SELECTION OF ALLOYS FOR FABRICATION OF EQUIPMENTS USED IN HYDROGEN PRODUCTION BASED ON THEIR TENSILE STRENGTH –A REVIEW.

Silky Das[1] , Preethi Priya [2]
Project Engineer, Wipro Technology, Kolkata
Project Trainee, Inovonz Engineering Private Limited, Chennai
Email-id: silk0708@gmail.com

Abstract:—

A well recognized fact is that Hydrogen represents an abundant, clean and mobile energy carrier. It is one of the lightest gas hence can be widely used for the production of biofuels and preparing mineral acids. It is the greatest safety asset in an outdoor environment. In lieu to this it is used for powering automobiles and generating electricity. Thus it is a widely used fuel which should be produced on a large scale. Research is being carried out in the production of Hydrogen from large amount of –"food waste". Other useful gases such as Methane(CH_4),Propane(C_3H_6), Ammonia(NH_3) and many more can be produced from – food waste. But our focus would be to produce Hydrogen as it's the most requisite fuel with advantageous features. A major issue here is the containment of Hydrogen during its storage and transportation as its presence can lead to severe degradation in the mechanical properties, especially in stainless steel alloys. This phenomenon is known as Hydrogen embrittlement and will lead to unexpected catastrophic features such as decrease in - ductility, tensile strength and elongation percentage. This article would focus on the comparision of the tensile strength of different alloys of steel before and after to Hydrogen embrittlement . As Hydrogen embrittlement cannot be prevented, this comparative study would envisage methods to reduce embritllement and select materials that can withstand Hydrogen embrittlement .

Key words: Embrittlement, Steel alloys, Ductility, Tensile strength, Nanocoating, Galvanizing

.

I. INTRODUCTION

All types of stainless steels, aluminum, copper, nickel, and their alloys; titanium and zirconium alloys; and refractory materials such as tungsten, niobium, vanadium, and tantalum are subjected to Hydrogen embrittlement. Hence a proper material selection for fabricating equipments while used in Hydrogen Production gains primary importance. Hydrogen embrittlement is a process in which atomic hydrogen generated on the surface of the steel due to cathodic reactions, diffuses within the microstructure causing a deleterious effect on its mechanical properties. Atomic hydrogen could be generated during electroplating of steel or when the steel components are exposed to corrosive environments such as marine atmosphere. This being the case for steel subjected to electroplating, utmost care has to be given when fabricating equipments for use in Hydrogen Production. Unfortunately, the current efficiency of this process is less than 100%, hence inevitable hydrogen evolution on the steel surface takes place during this process. On the other hand, a stress corrosion cracking process (*SCC)*, usually involves the anodic polarization of the steel surface, leading to partial dissolution of the steel component in the electrolyte together with the simultaneous effect of mechanical stresses. SCC is associated with hydrogen embrittlement. Hydrogen is also absorbed when a sacrificial coating undergoes corrosion in service and this process is known as re-embrittlement.

Sources of hydrogen causing embrittlement have been encountered in the fabrication of steel, in processing parts, in welding, in storage or containment of hydrogen gas, and related to hydrogen as a contaminant in the environment that is often a by-product of general corrosion. Hydrogen ,either as an external gas resulting from electrochemical reactions in an aqueous environment,or dissolved in the metal during processing, is known to lower ductility ,fracture strength and fracture toughness ,and to accelerate cracking .Hydrogen damage may be in the form of Loss of ductility , tensile strength , elongation% , area occupied, Internal damage due to defect formation, Macroscopic damage, such as internal faking, blistering.

II. COMPARITIVE STUDY:-

Table 1 A Comparision on Tensile Value of Different Grades of Stainless Steel:-

STAINLESS STEEL TYPE	TENSILE STRENGTH BEFORE BRITTLEMENT (MPa)	TENSILE STRENGTH AFTER EMBRITTLEMENT(MPa)
1137	610	515
444	690	415
316	650	515
316L	620	485
316H	650	515
304	620	515
304L	650	485
304N	550	550
2205	590	450
2304	540	400
2507	680	500
S690Q	1250	935
S690Q (SAW)	920	631
S690Q (SMAW)	934	687

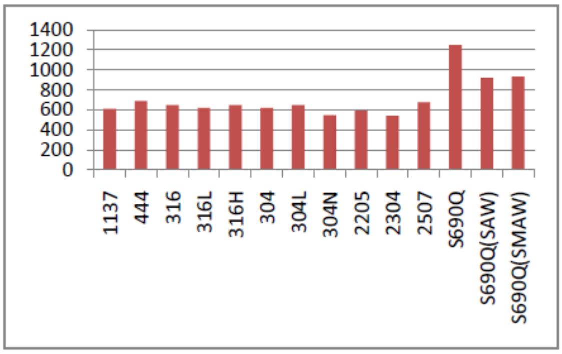

Fig 1 Representation For Tensile Strength Before Embrittlement.

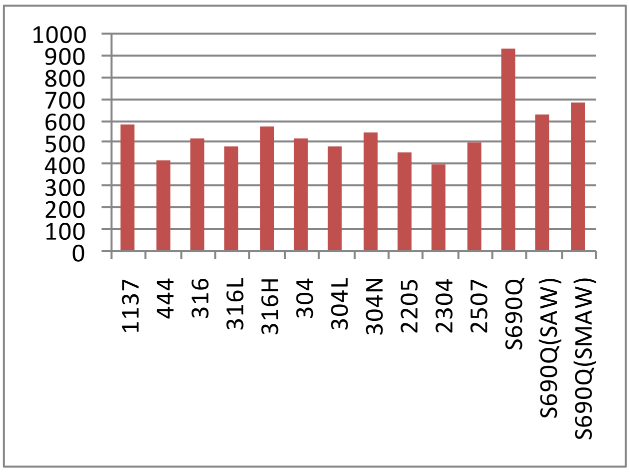

Fig 2 Representation For Tensile Strength After Embrittlement

Properties of The Mentioned

Stainless Steel Types:-

1137-Has high Carbon, Sulfur content, should be preheated to attain strength. Used in automotive industries, making studs, axles, pins , bolts.444-low carbon, low nitrogen ,feritic stainless steel. Superior chloride stress corrosion resistance. Its uses include food making, brewery, wine making equipments, hot water tanks and heat exchanger tubing.316- standard Mo grade austenitic stainless steel. Excellent forming and welding characteristics for applications in the industrial, architectural and transportation field. In food processing and petrochemical equipments.316L – low carbon version of 316 and used for heavy gauge components.316H-high carbon version of 316.304 – standard , versatile and widely used stainless steel with excellent forming and welding characteristics. Used in manufacture of sink saucepans , hollow wares , etc.

304 L-is the low carbon form of 304 and used for making gauge components.

304H-is the high carbon form of 304 used in elevated temperatures.

2205 –most widely used (ferritic and austenitic) steel grade with high Cr and Mo content. Thus it has excellent corrosion resistance.

2304-is Mo free duplex stainless steel with resistance properties similar to 316L.Used in pulp and paper industry , food processing , mining.

2507-super duplex stainless steel designed for demanding applications which require strength and corrosion resistance such as chemical process, sea water and petrochemical equipments. Has high thermal conductivity and low coefficient of thermal expansion.

S690Q is a high yield strength steel in quenched and tempered condition. SAW and SMAW are the welded components of S690Q. Submerged arc welded joint (SAW) has higher resistance to .hydrogen degradation than base metal. However, shielded metal arc welded (SMAW) joint is more susceptible than base metal.

II. PREVENTION TECHNIQUE:-

Thus here we will be discussing the various methods adopted to prevent Hydrogen embritlement. They are Galvanizing, Nanocoating.

A. GALVANIZATION METHOD OF CORROSION PREVENTION:-

Galvanization is a method of coating iron, steel and aluminium with a thin zinc layer by passing the material through a zinc bath at 460 (degree Celsius). Here Zn and the target metal reacts metallurgically to form intermetallic layers. Thus Zn reacts with atm.O2 to give ZnO2 which again reacts with CO2 to give a dull – grey ZnCO3 which prevents Hydrogen Embrittlement. Lead is often added to the molten zinc bath to improve the fluidity of the bath. Galvanization can accommodate various different sizes and shapes of metals.

This includes electro galvanizing which deposits the layer of zinc from an aqueous electrolyte by electroplating forming a thinner and much stronger bond. Zn forms an impervious barrier between target metal and atmosphere. Zn is partly anodic to all these metals. Since Zn is a noble metal hence it will sacrifice itself and will be consumed before all the metals .Thus the obtained galvanized metal is sight inspected and measurement of the coating layer is done.

This method has a lower initial and maintenance cost than paint wheareas paint requires proper maintenance , partial repainting and full repainting several times.Duplex coatings are made that is Zn is coated with paint which provides twice the sum of corrosion effects of that provided by one alone. It has excellent safety marking system , color coding and extends the life of Zn coating. Galvanized coatings can be easily and affectively painted not only for aesthetics but also to extend the structures service life. Thus due to galvanizing the weight of the material increases by an average of 3.50%.

B. Nanocoating is a method to Prevent Corrosion and Erosion in Steel and Aluminum Pipes and Bars .

The possibilities offered by our nano surface treatments are numerous and exciting. And new developments are already being tested .Nanotechnology is revolutionizing the coatings industry. New materials and manufacturing methods make it possible to combine the characteristics of organic polymers with those of inorganic materials .The coating layers consisted of nanoparticles with different size distributions. Thus the formation of a a homogeneous, poreless nanostructure inside the coating layer was achieved. The advantages for the user are numerous. New decorative and functional surface characteristics can be created and custom-made for specific purpose.

Today's protective products are corrosion indicators, self repairing coatings like smart paints, erosion resistant coatings, nanosized decorative coatings as inks and paints. Nano materials can be used for abrasion resistance affecting color , gloss ,also ideal for cutting tools and small parts. Materials deposited thermally are easy to be nanolayered and removed.

CONCLUSION

This method of nanocoating will be least economic thereby increasing the cost effectiveness. Hence to make it cost effective a new and more advantageous method of nano coating is adopted i.e (nanocoating at atmospheric pressure).

A.NANOCOATING AT ATMOSPHERIC PRESSURE:-

Earlier Plasma polymerization was a process that could be carried out only in vacuum but now a new technology developed which allowed a nanometer thick coating of materials at atmospheric pressure. In this, a compound is mixed with atmospheric pressure plasma which produces a layer. Due to the high energy excitation in the plasma this compound fragments and gets deposited as a layer on the surface to be treated. This process has already entered into the industrial application. It has an anticorrosive effect on alloys. It protects the alloy for several days without the visual appearance of metal being affected. Here the corrosion protection is applied and a layer formation occurs without coming in contact with the metal surface. This selective in line , highly efficient anti corrosion coating of the bonded joints on metallic surface which is unaffected to the critical areas offers a high resistance to environmental conditions such as:-(corrosion , thermal resistance , splash water resistance and also a peel resistance substrate for adhesives and also resistance to moisture penetration) increases .

B.COST EFFECTIVENESS ON SURFACE PRE TREATMENT AND COATING:-

It is more efficient than surface pre treatment and does not require a costly low pressure chamber and occurs in normal atmospheric conditions. Here large number of equipments can be treated and the operation can be carried out automatically. Flexible method as its film thickness and speed depends upon its anticorrosive effect , it is eco friendly and no residues are left behind. Cleaning is implemented and is also compatible with use of robots.

REFERENCES

[1] Handbook of corrosion engineering-Mars .G. Fontana.

[2] Article on technical compatibility of materials by Sandia National Laboratory.

[3] Article on stainless steels by – Bela Lefler.

[4] Article on stainless steel by S. N. Robinson.

[5] Journal on mater ial and manufacturing technology - J.Cwiek.

[6] German article on Plasma Technology.

[7] Handbook on nanotechnology – Jurgen Schulte.

[8] Jurgen Schulte, Nanotechnology: Global Strategies, Industry Trends and Applications, ISBN: 978-0-470-85400-6

[9] J. D. FARREN, J. N. DUPONT, AND F. F. NOECKER II, Fabrication of a Carbon Steel-to-Stainless Steel Transition Joint Using Direct Laser Deposition — A Feasibility Study, SUPPLEMENT TO THE WELDING JOURNAL, MARCH 2007, 55-6

[10] Corrosion Engineering, Fontana, M. G. and Greene, N. D., McGraw-Hill (1967)

[11] Bela Leffler, Stainless steels and their properties. 1998

[12] J Ćwiek, A Zieliński, Methods for the characterizing hydrogen degradation of materials, Advances in Materials Science 3 (1 (3)), 60-66

[13] Jurgen Schulte, Nanotechnology: Global Strategies, Industry Trends and Applications, ISBN: 978-0-470-85400-6

[14] J. D. FARREN, J. N. DUPONT, AND F. F. NOECKER II, Fabrication of a Carbon Steel-to-Stainless Steel Transition Joint Using Direct Laser Deposition — A Feasibility Study, SUPPLEMENT TO THE WELDING JOURNAL, MARCH 2007, 55-61

.