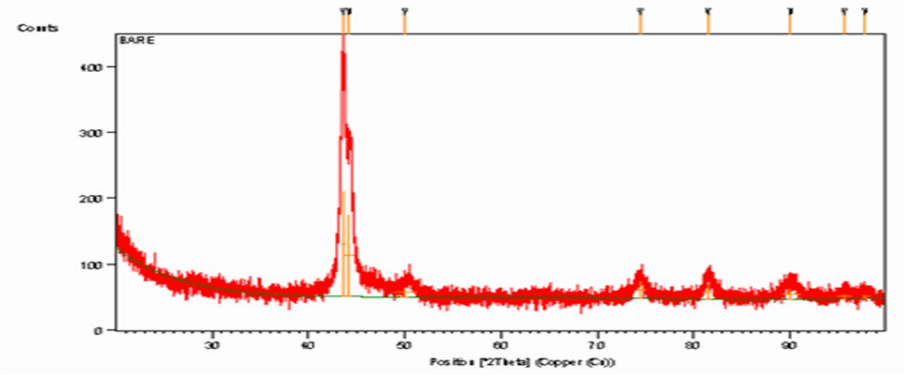

Fig.5.11 (a) XRD RESULTS (Before Corrosion)

a) These are the XRD results of stainless steel 304 sample before performing corrosion testing
b) There are some peaks at 2θ= 43.61°, 44.24, 50, 74.45, 81.52, 90.13, 95.67, 97.82 degree.

6) XRD Results (After corrosion)

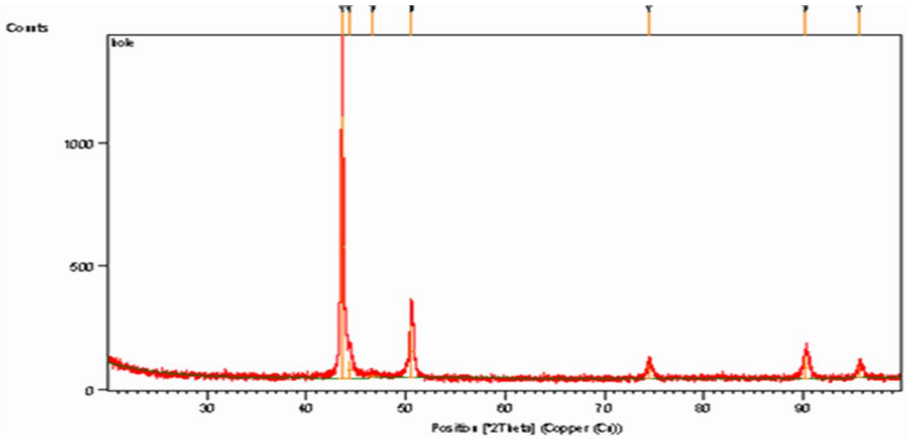

Fig.5.11 (b) XRD Results (After corrosion)

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a) These are the XRD results of stainless steel 304 sample after performing corrosion testing.
b) Here the peaks are at 2θ = 43.58°, 44.61, 50.570, 74.508, 90.259, 95.65 degree.
c) These peaks are little bit different in angle however large change in intensity has been observed, it is because after corrosion it has been observed that chromium after reacting with NaCl electrolytic solution form chloride ($CrCl_3$) on the surface of the sample.
d) The intensity of 50.570 degree peak is very large when comparing with before corrosion data.

VI. CONCLUSIONS AND FUTURE SCOPE

A. *Conclusions*

1) Electrochemical corrosion test of 304 Stainless Steel was successfully carried out in 4% NaCl solution under room temperature conditions. It was observed that the corrosion rate of 304 SS under given working conditions was found to be 0.112 mm/year.
2) Polarization Curve, Nyquist plot and Bode plot revealed the corrosion properties of 304 SS under given conditions.
3) SEM results confirmed the presence of corrosion spots.
4) EDS results confirmed the presence of elements which are responsible for the occurrence of corrosion.
5) XRD results revealed the presence of chromium chloride($CrCl_3$) phase after corrosion.

B. *Future Scope*

1) Electrochemical Corrosion testing of 304 SS under different concentrations of electrolyte can be carried out.
2) Different surface characterization techniques like Raman Spectroscopy, EBSD, TEM etc. for better compositional and phase analysis.

REFERENCES

[1] Juliana Sarango de Souza, Leandro Antônio de Oliveira, Isaac JamilSayeg, Renato AltobelliAntunesb, “Electrochemical Study of the AISI 409 Ferritic Stainless Steel: Passive Film Stability and Pitting Nucleation and Growth” Materials Research.
[2] Praveen B M and Venkatesha T V 2009 J. Alloys. Compounds482 53–7.
[3] Azizi M, Schneider. W,Plieth W 2005 J. Solid. State.Electrochem.9 429–37.
[4] Prabhu R A, Venkatesha T V, Shanbhag A V, Praveen B M,Kulkarni G M and Kalkhambar R G 2008 Mater. Chem.Phys. 108 283–9.
[5] Wang C B, Wang D L, Chen W X and Wang Y Y 2002 Wear253 563–71.
[6] Li J, Sun Y, Sun X and Qiao J 2005 Surf. Coat.Technol.192 331–5.
[7] Wu G, Li N, Zhou D, Mitasuo K Surf. Coat.Technol2004.
[8] Paredes EC, Bautista A, Alvarez SM, Velasco F. Influence of the forming process of corrugated stainless steels on their corrosion behaviour in simulated pore solutions. Corrosion Science. 2012;58:52-61.
[9] Lv J, Liang T. Improved corrosion resistance of 316L stainless steel by nanocrystalline and electrochemical nitridation in artificial saliva solution. Applied Surface Science. 2015;359:158-165.
[10] Carmezim MJ, Simões AM, Montemor MF, da Cunha Belo MD. Capacitance behaviour of passive films on ferritic and austenitic stainless steel. *Corrosion Science*. 2005;47(3):581-591.
[11] BenSalah M, Sabot R, Triki E, Dhouibi L, Refait P, JeanninM. Passivity of Sanicro28 (UNS N-08028) stainless steel inpolluted phosphoric acid at different temperatures studied byelectrochemical impedance spectroscopy and Mott-Schottky analysis. *Corrosion Science*. 2014;86:61-70.
[12] Niu W, Lillard RS, Li Z, Ernst F. Properties of The Passive Film Formed on Interstitially Hardened AISI 316L Stainless Steel. *ElectrochimicaActa*.2015;176:410-419.
[13] Heuer AH, Kahn H, Ernst F, Michal GM, Hovis DB, Rayne RJ,et al. Enhanced corrosion resistance of interstitially hardenedstainless steel: Implications of a critical passive layer thicknessfor breakdown. *ActaMaterialia*. 2012;60(2):716-725.
[14] Olsson COA, Landolt D. Passive films on stainless steels- chemistry, structure and growth. *Electrochimica Acta*.2003;48(9):1093-1104.

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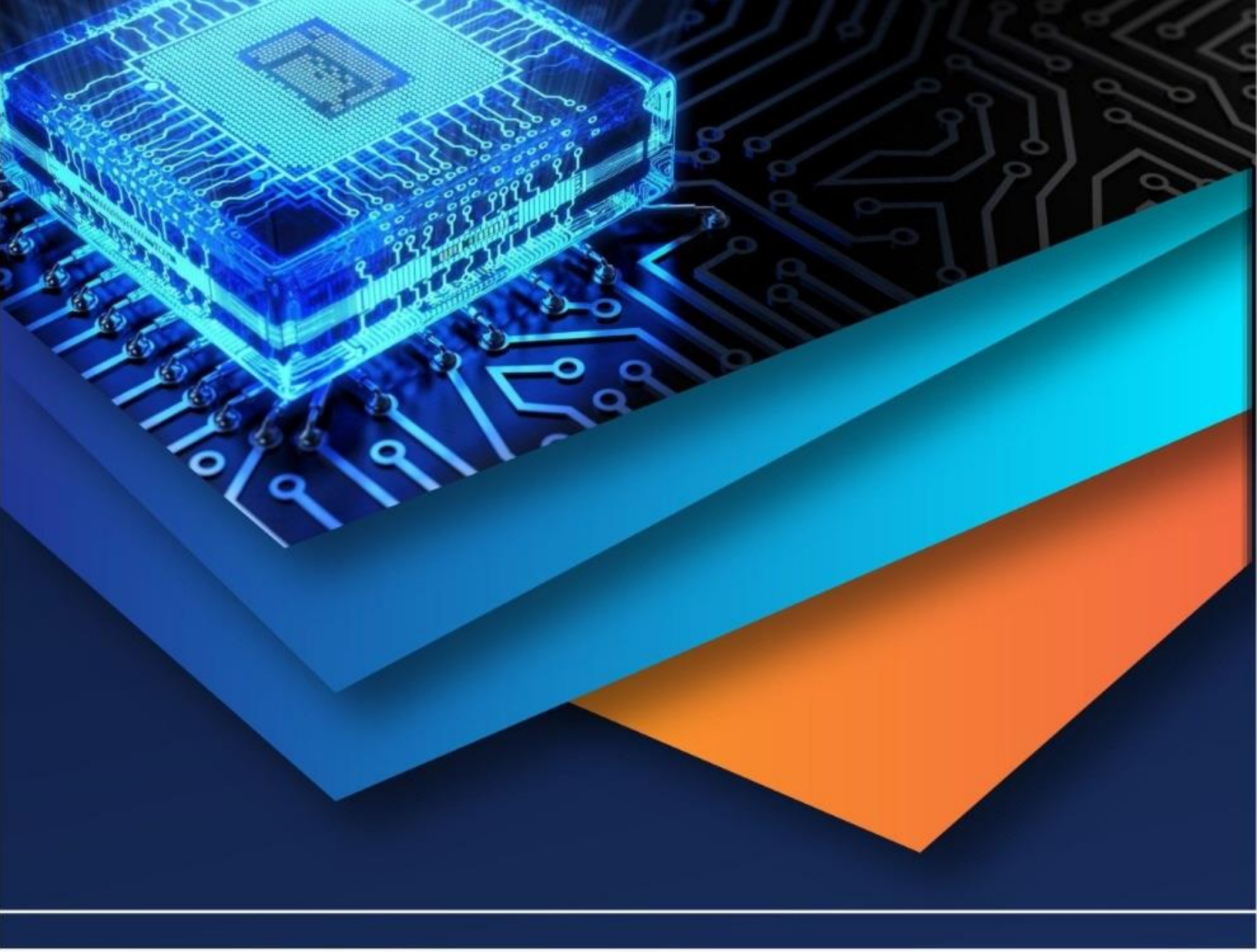

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