A Literature Review of Corrosion on Welding

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Abstract- *This paper presents the extensive literature review conducted on corrosion studies carried out in various weldment used in Electronics, Medical, Automotive, Ship Building and Aerospace Industries. Corrosion are serious problems in those industries. Welding is commonly used for connecting steel components in steel bridge fabrication and construction. Welding processes change the microstructures, properties of surrounding steel and its surface texture. At different temperature of environmental conditions, the weldments is tends to corrosion which will reduce the life cycle of the weldments. Hence the detailed study on Corrosion types, Corrosion behaviour, Corrosion mechanism and metallurgical characteristics changes occurring with respect to mechanical properties at various environmental conditions in various steel grade pipes is very important in estimating the life cycle of the weldments. However, it will lead to premature failure of the components there are also many instances in which the weld exhibits corrosion resistance superior to that of the non-welded base metal. The main objective of this literature review is to gather salient information of the previously carried out research works with reference to corrosion studies, so that it will provide the strong base for carrying out experimental investigations. Through SEM images, types of corrosion, corrosion mechanism was discussed in detail in this paper.*

I. INTRODUCTION

Welding is defined by the American Welding Society (AWS) as a localized coalescence of metals or non-metals produced by either heating of the materials to a suitable temperature with or without the application of pressure, or by the application of pressure alone, with or without the use of fillermetal. There are various welding processes used in industry today, the main factors for their distinctions being the Source of the energy used for welding, and the means of protection or cleaning of the welded material.

Corrosion is a process, which converts a refined metal to a more chemically stable form, such as its oxide, hydroxide, or sulphide. It is the gradual destruction of materials by chemical or electrochemical reaction with their environment. Rusting, the formation of iron oxide is a well-known example of electrochemical corrosion. The corrosion is one of major problem in all the kinds of materials. Especially in industries they are only most suffering people. Because of corrosion the material properties and behaviours will get changed and also breakage of the material takes place.

II. CORROSION

Corrosion is a chemical reaction of the metal with the environment to form oxide, nitride, carbonate, sulphate or other stable compound. It is the tendency of the metal to return to its most stable thermodynamic state that with the most negative free energy of formation. Corrosion can be broadly classified into two main types i) where the metal dissolve chemically, ii) where the metal dissolution is electrically driven. Factors influencing the corrosion are as follows: weldment design, Fabrication technique, Welding practice, Welding sequence, oxide film and scale, weld slag and spatter, improper choice of filler metal etc.

Corrosion degrades the useful properties of materials and structures including strength, appearance and permeability to liquids and gases. When a material corrodes, it changes and becomes weaker. Corrosion has an adverse effect on structural steel products in terms of reduction of their cross section, damage of their surface, and thus shortens their service life. Corrosion of steel has become one big threat to the society and economy in the worldwide.

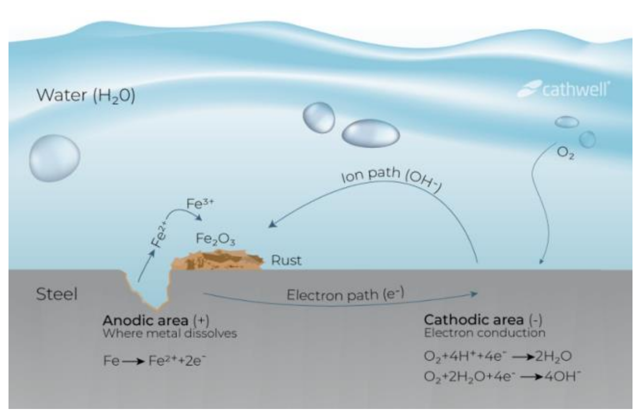

Fig 1 : Mechanism of Corrosion

TYPES OF CORROSION:

Galvanic corrosion:

Galvanic corrosion is an electrochemical process in which one metal corrodes preferentially when it is in electrical contact with another, in the presence of an electrolyte

Stress-corrosion cracking:

Stress corrosion cracking is the growth of crack formation in a corrosive environment. It can lead to unexpected and sudden failure of normally ductile metal alloys subjected to a tensile stress, especially at elevated temperature.

General corrosion:

General corrosion is a type of corrosion that takes place at almost the same rate on the surface of the entire metal that is exposed to the corrosion-causing conditions.

Localized corrosion:

Localized corrosion is defined as the type of corrosion in which there is an intense attack at localized sites on the metal surface.

Environmental cracking:

Environmental cracking is defined as the brittle fracture of a normally ductile material in which the corrosive effect of the environment is a causative factor.

Flow-accelerated corrosion:

Flow-accelerated corrosion, also known as flow-assisted corrosion, is a corrosion mechanism in which a normally protective oxide layer on a metal surface dissolves in a fast flowing water. The underlying metal corrodes to re-create the oxide, and thus the metal loss continues.

Intergranular corrosion:

Intergranular corrosion (IGC) is a selective attack in the vicinity of the grain boundaries of a stainless steel. It is as a result of chromium depletion, mainly due to the precipitation of chromium carbides in the grain boundaries.

De-Alloying, Fretting corrosion:

Dealloying is an unusual type of corrosion, occuring mainly in certain alloy metals such as copper alloys as well as in gray cast iron. When the dealloying takes place, the alloy metal loses its reactive element and retains the more stable corrosion-resistant element in a porous state.

High Temperature corrosion:

High-temperature corrosion is a mechanism of corrosion that takes place when gas turbines, diesel engines, furnaces or other machinery come in contact with hot gas containing certain contaminants.

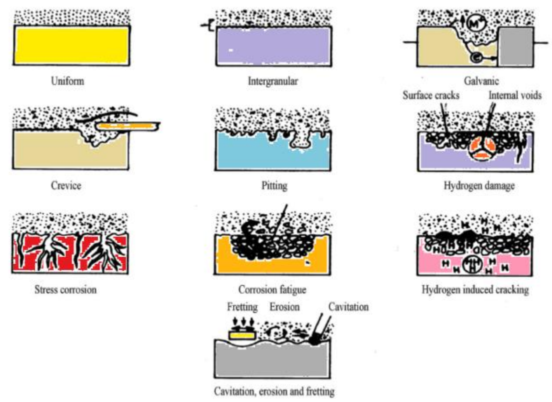

Fig 2 : Types of Corrosion

III. CHEMICAL THEORY OF CORROSION

According to this theory, corrosion on the surface of a metal is due to direct reaction of atmospheric gases like oxygen, halogens, oxides of sulphur, oxides of nitrogen, hydrogen sulphide and fumes of chemicals with metal.

The extent of corrosion of a particular metal depends on the chemical affinity of the metal towards reactive gas. Oxygen is mainly responsible for the corrosion of most metallic substances when compared to other gases and chemicals.

There are main types of chemical corrosion:

(i) Oxidation corrosion (Reaction with oxygen)
(ii) Corrosion by other gases
(iii) Liquid metal corrosion

FACTORS INFLUENCING CORROSION OF WELDMENTS:

It is sometimes difficult to determine why welds corrode; however, one or more of the following factors often are implicated:

- Weldment design
- Fabrication technique
- Welding practice
- Welding sequence
- Moisture contamination
- Organic or inorganic chemical species
- Oxide film and scale
- Weld slag and spatter
- Incomplete weld penetration or fusion
- Porosity
- Cracks (crevices)
- High residual stresses
- Improper choice of filler metal
- Final surface finish

Metallurgical Factors:

The cycle of heating and cooling that occurs during the welding process affects the microstructure and surface composition of welds and adjacent base metal. Consequently, the corrosion resistance of autogenous welds and welds made with matching filler metal may be inferior to that of properly annealed base metal because of:

- Micro segregation
- Precipitation of secondary phases
- Formation of unmixed zones
- Recrystallization and grain growth in the weld heat-affected zone (HAZ)
- Volatilization of alloying elements from the molten weld pool
- Contamination of the solidifying weld pool Corrosion resistance can usually be maintained in the welded condition by balancing alloy compositions to inhibit certain precipitation reactions, by shielding molten and hot metal surfaces from reactive gases in the weld environment, by removing chromium-enriched oxides and chromium-depleted base metal from thermally discolored (heat tinted) surfaces, and by choosing the proper welding parameters.

CORROSION TESTING AND MONITORING TECHNIQUES

1. Weight loss coupon
2. Oxalic test
3. Ferritic test
4. Electrical resistance (ER)
5. Electrochemical impedance spectroscopy (EIS)
6. Potentiodynamic anodic polarisation
7. Electrochemical noise
8. Hydrogen monitoring

WELDING PRACTICE TO MINIMIZE CORROSION

Several methods are available to minimize corrosion in weldments. The most important of these are discussed below.

Material and Welding Consumable Selection:

Careful selection of materials and welding consumables can reduce the macro- and micro-compositional differences across the weldment and thus reduce the galvanic effects.

Surface Preparation:

A properly selected cleaning process can reduce defects that are often sites for corrosive attack in aggressive environments. However, the cleaning process can also be a source of trouble. For example, any mechanically cleaned surface (i.e., cleaned by sand blasting or grinding) can leave impurities on the surface. The type of wire brush used can also be an important consideration .Stainless steel brushes are generally preferred because they do not form corrosion products capable of holding moisture.

Welding design:

It should promote deposits that have relatively flat beads with low profiles and have minimal slag entrapment. A poor design can generate crevices that trap stagnant solutions, leading to pitting and crevice corrosion. Irregular weld deposit shapes can promote turbulent flow in a tubular product and result in erosion corrosion.

Welding Practice:

Complete penetration is preferred to avoid underbead gaps. Slag should be removed after each pass with a power grinder or power chipping tool. If the welding method uses flux, the geometry of the joint must permit thorough flux removal, because many flux residues are hydrophilic and corrosive.

Weld Surface Finishing:

The weld deposit should be inspected visually immediately after welding. Maximum corrosion resistance usually demands a smooth uniformly oxidized surface that is free from foreign particles and irregularities. Deposits normally vary in roughness and in degree of weld spatter, a concern that can be minimized by grinding. For smooth weld deposits, wire brushing may be sufficient. For stainless steel, however, brushing disturbs the existing passive film and may aggravate corrosive attack.

Surface Coating:

When a variation in composition across the weld metal can cause localized attack, it may be desirable to use protective coatings. The coating needs to cover both the weldment and the parent metal and often requires special surface preparation.

Postweld Heat Treatment:

A posted heat treatment can be an effective way to reduce corrosion susceptibility. This improved corrosion resistance is accomplished through a reduction in residual stress gradients that influence SCC growth. Post weld heat treatment can assist in the transport of hydrogen from the weldment and reduce susceptibility to hydrogen cracking. The treatment can also reduce compositional gradients (i.e., micro segregation) and corresponding microgalvanic cells.

Preheat and Interpass Temperature:

The selection and use of proper preheat treatment and interpass temperature may prevent hydrogen cracking in carbon and low-alloy steel.

Passivation Treatment:

A passivation treatment may increase the corrosion resistance of stainless steel welded components.

Avoidance of Forming Crevices:

Slag that is still adhering to the weld deposit and defects such as lack of penetration and microfissures can result in crevices that can promote a localized concentration cell, resulting in crevice corrosion. Proper selection of welding consumables, proper welding practice, and thorough slag removal can alleviate this form of corrosion damage.

Removing Sources of Hydrogen:

Through proper selection of welding consumables (that is, low-hydrogen shielded metal arc welding electrodes), proper drying of flux, and welding clean surfaces, the hydrogen pickup can be drastically reduced.

ADVANTAGES OF CORROSION:

Corrosion of metals is an advantage as it prevents the metal underneath from further damage. For example: On exposure to air the surface of metal like aluminium and Zinc forms layers of their oxides which are very sticky and impervious in nature and hence act as protective layer.

DISADVANTAGES OF CORROSION:

- Lose of metal from the surface.
- Change in the physical appearance of a metal object.
- Change in chemical properties of metal.
- Change in mechanical properties of metal.
- Lose of the efficiency of metallic machines.
- A decrease in the life span of metallic objects.

IV. LITERATURE REVIEW

Kang et al. [1]This study examined the effects of secondary phase and carbide formation, with varying Si content and aging time, on the intergranular corrosion of duplex stainless steel weldments. With longer aging time, accordingly greater formation of secondary phases and carbides was observed. A DL-EPR test was carried out to assess the resistance to intergranular corrosion, and from the results greater degrees of sensitization were associated with larger amounts of secondary phases and carbides.

Venkata et al. [2]There is an attempt to obtain different welding of Inconel 718 and ASS316 stainless steel through the pulsed current gas tungsten arc welding process. The mechanical and metallic properties of the dissimilar weld metals were studied. A more descriptive analysis is in molten salt to estimate the behavior of hot corrosion by exposing coupons.

Dawan et al. [3]This work was carried out to investigate the effect of welding variables (includes wire feeding techniques, wire feeding rates and heat inputs) on the cooling rate, _t8=5 (cooling time from 800 to 500_C), in the weld and heat affected zone (HAZ) areas of multi-pass weldments in a super duplex stainless steel. Furthermore, changes in thermal condition caused by welding variables can affect the microstructure and consequently the material properties. Therefore, supporting tests, including pitting corrosion resistance and microstructure analysis were investigated.

Sudakar et al.[4] presents the extensive literature review conducted on erosion and corrosion studies carried out in various grades of steel weldments used in applications such as chemical and processing industries. The various grades of steel pipes are employed in the above stated application for the transportation of hot gases and oils.

Navaneethakrishnan et al. [5] analyzed the corrosion behaviors of Gas tungsten arc welded AA5083. We were took 5 different specimens, all are differ by process parameters like current and voltage when Gas tungsten arc welding process.

Oyewole et al. [6]examined the crack growth behaviours in HAZ and weld materials fabricated from S355J2+N steel were investigated in air and in a laboratory simulated seawater environment similar to what is experienced by offshore installations in service.

Qusay et al. [7]revealed that A572 steel welds have over 44% higher in corrosion rate, as compared to the base metal, while 23% higher corrosion rate for weathering steel. Therefore, use of combined electrochemical tests can give a relatively more comprehensive information to understand the corrosion behavior in bridge steel welds. Corrosion current and corrosion rate predicted by the electrochemical tests helps bridge engineers to understand the corrosion behavior of steel bridge welds and corrosion resistance obtained by varying coating systems in welds.

Ambade et al. [8]focuses light on analysis of sensitization and corrosion by the different authors for controlling sensitization and corrosion in ferritic stainless steel by using different welding processes. Besides the problem of low ductility and poor toughness of ferritic stainless steel, welds due to the microstructures characteristics of the weld section as a result of weld heat input rate and heat transfer rate factor , susceptibility to intergranular corrosion caused by the depletion of the chromium content of the weld matrix particularly in the HAZ is a major concern limiting the full deployment of the material in certain engineering application regardless its attractive economics combined with moderate strength and excellent corrosion characteristics of AISI 409 M.

Fourie et al. [9] research has shown that higher heat inputs and slower cooling rates can actually be beneficial to the weldment properties of duplex stainless steels. It is the aim of this paper to highlight the differences in the physical metallurgy of austenitic and duplex stainless steels, and to review recent work conducted on the weldment properties of duplex stainless steels.

Rana et al. [10] involves studying the mechanical properties and corrosion behavior of “low carbon steel” (0.077wt% C) before and after welding using Arc, MIG and TIG welding. The mechanical properties include testing of microhardness, tensile strength, the results indicate that microhardness of TIG, MIG welding is more than arc welding, while tensile strength in arc welding more than TIG and MIG.

V. CONCLUSION

From the various literature review of corrosion on welding we have made this literature review to help in understanding the corrosion in detail.

- It is concluded that the corrosion will leads to decrease in the strength and makes the welded material weaker.
- While welding the materials, Corrosion prevention technique has to be taken in account to prevent corrosion.
- Use non-corrosive metals to prevent corrosion.
- Use a coating or barrier product such as grease, oil, paint or carbon fibre coating.

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