IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 15, Issue 4 Ver. I (Jul. - Aug. 2018), PP 39-43
www.iosrjournals.org

Quenching & Partitioning In Stainless Steels

G V S Karthik[1], G Rakesh[2]
[1](Mechanical, Vidya Jyothi Institute of Technology, INDIA(Hyderabad))
[2](Mechanical, Vidya Jyothi Institute of Technology, INDIA(Hyderabad))
Corresponding Author: G V S Karthik[1]

Abstract: *In the modern age, stainless steel (SS) can be used for the variety of applications because of its unique properties-resistance to corrosion and high strength. Typically, most of the steels are quenched to obtain martensite for high strength. In line with philosophy, when the SS is worked for high strength, by way of quenching, it loses ductility and hence the formability. Thus, the loss of formability limits its applications where we need material to bend at most but not to break. Recently, a new concept, known as quenching and partitioning (Q & P) is followed to realise both high strengths as well as ductility in the same material. In the two-step Q&P process, SS is heated first to single phase zone of austenite and quenched to a temperature just below the start of martensitic transformation (Ms) where a considerable amount of soft austenite retained along with hard martensite. In the second step, the temperature of quenched SS is raised above Ms so that trapped carbon atoms in the BCT martensite can move and make austenite richer in quantity. This enriched austenite with carbon is stable at room temperature.*

Keywords: *Martensite, Quenching and Partitioning, Ductility, Formability, Austenite.*

Date of Submission: 02-07-2018 Date of acceptance: 18-07-2018

I. Introduction

Good ductility at room temperature and superplasticity at elevated temperatures are the main features of the Q&P heat treated steels. This hardening process also increases the ductile nature of the material.

Carbon partitioning between martensite and retained austenite is usually ignored in quenched steels, because the temperature usually is too low for substantial amounts of carbon diffusion to occur after quenching, and because a different mechanism ordinarily eliminates carbon supersaturation in martensite, viz. carbide precipitation during tempering. Consequently, while carbon-enriched retained austenite has identified in martensitic steels for some time, the thermodynamics of carbon partitioning between martensite and retained austenite has been scarcely considered.

The concept of heat treatment of martensite, different from conventional quenching and tempering, is described. This involves quenching to below the martensite-start temperature and directly ageing, either at or above, the initial quench temperature. If competing reactions, principally carbide precipitation, are suppressed by appropriate alloying, the carbon partitions from the supersaturated martensite phase to the untransformed austenite phase, thereby increasing the stability of the residual austenite upon subsequent cooling to room temperature. This novel treatment has been termed ‘quenching and partitioning (D.V.Edmonds 2006).

II. Importance of Suppressing Carbide Precipitation

The absence of carbide formation is a fundamental element of the constrained par equilibrium model since the existence of a metastable equilibrium between ferrite and austenite is precluded if the more stable ferrite plus iron carbide equilibrium can be achieved. Any carbide formation effectively "consumes" carbon, since these carbon atoms are no longer available to enrich the austenite. For Q&P processing, however, any transition carbide precipitation diminishes the potential for carbon enrichment of austenite, and it is necessary to develop a better understanding of the onset of transition carbide formation, including composition and processing effects.

Since the chemical potential of carbon is much higher in as-quenched martensite than in the retained austenite, it is reasonable to conclude that carbide nucleation would be more likely in bcc ferrite than in austenite.

III. Indentations And Equations

Although it is considered that some heat treatment processes may have been done, or do currently follow the Q&P temperature/time profile, the intentional use of a heat treatment process to bring about the multiphase Q&P microstructures and associated mechanical properties that have been achieved in recent years is thought to be a new development. (Edmonds, 2006). A number of studies have now been published examining Q&P over carbon ranges from low-carbon TRIP steels to medium-carbon bar steels; although it is well to bear in mind that it is the carbon concentration of the quenched austenite which is essential, which in the case of austenite carbon enrichment is not the same as that of the bulk steel. (Gerdemann & J. G. Speer, 2004)

IV. Mechanical Properties of Q&P

One of the characteristics of dual/multi-phase structures is that they commonly exhibit continuous yielding behaviour. In this respect, Q&P steels do not disappoint. The difference in properties achieved by relatively small changes in the heat treatment procedure is noteworthy. This characteristic of the Q&P process led De Moor (who also studied the tensile properties of Q&P steel) to state that, 'a variety of properties can be obtained even with a single chemical composition by adapting the heat treatment parameters' (De Moor, 2009).

Mechanical properties in conjunction with technological properties, such as weldability, formability, and machinability, and their optimum combinations, are widely discussed in some mechanical engineering disciplines. In this manner, requirements arise for developing steels which could offer high strength and good formability, and which could be used for making parts with high resistance to failure and with a long life. Their properties are dictated by their treatment, as well as their alloying, mainly by the silicon content. Silicon fundamentally affects microstructure evolution during Q&P processing and, as a result, mechanical properties

V. The material used for the Experiment

In this experiment we used a stainless steel grade of 440C containing C% - 0.96, Mn% - 0.4, Si% - 0.82, Cr% - 16.43, Ni% - 0.19, Mo% - 0.47,V% - 0.106, Cu% - 0.039

440**C** is stainless steel and has the highest carbon content from 400 stainless steel series. It is usually heat treated to reach a hardness of 58–60 HRC. 440C can be oil quenched to achieve maximum hardness. It can be hardened to approximately Rockwell hardness no of 58, making it one of the hardest stainless steels. Because of its toughness and relatively low cost. These properties make this grade suitable for applications such as valve components and ball bearings. Grade 440A and 440C stainless steels have similar properties - except for a slightly lower percentage of carbon in grade 440A.

All three forms of grade 440 sheets of steel are commonly used. However, grade 440C is more readily available than the other standard grades. Grade 440F, a free-machining type of grade 440 series, is also available with a high carbon content similar to that of grade 440C. Martensitic steel grades are high-hardness steels, usually fabricated using techniques that require hardening and tempering treatments.

These grades have a corrosion resistance lower than that of other austenitic grades. The applications of martensitic steels are limited by the loss of strength caused by over-tempering at high temperatures and loss of ductility at temperatures below zero.

VI. Hardness Before Q&P

The hardness of the stainless steel 440C material has been tested by using Brinell harness machine. In this testing, the 3000kgf is used to make an indent with the titanium coated ball. The diameters of the indent are measured using Brinell microscope. The hardness values have been determined from the mean indent diameter values. BHN for stainless steel 440C is 241.18.

$$\mathrm{BHN} = \frac{2P}{\pi D\left(D - \sqrt{D^2 - d^2}\right)}$$

where:

BHN = Brinell Hardness Number (kgf/mm^2)

P = applied load in kilogram-force (kgf)

D = diameter of indenter (mm)

d = diameter of indentation (mm)

VII. Hardness Of The Experimental Component After Heat Treatment

The component used in this experiment when it is heated to quench at different temperatures for a variety of time periods has been tested for their hardness and are tabulated below.

Table 1. The hardness of the 440C Stainless Steel After Heat Treatment

	5	10	20	30	300	3000
300	228.76	228.76	351.81	414.63	351.81	301.95
350	414.63	228.76	400.82	414.63	228.76	228.76
400	228.76	196.54	228.76	241.18	201.44	414.63

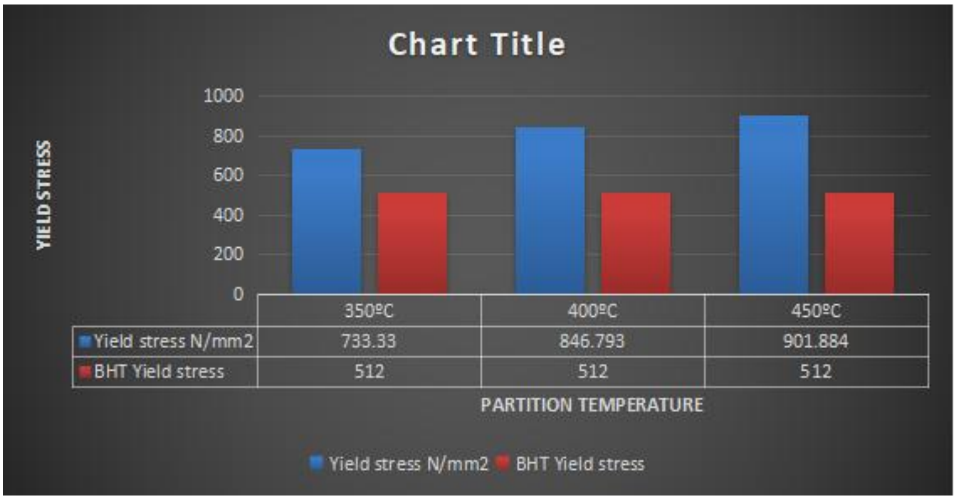
VIII. Tensile Test Of The Experimental Component Before And After Heat Treatment

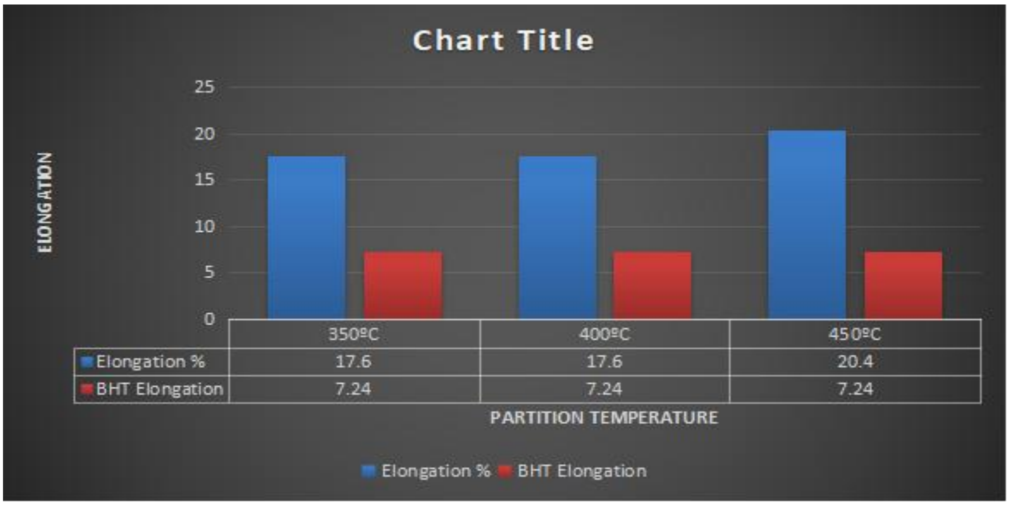
(1) **Table 2-**Tensile Testing Before Heat Treatment

UTM Results	**440C**
Ultimate Tensile Strength (N/mm^2)	773.565
Elongation (%)	7.240
Yield Stress (N/mm^2)	512

(2) **Table 3-**440C Tensile Testing After Heat Treatment

Temperature	**350°C**	**400°C**	**450°C**
Ultimate tensile strength (N/mm^2)	734.667	1363.908	1311.241
Elongation %	17.6	17.6	20.40
Yield stress N/mm^2	733.33	846.793	901.884





BHT - Before Heat Treatment

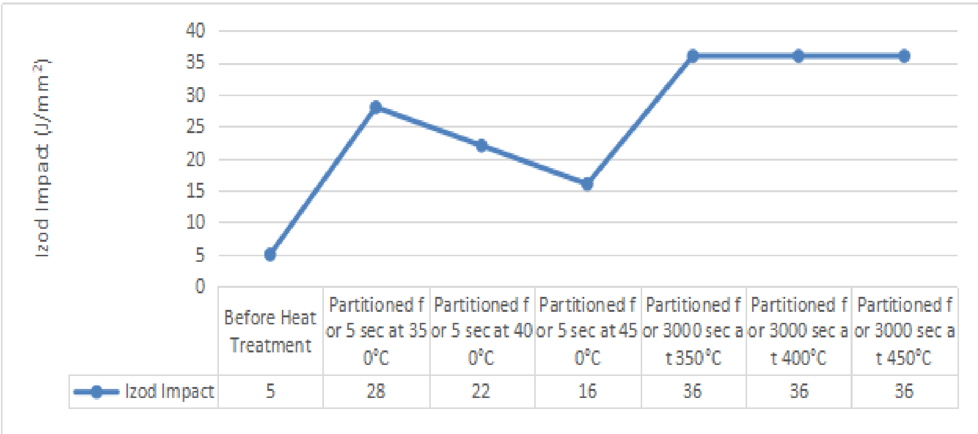
IX. Conclusion

For 440C partitioned at 350 ºC for 3000sec hardness value increases by 60 and the tensile strength gets decreased by 39N/mm^2 before heat treatment.

At 400 ºC for 3000sec hardness value gets decreased by 20 and tensile strength increases 600N/mm^2 by initial value.

At 450 ºC for 3000sec hardness value gets increased by 173 and tensile strength increases 550N/mm^2 by initial value.

For this grade of Stainless steel if the material is partitioned at 450 ºC for 3000sec having improved hardness and ductility



Acknowledgements

It is our great privilege that we got an opportunity to be associated with Dr B.V.Reddi, Professor in the Mechanical Engineering Department (MED) of Vidya Jyothi Institute of Technology(VJIT) during last three years who has been a source of inspiration for us to undertake advanced research in materials technology. He motivated and supervised in doing this research topic. The results of this investigation have taken fruitful destination in the form of this Report because of discussions in depth with Dr.Reddi for hours, days and nights. Therefore, we were indebted to him for discovering our research potentials. We take this opportunity to thank him from the bottom of the heart. We wish to acknowledge Prof. G. Sreeram Reddy, HOD of MED, VJIT for encouragement and freedom that he has given in utilizing the college laboratory throughout this investigation. Our sincere thanks to him. We thank Dr Afroz Mehar and Mr S.Prasad, Faculty of MED for their valuable critique and suggestions at the first and second review stages of the project.

We also thank Mr Sammaiah of Osmania University for SEM work Hyderabad Testing Labs, for Tensile Test work We finally thank my family members who have supported morally with their generous financial contribution throughout our education including this expensive B.Tech Course.

References

[1]. Andrews, K. W. (1965). Empirical formulae for the calculation of some transformation temperatures. *Journal of the Iron and Steel Institute, Vol. 203(July)*, 721-727.

[2]. Angel, T. (1954). Formation of martensite in austenitic stainless steels. Effects of deformation, temperature, and composition. *Journal of the Iron and Steel Institute, Vol. 177(May)*, 165-174.

[3]. Bain, E. C. (1924). The nature of martensite. *Transactions of the American Institute of Mining Engineers, Vol. 70*, 25-46.

[4]. Bhadeshia, H. K. (1979). *The theory and significance of retained austenite in steels.* Cambridge: Department of Metallurgy and Materials Science, Darwin College.

[5]. Cahn, R. W., & P. Haasen, e. a. (1992). *Constitution and properties of steels, Materials science and technology*. VCH.

[6]. Christian, J. W. (1965). Military transformations: an introductory survey. *Physical properties of martensite and bainite* (pp. 1-19). Scarborough, UK: Iron and Steel Institute.

[7]. Clarke, A. (2006). *Carbon partitioning into austenite from martensite in a silicon-containing high strength sheet steel - T6142.* Colorado: Advanced Steel Processing and Products Research Center, Colorado School of Mines.

[8]. Davies, R. G., & Magee, C. L. (1979). Physical metallurgy of automotive high strength steels. *Journal of Metals, Vol. 31(11)*, 17-23.

[9]. De Moor, E. (2009).

[10]. Edmonds, D. V. (2006). 25-34.

[11]. Gerberich, W. W., & C. F. Martin, e. a. (1965). Serrated stress-strain curves of metastable austenite in alloy steels. *Transactions of the American Society for Metals, Vol. 58(1)*, 85-94.

[12]. Gerdemann, F. L., & J. G. Speer, e. a. (2004). Microstructure and hardness of steel grade 9260 heat-treated by the quenching and partitioning (Q&P) process. *Material Science and Technology 2004* (pp. 439-449). New Orleans, Louisiana, USA: Association for Iron & Steel Technology.

[13]. Honeycombe, R. W., & Bhadeshia, H. K. (1995). *Steels - Microstructure and properties. Second Edition.* Edward Arnold.

[14]. Kim, A. M. (1968). History of the development of iron-carbon diagram. *Metallovedenie I Termicheskaya Obrabotka Metallov (translated from), Vol. 1968(5)*, 11-19.

[15]. Koistinen, D. P., & Marburger, R. E. (1959). A general equation is prescribing the extent of the austenite-martensite transformation in pure iron-carbon alloys and plain carbon steels. *Acta Metallurgica*, 59-60.

[16]. Kurdjumov, G. V. (1960). Phenomena are occurring in the quenching and tempering of steels. *Journal of the Iron and Steel Institute, Vol. 195(May)*, 26-48.

[17]. Magee, C. L. (1970). The nucleation of martensite. *American Society for Metals Seminar on Phase Transformations.* Detroit, Michigan, USA: American Society for Metals.

[18]. Matlock, D. K., & Speer, J. G. (2010). Processing opportunities for new advanced high-strength sheet steels. *Materials and Manufacturing Processes, Vol. 25(1-3)*, 7-13.

[19]. Nair, J. (2015, April 15). *Quora*. Retrieved from https://www.quora.com/What-is-an-intuitive-explanation-of-the-iron-carbon-phase-diagram

[20]. Parr, J. G. (1952). X-ray investigation of the epsilon phase in an iron-manganese alloy. *Journal of the Iron and Steel Institute, Vol. 171(6)*, 137-141.

[21]. Porter, D., & Easterling, K. (1992). *Phase transformations in metals and alloys. Second Edition.* Chapman and Hall.

[22]. Qiu, D., & Zhang, W.-Z. (2003). A systematic study of irrational precipitation crystallography in fcc-bcc systems with an analytical O-line method. *Philosophical Magazine, Vol. 83(27)*, 3093-3116.

[23]. Rollason, E. C. (1968). *Metallurgy for engineers, Third Edition.* Edward Arnold.

[24]. Sherif, M. Y., & C. Garcia-Mateo, e. a. (2004). Stability of retained austenite in TRIP-assisted steels. *Materials Science and Technology, Vol. 20(3)*, 319-322.

[25]. Sinha, A. K. (1989). *Ferrous physical metallurgy. First Edition.* Butterworths.

[26]. Smith, R. P. (1953). Diffusivity of carbon in iron by the steady-state method. *Acta Metallurgica, Vol. 1(September)*, 578-587.

[27]. Speer, J. G., & A. M. Streicher, e. a. (2003).

[28]. Steven, W., & Haynes, A. G. (1956). The temperature of formation of martensite and bainite in low-alloy steels. Some effects of chemical composition. *Journal of the Iron and Steel Institute, Vol. 183(August)*, 349-359.

[29]. Takechi, H. (1987). Developments in high-strength hot and cold-rolled steels for automotive applications. *The metallurgical society of AIME.* , 117-138.

G V S Karthik1 “Quenching & Partitioning In Stainless SteelsIOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE) , vol. 15, no. 4, 2018, pp. 39-43.