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Determination and Regression Modelling of AISI-430 Quality Stainless Steel Production Heat Treatment Standard Limits

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Abstract

Ferritic stainless steels, which are a group of stainless steels whose production and consumption are constantly increasing thanks to their constantly increasing design volumes and wide range of uses, are relatively inexpensive stainless steels compared to other stainless steel qualities due to the alloying elements they contain. Ferritic stainless steels, which make up 26% of the entire stainless steel market: they are produced cheaper compared with the production of other stainless steels due to the alloying elements they contain. Because of its ferrite structure, its hardness first decreases and then hardens depending on time and temperature in the heat treatment applied after deformation. When this situation occurs, it causes undesirable mechanical properties to occur and therefore the produced material goes out of the standards which is something we don't desire. In this study, the heat treatment conditions necessary for the production of AISI - 430 quality stainless steels within the standards are explained with their energy diagrams. It was then examined and modeled with various regression models.

Keywords: Stainless Steel, Heat Treatment, Regression Modelling.

1. INTRODUCTION

Production of stainless steels; It consists of casting, hot rolling, cold rolling and solution annealing stages. In the solution annealing phase, the steel is given its stainless feature by first heat treatment and then pickling. Heat treatment is applied both to bring the stainless steel sheet to the required temperature for solution annealing and to provide the desired mechanical properties[1][2].

AISI - 430 grade stainless steel is a ferritic stainless steel. They are preferred in decorative structures, automotive industry, various machines, applications where glossy surfaces are required, household appliances and kitchen utensils by being shaped in various shapes. It is a stainless steel quality that is rapidly increasing in use in the world and in our country. They stand out with their suitability for polishing and formability[3][4].

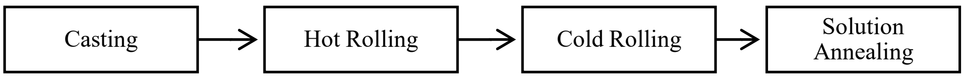

Fig. 1. Production stages of stainless steel

The heat treatment applied varies depending on the alloy and thickness of the stainless steel plate. As a result of faulty parameters, secondary hardening is observed after deformation as a result of loss of energy, time loss in the process and/or exposure of the ferritic stainless steel plate to an excessive heat treatment power. In this experiment, the heat treatment limits required to ensure the production of AISI-430 quality stainless steel, which belongs to the ferritic stainless steel group, were determined and mathematically modeled[5].[1]

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1.1. AISI – 430 Quality Stainless Steel and Its Heat Treatments

Stainless steels generally undergo different heat treatments depending on their quality, usage areas and thickness.

Depending on the heat treatment conditions and alloys, they have different carbide and grain structures. These properties affect the mechanical properties of the material. Increasing grain size with increasing heat treatment power; It causes the grain boundaries to decrease and hardness decreases[6].

In ferritic stainless steels, elements called alphagen (Cr, Si, Ti, Al, Mo, V, Nb and W) tend to form carbide with the increase in heat treatment power. The resulting carbides slow down grain growth and increase hardness because the interphase boundaries act as strong barriers to dislocation movement. Due to this mechanism, although the material cannot reach its hardness before heat treatment, the material starts to harden again after softening a little[7][8]. In this experiment, AISI-430 quality ferritic stainless steels were heat treated under different conditions and their mechanical properties were investigated after heat treatment. The heat treatment conditions at which secondary hardening started were observed.

2. EXPERIMENTAL METHOD

In order to determine the limits of the production of AISI-430 quality stainless steel at different temperatures and times, 39 samples to be used in the experiments were taken from a stainless steel cold rolling plant. The heat treatment conditions of the samples were determined according to the test method and the heat treatment was simulated in the laboratory environment.

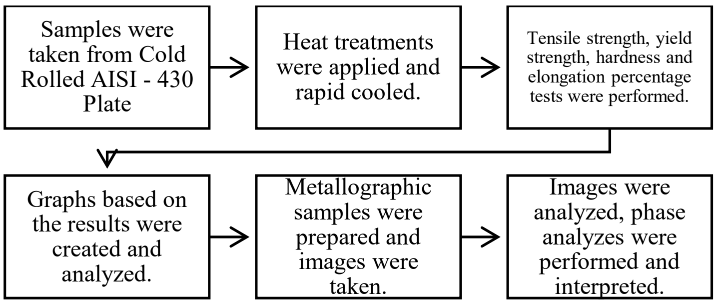

Fig. 2. Experiment stages

Table I. Heat Treatment Parameters

Sample No.	Heat (K)	Time (sec.)	Sample No.	Heat (K)	Time (sec.)	Sample No.	Heat (K)	Time (sec.)
1	923,15	100	14	1023,15	140	27	1123,15	220
2	923,15	140	15	1023,15	180	28	1123,15	260
3	923,15	180	16	1023,15	220	29	1123,15	300
4	923,15	220	17	1023,15	260	30	1173,15	100
5	923,15	260	18	1023,15	300	31	1173,15	140
6	923,15	300	19	1073,15	100	32	1173,15	180
7	973,15	100	20	1073,15	140	33	1173,15	220
8	973,15	140	21	1073,15	220	34	1173,15	260
9	973,15	180	22	1073,15	260	35	1173,15	300
10	973,15	220	23	1073,15	300	36	1173,15	380
11	973,15	260	24	1123,15	100	37	1173,15	420
12	973,15	300	25	1123,15	140	38	1173,15	460
13	1023,15	100	26	1123,15	180	39	1173,15	500

These processes were carried out at predetermined times and temperatures. It was then subjected to rapid cooling as in the production line. After these processes, various mechanical properties were measured and tables and graphics of mechanical properties were created.

Vickers Hardness Measurement according to ASTM E384 Standard, tensile, yield and percent elongation tests were applied according to ASTM E8 Standard.

The mechanical properties were investigated and the places where the hardness decreased, remained constant, increased the hardness and stopped the increase in hardness were determined. Samples representing the trend in the heat treatment graphs (sample 3, sample 4, sample 9, sample 16, sample 30, sample 33)

The determined samples were prepared as metallography samples in accordance with ASTM E3 Standard. Then, images at different scales were taken from the metallographed samples.

3. RESULTS AND DISCUSSION

The results of the hardness, yield strength, tensile strength and percent elongation tests performed in accordance with the standards after line simulation of cold rolled AISI-430 quality stainless steels are given below.

Table II. Mechanical properties after heat treatment and rapid cooling

Sample No	Heat K	Time (sec).	Hardness (HV)	Yield S. (MPa)	Tensile S. (MPa)	Elongation (%)
1	923,15	100	255	818,741	848,4	1,437
2	923,15	140	231,5	737,656	779,4	3,874
3	923,15	180	220	686,109	743,6	6,253
4	923,15	220	211,33	642,321	704,3	6,768
5	923,15	260	180	484,878	613,4	8,154
6	923,15	300	192	519,185	636,9	10,994
7	973,15	100	247,5	686,872	733,6	2,626
8	973,15	140	216	611,301	673,4	3,83
9	973,15	180	155	386,664	544,7	19,559
10	973,15	220	150	351,275	508,1	16,531
11	973,15	260	147	346,596	497,7	29,79
12	973,15	300	155,66	348,044	494,9	31,304
13	1023,15	100	224	635,86	666,9	1,399
14	1023,15	140	156	357,696	511,2	18,362
15	1023,15	180	146,5	354,809	499,4	30,423
16	1023,15	220	148,5	359,361	496,9	29,442
17	1023,15	260	154	375,991	491,2	28,494
18	1023,15	300	154,5	339,845	498,2	29,985
19	1073,15	100	212	488,833	560,9	1,697
20	1073,15	140	156,5	349,206	497,6	31,253
21	1073,15	220	157	352,918	497,9	31,637
22	1073,15	260	157,5	344,203	494,9	29,224
23	1073,15	300	155	340,363	494,2	30,75
24	1123,15	100	157	344,232	497,9	32,3
25	1123,15	140	156	340,121	498,1	30,638
26	1123,15	180	160	291,304	517,2	21,719
27	1123,15	220	174,33	294,204	540,8	13,519
28	1123,15	260	179	314,309	588,7	15,302
29	1123,15	300	200,5	327,969	630,5	19,165
30	1173,15	100	161	303,549	572,7	22,774
31	1173,15	140	217,33	368,474	708,8	19,551
32	1173,15	180	238	399,288	757,9	17,273
33	1173,15	220	242,67	424,219	797,1	14,723
34	1173,15	260	245	404,008	799,4	16,864
35	1173,15	300	246	439,097	815,3	16,949
36	1173,15	380	266	624,029	1151,6	15,525
37	1173,15	420	260	620,001	1153,4	19,166
38	1173,15	460	267,66	625,34	1154,2	14,675
39	1173,15	500	261,5	634,377	1172,2	17,156

The mechanical properties obtained as a result of the experiments were examined in 6 different groups according to the experimental temperatures.

3.1. Results Obtained at 923.15 Kelvin Temperature

6 different times (100sec.,140sec.,180sec.,220sec.,260sec.,300sec.) were selected in the experiments performed at 923.15 Kelvin temperature. In the experiments performed on the selected parameters, it was observed that the hardness, yield strength and tensile strength of the first five samples decreased continuously and the

percentage elongation amount increased continuously. It was observed that the hardness, yield strength, tensile strength and at the same time the percentage elongation amount of the sample, which was subjected to the test at 923.15 K temperature for 300 seconds, increased.

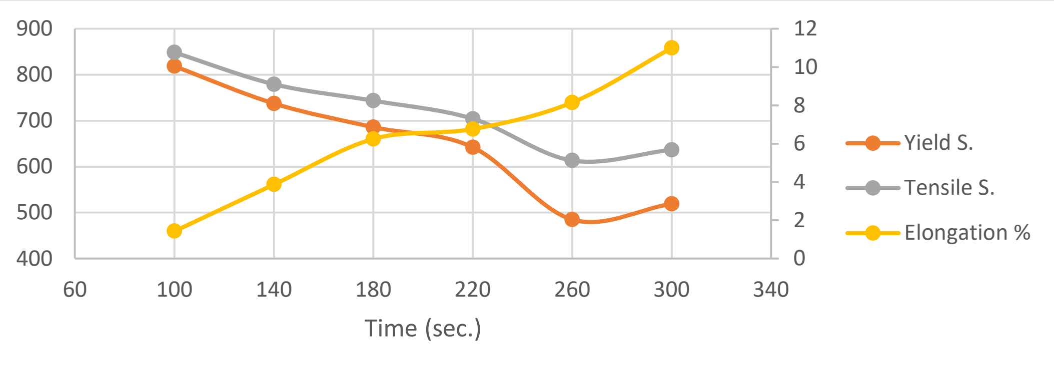

Fig. 3. Mechanical properties of samples 1-6

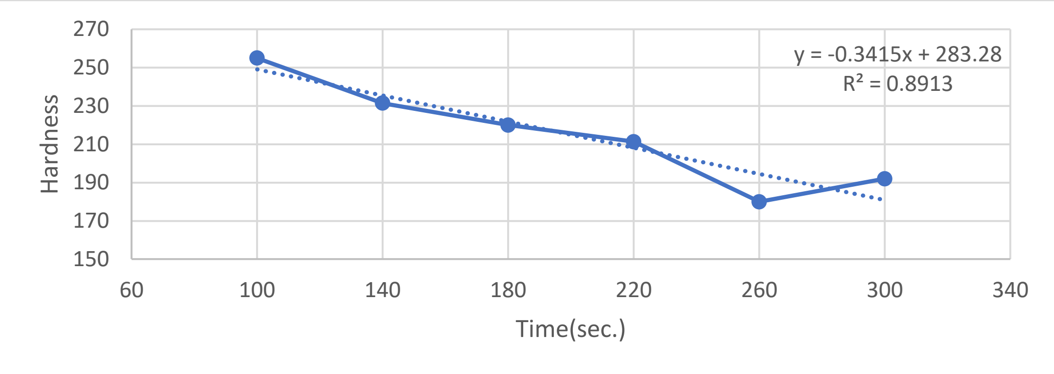

Fig. 4. Hardness values of samples 1-6

3.2. Results Obtained at 973.15 Kelvin Temperature

In the next experimental group, experiments performed at 973.15 Kelvin temperature, 6 different times (100sec.,140sec.,180sec.,220sec.,260sec.,300sec.) were selected.

In the experiments performed at the selected parameters, it was observed that the hardness, yield strength and tensile strength of samples 7, 8, 9, 10, 11 decreased continuously, while the percentage elongation amount increased suddenly in sample number 9 and then increased continuously. In the sample number 12, which was subjected to heat treatment for 300 seconds, an increase in hardness, yield strength and percent elongation values, while a decrease in tensile strength was observed. The change in the percentage elongation was observed as fluctuating.

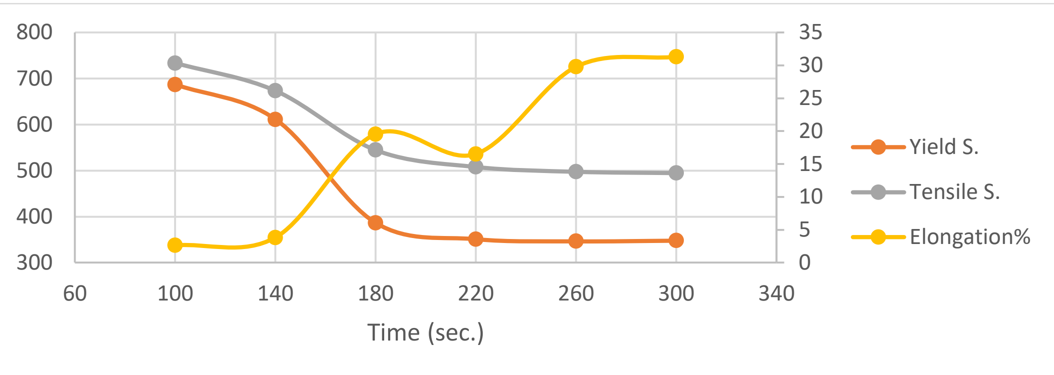

Fig. 5. Mechanical properties of samples 7-12

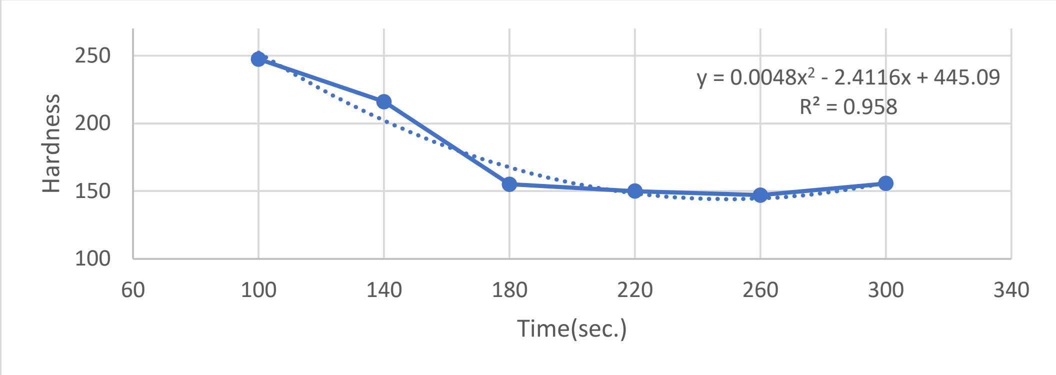

Fig. 6. Hardness values of samples 7-12

3.3. Results Obtained at 1023.15 Kelvin Temperature

In the third experimental group, the experiments were carried out at 1023.15 Kelvin temperature, in 6 different times (100sec.,140sec.,180sec.,220sec.,260sec.,300sec.). In this experimental group, a continuous decrease in hardness, yield strength and tensile strength and a rapid increase in percent elongation value were observed in the lowest three times (100sec., 140sec., 180sec.). From the 16th sample on, it was observed that the hardness increased with increasing time, the yield strength first increased and then decreased, and the tensile strength and percent elongation values first decreased and then increased.

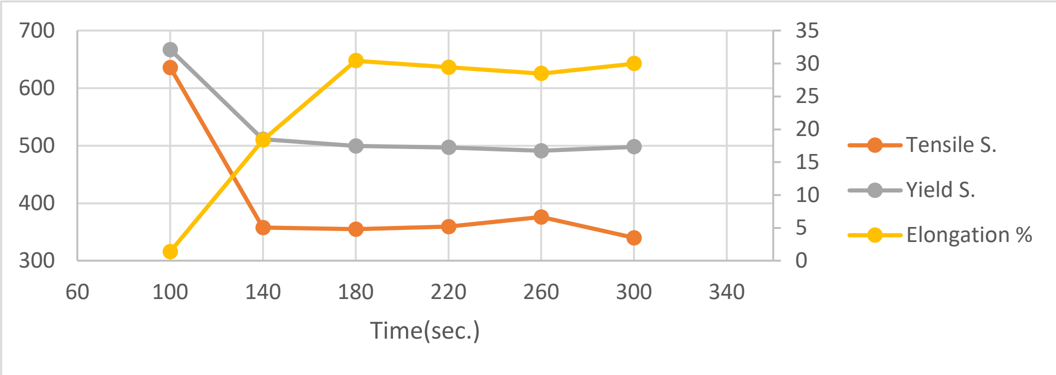

Fig. 7. Mechanical properties of samples 13-18

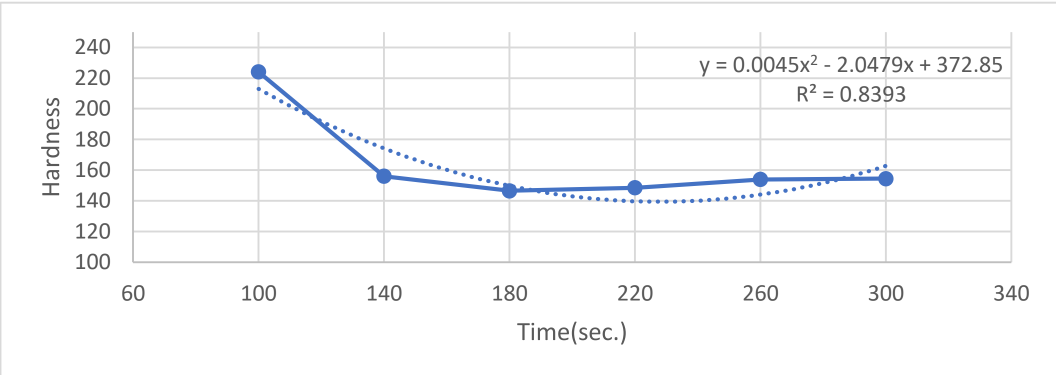

Fig. 8. Hardness values of samples 13-18

3.4. Results Obtained at 1073.15 Kelvin Temperature

5 different times (100sec., 140sec., 220sec., 260sec., 300sec.) were selected at 1073.15 Kelvin temperature. In this test set, a sudden decrease in hardness, yield strength and tensile strength and a sudden increase in percent elongation were observed in the test conditions carried out in 100 and 140 seconds in the first two samples numbered 19 and 20. In samples 21, 22 and 23, the hardness first increased and decreased in sample number 24 compared to sample number 20. Yield strength and tensile strength decreased continuously. The percentage elongation amount was close to each other.

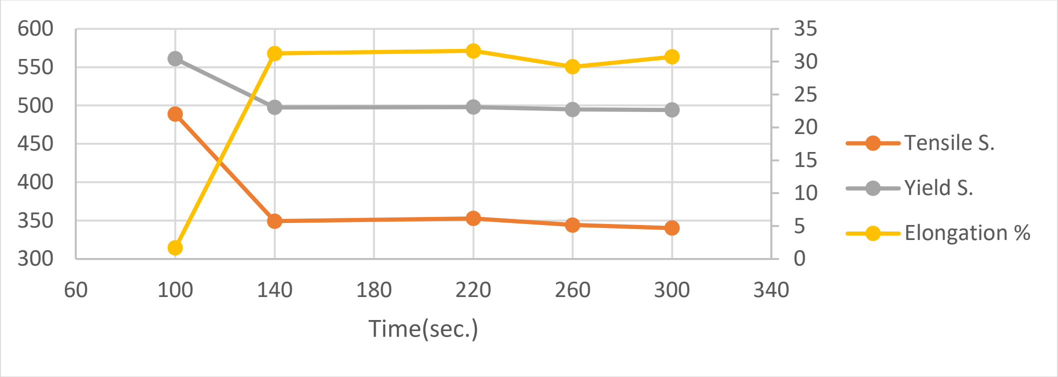

Fig. 9. Mechanical properties of samples 19-23

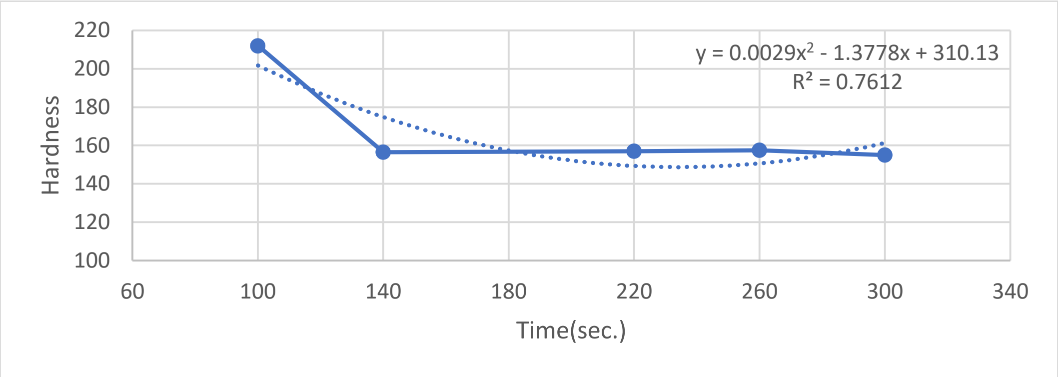

Fig. 10. Hardness values of samples 19-23

3.5. Results Obtained at 1123.15 Kelvin Temperature

Experiments were carried out in 6 different times at a temperature of 1123.15 Kelvin. Hardness, yield strength and percent elongation values decreased in the first two samples. The tensile strength has increased. In other experiments carried out at this temperature, it was observed that the hardness, yield strength and tensile strength increased continuously with increasing test time.

It was observed that the percent elongation value first decreased after entering the cycle, and the percent elongation value, which decreased until sample 27, annealed for 220 seconds, started to increase.

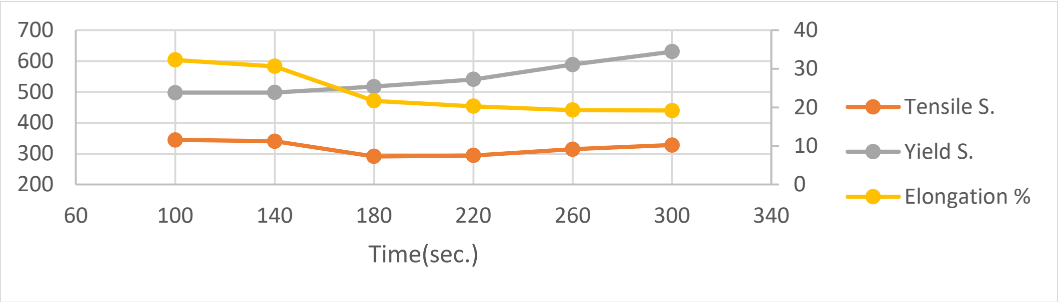

Fig. 11. Mechanical properties of samples 24-29

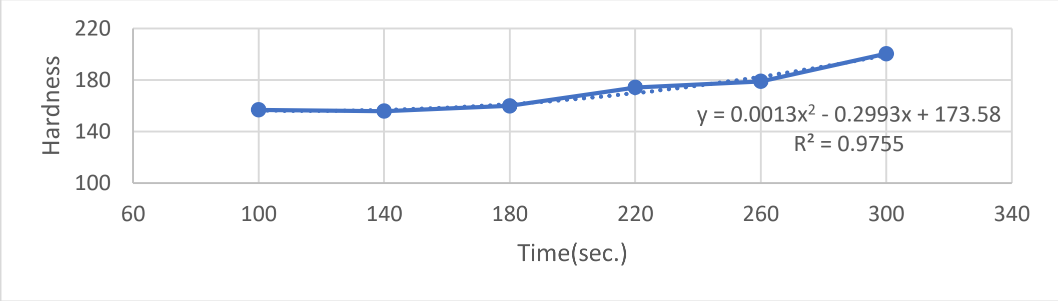

Fig. 12. Hardness values of samples 24-29

3.6. Results Obtained at 1173.15 Kelvin Temperature

At this temperature, the experiments were carried out in 10 different times (100sec., 140sec., 180sec., 220sec., 260sec., 300sec., 380sec., 420sec., 460sec., 500sec). In the experiments carried out at this temperature, it was observed that the hardness, yield strength and tensile strength increased continuously, while the percent elongation value first showed a decreasing trend and then fluctuated and did not have a specific pattern.

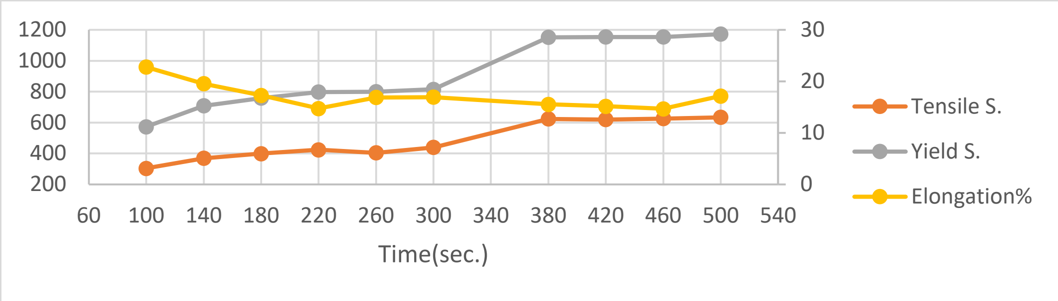

Fig. 13. Mechanical Properties of Samples 30-39

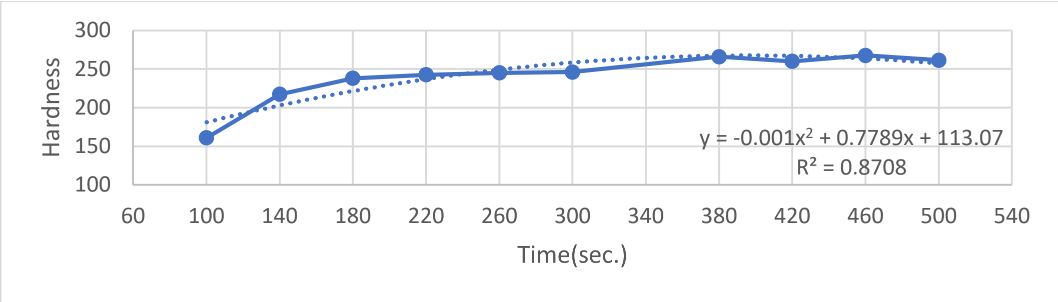

Fig. 14. Hardness Values of Samples 30-39

The graphs created with the obtained data showed us that; These data can be modeled, the value limits of the mechanical properties can be determined and these values can provide the necessary parameters for proper production.

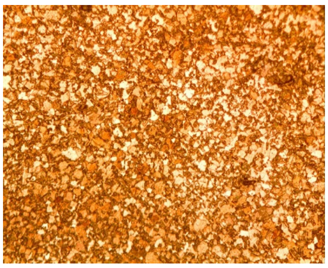

Fig. 15 A. Sample 4

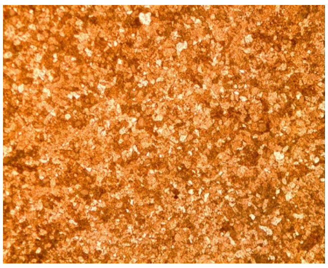

Fig. 15 B. Sample 9

Fig. 15 C. Sample 33

It was observed that the grain boundaries decreased, the grains got bigger, the hardness, yield strength and tensile strengths decreased, and the percent elongation value increased with the increase in heat treatment power in the metallography samples numbered 4 and 9.

While this behavior is expected to continue with the increasing heat treatment power, it was observed that the grain boundaries increased, the grains got smaller, the hardness, yield strength and tensile strengths increased, and the percent elongation value decreased in sample 33. These results also support the question of our study.

4. CONCLUSIONS

It is possible for AISI-430 quality stainless steel, which is heat treated at high temperatures and times, to form carbide precipitates over time through the alphagens in its structure and show different mechanical property tendencies over time, unlike non-ferritic stainless steels.

As a result of the experiments, it was observed that the heat treatment power and heat treatment time should be adjusted with precision in order to prevent non-standard production of AISI-430 quality stainless steel and to prevent the emergence of undesirable mechanical properties.

In this study, these parameters were examined and the values of mechanical properties depending on time and temperature were modeled mathematically.

These values should be observed in order to produce as desired in the production to be made.

Even if the same hardness values are reached in the heat treatments of the same alloy at different heat treatment temperatures and different heat treatment times, different yield strength, tensile strength and percent elongation values can be observed. Productions to be made in this direction can enable the use of the same alloy in different areas.

It has been observed that it is possible to model different mechanical properties in accordance with the experiments performed on different qualities of ferritic stainless steels. This way usage variation of different stainless steel qualities can be possible.

As a result of the data obtained from the experiments, it was observed that the experimental range should be expanded in order to mathematically model the mechanical property values other than hardness.

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