A COMPARISION ON TENSILE STRENGTH VALUES OF DIFFERENT GRADES OF STAINLESS STEEL ALLOYS WHEN SUBJECTED TO HYDROGEN ENVIRONMENT- A REVIEW

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Abstract:—

In today's date large scale production of Hydrogen gas is of utmost importance as it's the water forming lone gaseous element. Because of its high flammable nature it is used for powering automobiles and generating electricity. Hydrogen became the greatest safety asset in an outdoor environment. It is one of the lightest gas hence can be widely used for the production of biofuels. In addition to this it is well known that Hydrogen represents an abundant, clean and mobile energy carrier. With increasing energy demand waste generation is also increasing. Waste minimization, utilization and appropriation are gaining importance. Enormous quantity of organic waste is being generated across the globe. Composting, biomethanization etc are the popular proven technologies for handling the bio-degradable organic waste. Research is in full achievement to establish technologies for large scale production of Hydrogen from municipal solid waste comprising of the food and the sewage waste. Newer methodologies for Hydrogen production from waste are being reported consistently. During the course of Hydrogen production materials of the equipments used are enforced to variation in mechanical properties that includes ductility, tensile strength, yield stress, reduction in material surface area due to Hydrogen embrittlement. This article would focus on addressing such a serious material predicament, Hydrogen embrittlement by comparing the tensile strength of different grades of Austenitic steel and reporting a suitable material for fabricating equipments used in Hydrogen Production from food waste.

Keywords: Hydrogen embrittlement, austenitic steel, ductility, tensile strength, yield stress, material surface area

I. INTRODUCTION

Hydrogen embrittlement is a process during which a material is exposed to Hydrogen becomes brittle and fracture. Usually such change in material property happens due to unintentional contact of Hydrogen with susceptible materials during forming or finishing operations. A material susceptible to Hydrogen embrittlement will allow the diffusion of atomic Hydrogen, into the metal due to temperature or concentration gradient and enter into the minuscule voids of the metal matrix. When two such atoms combine in the voids, Hydrogen molecules that create pressure inside the cavity are formed. The trapped Hydrogen molecule would end up increasing pressure inside the voids of the material and would tend to come out by creating cracks on the material surface. This phenomenon is popularly referred to as Hydrogen embrittlement. Materials like austenitic stainless steel alloys have been reported as best materials in Hydrogen environment. Earlier reports however have shown variations in tensile strength values for Austenitic steel in Hydrogen environment. This article would focus on comparing the changes in the tensile strength values of different grades of stainless steel and envisage the application of one of the types for fabrication of equipments used in the production of Hydrogen from food waste.

II. MATERIAL SELECTION

A. Criteria for selecting material to be used in Hydrogen Environment

Material suitability for hydrogen service should be evaluated carefully before it is used. A material should not be used unless data are available to prove that it is suitable for the planned service conditions. As the compatibility of a metal with its environment is a prime requirement for its reliable performance. In case of any doubt the material can be subjected to hydrogen embrittlement susceptibility testing. Most of the metallic materials present a certain degree of sensitivity to hydrogen embrittlement. However, there are some that can be used without any specific precautions as for example brass and most of the copper alloys or aluminium and its alloys. On the other hand, nickel and high nickel alloys or titanium and its alloys are known to be sensitive to hydrogen embrittlement. For steels the sensitivity may depend on several factors as the exact chemical composition, heat or mechanical treatment, microstructure, impurities and strength. As for example, the stainless steel containing (1 to 2.25)% Cr and Mo are recommended for use in Hydrogen atmosphere at high temperature because these Carbide forming elements increase the resistance of steel to Hydrogen attack. Conversely the carbon content should be kept low increased Carbon content decreases the resistance to Hydrogen attack. Fortunately many materials can be safely used under controlled conditions. Stainless steels are specified for hydrogen service when enhanced compatibility, safety, and reliability are required. On the contrary austenitic steel is immune to Hydrogen attack. Prior to consideration of the issues surrounding containment applications, we will review the compatibility of Austenitic Stainless Steels during Hydrogen damage and will outline a graph to conclude the stainless type best suited for Hydrogen environment. In this selection process cost is also an important consideration.

B. Properties of the Austenitic Stainless Steel

1137, 444, 316, 316L, 316H, 304, 304L, 304H, 2205, 2304, 2507, S690Q,S690Q(SAW), S690Q(SMAW) are the different grades of Stainless Steel considered for study. The characteristics of these steel grades are given .***1137*** has high Carbon and Sulfur content. Requires preheating to attain the suitable strength. Popularly used in automotive industries, in making studs, axles, pins , bolts.***444*** **i**s a low carbon, low nitrogen stainless steel. It possesses Superior chloride stress corrosion resistance. It is used in food making, brewery, wine making equipments, hot water tanks and heat exchanger tubing.***316*** is a standard Mo grade austenitic stainless steel. This steel has excellent forming and welding characteristics for applications in the industrial, architectural and transportation field. It is also used in fabricating food processing and petrochemical equipments.***316L*** is a low carbon version of 316 and is used for heavy gauge components.***316H*** is a high carbon version of 316.***304*** **i**s a standard, versatile and widely used stainless steel with excellent forming and welding characteristics. Widely used in manufacture of sink , saucepans , hollow wares , etc. ***304 L is*** the low carbon form of 304 and is used for making gauge components.***304H*** is the high carbon form of 304 and is used for elevated temperature requirements.***2205*** is most widely used (ferritic and austenitic) steel grade with high Cr and Mo content. Hence it has excellent corrosion resistance.***2304*** is Molybdenum free duplex stainless steel with resistance properties similar to 316L and is used in pulp and paper industry, food processing and mining.***2507*** is a super duplex stainless steel designed for demanding applications which require strength and corrosion resistance such as chemical process, sea water and petrochemical equipments. Also has high thermal conductivity and low coefficient of thermal expansion.***S690Q*** is 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. Shielded metal arc welded ***(SMAW)*** joint is more susceptible than base metal.

III. COMPARATIVE STUDY

The phenomenon of Hydrogen embrittlement not just occurs during production or storage of Hydrogen but also takes place due to welding and forging operations during which initially Hydrogen gas enters into the metallic structure thus causing this defect. Now, when these initially embrittled equipments are used for storage or transportation of Hydrogen, then Hydrogen embrittlement occurs to a much larger extent which decolorizes the metals and brings abnormal changes in its catastrophic features such as tensile strength. A comparison as shown in figure1 is made on different grades of Austenitic stainless steel for its tensile strength before and after embrittlement in order to have an understanding of the material property variation due to embrittlement.

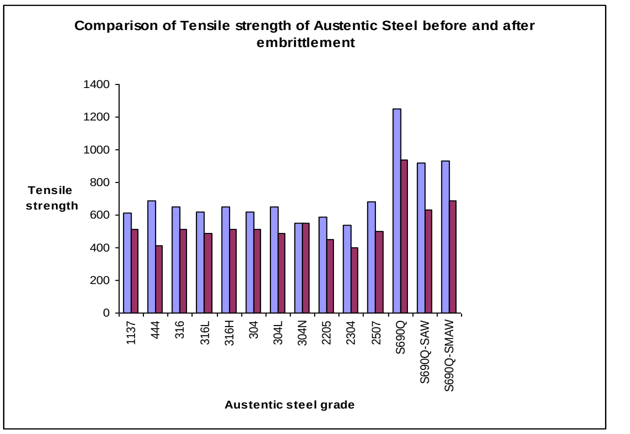

Fig.1: Comparison of tensile strength before and after embrittlement

Fig.1 describes the decrease in tensile strength in MPa for various grades of Austentic steel due to Hydrogen embrittlement. It is evident from the figure that though the steel grade -**S690Q** has a high tensile value initially it undergoes a considerable change after getting embrittled. On the contrary, **304L** initially has lower value of Tensile strength but there is no considerable change in its tensile value after embrittlement.

IV. CONCLUSION

304L is identified as the most suitable material in an Hydrogen environment among those discussed above as it will not contribute to an abnormal variation in the property of material to be handled during fabrication. However the other mentioned grades can also be used, though there is a considerable reduction in their tensile strength values by incorporating various proven technologies for preventing the occurrence of Hydrogen embrittlement like galvanizing, nanocoating at atmospheric conditions, Hydrogen embrittlement relief (baking) etc.,

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