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Investigation of the Effect of Normalization Process on Mechanical Properties and Microstructure of the AISI 4140 Alloy Steel

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Abstract: ***In this study, the effect of the normalization process on the mechanical properties of AISI 4140 alloysteel and the changes in the microstructure of the material were investigated experimentally. For this study, test samples were prepared from AISI 4140 alloysteel. These test samples were collected in 2 groups. While no heat treatment was applied to one of these groups, the other group was only subjected to Normalization. The changes in the mechanical properties and microstructures of the untreated and normalized samples were investigated.***

Keywords: Steel, Quenching, Tempering, Tensile Test, Impact Test, Microstructure

1. Introduction

AISI 4140 alloy steels are widely used in the machinery manufacturing industry. For example, AISI 4140 alloy machine-building steel is used at a rate of 10% in the machining industry and is a steel with high hardenability due to the alloying elements it contains (MKE, 1993).The most important feature of AISI 4140 alloy steel is that it can form a hard martensitic structure after quenching due to the Cr and Mo alloying elements it contains, allowing mechanical properties such as strength, ductility, and toughness to be provided together. For all these reasons, AISI 4140 alloy steel is always common steel. (Avner, 1986; Choo et al., 2000).The brittleness that may occur during tempering at specific temperature values in most machine elements is one of its biggest disadvantages (Oliveira et al., 2000). In order to prevent this negative effect, it is very important to choose the appropriate temper temperature (Charre, 2004; Buytoz, 2004). Therefore, it is necessary to determine the properties of AISI 4140 alloy steel after tempering.

2. Normalization

The main purposes of normalization annealing are;

a) grain reduction,
b) To obtain a homogeneous internal structure,
c) To distribute the carbide network at the grain boundaries in supraeutectoid steels,
d) To improve the processing properties of steels,
e) Improving mechanical properties
f) To increase the hardness and strength of steels subjected to softening annealing.

The waiting time at the normalization level should not be long as it will cause grain growth. In Table 1, normalization times are given according to the thickness of the material to be annealed.

Table 1: Normalization heat treatment times according to part thickness (Töre, 2007)

Part thickness (mm)	Heating Time (min)		Waiting Time at Norm. Temp. (min.)
	Furnace	Salt bath	
T ≤ 6	20	10	15
6.1 ≤ T ≤ 12	30	10	25
12.1 ≤ T ≤ 25	45	10	30
25.1 ≤ T ≤ 38	60	15	30
38.1 ≤ T ≤ 50	75	20	30
50.1 ≤ T ≤ 63	90	25	40
63.1 ≤ T ≤ 75	105	30	45
75.1 ≤ T ≤ 90	120	35	55
90.1 ≤ T ≤ 100	135	40	60
100.1 ≤ T ≤ 125	165	50	75
125.1 ≤ T ≤ 150	195	60	90
150.1 ≤ T ≤ 180	225	75	105
180.1 ≤ T ≤ 200	225	90	120

3. Experiments

3.1 Specimen Material

Rolled low alloy AISI 4140 alloy steel was used in this experiment. Chemical analyzes were carried out in the laboratory of Eti Aluminum A.Ş., Quality Control and R&D Department, using the ARL ADVANT'X XFR spectrometer device. Its chemical analysis is given in Table 2.

Table 2: Chemical composition of AISI 4140 alloysteel

Material	% C	% Si	% Mn	% S	% P	% Cr	% Mo	% Ni
Ç-4140	0,450	0,340	0,790	0,020	0,023	0,860	0,155	0,090

3.2 Experiments

While 3 of the 6 test samples prepared were subjected to the normalization process, no treatment was applied to the other 3 samples.

3.3 Normalization process

A resistance heat treatment furnace was used in these experiments. Two test samples were subjected to the

normalization process. The temperature required for normalization was determined as 870°C from the iron carbon balance diagram. The samples were placed in the furnace and the furnace was started.When the oven temperature reached 870°C, the test samples were kept in the oven for 25 minutes and left to cool in still air.

4. Results

4.1 Effect of Normalization Process on Mechanical Properties

With the normalization process, the microstructure of the material is transformed from coarse pearlite to fine pearlite. This change increases the tensile and yield strength of the steel. This causes a decrease in elongation at break, narrowing of the section and impact strength. Table 3 shows the untreated AISI 4140 alloy steels and the mechanical properties of these steels as a result of the normalization process. Table 4 and Table 5 are compared with other studies.

Table 3: Mechanical properties of untreated and normalized AISI 4140 alloy steels

Compared properties	Untreated	Normalized
Hardness (HRC)	20	26
Tensile Strength (N/mm²)	992	1078
Yield Strength (N/mm²)	723	721
Elongation (%)	14	11
Reduction in cross section (%)	33	22
Impact Resistance (Joule)	46	21

Table 4: Comparison of mechanical properties of untreated AISI 4140 alloysteels with other studies

Compared properties	Our Study	ASME Handbook	Turhan Çökelek (2001)
Hardness (HRC)	20	20	26
Tensile Strength(N/mm²)	992	655	600
Yield Strength(N/mm²)	723	420	500
Impact Resistance(Joule)	46	54	----

Table 5: Comparison of mechanical properties of normalized AISI 4140 alloy steels with other studies

Compared properties	Our Study	ASME Handbook	Turhan, Çökelek (2001)
Hardness (HRC)	26	30	----
Tensile Strength (N/mm²)	1078	1020	1000
Yield Strength (N/mm²)	721	655	950
Impact Resistance (Joule)	21	23	----

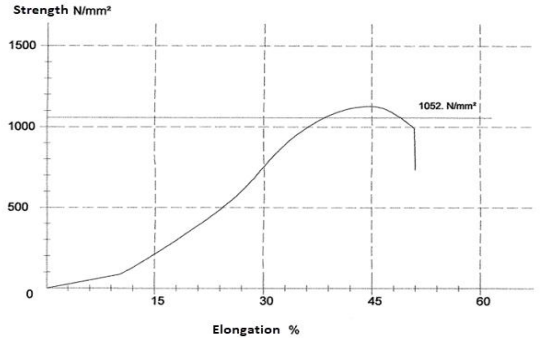

Figure 1: Tensile diagram of untreated AISI 4140 alloy steel

4.2 Effect of Normalization Process on Microstructure

The microstructure of the untreated steel is shown in Figure 2, The microstructure formed as a result of the normalization process is shown in Figure 3. The microstructure of the normalized steel is in the form of ferrite + perlite. The white regions are ferrite and the black regions are pearlite. The structure is in a more homogeneous distribution than untreated steel.

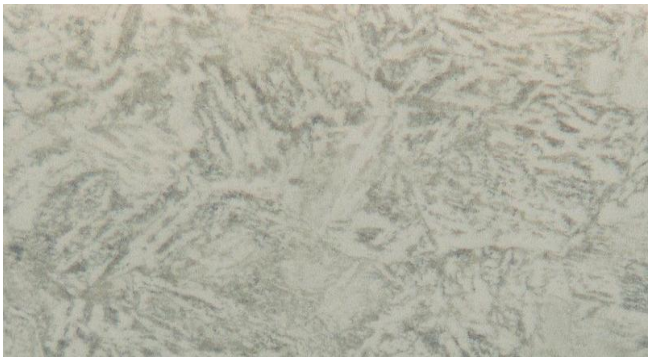

Figure 2: Microstructure of untreated AISI 4140 alloy steel (500X)

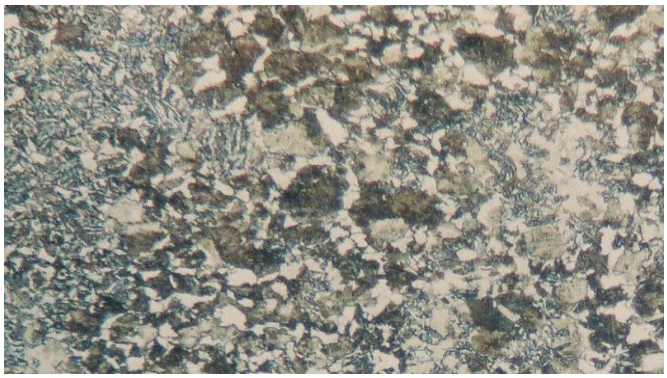

Figure 3: Microstructure of Normalized AISI 4140 alloy steel (500X)

5. Conclusion

An increase in the mechanical properties of the material was observed with the normalization process. And also an increase was observed in tensile and yield strengths due to the thinning of the perlite structure in the microstructure. On the other hand, the impact strength decreased due to the thinning of the grain structure.In the microstructure photographs, it was observed that a homogeneous structure was formed in the material with normalization.

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Author Profile

Yusuf YILMAZ was born in 1960 in Konya. He completed his primary education in Konya. Then he graduated from METU, Mechanical Engineering Department in 1985. He received his master's and doctorate degrees from Selcuk University, Institute of Science. He is still working as a lecturer and Academic Stuff at Konya Technical University.