International Journal of Research

International Journal of Research (IJR)

e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 05, May 2015

Available at http://internationaljournalofresearch.org

Mechanical Property Evolution of Heat Treated Stainless Steel Grade 304

[1]Kamal Kumar Pradhan; [2]Brijesh Patel& [3]Kalpit P Kaurase

[1]Research Scholar (PG), Department of Mechanical Engineering, MATS University Raipur, CG
Email:kamalpradhan09@gmail.com
[2]Assistant Professor, Department of Aeronautical Engineering, MATS University Raipur, CG
[3]Assistant Professor, Department of Aeronautical Engineering, MATS University Raipur, CG

Abstract—
AUSTENITIC stainless steels represent a large family of alloys and end uses. These steels enjoy a wide range of applications because of good corrosion resistance, good high and low temperature strength and ductility, and excellent weld ability. The high work-hardening rate and ductility of austenitic stainless steels in the annealed state allows the application of severe forming operations. Engineering materials, mostly steels are heat treated under controlled sequence of heating and cooling to alter their physical and mechanical properties to meet desired engineering applications. In this study, the effect of heat treatment (annealing, normalizing, hardening, and tempering) on the microstructure and some selected mechanical properties were studied. Erosion of metal parts is the serious problem in many engineering systems such as turbines, boilers, etc. SS304 and SS310 steel is used to make nozzle of the boiler for feeding coal with certain advantages i.e. price, strength & formability. But the main limitation of stainless steel is erosion due to which the nozzle needs to be replaced frequently. Hard facing is commonly applied method to improve the surface properties of components.

Keywords— SS304; Stress; Strain; Heat treatment; Cold work; annealing; Corrosion

I. INTRODUCTION

Heat treatment is process of heating and cooling of material. It is possible the desirable mechanical properties to steel or alloys for normal operation by heat treatment. In heat treatment temperature variation with time is basic parameter to alter mechanical property of the component.

Stainless steel is widely used in oil production, chemical, and mining industries to make hydro-turbines, pumps and pipelines, because of its combination of good corrosion resistance and mechanical properties. The corrosion resistance of stainless steel is attributed to the formation of passive film, which protects the material from continuous corrosion attack. However, when subjected to the attack combining corrosion and erosion, the passive film could be damaged by solid particle impingement, resulting in exposure of bare metal surface to the corrosive medium and thus increasing the corrosion-erosion rate. Here we study the mechanical property evolution of SS304, Mechanical Property changes and microstructural evolution of deformed and subsequently annealed and Cold work stainless steel are investigated, Meta stable SUS304 austenitic stainless steel (ASS) possesses excellent corrosion resistance, toughness, weld ability but relatively low-yield strength (≈200 MPa). Substantial strengthening can be obtained in the steels by plastic deformation. During plastic deformation, depending on cold working variables, deformation-induced martensite can be formed by transformation. The evolution of martensite during plastic deformation increases the work hardening rate during deformation which results in an increase in strength of stainless steels. It is generally well known that austenitic stainless steels cannot be hardened by heat treatments. On the other hand, cold or warm working (drawing, rolling, forging, etc) can make such stainless steels harden. For austenitic stainless steels, the greater the amount of plastic strain induced, the higher is the stress required to deform the material further. This phenomenon is known as strain (or work) hardening, and is attributed to the increasing difficulty of dislocations movement as their density increases with deformation. A suitable annealing treatment can be used to desensitize austenitic stainless steels and avoid localized corrosion attack. Moreover, it has been reported that plastic deformation strongly affects the degree of sensitization of austenitic stainless steels. Austenitic stainless steels have a complex mechanical behavior at room temperature. Generally, behavior differences are associated to a higher or lower stability related to marten site transformation.

II. Background

Stainless steel 304 are categorized into three grades 304, Grade304H and 304L respectively. Type 304 is the most versatile and widely used stainless steel. It is still sometimes referred to by its old name 18/8 which is derived from the nominal composition of type 304 being 18% chromium and 8% nickel.

304 Stainless Steel

Stainless steel 304 is an austenitic grade that can be severely deep drawn. This property has resulted in 304 being the dominant grade used in applications like sinks and saucepans.

304L Stainless Steel

Type 304L is the low carbon version of Stainless steel 304. It is used in heavy gauge components for improved weld ability.

304H Stainless Steel

Type 304H is the high carbon content variant, is also available for use at high temperatures. It can applicable for high temperature application.

The chemical composition SS304 are shown in TABLE I

TABLE II

Chemical Composition of Stainless Steel 304

%	304	304L	304H
C	0-0.07	0-0.03	0.04-1
Mn	0-2.0	0-2.0	0-2.0
Si	0-1	0-1	0-1
P	0-0.05	0-0.05	0-0.05
S	0-0.02	0-0.02	0-0.02
Cr	17.5-19.5	17.5-19.5	17.5-19.5
Ni	8-10.5	8-10.5	8-10.5
Fe	Balance	Balance	Balance

III. Heat treatment and Property evolution

There have analysis to many processes to increase the property of stainless steel grade 304, we have conclude the two main process to optimize the efficiency such as annealing and Cold working, Manganese steels are not harden able by heat treatment and are nonmagnetic in the annealed condition. They may become slightly magnetic when cold worked or welded.

Austenitic stainless steels (which contain 18% Cr–8% Ni) are engineering materials widely used in many branches of industry, especially in the food and beverage manufacturing and processing sector, due to their attractive combination of good mechanical properties, formability, and corrosion resistance. Their corrosion resistance is afforded by a thin Cr_2O_3 surface film (typically 1–3 nm thick), known as passive film, which has self-healing capability in a wide variety of environments.

A. COLD WORKING

High hardness and strength are achieved through cold working. In the annealed condition, type 304 and 304L are very ductile and can be cold worked easily by roll forming, deep drawing, bending and other common fabricating methods. Since the material work hardens rapidly, in- process annealing may be necessary to restore ductility and to lower hardness.

B. ANNEALING

Type 304 is non-hardenable by heat treatment. Annealing: Heat to 1900 - 2050°F (1038 - 1121°C), then cool rapidly. Thin strip sections may be air cooled, but heavy sections should be water quenched to minimize exposure in the carbide precipitation region. Stress Relief Annealing: Cold worked parts should be stress relieved at 750°F (399°C) for 1/2 to 2 hours.

C. *FORMABILITY*

Type 304 and 304L can be readily formed and drawn. The higher nickel versions of Type 304 are well suited to severe forming application involving multi-draw operations and forming of complex shapes. This is largely due to its combination of lower strength and lower work hardening rate. As with all austenitic stainless steels, annealing or stress-relieving can be performed following fabrication.

D. OXIDATION RESISTANCE

The maximum temperature to which type 304 can be exposed continuously without appreciable scaling is about 1650^0F (899^0C) for intermittent cyclic exposure, the maximum exposure temperature is about 1500^0F (816 ^{0}C).

E. CORROSION ANALYSIS:

Corrosion is defined as the destruction or deterioration of material because of reaction with its environment. Some insist that the definition should be restricted to metals, but often the corrosion engineers must consider both metals and nonmetals for solution of a given problem. The corrosion resistance of the martensitic stainless steels is lower than that of the austenitic steels. These alloys are normally used in atmospheric corrosive applications

F. HOT CORROSION

High-temperature corrosion is chemical deterioration of a material (typically a metal) as a result of heating. This non-galvanic form of corrosion can occur when a metal is subjected to a hot atmosphere containing oxygen, sulphur or other compounds capable of oxidizing (or assisting the oxidation of) the material concerned. Oxidation is a type of corrosion involving the reaction between a metal and air or oxygen at high temperature in the absence of water or an aqueous phase. It is also called dry-corrosion. The rate of oxidation of a metal at high temperature depends on the nature of the oxide layer that forms on the surface of metal. Metals and alloys may experience accelerated oxidation when their surfaces are coated by a thin film of fused salt in an oxidizing gas. This mode of attack is called hot corrosion.

G. CREEP TESTING:

Creep testing was performed at 650 °C (1200 °F) for 150 h with a stress of 69 MPa (10 ksi). The same three heat treatment conditions tested at room temperature were tested for creep strength. The high creep rates are attributed to the very fine grain size that developed during recrystallization. Type 304H stainless steel has significantly lower creep rates than the Type 304 samples. The lower creep rates are attributed to the larger grain size and the higher carbon content in Type 304H.

H. HARDNESS TEST:

Hardness is a measure of how resistant solid matter is to various kinds of permanent shape change when a force is applied. Macroscopic hardness is generally characterized by strong intermolecular bonds, but the behaviour of solid materials under force is complex; therefore, there are different measurements of hardness: scratch hardness, indentation hardness, and rebound hardness. Hardness is dependent on ductility, elastic, stiffness, plasticity, strain, strength, toughness, viscoelasticity and viscosity.

IV. High Temperature Design Factor

There are four design factor that engineer consider when choosing materials for service at elevated temperature. These design factors are:-

1. Service life
2. Allowable Deformation
3. Environment
4. Cost

Service life

The design service life requirement of any given component or piece of equipment can vary from seconds in certain aerospace application, such as rocket engine, to 25 or more years for power plant condenser tubes. Between these extremes are other more moderate service life requirement such as those in chemical, petrochemical, or petroleum processing, where process design changes are more likely to occur at 10 to 15 year intervals life expectancy may also vary form company to company within any given industry, for example in thermal cracking steels in the petroleum industry some plant have standardized on type 304 stainless steel whereas, other plant with similar equipment and operating condition use chromium-molybdenum steels with lower alloy contents, naturally the latter materials will not last as long as the former, but that is part of the design plan for those plants; i.e., low cost material but more frequent replacement versus more expensive material having longer service life.

For a given type of steel specify thickness the expected service life depend on the maximum temperature to with it is exposed plus the maximum stresses to which it is subjected, also whether service is at a constant temperature or at intermittently high temperature.

Allowable deformation

Another factor to consider in designing for high temperature service is the amount of deformation that can be permitted during the total service life these factor determine which up to high temperature strain properties should be given priority creep or creep rupture(sometimes called stress rupture) if the component is small and/or the tolerance very close, such as in turbine blades creep is regarded as the over reading but if the component is large and capable of accommodating greater deformation, such as shell and tube heat exchanger, the creep rupture the strength is the usual basis for selection. Where considerable deformation is permitted it is well to know the anticipated time to rupture, so part can be scheduled for replacement before failure occurs. It is also useful to know whether or not service elevated temperature is cyclic or continuous cyclic operation may lead to failure by fatigue or lose of metal due to flaking the oxide scale prior to the expected Creep-rupture time.

Environment

The effect of exposure of a material to media can be very complex subject. Elevated temperatures tend to increase corrosive action, heat transfer may affect corrosivity, thermal cycling can increase metal wastage through spalling of protective scale on the metal surface, and metal temperature probably will not be the as the environment to which it is exposed . Generally if oxidation or other forms of scaling are expected to be severe, a greater cross- sectional area beyond that indicated by mechanical-property requirement- is usually specified. Problems like this cannot be solved by laboratory analysis. It requires observation of test specimens in actual operating environment in pilot plants or full- size units.

Cost

The consideration of cost in selecting materials for high temperature service must reflect not only the initial cost of the equipment and downtime as well. Designers should not rule out the more highly alloyed, more-costly materials if a premature failure could result in shutting down the entire plant and loss of valuable production. Designers should consider the possibility of using different steels within the same application.

V. CONCLUSION

Strain-hardening and plastic-instability behavior was investigated for annealed and cold-worked austenitic stainless steels in the temperature range) 150 to 450 ^{0}C. These studies we conclude in both annealed and cold-worked conditions the strength of stainless steels decreased with increasing temperature, while ductility peaked at room temperature or below.

Various temperatures is found to be the optimum to avoid grain growth on solution annealed 304 stainless steels. Overall analysis they cannot be hardened by heat treatment process but harden rapidly cold work and or non magnetic, Stainless steel can pose special Corrosion challenges, since its passivation behaviour relies on the presence of a major alloying component (chromium, at least 11.5%).

Finally we conclude the analysis of Mechanical Property of Stainless steels improve the reliability and efficiency. Their performance has already been demonstrated. making them the material of choice for Used as many Domestic and Industry processing equipment.

The effect of increasing strain rate and associated heating of the specimen on mechanical behavior of 304L is distinctly demonstrated by the variation of work-hardening rate with strain.

REFERENCES

[1] Singh J (1985) J Mater Sci 20:3157. doi:10.1007/BF00545181

[2] Milad M et al, The effect of cold work on structure and properties of AISI 304 stainless steel, journal of materials processing technology 2 0 3 (2 0 0 8) 80–85.

[3] S.D. Washko and G. Aggen, in ASM Handbook, 10th ed., Vol. 1, ASM International, Materials Park, OH, 1990, pp. 1303–1304.

[4] Fundamentals of corrosion: mechanisms, causes, and preventative methods / Philip A. Schweitzer, pp.122-125.

[5] Gopalakrishnan V et al, CORROSION STUDY ON WELDMENTS OF AUSTENITIC STAINLESS STEEL, International Journal of Scientific Research Engineering & Technology (IJSRET), ISSN 2278 – 0882 Volume 3, Issue 5, August 2014.

[6] Singh Balwinder, Microstructural Behaviour of SS304 & SS310 Hardfaced Steels, International Journal of Surface Engineering & Materials Technology, Vol. 3 No. 1 January-June 2013, ISSN: 2249-7250.

[7] J. L He, K.C. Chen, C.C Chen, A. Leyland, and A. Matthews, "Cyclic Oxidation Resistance of Ni-Al Alloy Coatings Deposited on Steel by a Cathodic Arc Plasma Process," Surf. Coat. Technol.,Vol. 135, 2001, pp. 158-65.

[8] A. F. Padilha and P. R. Rios, "Decomposition of austenite in austenitic stainless steels," ISIJ International, vol. 42, no. 4, pp.325–337, 2002.

[9] Krafft H, Structural Instability of Cold Worked Alloy 304 in 650^{o}C Service, ASM International, Submitted 5 June 2001; in revised form 14 June 2001, Volume 1(4) August 2001.

[10] Sedrik A J, Corrosion of Stainless Steels, 2nd ed., Wiley, New York, (1996).

[11] George G, and Shaikh H, in Corrosion of Austenitic Stainless Steels: Mechanism, Mitigation and Monitoring, (ed) Khatak H S and Baldev Raj, Woodhead Publishing House, Cambridge, England, (2002) p 1.Stainless steel Industry Data.

[12] High temperature characteristics of stainless Steels, Distributed by Nickel DEVELOPMENT INSTITUTE, Produced By AMERICAN IRON AND STEEL INSTITUTE.

[13] Tukur S.A. et al, Effect of Heat Treatment Temperature on Mechanical Properties of the AISI 304 Stainless Steel, International Journal of Innovative Research in Science, Engineering and Technology, Vol. 3, Issue 2, February 2014

[14] Ravi Kumar B et al, Cold rolling in AISI 304 stainless steel, Materials Science and Engineering A 364 (2004) 132-139.

[15] KASSNER M. E. et al, Changes in the sub boundary mesh size with creep strain In 304 stainless steel, METALLURGICAL TRANSACTIONS A, 2094-VOL 17 A NOVEMBER 1986.

[16] Khobragade N. N. et al, Corrosion Behaviour of Chrome–Manganese Austenitic Stainless Steels and AISI 304 Stainless Steel in Chloride Environment, Received: 17 March 2013 / Accepted: 1 July 2013 / Published online: 8 October 2013© Indian Institute of Metals 2013, Trans Indian Inst Met (2014) 67(2):263–273, DOI 10.1007/s12666-013-0345-8

[17] LICHTENFELD JOSHUA A. et al, Effect of Strain Rate on Stress-Strain Behavior of Alloy 309 and 304L Austenitic Stainless Steel, METALLURGICAL AND MATERIALS TRANSACTIONS A, VOLUME 37A, JANUARY 2006—147B. S . MANN, *Wear* 208 (1997) 125.

[18] C. J . LIN and J. G. DUH, Surface and Coatings Technology 73 (1995) 52.

[19] Shuro I. et al,, Property evolution on annealing deformed 304 austenitic stainless steel, Received: 22 March 2012 / Accepted: 2 July 2012 / Published online: 14 July 2012 © Springer Science+Business Media, LLC 2012, J Mater Sci (2012) 47:8128–8133 DOI 10.1007/s10853-012-6708-4.

[20] Source book on stainless steels. Am Soc Met; 1976.

[21] Lula RA. Stainless steel. Am Soc Met 1966; 15.

[22] Byun T.S. et al, Temperature dependence of strain hardening and plastic instability behaviors in austenitic stainless steels, Elsevier-Acta Materialia 52 (2004) 3889–3899.

[23] Sarkar A et al, Effect of mean stress and solution annealing temperature on ratcheting behaviour of AISI 304 Stainless Steel, Elsevier XVII International Colloquium on Mechanical Fatigue of Metals (ICMFM17), procedia engineering 74 (2014)376-383.

[24] Pradhan K K et al, Analysis of erosion-corrosion resistance and Various Application in domestic and Industrial field of Stainless Steel Grade 304, International Journal of Research (IJR) e-ISSN: 2348-6848, p- ISSN: 2348-795X Volume 2, Issue 4, April 2015