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Study On Hardness, Elemental Composition And Corrosion Behavior Of EN31 Steel After Brine Quenching

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Abstract: This project investigates the effects of heat treatment and quenching in a brine (NaCl) solution on the mechanical properties and corrosion behavior of EN31 steel, a high-carbon alloy widely used in manufacturing industries. The experimental procedure involved heating EN31 steel specimens to temperatures between 850°C and 888°C, followed by quenching in a brine solution to achieve enhanced surface hardness. The Rockwell hardness test was used to assess mechanical strength, while optical emission spectroscopy (OES) was conducted to examine changes in the elemental composition before and after treatment. Corrosion behavior was visually inspected under natural environmental conditions. Results indicate a significant increase in hardness (from 25 HRC to 55–56 HRC) and slight variations in elemental composition within standard limits. However, rapid cooling in brine introduced surface cracks in some specimens, highlighting the importance of process control. The study emphasizes the potential of brine quenching in enhancing steel properties while identifying its limitations in certain use cases.

Keywords: selection of steel, Quenching in brine (NaCl), Increase in hardness and Corrosion behavior of EN31 steel.

I. INTRODUCTION

Steel is a strong material made mainly from iron and carbon, and it's used in almost every part of our daily lives. EN31 is a special type of steel that's especially popular in the automotive industry. It's used to make strong and durable parts like axles, roller bearings, cutting blades, spindles, molds, ball bearings, spinning tools, and various machine components such as shafts, bolts, and punches especially where high pressure or heavy loads are involved. This steel is also used in aircraft and other engineering fields, especially for parts like propellers and gears that need to be tough and reliable. The conventional chemical composition of EN31 steel is displayed in the below table For the present experiment, EN31 a high carbon steel grade was selected due to its ready availability from the supplier in a hot- rolled condition. To verify the material's elemental composition, spectrochemical analysis via optical emission (OES) was conducted. The obtained results confirmed that the steel conformed to the specified standards. Furthermore, it is essential to consider the environmental characteristics during testing to prevent the introduction of extraneous corrosion of a bolts and test specimen forming a galvanic couple can lead to ambiguous or potentially misleading results [2].

Fig.1 EN31 steel specimens

Compared to other materials within its class, steel demonstrates greater cost-efficiency in manufacturing. The extraction of iron from its ore consumes substantially less energy than the extraction of aluminum—approximately one-quarter as much—thereby enhancing the overall efficiency and economic viability of the process. Predominantly composed of iron, steel also offers environmental advantages due to its high recyclability. Given that iron constitutes approximately 5.6% of the Earth's crust, it represents a stable and abundant resource. Presently, global steel production surpasses the combined output of all non-ferrous metals by a factor of about twenty, highlighting its essential role in contemporary industry. The steel industry continues to advance by developing techniques to improve the strength and ductility of this versatile material. To date, roughly 2,000 steel grades have been formulated, with approximately 1,500 classified as high-grade, indicating substantial potential for the development of new steel variants with diverse properties.

Steel has historically been fundamental to everyday life, offering numerous advantages, and it is expected to retain its importance in the future. For the current investigation, EN31, a high-carbon steel grade, was selected due to its ready availability from the supplier in hot-rolled form. To confirm its elemental composition, optical emission spectrometry (OES) was utilized. The analysis verified that the material complied with the specified standards. Table 1 below details the chemical composition of the EN31 steel as provided by the supplier. In comparison to other materials within its category, steel is more cost-effective to manufacture. The extraction of iron from ore requires significantly less energy than that of aluminum—approximately one-quarter of the energy—rendering the process more efficient and economical. Steel, which is primarily composed of iron, offers environmental benefits due to its high potential for recycling. Given that iron constitutes roughly 5.6% of the Earth's crust, it represents a stable and abundant resource. At present, the worldwide production of steel surpasses the total output of all non-ferrous metals by an approximate factor of twenty, highlighting its essential significance in contemporary industrial sectors. The steel sector continues to evolve, developing methods to enhance the strength and flexibility of this versatile material. To date, approximately 2,000 steel variants have been developed, with around 1,500 classified as high-grade, and there remains considerable potential for the creation of new steel types with diverse properties. Steel has long been integral to daily life, providing numerous benefits, and it is anticipated to maintain its significance in the future. In the present investigation, EN31, a high-carbon steel grade, was selected due to its immediate availability from the supplier in a hot-rolled state. Optical emission spectrometry (OES) was utilized to determine the elemental composition. The analysis verified that the material complied with the established standards. Table 1 below presents the chemical composition of the EN31 steel obtained from the supplier.

Element	Observed Value (%)	Specification Range (%)
Carbon	1.066	0.90 – 1.20
Silicon	0.216	0.10 – 0.35
Manganese	0.325	0.30 – 0.75
Sulphur	0.022	< 0.04
Phosphorus	0.013	< 0.04
Chromium	1.415	1.00 – 1.60
Molybdenum	0.022	Not specified
Nickel	0.005	Not specified
Iron	Remaining	Remaining

Table.2 Chemical composition of EN31 steel

II. OBJECTIVE

The aim of this study is to investigate the corrosion behavior and elemental composition of EN31 steel following heat treatment and subsequent quenching in a brine solution. The heat treatment was conducted for a duration of six hours at temperatures ranging from 850°C to 888°C, after which the specimens were quenched in a sodium chloride (NaCl) brine solution.

- The objective was to attain the desired surface hardness of EN31 steel by utilizing a brine solution for rapid quenching, thereby enhancing the rate of heat transfer without inducing any Modifications in the mechanical characteristics or the dimensional stability of the product.
- The objective of this study is to evaluate the corrosion behavior of EN31 steel under environmental conditions and to analyze the changes in its chemical composition, as determined by spectrographic testing, from the untreated state to the heat-treated condition. These insights can offer significant support to the industry before the commencement of the manufacturing process.

III. METHODOLOGY

- **MATERIAL CHOSEN: EN31 STEEL:** In the manufacturing sector, EN31 carbon steel, characterized by its high carbon content, is extensively utilized owing to its advantageous mechanical properties. This particular steel grade is frequently utilized in the fabrication of various components, including heavy-duty gears and camshafts within the automotive sector. Moreover, EN31 steel is preferred for the production of cutting tools, attributed to its exceptional strength and toughness, which enhance tool durability and preserve sharp cutting edges It is also widely utilized in the production of components that require high wear resistance. Furthermore, EN31 steel serves as a common material in investigations aimed at identifying and differentiating parameters subsequent to heat treatment processes. The material is readily accessible from suppliers in the form of solid steel bars, thereby facilitating its practical application in both manufacturing and research contexts.

- **PREPARING THE SPECIMENS FOR TESTING:** The initial dimensions of the EN31 steel rod samples were 25 mm in diameter and 38 mm in length. A total of ten individual specimens were prepared for the experimental procedures. The steel bars utilized in the study were sourced from Sunrise Steel Enterprises, located in Belagavi. Subsequently, the thickness and length of the test specimens were reduced to 22 mm and 35mm, respectively, through turning and facing operations performed on a lathe machine. Prior to conducting the experiments, all metal workpieces underwent heat treatment to ensure uniform material properties.

- **HEAT TREATMENT PROCESS:** In this process the metal undergoes heating and operations to achieve specific desirable properties without any change in shape and their composition of metals.

- **HARDENING:** Ahead of heat treatment the hardness of EN31 steel is checked under the Rockwell hardness tester.The furnace temperature is set at 885ºC- 888ºC for heat treatment. Putting a metals work pieces in stainless steel wire mesh to steady hold and adjusted in the furnace. The metal pieces put in the furnace for 6 hours (Industrial standard) for heat treated for hardening process.

- **BRINE SOLUTION (SODIUM CHLORIDE):** After the hardening process of 6 hours the metal specimens of red- hot metal is removed from the furnance and the quenching is done in the NaCl solution. In the ration 1:1 of sodium and chlorium in brine solution is made of the aqua and the crystal sodium chloride (950gram) in the separate container. Further the heated specimens are quenched in brine solution for 36minutes and preserved for settle down the temperature.

- **ROCKWELL SCALE HARDNESS TESTER:** The Rockwell hardness test quantifies the difference in indenter depth between the initial and final applied loads, relative to a zero reference point. Initially, a minor load is applied to establish a baseline reference, which is then succeeded by the application of the main load within a specified time interval. The final load is sustained for a predetermined period, usually a few seconds after the initial application, to ensure precise measurement. The complete testing process typically takes between 10 and 15 seconds. In this study, a hardness tester with a load of 15 kgf was employed, selected in accordance with industry standards relevant to various metallurgical grades and heat treatment conditions. The corresponding data are presented in Table below.

Fig.2 Hardness tester

Scale	Indentor	Load (kgf.)	Dial	Application
C	Diamond	150	Black	Hard cast iron, Deep case, Titanium.

Table. 2 Rockwell hardness scale

- **SPECTRO TEST:** Techniques used to identifying and estimating the chemical composition of the steel samples by using the method of optical emission soectroscopy (OES). After the heat treated specimens are assigned to the spectro test were the surface of the specimen is polished untill it achieve a shiny surface of sample and then the electric arc give energy to charged. Then the charged atoms returns to the normal condition, release the light on the surface and analysing the light and identify the elements are in the specimens accurately.

Fig. 3 Surface section where the OES is done.

IV. DIMENSIONAL DATA OF SAMPLES

Fig.4 Specimen placed in the vernier caliper

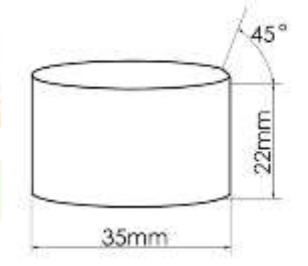
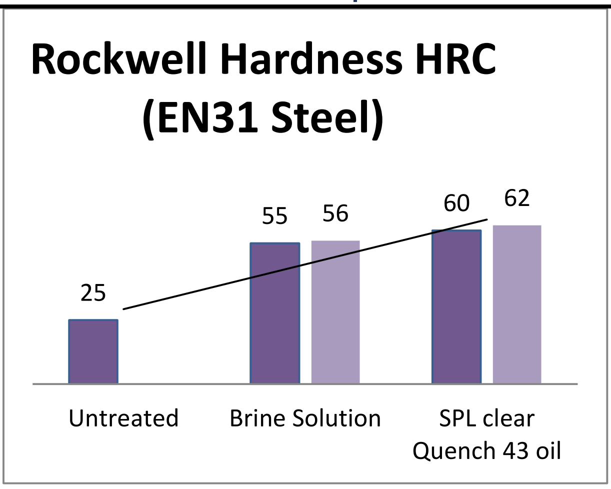


Fig.5 Specimen diagrammatic visual

V. RESULT

Heat- treatment	EN-31 Steel
	Rockwell Hardness HRC
Untreated	25 HRC
Brine solution Quenching	55-56 HRC
‘SPL’ clear quench 43 oil[1]	60-62 HRC

Table.3 Resultant hardness test table



Graph. 1 EN31 steel Hardness Levels

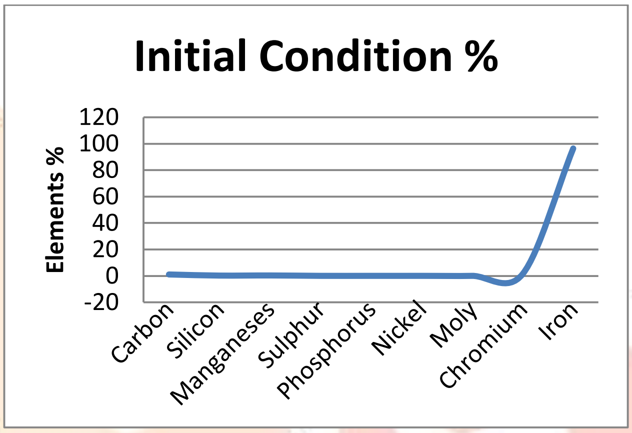
- **EXAMINATION OF SPECIMENS:** In this metallurgical heat treatment process, ten metal specimens were subjected to quenching utilizing a brine solution. Among these specimens, three exhibited identical cracking patterns, an illustrated in Figure The occurrence of cracks can be attributed to the phase transformations induced by quenching, which affect the metallurgical properties, including carbon content, thereby increasing susceptibility to failure. The accelerated cooling induced a faster contraction of the specimen's outer layer relative to its inner layer, leading to differential shrinkage and the subsequent development of cracks. The use of a sodium chloride (NaCl) solution a the quenchant generates substantial thermal stresses due to its aggressive cooling rate, which can accelerates cooling and amplify internal stresses. Furthermore, improper geometric design, particularly variations in thickness, leads to unbalanced sectional mass and localized stress concentrations at points subjected to direct central loading, thereby promoting cracking initiation under these conditions.

Fig.6 Crack was observed in the specimens

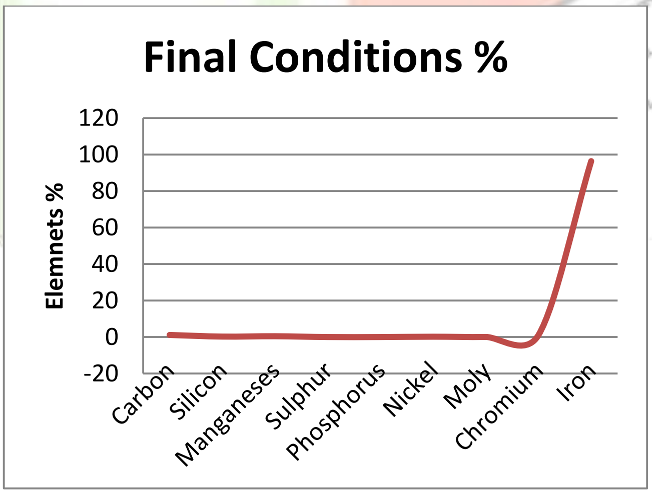
- **SPECTRO ANALYSIS:** Subsequent to the metallurgical treatment procedure, the specimens underwent analysis to ascertain the elemental composition of EN31 steel through optical emission spectroscopy (OES). Elemental analysis of the specimens to heat treatment as detailed in Table 4.2 below, revealed a slight increase in elemental composition. In particular, carbon content changed slightly by 0.08% which falls within the standard specified ranges of 0.90-1.20%.

Element	Initial condition (%)	Final condition (%)
Carbon	1.066	1.1534
Silicon	0.216	0.2771
Manganese	0.325	0.4665
Sulphur	0.022	0.0204
Phosphorus	0.013	0.0184
Nickel	0.005	0.2079
Moly	0.022	0.0590
Chromium	1.415	1.1147
Iron	96.377	96.4611

Table.4 Element composition of EN31



Graph. 2 Initial condition %



Graph.3 Final condition %

- **CORROSION OBSERVATION:** After undergoing the heat treatment specimens are exposed to environment condition at 26⁰C and visual observation carried out to assess electrochemical effects particularly water vapor and oxygen that causes a deposition iron oxides shown in the figure. The observed oxidation phenomena, encompassing surface irregularities, oxidation markings, and oxidative discoloration, signify localized degradation of the material on the specimen surface, as depicted in Figure. This degradation is attributed to the presence of high carbon that leads to surface transformation features rust development.

Fig.7 Corrugated surface

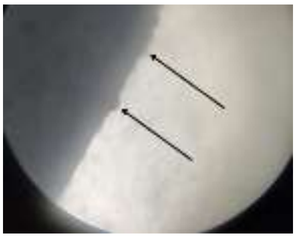


Fig.8 Indented specimen surface

CONCLUSION

The present study effectively demonstrated that quenching EN31 steel in a brine solution markedly improves its hardness, thereby enhancing its suitability for high-performance applications such as cutting tools and automotive components. Spectrochemical analysis revealed marginal increases in the percentages of elemental composition all of which remained within established acceptable ranges, thereby confirming the material's stability subsequent to the heat treatment. Nevertheless the rapid cooling technique induced cracking in certain specimens, suggesting that while brine quenching is an effective method, it entails inherent risks that necessitate careful control. Additionally corrosion marks were observed, attributed to the elevated carbon content and environmental exposure, underscoring the necessity for appropriate surface treatments following quenching. In conclusion the results demonstrate that, when processing parameters are carefully controlled, brine quenching offers a cost-efficient means of enhancing steel performance; nevertheless considerations related to material geometry and safety during handling must be addressed imperative for practical implementation.

REFERENCES

1) Khushal Khera, Anmol Bhatia, Sanjay Kumar, Mehul Bhatia. "Investigation of the effects of various heat treatment processes on microstructure and hardness with respect to corrosion behavior for carbon steels." International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3 Issue-6, August 2014.
2) Tridib Kumar Mahata."Analysis of mechanical and corrosion properties of AISI50110 (EN31) steel with and without heat treatment." International Journal of Future Alloys Vol. 1:Issue 1 www.journalspub.com
3) Luis H. Pizetta Zordao, Vinícius A. Oliveira, George E. Totten, Lauralice C.F. Canale. "Quenching power of aqueous salt solution. " International Journal of Heat Transfer 140 (2019) 807 – 818 www.elsevier.com/locate/ijhmt
4) Jamiu Kolawole Odusote, Tajudeen Kolawole Ajiboye, Abdulkarim Baba Rabiu. "Evaluation of mechical properties of medium carbon steel quenched in water and oil." AU J.T. 15(4): 218-224 (Apr. 2012)
5) Daiula E. T, Nyior G. B, Mohammed R. A. "Quenching effects of water and brine on the hardening properties of plain carbon steels." The Nigerian Academic Forum, Volume 9 No. 4, November, 2005.