SUMMARY

Corrosion is the disintegration of an engineered material into its constituent atoms due to chemical reactions with its surroundings. In the most common use of the word, this means electrochemical oxidation of metals in reaction with an oxidant such as oxygen. Formation of an oxide of iron due to oxidation of the iron atoms in solid solution is a well-known example of electrochemical corrosion, commonly known as rusting. This type of damage typically produces oxide(s) or salt(s) of the original metal. Corrosion can also occur in materials other than metals, such as ceramics or polymers, although in this context, the term degradation is more common.

In other words, corrosion is the wearing away of metals due to attack of atmospheric gases on the surface of metal resulting in a chemical or electrochemical reaction.

Many structural alloys corrode merely from exposure to moisture in the air, but the process can be strongly affected by exposure to certain substances [1-3]. Corrosion can be concentrated locally to form a pit or crack, or it can extend across a wide area more or less uniformly corroding the surface. Because corrosion is a diffusion controlled process, it occurs on exposed surfaces. As a result, methods to reduce the activity of the exposed surface, such as passivation and chromate-conversion, can increase a material's corrosion resistance. However, some corrosion mechanisms are less visible and less predictable.

Galvanic corrosion occurs when two different metals have physical or electrical contact with each other and are immersed in a common electrolyte, or when the same metal is exposed to electrolyte with different concentrations. In a galvanic couple, the more active metal (the anode) corrodes at an accelerated rate and the more noble metal (the cathode) corrodes at a retarded rate. When immersed separately, each metal corrodes at its own rate. What type of metal(s) to use is readily determined by following the galvanic series. For example, zinc is often used as a sacrificial anode for steel structures. Galvanic corrosion is of major interest to the marine industry and also anywhere water (via impurities such as salt) contacts pipes or metal structures [4-9].
Factors such as relative size of anode, types of metal, and operating conditions (temperature, humidity, salinity, etc.) affect galvanic corrosion. The surface area ratio of the anode and cathode directly affects the corrosion rates of the materials. Galvanic corrosion is often utilized in sacrificial anodes [10-14].

In a given environment (one standard medium is aerated, room-temperature seawater), one metal will be either more noble or more active than the next, based on how strongly its ions are bound to the surface. Two metals in electrical contact share the same electrons, so that the "tug-of-war" at each surface is analogous to competition for free electrons between the two materials. Using the electrolyte as a host for the flow of ions in the same direction; the noble metal will take electrons from the active one. The resulting mass flow or electrical current can be measured to establish a hierarchy of materials in the medium of interest. This hierarchy is called a galvanic series, and can be a very useful in predicting and understanding corrosion [15-17].

Often it is possible to chemically remove the products of corrosion to give a clean surface, but one that may exhibit artifacts of corrosion such as pitting. For example phosphoric acid in the form of naval jelly is often applied to ferrous tools or surfaces to remove rust.

Corrosion removal should not be confused with electropolishing which removes some layers of the underlying metal to make a smooth surface. For example phosphoric acid (again) may be used to electropolish copper but it does this by removing copper, not the products of copper corrosion.

Some metals are more intrinsically resistant to corrosion than others, either due to the fundamental nature of the electrochemical processes involved or due to the details of how reaction products form. For some examples, Galvanic series.

There are various ways of protecting carbon steel from corrosion including painting, hot dip galvanizing, and combinations of these. If a more susceptible material is used, many techniques can be applied during an item's manufacture and use to protect its materials from damage [18-20].
The materials most resistant to corrosion are those for which corrosion is thermodynamically unfavorable. Any corrosion products of gold or platinum tend to decompose spontaneously into pure metal, which is why these elements can be found in metallic form on Earth, and is a large part of their intrinsic value. More common "base" metals can only be protected by more temporary means.

Metals have naturally slow reaction kinetics, even though their corrosion is thermodynamically favorable. These include such metals as zinc, magnesium, and cadmium. While corrosion of these metals is continuous and ongoing, it happens at an acceptably slow rate. An extreme example is graphite, which releases large amounts of energy upon oxidation, but has such slow kinetics that it is effectively immune to electrochemical corrosion under normal conditions [21-25].

The US Federal Highway Administration released a study, entitled *Corrosion Costs and Preventive Strategies in the United States*, in 2002 on the direct costs associated with metallic corrosion in nearly every U.S. industry sector. The study showed that for 1998 the total annual estimated direct cost of corrosion in the U.S. was approximately $276 billion (approximately 3.2% of the US gross domestic product).

Rust is one of the most common causes of bridge accidents. As rust has a much higher volume than the originating mass of iron, its build-up can also cause failure by forcing apart adjacent parts. It was the cause of the collapse of the Mianus river bridge in 1983, when the bearings rusted internally and pushed one corner of the road slab off its support. Three drivers on the roadway at the time died as the slab fell into the river below. The following NTSB investigation showed that a drain in the road had been blocked for road re-surfacing, and had not been unblocked so that runoff water penetrated the support hangers. It was also difficult for maintenance engineers to see the bearings from the inspection walkway. Rust was also an important factor in the Silver Bridge disaster of 1967 in West Virginia, when a steel suspension bridge collapsed in less than a minute, killing 46 drivers and passengers on the bridge at the time.

Similarly, corrosion of concrete-covered steel and iron can cause the concrete to spall, creating severe structural problems. It is one of the most common failure modes of reinforced concrete
bridges. Measuring instruments based on the half-cell potential are able to detect the potential corrosion spots before total failure of the concrete structure is reached.

Carbon steel and mild steel are the most common metallic material being used for numerous applications in a variety of industries as well as in daily life for structural and fabrication purposes. Carbon steel and mild steel corrodes heavily when it comes in contact with corrosive environment i.e. acid but their use is still the most common because of its low cost and reasonably good mechanical strength. Stainless steel is widely used in kitchen utensils, sinks, nut bolts, engine parts etc. [26-29].

Plating, painting, and the application of enamel are the most common anti-corrosion treatments. They work by providing a barrier of corrosion-resistant material between the damaging environment and the structural material. Aside from cosmetic and manufacturing issues, there are tradeoffs in mechanical flexibility versus resistance to abrasion and high temperature. Platings usually fail only in small sections, and if the plating is more noble than the substrate (for example, chromium on steel), a galvanic couple will cause any exposed area to corrode much more rapidly than an unplated surface would. For this reason, it is often wise to plate with active metal such as zinc or cadmium. Painting either by roller or brush is more desirable for tight spaces; spray would be better for larger coating areas such as steel decks and waterfront applications. Flexible polyurethane coatings, like Durabak-M26 for example, can provide an anti-corrosive seal with a highly durable slip resistant membrane. Painted coatings are relatively easy to apply and have fast drying times although temperature and humidity may cause dry times to vary.

Most ceramic materials are almost entirely immune to corrosion. The strong chemical bonds that hold them together leave very little free chemical energy in the structure; they can be thought of as already corroded. When corrosion does occur, it is almost always a simple dissolution of the material or chemical reaction, rather than an electrochemical process. A common example of corrosion protection in ceramics is the lime added to soda-lime glass to reduce its solubility in water; though it is not nearly as soluble as pure sodium silicate, normal
glass does form sub-microscopic flaws when exposed to moisture. Due to its brittleness, such flaws cause a dramatic reduction in the strength of a glass object during its first few hours at room temperature [30-31].

Metals are elements that tend to lose electrons when they are involved in chemical reactions, and nonmetals are those elements that tend to gain electrons. Sometimes these elements form ions, charged elements or groups of elements. Metallic ions, because they are formed from atoms that have lost electrons, are positively charged (the nucleus is unchanged). When an atom or ion loses electrons it is said to have been oxidized.

A common oxidation reaction in corrosion is the oxidation of neutral iron atoms to positively charged iron ions:
\[
\text{Fe} \rightarrow \text{Fe}^{2+} + 2e^-
\]
The electrons lost from a metal must go somewhere, and they usually end up on a nonmetallic atom forming a negatively charged nonmetallic ion. Because the charge of these ions has become smaller (more negative charges) the ion or atom which has gained the electron(s) is said to have been reduced.
\[
4\text{H}^+ + \text{O}_2 + 4e^- \rightarrow 2\text{H}_2\text{O}
\]
or
\[
2\text{H}^+ + 2e^- \rightarrow \text{H}_2
\]
While other reduction reactions are possible, the reduction of oxygen is involved in well over 90% of all corrosion reactions. Thus the amount of oxygen present in an environment, and its ability to absorb electrons, is an important factor in determining the amount of oxidation, or corrosion, of metal that occurs.

Carbon steel, stainless steel and mild steel are the most common materials used for structural and fabrication purposes. Mild steel has remarkable economic and attractive materials for engineering applications owing to its low cost, easy availability and high mechanical strength. The interest of the materials arises from their importance in recent civilization. Mild steel is widely used in body of trunks, desert coolers, storage tanks of food grains, boats and
ships, engine parts etc. Carbon steel has remarkable economic and attractive materials for engineering applications owing to its low cost, easy availability and high mechanical strength.

Stainless steel has remarkable attractive materials for engineering applications owing to its easy availability, possess good luster, corrosion resistance and high mechanical strength. Due to this, stainless steel is widely used in making utensils, doors, windows, partitions frames, parts of engines, body of planes, cars, trains etc. and others daily use households wares. Main difference in the composition of these three metallic alloys is in its carbon content. Stainless steel has highest carbon content, due to this it possess highest mechanical strength and almost non corrosive in neutral aqueous solutions.

Corrosion commonly occurs at metal surface in the presence of oxygen and moisture and involves two electrochemical reactions i.e. oxidation and reduction. Oxidation takes place at anodic site and reduction occurs at cathodic site. In acidic medium, hydrogen evolution reaction predominates while in neutral medium reductions of oxygen takes place. Corrosion inhibitors reduce or prevent these reactions, they are adsorbed on to the metal surface and act by forming a barrier to oxygen and moisture, by complexing with metal ions or by removing corrodents from the environment, some of the inhibitors facilitate formation of passivating film on the metal surface.

The selection of an appropriate inhibitor depends not only upon, its structure but also on environmental factors. Processes in which acids play a very important part are ; industrial acid cleaning, oil well acidizing, acid pickling, manufacturing process and vapour liquid systems. Several compounds containing hetero atoms like nitrogen containing organic compounds have been tested as corrosion inhibitor for metal in acidic environment. It has been observed that organic compounds containing those with heteroatoms with high electron density such as nitrogen, oxygen and sulfur or having multiple bonds are effective corrosion inhibitors in acidic conditions. The corrosion inhibition is a surface phenomenon which primarily involves adsorption of the inhibitor molecule i.e. organic compounds on metal surface. The mode of interaction affect the inhibition efficiency of organic compounds with the metal surface and molecular structure.
Losses due to corrosion includes the two i.e. direct and indirect. Indirect loss are more severe than direct loss because indirect loss can not be predicted, they occur suddenly and result in complete damage of structure or building. Corrosion is unavoidable phenomenon, but losses due to corrosion can e minimized by applying suitable corrosion protection methods. Losses due to corrosion are in billions. It includes repair of bridges, fuel systems, automobiles radiators, exhaust system, machinery parts, equipments, body of appliances etc. Total annual costs of floods, hurricanes, tornadoes, fires, lighting and earthquake are less than costs of corrosion. There are numerous methods available to prevent the metals from corrosion. Application of particular method depends upon the environmental conditions, nature of metals to be protected, ease of application, cost etc.

A corrosion inhibitor is a chemical compound that, when added to a liquid or gas, decreases the corrosion rate of a material, typically a metal or an alloy. The effectiveness of a corrosion inhibitor depends on fluid composition, quantity of water, and flow regime. A common mechanism for inhibiting corrosion involves formation of a coating, often a passivation layer, which prevents access of the corrosive substance to the metal. Permanent treatments such as chrome-plating are not generally considered inhibitors, however. Instead corrosion inhibitors are additives to the fluids that surround the metal or related object.

The nature of the corrosive agent depends on (i) the material being protected, which are most commonly metal objects, and (ii) on the corrosive agent(s) to be neutralized. The corrosive agents are generally oxygen, hydrogen sulfide, and carbon dioxide. Oxygen is generally removed by reductive inhibitors such as amines and hydrazines:

\[
O_2 + N_2H_4 \rightarrow 2 H_2O + N_2
\]

In this example, hydrazine converts oxygen, a common corrosive agent, to water, which is generally benign. Related inhibitors of oxygen corrosion are hexamine, phenylenediamine, and dimethylethanolamine, and their derivatives. Antioxidants such as sulfite and ascorbic acid are
sometimes used. Some corrosion inhibitors form a passivating coating on the surface by chemisorption. Benzotriazole is one such species used to protect copper. For lubrication, zinc dithiophosphates are common - they deposit sulfide on surfaces.

Benzotriazole inhibits corrosion of copper by forming an inert layer of this polymer on the metal's surface.

The suitability of any given chemical for a task in hand depends on many factors, including their operating temperature.

In the present work, an attempt has been made in this work to find surfactants as corrosion inhibitor of carbon steel, mild steel and stainless steel in hydrochloric acid solution which will reduce the losses due to corrosion. As temperature varies a lot in different types of industries and also from place to place in a industry. So, we have selected three different temperatures for investigation i.e. 30, 40 and 50 °C.

To achieve above said objectives, investigations have been carried out using four organic surfactant molecules namely Decyl sulphate sodium salt (SSDS), Dodecyl sulphate sodium salt (SSDDS), Hexadecyl sulphate sodium salt (SSHDS) and Dodecyl benzene sulfonate sodium salt (SSDDBS) as corrosion inhibitors for Carbon steel, mild steel and stainless steel in 1.0 M hydrochloric acid solutions using the following techniques.

1. Weight loss technique.
2. Electrochemical polarization technique.

Concentration of the different organic surfactants as corrosion inhibitor ranged from 10, 20, 30, 50 and 100 ppm. The experiments were performed at 30, 40 and 50 °C.

In the 1st chapter of the manuscript, the research topic has been introduced in detail. A brief idea about corrosion and corrosion inhibitors, electrochemistry of corrosion, forms of corrosion and methods to control has been given. Use of corrosion inhibitors, their classification, mechanism of inhibitors and factors influencing efficiency of corrosion inhibitors have been discussed in detail. Basic principle and mechanism of electrochemical corrosion has been discussed in length. Electrochemical polarization curves (Evans’s diagram) have also been discussed in detail. Various theories involved in electrochemical corrosion, method to find corrosion rate and percentage corrosion inhibition efficiency from stern Gerry equation and polarization curves have also been discussed at full length. Experimental procedure to be followed in electrochemical method of corrosion is also discussed in detail.

The chapter starts with brief introduction of topic followed by detailed study of electrochemical aspects of corrosion. In the next section, different forms of corrosion have been discussed at full length. In the next section, kinetic aspects of corrosion have been described in detail. In the subsequent section, polarization phenomenon related to the polarization of metal electrode have been discussed in detail. In the next section, different methods to prevent metal specimens and their alloys from corrosion have been discussed in detail. In the last, different factors influencing the rate of corrosion have been discussed in full length.

In the second chapter of the manuscript, an exhaustive literature survey has been made to control the corrosion in acidic medium has been described to give up to date knowledge of the research problem. The literature survey was conducted in a systematic way starting from the very beginning to the latest invention in the field. We have covered literature survey of more than last 50 years. We have started the literature survey with brief introduction followed by introduction to different surfactant and surfactants acting as micelle.
In the next section classification of different surfactants has been described in detail. In the next section, various types of micelle, their structure and properties has been described in detail. After that, critical micelle concentration required by the surfactant molecules in order to form micelle has been described in detail. In the next section corrosion characteristics of different materials i.e. metals and their alloys have been discussed in detail. In the last section, different surfactants acting as corrosion inhibitors for different metallic alloys have been discussed in detail. In the end of the chapter, objectives of the present research work have been elucidated and presented point wise.

In the 3rd chapter of the manuscript, details of the materials used for the experimental work and methods adopted for the preparation of working specimen have been reported. Composition of all the three investigated metal alloys i.e. carbon steel, mild steel and stainless steel have been tabulated in table. In the next section, detailed procedure for polishing of the metal specimens have been described in detail. Source of various chemicals like surfactants, metal sheets etc. have also been described in detail. Sample preparations techniques both for weight loss and electrochemical polarization techniques have been discussed at full length. Experimental technique viz. weight loss method and electrochemical polarization technique employed for carrying out the experimental work have been described in detail. Various theoretical calculations and equations have also been discussed in detail.

In the 4th chapter of the manuscript, the results of the experiments carried out on carbon steel in 1.0 M hydrochloric acid by using four surfactants i.e. Decyl sulphate sodium salt (SSDS), Dodecyl sulphate sodium salt (SSDDS), Hexadecyl sulphate sodium salt (SSHDS) and Dodecyl benzene sulfonate sodium salt (SSDDBS) as corrosion inhibitors were given. Results have been nicely presented in the form of tables and figures.

The fourth chapter starts with a brief introduction of the subject. After that chemical formula and structure of all the four surfactant was presented. After that results obtained form corrosion experiments for the four investigated surfactants has been discussed in detail. It is observed that all these surfactants molecules get adsorbed on the surface of Carbon steel and forms a protective coating layer over Carbon steel surface. In all the four investigated surfactants
molecules, corrosion inhibition efficiency increases with increase in concentration of surfactant molecule from 20 to 150 ppm and decreases with increase in temperature from 30 to 50 °C. The percentage corrosion inhibition has been found in the following order:

Decyl sulphate sodium salt (SSDS) > Dodecyl sulphate sodium salt (SSDDS) > Hexadecyl sulphate sodium salt (SSHDS) > Dodecyl benzene sulfonate sodium salt (SSDDBS).

It is also observed that addition of KMnO₄ to the surfactant formulation, increases the corrosion inhibition efficiency of surfactant molecules, i.e. KMnO₄ shows synergistic effect for carbon steel in acidic medium.

The degree of surface coverage (θ) of carbon steel surface by all the four investigated surfactant molecules was also calculated and has been shown in Table 4.4. It is observed that degree of surface coverage of metal surface by the surfactant molecules increases with increase in concentration of surfactants molecules from 20 to 150 ppm. It is also observed that degree of surface coverage of metal surface by the surfactant molecules decreases with the increase in temperature of the corroding medium from 30 to 50 °C.

It is observed that corrosion rate (mpy) decreases by a unit per degree rise in temperature. The optimum concentration of all the four investigated surfactant molecules was found to be 150 ppm, because no significant increase in percentage corrosion inhibition efficiency was observed at higher concentration.

The interaction of inhibitor molecules with the metal surface can be described by introducing of an parameter, $S_\theta$, obtained from the surface coverage values (θ) of the organic surfactant molecules and has been shown in Table 4.3. It is observed from the Table 4.3 that, the magnitude of interaction parameters of the surfactant molecules with the metal surface increases with increase in concentration of organic surfactant molecules from 10 to 100 ppm and decrease with increase in temperature from 30 to 50 °C.

Mechanism of action of surfactant molecules was explained with the help of degree of surface coverage, magnitude of interaction parameters, synergism parameters and
electrochemical Tafel plots. It is observed that all the four investigated surfactant molecules acts as mixed type inhibitors and got physically adsorbed on the surface of metal and form a uniform continuous barrier film and follows Freundlich adsorption isotherm.

All the four surfactant molecule adsorb on the surface of metal sheet through the sulphate molecules and form a continuous uniform film over the metal surface. Surfactant molecule adsorb through Sulphate molecule to the Fe\(^{2+}\) ion of metal sheet present in the surface film through donar accepter charge transfer complex resulting into stable, continuous passive film which protect the metal surface from corrosion.

It is also observed that results observed from electrochemical polarization methods are in close agreements with the results obtained from weight loss experiments. It is concluded from the chapter fourth that,

- The investigated surfactant compounds act as corrosion inhibitors for the carbon steel in hydrochloric acid solution.
- Surfactant compounds adsorb on carbon steel surface according to the Freundlich adsorption isotherm.
- The inhibitors increase the value of activation energy of corrosion and consequently, decrease the rate of dissolution of Carbon steel in HCl solution.
- Polarization data showed that these investigated surfactant compounds acted as mixed-type inhibitors.
- The inhibition efficiencies obtained from polarization and weight loss measurements are in good agreement with each other.
- Increase of temperature leads to the decrease in corrosion rate of carbon steel in HCl solution.
- Addition of KMnO\(_4\) to inhibitor formulation shows synergistic effect on corrosion inhibition efficiency of organic surfactant towards carbon steel.

In the 5\(^{th}\) chapter of the manuscript, the results of the experiments carried out on stainless steel in 1.0 M hydrochloric acid by using four surfactants i.e. Decyl sulphate sodium salt
(SSDS), Dodecyl sulphate sodium salt (SSDDDS), Hexadecyl sulphate sodium salt (SSHDS) and Dodecyl benzene sulfonate sodium salt (SSDDBS) as corrosion inhibitors were given. The fifth chapter starts with a brief introduction of the subject. After that chemical formula and structure of all the four surfactant was presented. After that results obtained from different corrosion experiments for the four investigated surfactants has been discussed in detail.

It is observed that all these surfactants molecules get adsorbed on the surface of stainless steel and forms a protective coating layer over stainless steel surface. In all the four investigated surfactants molecules, corrosion inhibition efficiency increases with increase in concentration of surfactant molecule from 20 to 150 ppm and decreases with increase in temperature from 30 to 50 °C. The percentage inhibition has been found in the following order;

Decyl sulphate sodium salt (SSDS) > Dodecyl sulphate sodium salt (SSDDDS) > Hexadecyl sulphate sodium salt (SSHDS) > Dodecyl benzene sulfonate sodium salt (SSDDBS).

It is also observed that addition of KMnO₄ to the surfactant formulation, increases the corrosion inhibition efficiency of surfactant molecules, i.e. KMnO₄ shows synergistic effect for stainless steel in acidic medium.

The degree of surface coverage (θ) of carbon steel surface by all the four investigated surfactant molecules was also calculated and has been shown in Table 5.4.

The interaction of inhibitor molecules with the metal surface can be described by introducing of an parameter, $S_\theta$, obtained from the surface coverage values (θ) of the organic surfactant molecules and has been shown in Table 5.3.

Mechanism of action of surfactant molecules was explained with the help of degree of surface coverage, magnitude of interaction parameters, synergism parameters and electrochemical Tafel plots. It is observed that all the four investigated surfactant molecules acts as mixed type inhibitors and got physically adsorbed on the surface of metal and form a uniform continuous barrier film and follows Frendlich adsorption isotherm.
All the four surfactant molecule adsorb on the surface of metal sheet through the sulphate molecules and form a continuous uniform film over the metal surface. Surfactant molecule adsorb through Sulphate molecule to the Fe$^{2+}$ ion of metal sheet present in the surface film through donar accepter charge transfer complex resulting into stable, continuous passive film which protect the metal surface from corrosion.

It is also observed that results observed from electrochemical polarization methods are in close agreements with the results obtained from weight loss experiments. It is concluded from the chapter fifth that,

- The investigated surfactant compounds act as corrosion inhibitors for the stainless steel in hydrochloric acid solution.
- Surfactant compounds adsorb on carbon steel surface according to the Freundlich adsorption isotherm.
- The inhibitors increase the value of activation energy of corrosion and consequently, decrease the rate of dissolution of stainless steel in HCl solution.
- Polarization data showed that these investigated surfactant compounds acted as mixed-type inhibitors.
- The inhibition efficiencies obtained from polarization and weight loss measurements are in good agreement with each other.
- Increase of temperature leads to the decrease in corrosion rate of carbon steel in HCl solution.
- Addition of KMnO$_4$ to inhibitor formulation shows synergistic effect on corrosion inhibition efficiency of organic surfactant towards stainless steel.

In the 6th chapter of the manuscript, the results of the experiments carried out on mild steel in 1.0 M hydrochloric acid by using four surfactants i.e. Decyl sulphate sodium salt (SSDS), Dodecyl sulphate sodium salt (SSDDS), Hexadecyl sulphate sodium salt (SSHDS) and Dodecyl benzene sulfonate sodium salt (SSDDBS) as corrosion inhibitors were given. The sixth chapter starts with a brief introduction of the subject. After that chemical formula and structure of all the four surfactant was presented. After that results obtained from corrosion experiments for the four investigated surfactants has been discussed in detail.
It is observed that all these surfactants molecules get adsorbed on the surface of mild steel and forms a protective coating layer over mild steel surface. In all the four investigated surfactants molecules, corrosion inhibition efficiency increases with increase in concentration of surfactant molecule from 20 to 150 ppm and decreases with increase in temperature from 30 to 50 °C. The percentage inhibition has been found in the following order:

Decyl sulphate sodium salt (SSDS) > Dodecyl sulphate sodium salt (SSDDS) > Hexadecyl sulphate sodium salt (SSHDS) > Dodecyl benzene sulfonate sodium salt (SSDBS).

It is also observed that addition of KMnO₄ to the surfactant formulation, increases the corrosion inhibition efficiency of surfactant molecules, i.e. KMnO₄ shows synergistic effect for carbon steel in acidic medium.

The degree of surface coverage ($\theta$) of carbon steel surface by all the four investigated surfactant molecules was also calculated and has been shown in Table 6.4.

The interaction of inhibitor molecules with the metal surface can be described by introducing of an parameter, $S_\theta$, obtained from the surface coverage values ($\theta$) of the organic surfactant molecules and has been shown in Table 6.3.

Mechanism of action of surfactant molecules was explained with the help of degree of surface coverage, magnitude of interaction parameters, synergism parameters and electrochemical Tafel plots. It is observed that all the four investigated surfactant molecules acts as mixed type inhibitors and got physically adsorbed on the surface of metal and form a uniform continuous barrier film and follows Freundlich adsorption isotherm.

All the four surfactant molecule adsorb on the surface of metal sheet through the sulphate molecules and form a continuous uniform film over the metal surface. Surfactant molecule adsorb through Sulphate molecule to the Fe²⁺ ion of metal sheet present in the surface film.
through donor accepter charge transfer complex resulting into stable, continuous passive film which protect the metal surface from corrosion.

It is also observed that results observed from electrochemical polarization methods are in close agreements with the results obtained from weight loss experiments.

It is concluded from the corrosion experiments that mild steel is more corrosive than carbon steel which is more corrosive than stainless steel.

The work reported in the manuscript has got its direction applications in industry to control and minimize the corrosion of carbon steel, mild steel and stainless steel alloys in acidic medium. All the investigated surfactants molecules are very cheap and easy available. It will result in reduction of losses due to corrosion due to attack of acids.

Finally, it is concluded from all the corrosion experiments on different metallic alloys in acidic medium that;

**Conclusions:**

- The investigated all the four surfactant molecules i.e. Decyl sulphate sodium salt (SSDS), Dodecyl sulphate sodium salt (SSDDS), Hexadecyl sulphate sodium salt (SSHDS), Dodecyl benzene sulfonate sodium salt (SSDDBS) act as corrosion inhibitors for the carbon steel, stainless steel and mild steel in 1.0 M hydrochloric acid solution.
- All the four surfactant molecules adsorb on the surface of metal sheet and follows Freundlich adsorption isotherm.
- The surfactants molecule increases the value of activation energy required for electrochemical corrosion and consequently decrease the rate of dissolution of carbon steel, stainless steel and mild steel in HCl solution.
- Polarization data showed that these investigated surfactant molecules acted as mixed-type inhibitors.
- The corrosion inhibition efficiencies obtained from polarization and weight loss measurements are in good agreement with each other.
- Increase of temperature leads to the decrease in corrosion rate of carbon steel, stainless steel and mild steel in 1.0 M HCl solution.
- Addition of KMnO₄ to inhibitor formulation shows synergistic effect on corrosion inhibition efficiency of organic surfactant towards metal alloy sheet.
- All the four surfactant molecule adsorb on the surface of metal sheet through the sulphate molecules and form a continuous uniform film over the metal surface. Surfactant molecule adsorb through sulphate molecule to the Fe²⁺ ion of metal sheet present in the surface film through donar-accepter charge transfer complex resulting into stable, continuous passive film which protect the metal surface from corrosion.
- Corrosion inhibition efficiency increases with increase in concentration of the surfactant molecules from 20 to 150 ppm.
- Corrosion inhibition efficiency of the four investigated surfactant was found to be in the order; Decyl sulphate sodium salt (SSDS) < Dodecyl sulphate sodium salt (SSDDS) < Hexadecyl sulphate sodium salt (SSHDS) < Dodecyl benzene sulfonate sodium salt (SSDDBS).
- Corrosion inhibition efficiency of all the four investigated organic surfactant for different metallic alloys was found to be in the order Stainless Steel > Carbon steel > Mild steel.