Effect of Heat Treatment Process on Mechanical Property of 40Cr4 Material

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ABSTRACT: *The 40Cr4 is an alloy steel has a wide uses in engineering industry because of his geometric properties, such as resistance corrosion, high flexibility, appropriate hardness, and its ability to tolerate static and dynamic loads. And it is a very suitable in domestic uses and in manufacturing some of automotive parts and in many engineering applications. In this research a sample of 40Cr4 was selected, where heat treatment (Hardening and Tempering) was carried out for him, this process was carried out at (870, 890) ^{0}C respectively, after that tempering process was carried out at 580 so as to remove the internal stresses and to prevent carbides precipitation which occurs at a temperature of (450-800) ^{0}C for the 40Cr4 steel, also mechanical tests were carried out, which is MPI and hardness tests using Brinell method, This paper also include the theoretical and experimental research on heat treatment process carried out in industry in order to improve mechanical property of 40Cr4. In general the experimental results showed that the heat treatment leads to improve the mechanical properties such as tensile strength, toughness, and hardness the best cases appeared at 880 ^{0}C.*

Keyword :- Heat Treatment, 40Cr4, Hardning, Tempering, toughness

1. INTRODUCTION

40Cr4 is an alloy steel consisting of an average amount of carbon 0.35-0.45%, Silicon 0.10-0.35%, Manganese 0.6-0.9%, Chromium 0.9-1.2%. It is most widely used as a material for automobile component in industry as it possess the better mechanical property such as high tensile strength, toughness, ductility and hardness. Heat treatments or thermal treatment is heating processes usually takes place on 40Cr4 and keep them at a constant temperature for an appropriate period of time depends to bring change to the internal structure followed by a change in the natural and mechanical properties. Required mechanical property of 40Cr4 is achieved by carrying an hardening heat treatment (at 890^0) process followed by tempering(at 570^0) on 40Cr4.[3]

1.1 Hardening

In this process, 40Cr4 is heated to a temperature higher than the upper critical temperature heat and cooled by water or oil or any convenient liquid, where the resulting a single phase solution consists of a complex Carbides such chromium carbide and iron carbide and manganese carbide, this can lead to form a supersaturated solution, which will the saturated excessive carbon atoms be dissolved in the solution due to the rapid cooling, which will make crystal structure have a centered body prism-shaped (BCT). [1]

1.2 Tempering

Where heating to lower than critical temperature is carried out and before austenite reformation to allow again redeployment. This paper deals with heat treatments for a 40Cr4 alloy steel, which is carried out by heating it to temperature above upper critical temperature and stay at this temperature for specified period of time, and then cooling it by direct air, then process of tempering is carried out at 580 ^{0}C in order to remove internal stresses. Heat treatments aim is to change the mechanical and physical properties of metal, where soft stainless steel presence for example does not withstand stresses and does not resist the wear by friction. Processes of Hardening and Tempering where used and Normalising and annealing have been eliminated, that is because the alloying additions and cooling rate in 40Cr4 steel lead to increase in BHN along with that also increase the mechanical properties.[1]

2. RESEARCH METHODOLOGY

The research regarding the heat-treatment influence on the mechanical properties was carried out by going deeply into the following fields of research:

♦ Theoretical study of the 40Cr4 material by the specialty literature regarding the parameter values of the heat treatment applied to that it;

♦ Experimental study of the heat treatment process (hardening and tempering) carried in SANGO AUTO FORGE Pvt. Ltd. with the same chemical composition;

♦ Study of the microstructures resulted for each type of heat-treatment;[2]

2.1 Theoretical Research

The 40Cr4 austenitic structure can be varied by the heat treatment so that a wide range of hardness (229-275HB) and other mechanical properties can be obtained. In the hardened condition the martensitic structure contains agglomerated carbide particles [13]. Depending on the temperature of heat-treatment, the hardened alloy exhibits a austenitic to martensitic structure that results in a tough, erosion-resistant material. The melting temperature of 40Cr4 is 1510^0 C. For required hardness and strength, forged component may be hardened at minimum 890^0 C and usually between 870 ^{0}C and 890 ^{0} C and rapidly cooled in polymer quenching. After that tempering is carried out at a temperature of 570-580^{0}C. The effect of tempering is to reduce the brittleness and to increase the toughness. The corrosion resistance of these alloys is optimum when all carbide is in solution, a condition achieved by rapid cooling from the solution hardening temperature. However, carbide in solution will precipitate at grain boundaries when these alloys are exposed to temperature in the sensitizing range 427 to 871 ^{0}C.[2]

Chemical Composition of 40Cr4 is given in the table as follow:-

Table 1:- Chemical Composition of 40Cr4 steel[1]

Designation	C	Si	Mn	Cr
40Cr4	0.35-0.45	0.10-0.35	0.6-0.9	0.90-1.2

Table 2:- Mechanical properties of 40Cr4[1]

Designation	Tensile strength(N/mm^2)	0.2%proff stress(N/mm^2)	Elongation (%)	Izod impact value(J)	Brinell Hardness(BHN)
	690-840	490	14	55	201-248
40Cr4	790-940	550	12	50	229-277
	890-1040	650	11	50	255-311

The great influence of the hardening temperature and cooling rate on the value of the mechanical properties of 40Cr4as shown in [1] in the following figures. The Figure 1 shows a significant diminution of the hardness in respect of the hardening temperature without important effects regarding the mechanical strength. The propensity of the hardening brittleness in conjunction with the cooling rate possible after the stress-relieving operation may be avoided when the transition from a cooling operation under another conditions featuring rates smaller than 400 C/h.[1]

2.2 Effect of Hardening and Tempering temperature on hardness of 40Cr4

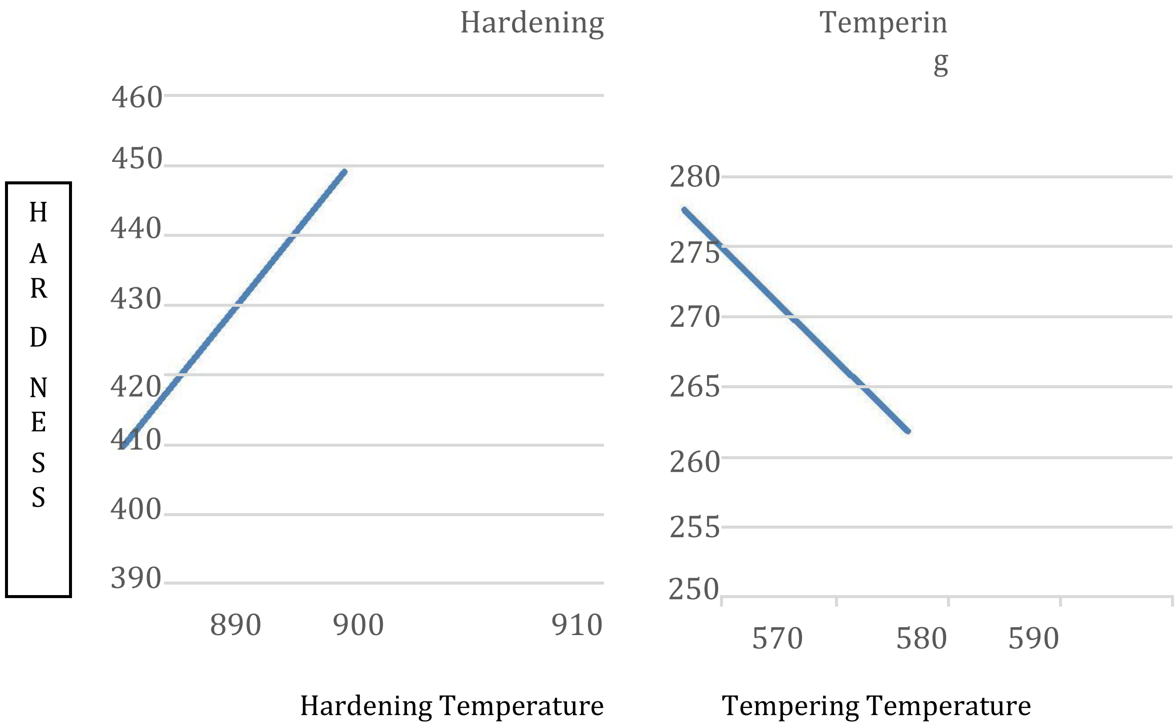

Fig 1:- Graph of Hardness Vs. Tempering Temperature and hardening Temperature[5]

From the graph, we can conclude that-

1. Increase in the hardening temperature, hardness of 40Cr4 increases but at the same time brittleness also tends to increases.

2. Increase in the tempering temperature, hardness of 40Cr4 is also decreases and at the same time ductility is increases in small amount.

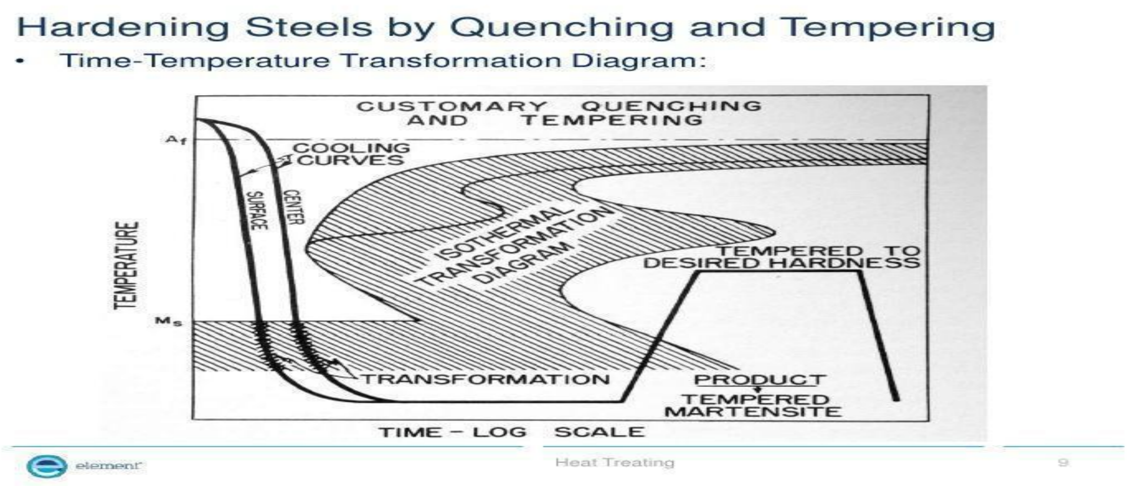

Fig 2:- TTT Diagam for Hardening and Tempering [1]

2.4 Experimental Research

Heat treatment of 40Cr4 steel required the following set up that we used in industry to performed this experiment:-

Furnace Type :- Continuous Automated Furnace with capacity 500 Kg/hr.

Quenchant Type :-

a) Polymer Quenchant(9-10% concen.).

b) Air(Tempering).

Material :- 40Cr4

On 40Cr4 material Hardening and Tempering is done in Sango AutoForge Pvt. Ltd.on trial and error basis and thus the result obtained during experiment is note down in below table:-

Table 2:- Process Experiment Report[5]

S.R.No	PROCESS PARAMETER	PROCESS SETTING SPECIFICATION	EXP.1	EXP.2
A)	**Hardning**			
1	Aust. Temperature °C	880 ^{0} C ± 10 ^{0} C	870 ^{0} C	890^{0}C
2	Cycle Time(Minutes)	20 min	20 min	20 min
3	Soaking Period(Minutes)	1.0Hrs.20 min	1.0Hrs.20 min	1.0Hrs.20 min
4	Quenching Media	Polymer	Polymer	Polymer
5	Agitation	5 Min	5 Min	5 Min
6	Bath Conc.%	Polymer (8 to 10 %)	Polymer (9.5%)	Polymer (9.5%)
7	Bath Temp °C	55 ^{0} C Max	44 ^{0} C	44 ^{0} C
8	Quenching Time(Minutes)	5 min	5 min	5 min
9	Quenching Delay(Sec)	-	-	-
10	As Quenched hardness(BHN)	380 BHN Min	401 – 477 BHN	401 - 477 BHN
B)	**Tempering**			
1	Tempering Temp °C	560 ± 10^0 C	560 – 570 BHN	570 – 580 ^{0} C
2	Time (Minutes)	4.0Hrs	4.0Hrs	4.0Hrs
3	Cooling Media	Air	Air	Air
4	MPI Report	100%	100%	100%
5	Tempered Hardness (BHN)	235 -277 BHN	235 – 255 BHN	241 - 269 BHN
6	Microstructure(Tempered)	Tempered martensite	Tempered martensite	Tempered martensite

From the above experiment, IIND experiment gives the optimum value of hardness(241-269BHN)as per the requirement for the particular application. Further the IInd experiment is finalised along with their parameter value.

This parameter is approved from the concerned authority of industry and given in the following table:-

Table 3:-Finalised process seting parameter[5]

S.R.No	PROCESS PARAMETER	PROCESS SETTING SPECIFICATION	FINALISED PROCESS SETTING PARAMETER
A)	**Hardning**		
1	Aust. Temperature °C	880 ° C ± 10 ° C	890°C
2	Cycle Time(Minutes)	20 min	20 min
3	Soaking Period(Minutes)	1.0Hrs.20 min	1.0Hrs.20 min
4	Quenching Media	Polymer	Polymer
5	Agitation	5 Min	5 Min
6	Bath Conc.%	Polymer (8 to 10 %)	Polymer (9.5%)
7	Bath Temp °C	55 ° C Max	44 ° C
8	Quenching Time(Minutes)	5 min	5 min
9	Quenching Delay(Sec)	-	-
10	As Quenched hardness(BHN)	380 BHN Min	401 - 477 BHN
B)	**Tempering**		
1	Tempering Temp °C	560 ± ° C	570 – 580 °C
2	Time (Minutes)	4.0Hrs	4.0Hrs
3	Cooling Media	Air	Air
4	MPI Report	100%	100%
5	Tempered Hardness (BHN)	235 -277 BHN	241 - 269 BHN
6	Microstructure(Tempered)	Tempered martensite	Tempered martensite

From this finalised process parameter it has been found that the mechanical property of 40Cr4 is mainly depend on –

- Cycle time
- Soaking Period
- Tempering Temperature
- Cooling Rate

2.5) Metallurgical Test Report

After hardening and tempering on 40Cr4, metallurgical property and structure is obtained from the profilometer as shown in following table:

CHEMICAL COMPOSITION %

		C	Mn	Cr	Ni	V	Mo	P	S	Si	Al	Other	Remark
SPECIFIED	MAX	0.35	0.60	1.00	0.00	0.00	0.00	--	0.020	0.10	0.020	--	
	MIN	0.40	0.90	1.20	0.25	0.050	0.050	0.035	0.035	0.35	0.060	--	
ACTUAL		0.361	0.74	1.07	--	--	--	0.015	0.021	0.20	0.260	--	

Table 4:- Metallurgical Test Report[5]

From the above report obtained from the metallurgical department of industry of 40Cr4, is found that the mechanical property of 40Cr4 is fulfill the requirement at a temperature of 880^0c

<table>
<tr><td colspan="4">MECHANICAL PROPERTIES:-</td><td colspan="6">METALLURGICAL PROPERTIES:-</td></tr>
<tr><td rowspan="3">TENSILE STRENGTH Kg/mm.sq</td><td rowspan="3">YIELD STRENGTH Skg/mm.sq</td><td rowspan="3">%E</td><td rowspan="3">%R</td><td colspan="5">INCLUSION RATING</td><td>GRAIN SIZE (ASTM)</td></tr>
<tr><td>SPECIFIED</td><td>A</td><td>B</td><td>C</td><td>D</td><td>SPECIFIED:- 5-8</td></tr>
<tr><td>THIN/THICK</td><td>2.5/1</td><td>2/-</td><td>2/-</td><td>2/-</td><td>OBSERVED:- 7.0</td></tr>
<tr><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td><td rowspan="2">--</td><td>OBSERVED</td><td></td><td></td><td></td><td></td><td rowspan="2"></td></tr>
<tr><td>THIN/THICK</td><td>1.5/0.5</td><td>1/-</td><td>-</td><td>1/-</td></tr>
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<table>
<tr><td>HEAT TREATMENT</td><td colspan="2">HARDNESS</td><td>MICROSTRUCTURE</td><td>ANY OTHER TEST</td></tr>
<tr><td rowspan="2">Hardened & tempered</td><td>SPECIFIED</td><td>235-277 BHN</td><td rowspan="2">Tempered Martensite</td><td rowspan="2">--</td></tr>
<tr><td>OBSERVED</td><td>241-269 BHN</td></tr>
</table>

SPARK TEST DONE	SPECTRAL TEST DONE	MAGNEFLUX DONE
100%	100%	100%

3. Conclusion

The theoretical and experimental study points out the fact that it is necessary to study the influence of the hardening parameters on the mechanical properties of the 40Cr4 steel in order to meet the requirements. Along with that, hardness in the range 236-276 BHN is obtained at a temperature of hardening 880 ^{0}C.
Analyzing the obtained mechanical properties the conclusions can be made:

- If the temperature of the hardening increases, the mechanical properties (i.e. the tensile, hardness and yield strength) increase.
- If the cooling rate during hardening increases, hardness of 40Cr4 is also increases but along with that brittleness is also increases.

4. References

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