Kurdistan Journal of Applied Research (KJAR) | Print-ISSN: 2411-7684 – Electronic-ISSN: 2411-7706 | kjar.spu.edu.iq
Volume 2 | Issue 3 | August 2017 | DOI: 10.24017/science.2017.3.60

The Influence of Annealing Temperature and Soaking Time on the Ductility of SG 255

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ABSTRCT: ***This study deals with the effect of annealing temperature on the mechanical properties of SG 255 steel. Furthermore it aims to experimentally obtain better mechanical properties in particular ductility with lower annealing temperature and to minimize the cost of the manufacturing. The SG 255 steel is used in manufacturing of domestic LPG cylinder at Halala Company located in Sulaimanyah/Iraq. A number of samples were made according to ISO 6892, and then heat treated with different annealing temperature (850, 900 and 950 ºC). Moreover, the mentioned samples were broken by tensile machine to obtain the required mechanical properties, and to be compared with that of Halala factory. It was shown that higher elongation percentage 34.18%El with lower annealing temperature 900 ºC can be achieved and this leads to decrease the cost of manufacturing without degrading of cylinder's quality.***

Keywords: Annealing, Ductility, Gas cylinder, SG 255, Soaking time, Tensile test.

1. INTRODUCTION

It is without doubt that steel and its alloys have outstanding usage in the engineering applications in particular structural. Also it is one of the crucial raw materials which plays prominent role in the production of petroleum pressure vessels, commonly for liquid petroleum gas (LPG) for household utilization. Furthermore, modern technology has also made a significant development in the enhancement of the steels' properties, specifically the mechanical properties of the steel. The crucial development illustrates the employment of annealing heat treatment to tailor the ductility of SG 255 steel. Here, safety is taken into consideration so that the LPG cylinders can well possess ductility. In this work, 11 tensile samples are made, and then 9 of them are annealed at different temperatures 850C, 900C and 950C (each 3 samples with a temperature). Afterwards, the samples are tensioned until fracture. The aim of this paper implies an attempt to obtain sheets with higher ductility at minimum cost which is the lowest temperature of annealing heat treatment [1], [2].

2. LITERATURE REVIEW

Pitakkorraras, Angroekwarasakul and Chokechaithananan [3] made a study in regard to the mechanical changes along with microstructural properties of hot rolled steel part strip after normalizing heat temperature. That type of steel was used for gas cylinder production. It was discovered that the increase of temperature and time is directly proportional to the ferrite structure decarburization at the surface of the steel strip samples which tested at a temperature of 860°C. That is due to the point that the samples were soaked at same temperature similar to that of the microstructure of the steel which grows into ferrite and austenite duplex phase. The amount of carbon depletion was established by micro hardness profile as well as EPMA mapping analysis. Moreover the Ferrite and pearlite structures could be observed at 900 °C although acicular ferrite obtained at a higher temperature.

Ramakrishna, Siddiqui and et al [4] believe that mechanical properties (tensile strength and yield strength) of (LPG) cylinder parent plates have been attempted to approximation yield strength and tensile strength of cylinder material using hardness values 55 number of national (LPG) Cylinders plate destructive test data were considered to grow empirical formulas for approximating yield and tensile values. Real test data are compared with projected results and recommended as the best method for approximating the tensile and yield stress by means of cylinder hardness result values. These experiential formulas can be used for approximating indicative tensile and yield strength values of parent metal without conducting a destructive test on LPG cylinder samples.

Fadare, Fadara and Akanbi [6] conducted a study in respect to the results of heat treatment processes and mechanical properties such as hardening, annealing , quenching and tempering on the micro structure and nearly selected mechanical properties of (NST 37-2) steel. The results revealed that the samples, which were treated by annealing with mostly ferrite structure, gave the lower most tensile strength and hardness values besides the highest ductility and toughness. However the latter sample, composing of martensite structure, supplied the maximum tensile strength, hardness and toughness values along with lowermost ductility.

Offor, Daniel and Okorie [5] indicate the outcome of intercortical heat treatment processes on contend of 0.14wt%C 0.56wt%Mn 0.13wt%Si structural steel. The results showed that single quenching treatment eliminated the yield strength and reduced the ductility. However it resulted in improving the tensile strength, hardness properties and notch impact toughness properties of the same steel samples. Furthermore, the results similarly revealed that dual quenching eliminated the yield strength, and produced a better increase in tensile strength and hardness properties when it was single quenching but a better reduction in the ductility and notch impact toughness properties than single quenching of the steel samples. Tempering improved the yield strength, ductility and notch impact toughness properties of the quenched steels nevertheless reduced their tensile strength and hardness properties.

3. METHODS AND MATERIALS

3.1 Material:

This study was conducted by utilizing SG 255 steel sheet which was obtained from the Halala Company for production of gas cylinder. In fact, the mentioned sheet steel was chosen for manufacturing of domestic LPG cylinder due to their chemical and mechanical properties, which are suit the criteria of the LPG cylinder production according to IS 6240 standards. The properties of the 3 mm thickness sheet are written and shown in the table below:, chemical composition and mechanical properties as outlined in JIS G 3116 SG255 (3.1 and 3.2 respectively).

Table 3.1 Chemical composition of SG 255

Chemical composition				
C Max	***Si Max***	***Mn Max***	***P Max***	***S Max***
0.20	***-***	***0.30***	***0.040***	***0.040***

Table 3.2 Mechanical properties of SG 255

Yield point or proof stress (N/mm2) (min.)	***Tensile Strength (N/mm2) (min.)***	***Elongation (% min.)***
255	***400***	***26***

3.2 Procedure:

The procedure plan was carried out to design different annealing temperatures which can be tested by using tensile test then making analysis for the outcome data. The main reason for this test is to compare with the steel obtained from Halala Company. The heat treatment condition is illustrated in table 3.3.

Table 3.3 Annealing Temperatures and Soaking time Procedure

Annealing Temperature, °C	***Soaking Time, Minute***
950	***15***
900	***30***
850	***30***

3.3 Tensile Test:

The SG 255 steels were cut off to small pieces which were machined by using CNC plasma cutting machine. The tensile test samples were produced in accordance with the (ISO: 6892). Specimens for annealing heat treatment were carried out in accordance with the temperatures mentioned in the above table 3.3. The most prominent point of employing tensile test machine was to determine the mechanical properties, in particular ductility. During the tensile test, the sample was held between the jaws at a constant speed rate until the fracture has occurred**.**

3.4Muffle furnace:

The samples were heat treated using electric furnace (furnace model) with different annealing as it can be seen in table 3.3.

4. RESULTS

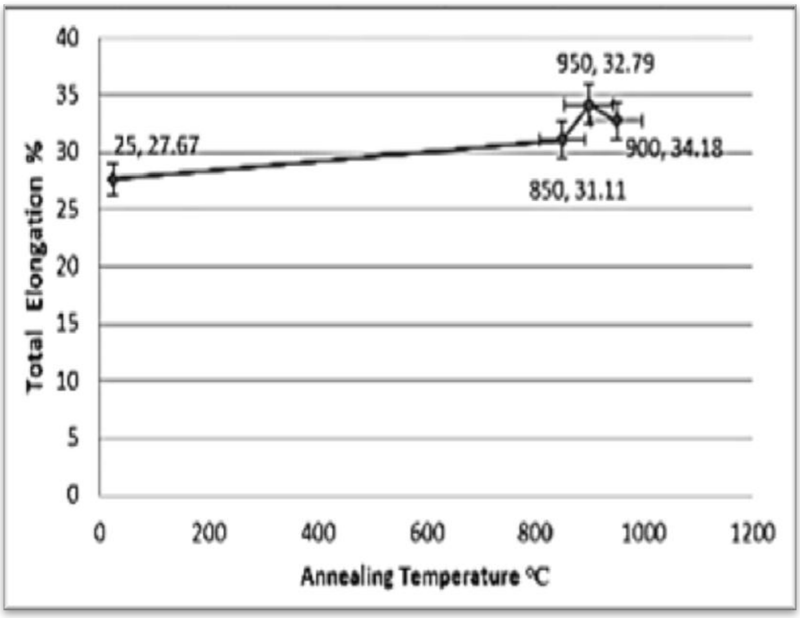
The following data contain a presentation and analysis of the annealed samples. Indeed, the samples are grouped according to the annealing temperature. And for each temperature three samples are selected as shown in table5.1. Subsequently, the samples are tensioned until fracture, and the mechanical properties are accomplished as shown in table2.2. According to the achieved data, the samples with 850 ºC annealing temperature can have the highest of total Elongation (%) but the value of Yield Strength (Mpa) and Ultimate Tensile Strength (Mpa) decreased when the annealing temperature was 850 ºC and higher than the results shown in fig 5.2, 5.3. In addition, the fractured surfaces as shown in fig5.2 indicate to a ductile failure mode for the majority of the samples. However, the samples with 850 ºC show more voids on their surfaces which are a clear indication of ductile failure

5. DISCUSSION

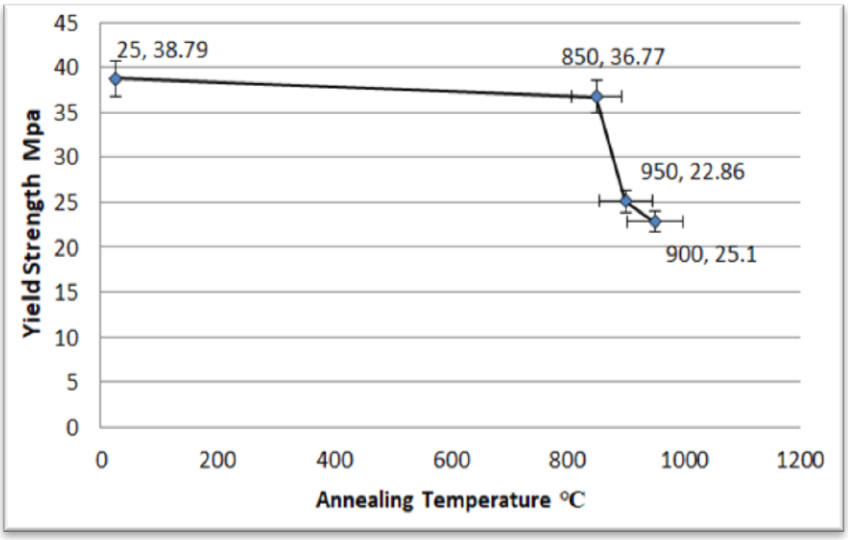
The prime reason behind annealing heat treatment experiment is to increase the ductility of SG 255 and to make ductile failure in the condition of fracture. During the annealing heat treatment, minimum temperature (850ºC) is selected according to the chemical composition of SG 255 chiefly carbon % through the phase diagram of Fe-c system. The mechanical properties of the received samples are significantly affected by the annealing heat treatment; this is also confirmed in the results of findings from the literature review. For instance, the ultimate tensile strength was fallen by 12 MPa, contrary to the ductility which was raised from 27.67% El to 34.18% El. Various temperatures are chosen for the purpose of comparison especially the (950ºC/15 minute), which possess the same condition used in the manufacturing of LPG cylinder in Halala factory.

According to the obtained data table 5.3, it was shown that the samples with 900ºC annealing temperature have the highest elongation percentage34.18 El% as compared with that of Halala factory 950ºC-32.79% El. In addition, comparable ductility to Halala factory was obtained with lower annealing temperature 850ºC -31.11%. In fact, the use of less annealing temperature will lead to a reduction in cost of manufacturing since the heat treatment is conducted with the ease of gasoil. Moreover, the necked area around the fractured surface is a clear indication of ductile failure which ensures the safety in the case of failure of the LPG cylinder.

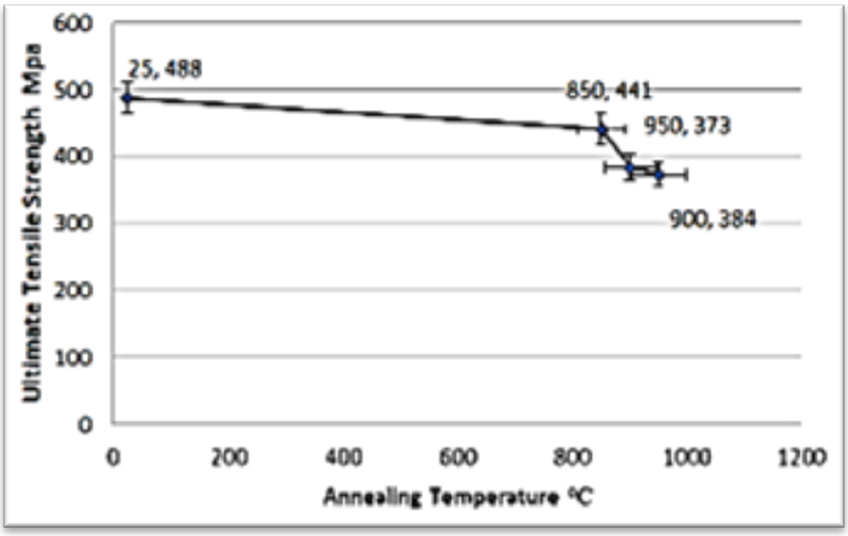
5.1. Figures and Tables



Figures5.1 Annealing *Temperature ℃ with Total Elongation% for all Samples*



Figures 5.2 Annealing Temperature℃ with Yield Strength (Mpa) for all Samples



Figures 5.3 Annealing Temperature ºC with Ultimate Tensile Strength (Mpa) for all Samples

5.2. Tables

Table **5.1. Number of samples and annealing temperature with soaking time**

No.	Number of Samples	Condition Temperature, °C	Soaking time Minute
1.	1-2	As-received	Room Temperature
2.	3-5	850Annealed	30
3.	6-9	900 Annealed	30
4.	9-12	950 Annealed	15

Table 5.2. Number of samples and Annealing Temperature with soaking time

No.	*Number of Samples*	*Ultimate Tensile Strength Mpa*	Yield Strength Mpa	Total Elongation %
1.	*1-2*	*488*	38.79	27.67
2.	*3-5*	*441*	36.77	31.11
3.	*6-9*	*384*	25.1	34.18
4.	*9-12*	*373*	22.86	32.79

Table 5.3.Halala data and the obtained results

No.	*Number of Samples*	*Condition Temperature, °C*	*Ultimate Tensile Strength Mpa*	Total Elongation %
1.	*1-2*	*As-received*	488	27.67
2.	*3-5*	*850 Annealed*	441	31.11
3.	*6-9*	*900 Annealed*	384	34.18
4.	*9-12*	*950 Annealed*	373	32.79

CONCLUSION

It can be concluded that, although, higher ductility can be achieved with lower annealing temperature at longer soaking time, the cost is still less than that of the higher annealing temperature with shorter soaking time.

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ACKNOWLEDGMENTS

The authors would like to take this opportunity to thank both Azadi Industrial Company and Halala Factory for their help, valuable values and contribution. Indeed, they motivated the authors to be able to finish this research in triumph. Furthermore, the authors are also grateful to the production and metallurgy department's laboratories and workshops.