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Effect of Quenching Media Variations on the Mechanical Behavior of Martensitic Stainless Steel

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Abstract

The purpose of this study is designate quenching and tempering heat treatment by using Taguchi technique to determine optimal factors of heat treatment (austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time) for increasing hardness, wear rate and impact energy properties of 420 martensitic stainless steel. An (L_{18}) orthogonal array was chosen for the design of experiment. The optimum process parameters were determined by using signal-to-noise ratio (larger is better) criterion for hardness and impact energy while (Smaller is better) criterion was for the wear rate. The importance levels of process parameters that effect on hardness, wear rate and impact energy properties were obtained by using analysis of variance which applied with the help of (Minitab18) software. The variables of quenching heat treatment were austenitizing temperature (985 C°,1060 C°),a soaking times (50,70 and 90 minutes) respectively, Percentage of volumetric fractions of nanoparticles with three different levels(0.01, 0.03 and 0.08 %) were prepared by dispersing nanoparticles that are (α-Al_2O_3,TiO_2 and CuO) with base fluids (De-ionized water, salt solution and engine oil).The specimens were tempered at 700°C after quenching of nanofluids for (2 hours).The results for (S/N) ratios showed the order of the factors in terms of the proportion of their effect on hardness, and wear rate properties as follow: Austenitizing temperature (1060 C°),Type of base media (salt solution), Nanoparticles type (CuO), Percentage of nanoparticles (0.08%) and Soaking time(90min) was the least influence while for the impact energy were as follows: Type of base media (oil), Austenitizing temperature (985C°), Percentage of nanoparticles (0.01%), Nanoparticles type (α-Al_2O_3) and last soaking time (50min).

Keywords: *Nanofluids, quenching, hardness, wear, impact energy, Taguchi technique.*

1. Introduction

Martensitic stainless steels occupy a unique status as engineering materials by virtue of their excellent combination of properties. These steels find extensive application in chemical plants, power generation equipments and many other applications [1,2]. Unlike other types of stainless steels, the properties of martensitic stainless steels are greatly modified by normal heat treatment procedures [3,4]. To enhance heat transfer to meet the cooling challenge necessary. New type of quenching media has been developed, it is called nanofluids [5]. Nanofluid is a fluid containing nanometer-sized particles, called nanoparticles. These fluids are engineered colloidal suspensions of nanoparticles with sizes typically of the order of (1-100 nm) in a base fluid. Choi in 1995 coined the term nanofluids for this new class of heat transfer fluids [6,7]. The nanoparticles used in nanofluids are typically made of metals, oxides, carbides, or carbon nanotubes. Nanofluids have novel properties that make them potentially useful in many applications in heat transfer. Nanofluids show improved stability compared to the conventional fluids added with micrometer or millimeter-sized solid particles because of its size effect and Brownian motion of the nanoparticles in liquids [8].Possible reasons of discrepancy in experimental data Attributed to the complexity of correlations between nanofluid parameters such as material , concentration, size and shape of nanoparticles and properties as density, pH value and thermal conductivity to obtain on the better type of nanofluids as well as many of heat treatment parameters to get optimum structural material for desired application. This study investigated with the Taguchi method to optimize 420 martensitic stainless steel heat treatment process parameters, austenitizing temperature, percentage of nanoparticles, type of base media, type of nanoparticles and soaking time to get the better hardness, wear and impact energy properties.

2. Experimental Procedure

2.1. Materials

The following materials were used in the nanofluids synthesis because of its good thermal properties: Nano titanium dioxide (TiO_2) powder, nano aluminum oxide(α-Al_2O_3) powder and copper oxide (CuO) nanoparticle (supplied by Zhengzhou Dongyao nano materials Co.LTD.). The properties of these nanoparticles are given on table (1). Those materials were added to base media (Deionized water, Salt solution (NaCl+water) and Engine oil). Sodium lauryl sulphate as surfactant was used.

Table1,
Physical properties of nanoparticles.

Nanoparticle material	APS (nm)	Purity (%)	Specific surface area (m2/g)	Volume density (g/cm^3)	Density(g/cm3)	Crystal form	Color
α-Al_2O_3	50	>99.99	160.1	0.916	3.91	γ	white
TiO_2	20	>99.9	220	0.25	3.9	Cube	white
CuO	50	>99.9	120	0.30-0.45	6.4	Sphere	black

2.2. Nanofluid Preparation

In this research, eighteen types of nanofluid are prepared [(Al_2O_3/ Deionized water), (Al_2O_3/ salt solution), (Al_2O_3/ engine oil)], [(TiO_2/ De ionized water),(TiO_2/ salt solution), (TiO_2/ engine oil)], [(CuO/ De ionized water), (CuO / salt solution), (Cuo / engine oil)] with volume fractions of (0.01, 0.03 and 0.08%).In this paper nanofluid was prepared by two step method where the given nanoparticle is mixed to the base fluid to obtain suspension. Law of mixtures was employed to determination quantity of nanoparticles wanted for preparation of nanofluids. The mass of nanoparticles (M_p) and base fluid (M_f) are measured with balance of (0.0001 g) an accuracy. The weight percentage (ϕ) can be calculated by using Eq (1).

$$\phi = \frac{M_{np}/\rho_{np}}{\frac{M_{np}}{\rho_{np}}+\frac{M_{bf}}{M_{bf}}} \quad \ldots (1)$$

Where:

Φ: volume fraction.

M_{np}: mass of nanoparticle(g).

ρ_{np}: density of the nanoparticle(g/L).

M_{bf}: mass of the base fluid (g).

ρ_{bf}: density of the base fluid(g/L) [9].

A mechanical stirrer was used to achieve a homogenously dispersed solution. This method was based on Han and Rhi (2011) [10] and Mahendran et al., (2012), [11]. After preparing the proper mix of the nanoparticles and fluids by mechanical stirrer, nanoparticles are dispersed in fluids using magnetic stirrer. During the process Sodium Dodecyl Sulphate (SDS) surfactant is added to the solution in proper proportions to ensure stability of nanofluid. For various purposes, sound energy is used to agitate the particles in nanofluid, this process is known as sonication. By breaking intermolecular interaction, sonication is also used for speed up the dissolution. Sonication is more useful when the magnetic stirring was not much effective for given sample. For nanoparticles which were not evenly dispersing in liquids, sonication is most preferable. The sonication process is achieved in two steps were:

A- Initially Sonicate the mixture continuously for (30 min) with sonicator of frequency (40 KHz) to obtain uniform dispersion of nanoparticles in fluids, this process is achieved with ultrasonic mixer (LUC – 410(50 Hz,400W)). B-Sonicate the mixture continuously for (90 min) with probe sonicator (model 300 VT ultrasonic homogenizer) of output frequency (20 KHz).

2.3. Material of the Research Specimens

The 420 martensitic stainless steel samples were taken for this study. The chemical composition analysis of the specimens was carried out at the (Specialized Institute for Inspection and Engineering Qualifying/Iraq) by x-ray fluorescent. The chemical composition of the 420 martensitic stainless steel is shown in table (2).

Table 2,
The chemical composition of 420 martensitic stainless steel specimens.

Element	C%	Si%	Mn%	P%	S%	Cr%	Mo%	Ni%	Al%	Cu%	Fe%
Composition %	0.279	0.519	0.348	0.029	0.01	12.64	0.065	0.14	0.005	0.055	Bal

2.4. Heat Treatment Process

Eighteen types of heat treatment were performed, these were exhibited of Schedule (4). Quenching heat treatment was implemented to harden the 420 martensitic stainless steel. Quenching heat treatment includes heating of samples to austenitizing temperature in an electric furnace (carbolite cwf 1200 muffle furnace) where the samples was held at (985°C, 1060°C) of heating rate (7°C /min)with soaking times (50,70 and 90 min) to ensure uniformity of temperature throughout the full volume to attain a identical structure of austenite, subsequently each group of samples were quenched in diverse quenching mediums (nanofluids) ,and finally tempered at (700°C) for (2)hours.

2.5. Wear and Hardness Properties

Calibrated Vickers hardness measurements were performed on all the samples to determine the hardness of the martensitic stainless steel in each heat treatment condition. Results were reported as adjusted from five tests per sample. All of the procedures were carried out according to the (ASTM E92-82/E2) standard method. The wear resistance of martensitic stainless steel being studied was evaluated using a Pin-on-Disc Tribometer, according to the testing procedure outlined in (ASTM Designation G 99 - 95A). The specimens of same dimensions were grinded and polished used for both abrasive wear rate analysis and hardness testing. Dimensions of the specimen are (10mm × 10mm × 5mm). A parameter referred to as wear rate used to define the wear severity was calculated using Equation (2).

$$W_R = \frac{\Delta V}{F_n * S_S} \quad \dots (2)$$

Where:
W_R= wear rate.
ΔV= Volume loss of the specimen.
Ss = Sliding distance (m).
F_n = Normal load (N). [12]

The wear test was carried out with constant sliding speed (200 rpm), time (10 min) and load (1٥ N) To find out the effect of the experiment parameters (austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time). Wear tests are performed under dry nonlubricated condition and at ambient temperature of 25 °C.

2.6. Charpy Impact Test

The charpy impact test of the quenched martensitic stainless steel sample was carried on JBS impact testing machine. The specimens were supported horizontally with the V-notch opposite to the strike end. The energy absorbed before fracture was then read directly on the digital gauge of machine. The Charpy V-notch test method has been standardized according to the (ASTM standard E23).

2.7. Microstructure Analysis

The analysis of the microstructures gained for several variants of heat treatment was analyzed by using optical Microscopic. In preparation for examination under the optical microscope, the samples were finely polished and etched to expose the microstructure. A Villela etchant was chosen from the list of etchants in (ASTM E407-07) Standard Practice for Micro etching Metals and Alloys (ASTM International,2007). The determination of the phases present in the treated samples was carried out by X-ray diffractometry

(XRD) technique, using a Shimadzu (XDR7000) X-ray.

3. Taguchi Method

The Taguchi method is a powerful tool for designing high quality systems based on orthogonal array experiments that provide much-reduced variance for experiments with an optimum setting of process control parameters [13,14]. The method has also been widely used in engineering analysis to optimize performance characteristics through design parameter settings. The Taguchi method is based on orthogonal arrays and analysis of variance (ANOVA) to minimize the number of experiments and to effectively improve product quality [14,15].

4. Design of Experiment

The experimental procedures include parameters (variables) and levels as shown in table (3) based on the Taguchi technique. Austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time, these are process parameters that considered for this study. In the present investigation an(L_{18}) orthogonal array was chosen as shown in table (4). The experiments were performed based on the run order generated by Taguchi model. This analysis involve the rank based on the delta statistics, which equals the relative value of the effects. The experimental results were transformed into signal-to-noise ratio (S/N). The (S/N) ratio for the (hardness and impact energy) using "Larger the better" characteristics as for the wear property using "Smaller the better" characteristics, which can be calculated as logarithmic transformation of the loss function is given as:

A.Larger the Better (LTB)

$$\frac{S}{N} = -10\log 10 1/n \sum[1/Y_i^2] \quad \dots (3)$$

B. Smaller the Better (STB)

$$\frac{S}{N} = -10\log 10 \sum[Y_i^2 /n] \quad \dots (4)$$

Where: Y: results of experiments, observations or quality, N: Number of trials of repetitions, S: the variance [16].

Table 3,
Control factors and their levels.

Symbol	Control factors	Levels			Unit
A	Austenitizing temperature	985	1060	-----	°C
B	Concentration media	0.01%	0.03%	0.08%	-----
C	Base media	Deionized water	Salt solution	Engine oil	-----
D	Nano particles type	α-Al_2O_3	TiO_2	CuO	-----
E	Soaking time	50	70	90	min

5. Results and Discussions
5.1. S/N Ratios Analysis

The (S/N) ratio response was analyzed using the equation (3) for the hardness and impact energy while equation (4) using for wear rate, Figures (1,2,3) and table (5) shows the main effects plots of (S/N) ratios for hardness, wear and impact energy. From the figures (1,2,3) and table (5) it is evident that the order of factors by effect was as follows: Austenitizing temperature (1060C°), Type of base media (salt solution), Nanoparticles type (CuO), Percentage of nanoparticles (0.08%) and Soaking time(90min) was the least influence while for the impact energy were as follows: Type of base media (oil), Austenitizing temperature (985C°), Percentage of nanoparticles (0.01%), Nanoparticles type (α-Al_2O_3) and last soaking time (50min).

Table 4,
Signal to Noise Ratios for the controlling factors considering Hardness, Wear rate and Impact energy.

Exp.t	Parameters					Hardness (HV)	S/N-hardness	wear rate mm3/N.m	S/N-Wear Rate	Impact Energy (J)	S/N - impact Energy
	A	B	C	D	E						
1	1	1	1	1	1	352	50.931	2.86E-07	130.881	61	35.707
2	1	1	2	2	2	434	52.75	1.71E-07	135.318	55	34.807
3	1	1	3	3	3	411	52.277	1.94E-07	134.23	56	34.964
4	1	2	1	1	2	401	52.063	2.06E-07	133.734	54	34.648
5	1	2	2	2	3	485	53.715	1.03E-07	139.755	51	34.151
6	1	2	3	3	1	411	52.277	1.94E-07	134.23	58	35.269
7	1	3	1	2	1	423	52.527	1.71E-07	135.318	51	34.151
8	1	3	2	3	2	471	53.46	1.14E-07	138.839	47	33.442
9	1	3	3	1	3	411	52.277	1.94E-07	134.23	58	35.269
10	2	1	1	3	3	499	53.962	9.14E-08	140.778	46	33.255
11	2	1	2	1	1	471	53.46	1.14E-07	138.839	53	34.486
12	2	1	3	2	2	446	52.987	1.37E-07	137.256	54	34.648
13	2	2	1	2	3	544	54.712	5.71E-08	144.86	47	33.442
14	2	2	2	3	1	544	54.712	5.71E-08	144.86	47	33.442
15	2	2	3	1	2	423	52.527	1.71E-07	135.318	56	34.964
16	2	3	1	3	2	528	54.453	6.86E-08	143.276	43	32.669
17	2	3	2	1	3	528	54.453	6.86E-08	143.276	44	32.869
18	2	3	3	2	1	471	53.46	1.14E-07	138.839	52	34.32
(untreated)						86 HRB		4.29E-04		35	

Table 5,
Responses table for SN ratio-(Hardness, Wear rate and Impact energy).

Hardness	Austenitizing temperature	percentage of nanoparticles	type of base media	nanoparticles type	soaking time
Level 1	52.47512277	52.72776842	53.10786924	52.61841352	52.89455189
Level 2	53.85840718	53.33422033	53.75835368	53.35842167	53.03988053
Level 3		53.43830616	52.634072	53.52345973	53.5658625
Delta	1.383284414	0.710537741	1.124281686	0.905046212	0.671310612
Rank	1	4	2	3	5
Wear Rate	**Austenitizing temperature**	**percentage of nanoparticles**	**type of base media**	**nanoparticles type**	**soaking time**
Level 1	135.1706082	136.2169574	138.1410788	136.046449	137.1612949
Level 2	140.8114511	138.7928115	140.1479454	138.5575413	137.2901705
Level 3		138.9633199	135.6840646	139.3690986	139.5216235
Delta	5.640842898	2.74636247	4.46388082	3.322649534	2.360328665
Rank	1	4	2	3	5
Impact Energy	**Austenitizing temperature**	**percentage of nanoparticles**	**type of base media**	**nanoparticles type**	**soaking time**
Level 1	34.71193002	34.64436004	33.97872639	34.65689387	34.56235025
Level 2	33.78830151	34.31925224	33.86619043	34.25332668	34.1963485
Level 3		33.78673501	34.90543048	33.84012675	33.99164854
Delta	0.923628509	0.857625031	1.039240057	0.816767126	0.57070171
Rank	2	3	1	4	5

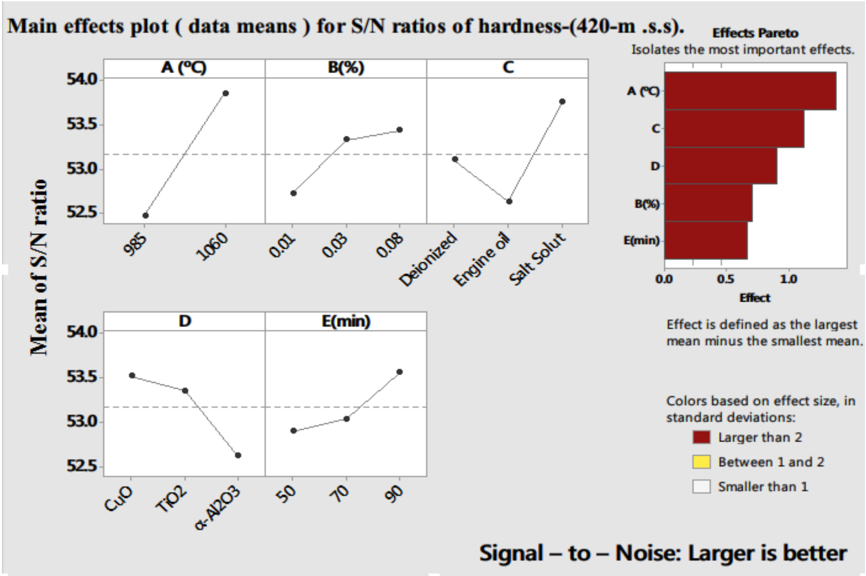

Fig. 1. Main effects plots for SN ratios-(Hardness).

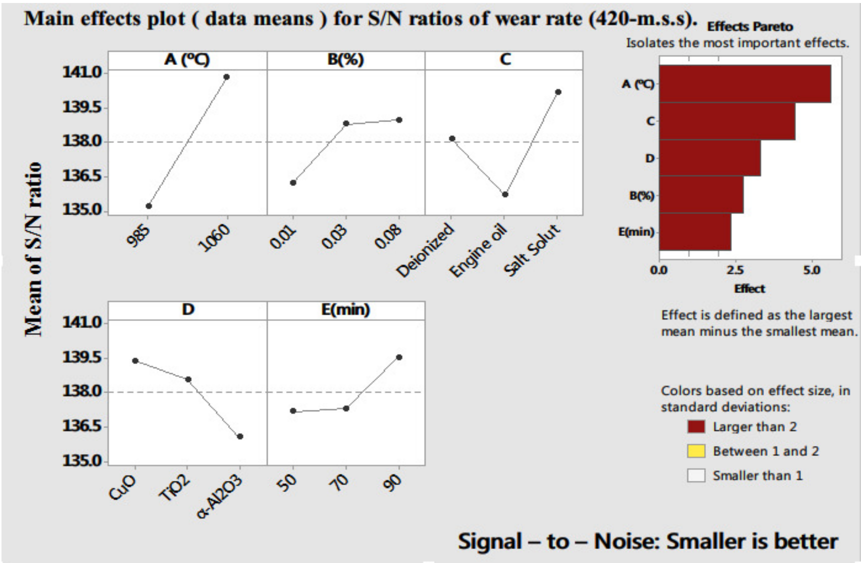

Fig. 2. Main effects plots for SN ratios- (Wear rate).

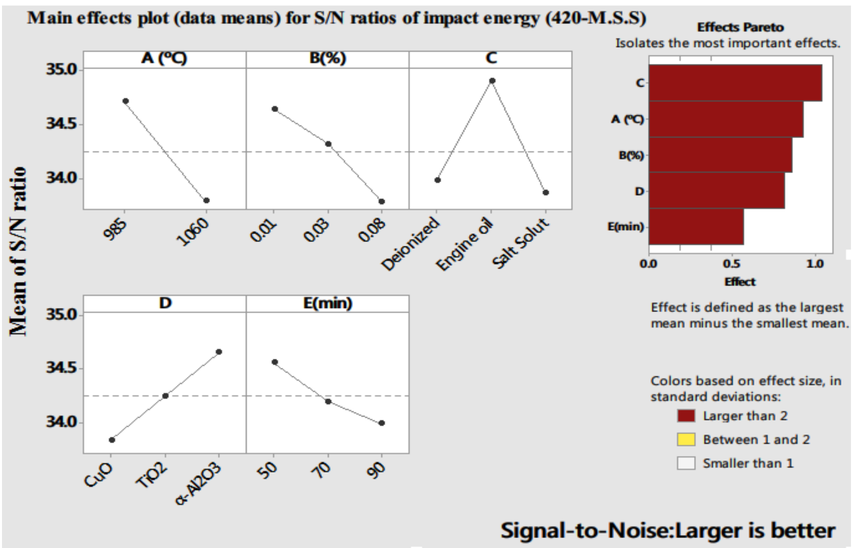

Fig. 3. Main effects plots for SN ratios- (Impact energy).

5.2. ANOVA Analysis

Analysis of variance (ANOVA) was used to analyze the influence of parameters (austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time) on the hardness, wear rate and impact energy properties of 420 martensitic stainless steel. The (ANOVA) determines the relative significances of factors in expressions of their percentage contribution to the response[17].We can observe from the (ANOVA) analysis (Table(6) that the ranking of parameters according to its influence on the total variation on hardness, and wear rate properties were as follows: Austenitizing temperature, Type of base media, Nanoparticles type, Percentage of nanoparticles and Soaking time was the least influence while for the impact energy were as follows: Type of base media , Austenitizing temperature , Percentage of nanoparticles, Nanoparticles type and last soaking time .

Table 6,
Results of the (ANOVA). (Hardness, Wear rate and Impact energy).

			Hardness			
Source	DF	AdjSS	Adj MS	F-Value	P-Value	% of contribution
A	1	23835	23834.7	171.76	1.09E-06	46.02506
B	2	4809	2404.5	17.33	0.0012372	9.286114
C	2	10804	5402	38.93	7.537E-05	20.86238
D	2	7116	3558.2	25.64	0.0003316	13.7409
E	2	4112	2056.2	14.82	0.0020416	7.940217
Error	8	1110	138.8			2.143395
Total	17	51787				100
			Wear Rate			
Source	DF	AdjSS	AdjMS	F-value	P-Value	% of contribution
A	1	3.16E-14	3.16E-14	135.07	2.74E-06	47.16418
B	2	6.4E-15	3.2E-15	13.61	0.002661	9.552239
C	2	1.23E-14	6.1E-15	26.26	0.000305	18.35821
D	2	1.03E-14	5.1E-15	21.98	0.000562	15.37313
E	2	4.6E-15	2.3E-15	9.8	0.007062	6.865672
Error	8	1.9E-15	2E-16			2.835821
Total	17	6.7E-14				100
			Impact Energy			
Source	DF	AdjSS	AdjMS	F-value	P-Value	% of contribution
A	1	133.39	133.389	88.11	0.0000136	28.96634
B	2	76	38	25.1	0.000357	16.5038
C	2	134.33	67.167	44.37	0.0000468	29.17047
D	2	70.33	35.167	23.23	0.0004657	15.27253
E	2	34.33	17.167	11.34	0.0046238	7.45494
Error	8	12.11	1.514			2.62975
Total	17	460.5				100

where: DF=Degree of Freedom, Seq SS=Sequential Sum of square, Adj SS=Adjacent Sum of Square, Adj MS=Adjacent mean Square, F=Fisher's test.

5.3. Regression Equation

A Regression model is developed using statistical software (MINITAB 18). Regressions equation make correlations correlations between the significant terms acquired from (ANOVA) analysis namely (austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time).

Hardness (HV) = 458.50 - 36.39 A(ºC)_985 + 36.39 A(ºC)_1060 - 23.00 B(%)_0.01 + 9.50 B (%)_0.03 + 13.50 B(%)_0.08 - 0.67 C_Deionized water - 29.67 C_Engine oil + 30.33 C_Salt Solution + 18.83 D_CuO + 8.67 D_TiO_2 - 27.50 D_α-Al_2O_3 - 13.17 E(min)_50 - 8.00 E(min)_70 + 21.17 E(min)_90 … (5)

Wear= Rate 1.3969E-07+ 4.191E-08A(ºC)_985 - 0.000000 A(ºC)_1060+ 2.603E-08 B(%)_0.01 - 8.25E-09 B(%)_0.03 - 0.000000 B(%)_0.08+ 6.98E-09 C_Deionized water + 2.794E-08 C_Engine oil- 0.000000 C_Salt Solution - 1.968E-08 D_CuO - 1.397E-08D_TiO_2+ 0.000000 D_α-Al_2O_3 + 1.651E-08 E(min)_50 + 5.08E-09 E(min)_70- 0.000000 E(min)_90 … (6)

Impact= Energy 51.833 + 2.722 A(oC)_985 - 2.722 A(ºC)_1060 + 2.333 B(%)_0.01 + 0.333 B(%)_0.03- 2.667 B(%)_0.08 - 1.500 C_Deionized water + 3.833 C_Engine oil - 2.333 C_Salt Solution - 2.333 D_CuO - 0.167 D_TiO_2 + 2.500 D_α-Al_2O_3 + 1.833 E(min)_50 - 0.333 E(min)_70 - 1.500 E(min)_90 … (7)

5.4. Model Summary

From the graphs (4-A,4-B,4-C) shows that the data closely follow the straight lines, denoting a normal distribution.

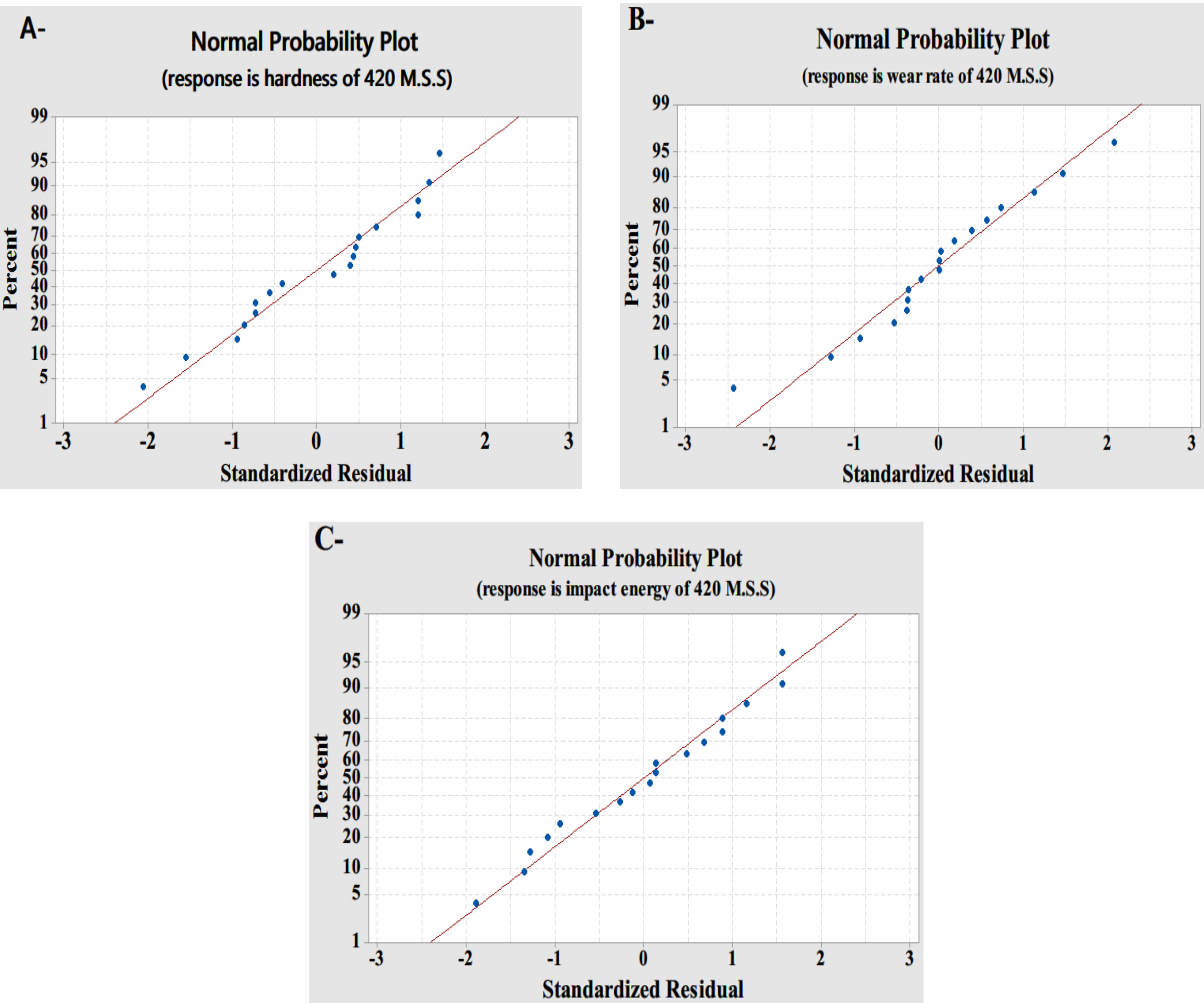

Fig. 4. Normal probability plot of residuals: A-hardness, B-wear rate and impact energy of 420 stainless steel).

Also table (8) shows that (R^2) approaches for this model very close to unity, and thus acceptable. It demonstrates that 97% approximately of the variability in the data can be explained by this model. Thus, this model provides reasonably good explanation of the relationship between the independent factors and the response.

Table 7,
Model summary of (Hardness, Wear rate and Impact energy).

	Hardness	Wear Rate	Impact Energy
S	11.7798	1.53E-08	1.2304
R-sq	97.86%	97.21%	97.37%
R-sq(adj)	95.44%	94.06%	94.41%
R-sq(pred)	89.15%	85.86%	86.69%

5.5. Microstructural Analysis

From the micrograph that shows in figure (7) of samples quenched at different quenchants medium and tempered at (700°C) for (2 hours), it is noted that a microstructure consisting of full martensitic matrix with different ratios of un dissolved carbide dependent on heat treatment variables (austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time).

Steels with more than (0.2%) carbon and (12-13%) chromium content consist of different volumes of (M3C, M7C3, and M23C6) carbide precipitate [18]. In this investigation, only (M23C6) carbides can be said to be identified due to the austenitizing and tempering temperatures used. As it is shows of the micrograph that shown in Figure (7) and the(XRD) spectrum in figures (5,6) for samples austenitized at temperatures of (985 and 1060 °C) if we take it as examples of the heat treatments that were conducted, it clearly appears a reduction in intensity associated with a displacement to smaller angles. The peak displacement increases with increasing quenched temperature, showing the greater chromium carbides decomposition with temperature and the increased martensite saturation by carbon.Getting (M23C6) carbide as a final consequence and decreasing it with increase of austenitizing temperature this explains increasing in hardness and decrease wear rate that can be attributed to increment of both chromium and carbon content dissolved in the martensite[19,20].

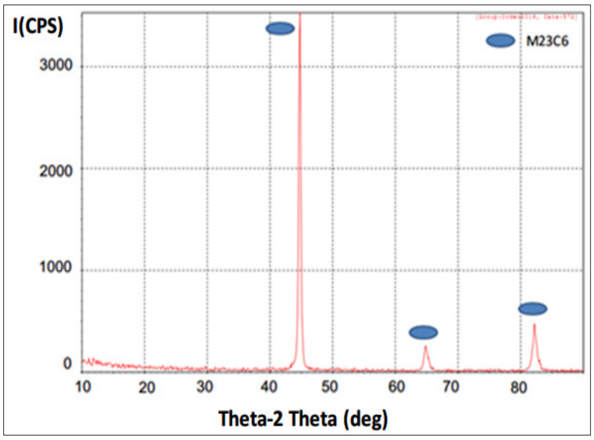

Fig. 5. X-ray diffraction pattern of AISI420 martensitic stainless steel cooled of (0.08%α-Al_2O_3+engine oil) at 985 ºC for 90 min and tempered at (700°C) for (2 hours).

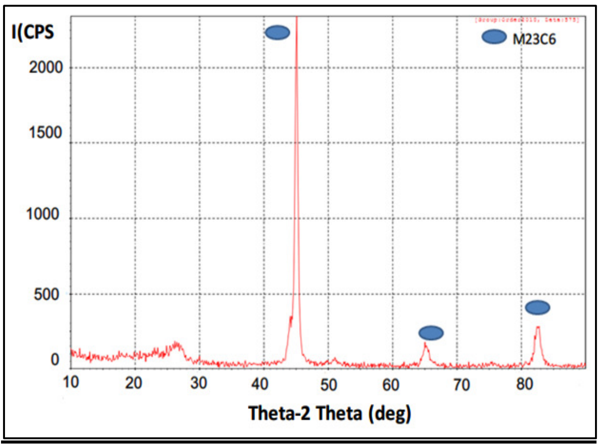

Fig. 6. X-ray diffraction pattern of AISI 420 martensitic stainless steel cooled of (0.03% α-Al_2O_3+engine oil) at 1060 ºC for 70 min and tempered at (700°C) for (2 hours).

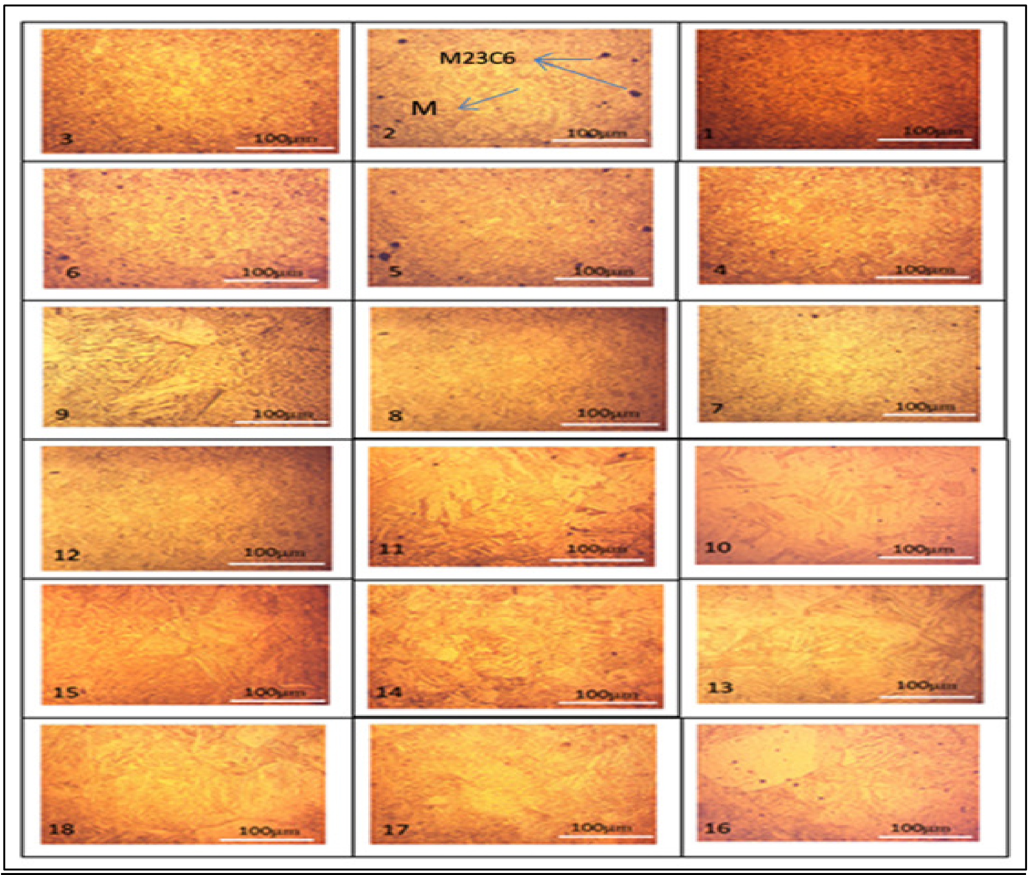

Fig. 7. Optical microstructure of the specimens rank from (1 to 18) according to design of experiment that shown in table (2).

6. Conclusions

The approach of (Taguchi's) robust design method to study hardness, wear rate and impact energy for 420 martensitic stainless steel led to conclude the following:

1-The Taguchi method was successfully applied to determine the optimal values of austenitizing temperature, percentage of nanoparticles, type of base media, nanoparticles type and soaking time in order to maximize the hardness, impact energy and minimize wear rate.

2-The hardness value and impact energy value of the heat treated specimens were greater than that of untreated specimens and the wear rate was less for heat treated specimens.

3-From response table for (S/N) ratio with respect to the hardness and wear rate we can marked on the most important factor where the ranking of factors as follows in terms of the proportion of their effect on hardness, and wear rate properties: Austenitizing temperature (1060C°), Type of base media (salt solution), Nanoparticles type (CuO), Percentage of nanoparticles (0.08%)and Soaking time(90min) was the least influence while for the impact energy were as follows: Type of base media (oil), Austenitizing temperature (985C°), Percentage of nanoparticles(0.01%), Nanoparticles type (α-Al_2O_3) and last soaking time (50min).

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تأثير اختلاف وسط التقسية على السلوك الميكانيكي لفولاذ مقاوم للصدأ مارتنسياتي

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الخلاصة

الغرض من هذه الدراسة هو تصميم معاملة حرارية (اخماد ومراجعة) بوساطة استخدام تقنية تاغوتشي لتحديد العوامل المثلى للمعاملة الحرارية (درجة حرارة الاوستنايت النسبة المئوية للجسيمات النانوية و نوع وسط الأساسو نوع الجسيمات النانوية ووقت النقع) لزيادة الخواص (الصلادة,معدل البلى وطاقة الصدمة) لفولاذ مقاوم الصدأ المارتنسايتي ٤٢٠. تم اختيار مصفوفة متعامدة($L_{١٨}$) لتصميم التجربة. عوامل العملية المثلى حددت باستخدام معيار (Signal/Noise) (الأكبر هو الأفضل) للصلادة وطاقة الصدمة بينما معيار (الأصغر هو الأفضل) كلا لمعدل البلى. تم الحصول على مستويات الأهمية لعوامل العملية على خواص الصلادة,معدل البلى وطاقة الصدمة باستخدام تحليل التباين المطبق بمساعدة برنامج (منتاب١٨).المتغيرات للمعاملة الحرارية (اخماد) كانت درجة حرارة الأوستنايت (٩٨٥ °C، ١٠٦٠°C) ، وأوقات النقع (٥٠،٧٠ ، ٩٠ دقيقة) على التوالي، النسبة المئوية للكسور الحجمية للجسيمات النانوية بثلاثة مستويات مختلفة (٠,٠٣، ٠,٠١، و٠,٠٨%) تم تحضيرها من خلال تشتيت جسيمات نانوية التي هي (CuO،TiO_2،α-Al_2O_3) بأوساط أساسية (الماء غير المتأين، محلول الملح، زيت المحرك).تم مراجعة العينات بدرجة (٧٠٠ °C) لساعتين بعد الاخماد بالموائع النانوية .أظهرت النتائج لنسب (S/N) ترتيب العوامل من حيث نسبة تأثيرها على الخواص الصلادة ومعدل البلى على وفق النحو الاتي : درجة حرارة الاوستنايت (١٠٦٠ °C),نوع وسط الاساس(محلول ملحي), نوع الجسيمات النانوية (CuO), وقت النقع(٩٠ دقيقة) واخيرا النسبة المئوية للجسيمات النانوية (0.08%) بينما لطاقة الصدمة كانت على وفق النحو الاتي: نوع وسط الاساس(زيت المحرك), درجة حرارة الاوستنايت (٩٨٥°C)، نوع الجسيمات النانوية (α-Al_2O_3)، النسبة المئوية للجسيمات النانوية (٠.٠١%) واخيرا وقت النقع (٥٠ دقيقة).