Optimization Process Parameters Of Aisi 1020 Gas Carburized Steel

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Abstract- In this investigation various mechanical properties of AISI 1020 steel at different process parameters like carburizing temperature, soaking time, tempering temperature and temperature time were optimized using L9 Taguchi technique. Hardness, impact strength and wear resistance were taken as response variables. It is observed during investigation that heat treatment followed by quenching and tempering tremendously improves the hardness, impact strength and wear resistance of AISI 1020. In order to predict optical parameter, confirmation test was conducted for implementation of L9 Taguchi technique.
Key words- Gas carburization, AISI 1020 Steel, Taguchi method

I. INTRODUCTION

With the advancement of technology, materials with better tribological properties are in demand. Researchers are getting more interested in the improvement of fatigue behaviours of machines and structures. High strength steel is widely used in the structures of various machines such as compressors, aircrafts, and in space applications [1]. In order to achieve these improved tribological properties, various heat treatment processes have been developed for many years. The aim of present study is to review the surface hardening processes, and their pros and cons. In surface hardening process steel is heated and held above the critical temperature, and rapidly cooled in water, oil or molten salt baths. Surface hardening improves the wear resistance of the metal part without affecting the interior soft core [2]. This combination of hard and tough surface, soft core helps during impact shocks in many machine parts such as bearings, shafts and turbines etc.[3]. Therefore enhancement in mechanical properties of materials is always mandatory. The process of case hardening by carburizing is very old and most effective process for hard steel production of swords and knives from medieval times[4]. Charcoal was applied directly onto the metal in early times, but with the invention of new methods carbon bearing gases and plasmas are being used for effective case depths. Heat treatments like carburization cause extensive rearrangements of atoms in metals at elevated temperature and transfer carbon by molecules CO, CO2, CH4 and other hydrocarbons in metal matrix to produce variation in physical, chemical and mechanical properties [5, 6].In this process of heat treatment carbon is introduced into the surface of steel when it is heated with carbon bearing material (gas, liquid , and solid) in order to increase hardness and wear resistance of metal [7, 8]. Gaseous carburization is carried between 900-950 degree Celsius [9, 10]. Gas carburizing is done on highly stressed machine parts like transmission parts, car engine parts, roller and ball bearings, rock drill parts, wear parts, fatigue-stressed parts such as shafts etc.[11, 12].It has been reported in the existing published literature [13] that carburization led to improve the wear resistance and fatigue strength. Success of the carburized components mainly depends upon the atmosphere of the process, temperature and time[14, 15], and flexibility of gas carburizing process is main advantage i.e. atmospheric composition and gas exchange rate can be controlled during the operation [16].

II. EXPERIMENTAL PROCEEDURE

2.1. Material Preparation-

AISI 1020 low carbon steel was selected for present research. The specimens were prepared on the basis of AISI standard specimen of (10×10×55) mm. The chemical composition of low carbon steel (AISI 1020) used in this research is shown in Table 1.

Table 1 Chemical composition of low carbon steel (AISI 1020) material

Element	C	Si	Mn	P	S	Cr	Ni	Al	Cu	V	Fe
Weight (;pp%)	.214	.222	.536	.017	.005	.052	.o41	.011	.015	.003	98.78

2.2 Gas Carburizing Procedure-

First of all gas carburization of 9 specimens was done by taking two carburizing input parameters i.e. is carburizing temperature and soaking time process parameters and three different levels of each. After carburizing process, quenching of all material was done. In this type of carburization liquid methanol (CH3OH) sprayed into the furnace containing nitrogen gas. This system is very significant in nature because carbon monoxide concentration can vary in range between 15 vol. % to 33 vol. %. When carbon monoxide concentration is lower it is used for heat treatment processes such as annealing/tempering or stress relieving. At higher concentration it is used for carburization. Mainly proportion of nitrogen to methanol is similar as nitrogen to oxygen in air that is 1.9.[8, 18] Various ratio of nitrogen to methanol as shown in figure 1:-

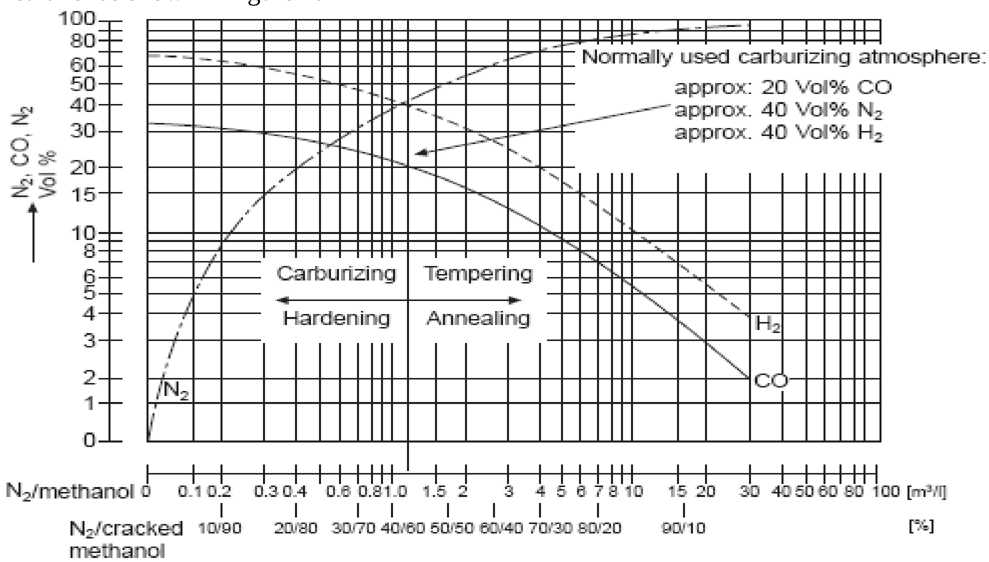


Figure 1 Composition of the furnace atmosphere produced by injecting (above 850°C) different ratios of nitrogen/methanol in the furnace.[18]

As soon as one volume of methanol get enters into furnace it dissociates into one volume of carbon monoxide and two volumes of hydrogen. Following reaction takes place:-

CH3OH + 1.89 N2→ CO + 1.89N2 + CH4 (1)

CO + 1.89N2 + CH4 +2.39 (0.209 O2+0.7905 N2) →CO+2H2 +1.89 N2 (2)

2.3 Selection of Process Parameters

After studying the literature on carburization process four important parameters are selected in this study which were suggested by the previous researchers of concerned field [19-21]

Table 2 Levels for Various Factors

Serial no	Carburizing temperature(°C)	Soaking time (hr.)	Tempering temperature(°C)	Tempering time (hr.)
1	870	4	200	0.5
2	900	5	240	1
3	930	6	280	1.5

III. RESULTS

The effects of carbon content on AISI 1020 carburized were observed after the experiment. Table no. 3 shows the results obtained after performing the tests i.e. are Rockwell hardness test, charpy test and wear test and table 4 represents the values observed by signal to noise (S/N) ratios and mean ratios using Taguchi analysis on hardness, impact strength and wear rate as response variable.

Table 3 Experimental results of carburized mild steel

Serial No..	Carburization Temperature(°C)	Soaking Time (hr.)	Tempering Temperature(°C)	Tempering time (hr.)	Hardness (Rc)	Impact strength(J)	Wear rate (cm2Micron)

1	870	4	200	0.5	54.0	33.5	46.8
2	870	5	240	1.0	55.0	33.	47.1
3	870	6	260	1.5	53.5	34	43.6
4	900	4	240	1.5	56.0	35.5	32.3
5	900	5	260	0.5	55.0	32.0	34.3
6	900	6	200	1.0	57	32.5	31.5
7	930	4	260	1.0	60.5	31.5	22.2
8	930	5	200	1.5	58.0	31.	23.6
9	930	6	240	0.5	61.4	32	22.0

Table 4 Observation of main effect of Mean and S/N ratio of hardness, toughness and wear rate

Comparability Sequence	Larger is better				Smaller is better	
	Hardness		Toughness		Wear rate	
	SNRA	MEAN	SNRA	MEAN	SNRA	MEAN
No.1	34.6479	54	30.5009	33.5	-33.4049	46.8
No 2	34.8073	55	30.3703	33	-33.4604	47.1
No 3	34.5671	53.5	30.6296	34	-32.7897	43.6
No 4	34.9638	56	31.0046	35.5	-30.1841	32.3
No 5	34.8073	55	30.1030	32	-30.7059	34.3
No 6	35.1175	57	30.2377	32.5	-29.9662	31.5
No 7	35.6351	60.5	29.9662	31.5	-26.9271	22.2
No 8	35.2686	58	29.8272	31	-27.4582	23.6
No 9	35.7634	61.4	30.1030	32	-26.8485	22.0

Table 5 and Table 6 represents response table of S/N ratio and MEAN of different input variables at different level there and there rank or their contribution in carburization process.

Table 5 Observation table of S/N ratio

OUTPUT PARAMETERS			Input Parameters	LEVEL			DELTA	RANK
				1	2	3		
	Larger is better	HARDNESS	Carburizing temperature(°C)	34.67	34.96	35.56	0.88	1
			Soaking time (hr.)	35.08	34.96	35.15	0.19	3
			Tempering temperature (°C)	35.07	35.18	35.00	0.17	4
			Tempering time (hr.)	35.07	35.19	34.93	0.25	2
		IMPACT STRENGTH	Carburizing temperature(°C)	30.50	30.45	29.97	0.53	1
			Soaking time (hr.)	30.49	30.10	30.32	0.39	2
			Tempering temperature (°C)	30.19	30.49	30.23	0.30	3
			Tempering time (hr.)	30.24	30.19	30.49	0.30	4
	Smaller is better	WEAR RATE	Carburizing temperature(°C)	-33.22	-30.29	-27.08	6.14	1
			Soaking time (hr.)	-30.17	-30.54	-29.87	0.67	2
			Tempering temperature (°C)	-30.28	-30.16	-30.14	0.14	4
			Tempering time (hr.)	-30.32	-30.12	-30.14	.020	3

Table 6 Observation table for MEAN ratio

OUTPUT			Input Parameters	LEVEL			DELTA	RANK
				1	2	3		
	Larger is better	HARDNESS	Carburizing temperature(°C)	54.17	56.00	59.97	5.8	1
			Soaking time (hr.)	56.33	56.00	57.30	1.30	3
			Tempering temperature (°C)	56.33	57.47	56.33	1.13	4
			Tempering time (hr.)	56.80	57.50	55.83	1.67	2

		IMPACT STRENGT	Carburizing temperature(°C)	33.50	33.33	31.50	2.00	1
			Soaking time (hr.)	32.50	32.00	32.83	1.509	2
			Tempering temperature (°C)	32.33	33.50	32.50	1.17	3.5
			Tempering time (hr.)	32.50	32.33	33.50	1.17	3.5
	Smaller is better	WEAR RATE	Carburizing temperature(°C)	45.83	32.70	22.60	23.23	1
			Soaking time (hr.)	33.77	35.00	32.37	2.63	2
			Tempering temperature (°C)	33.97	33.80	33.37	0.60	4
			Tempering time (hr.)	34.37	33.60	33.17	1.20	3

(a)

(b)

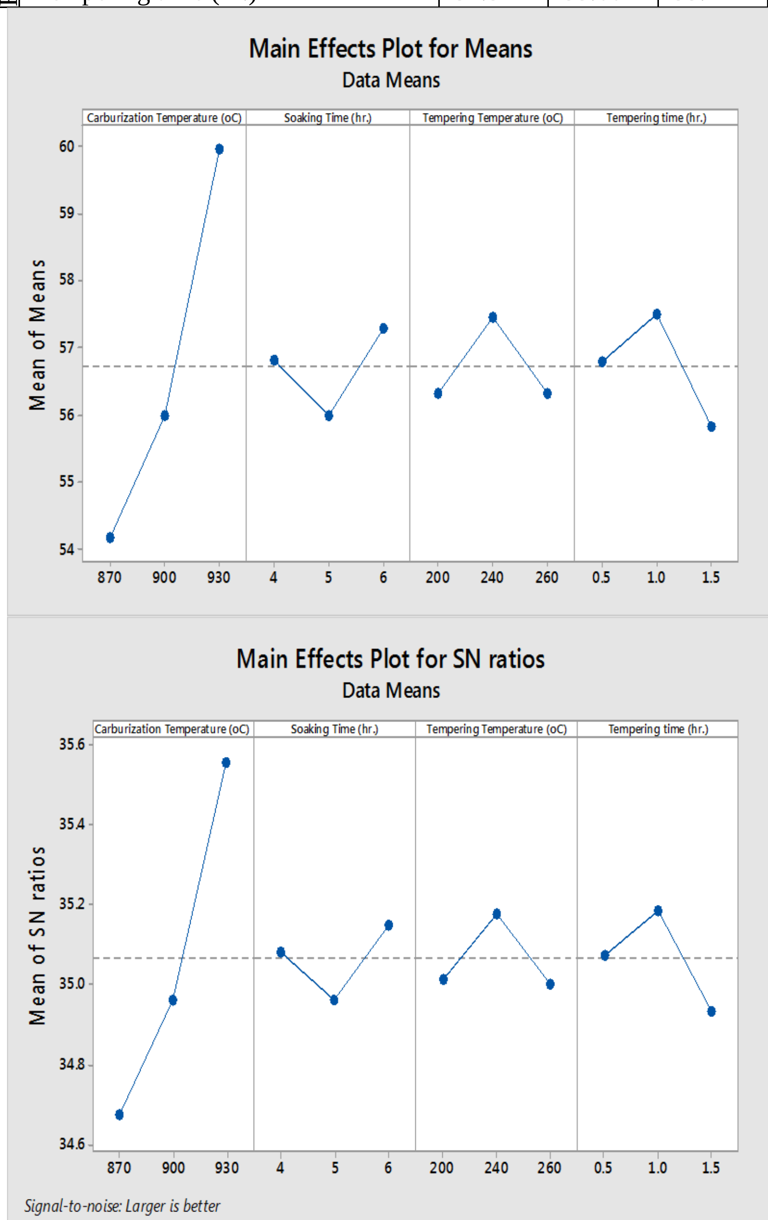
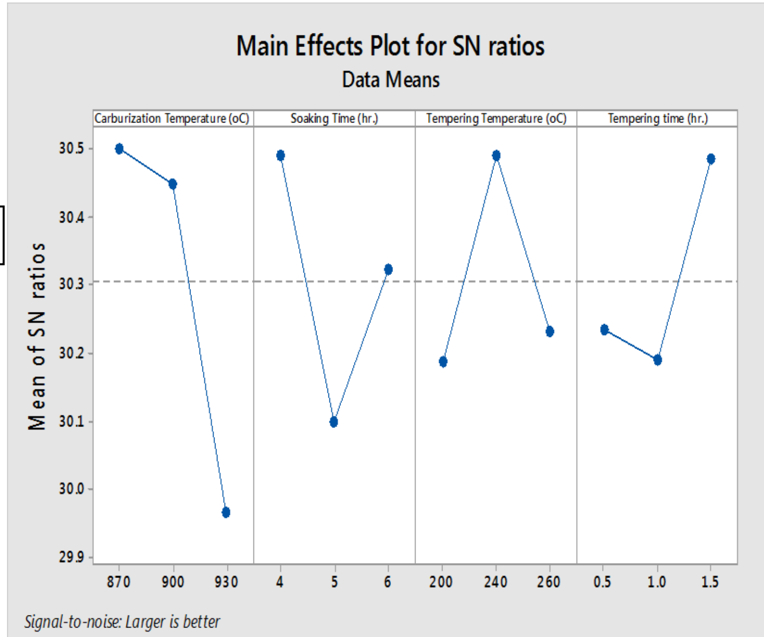


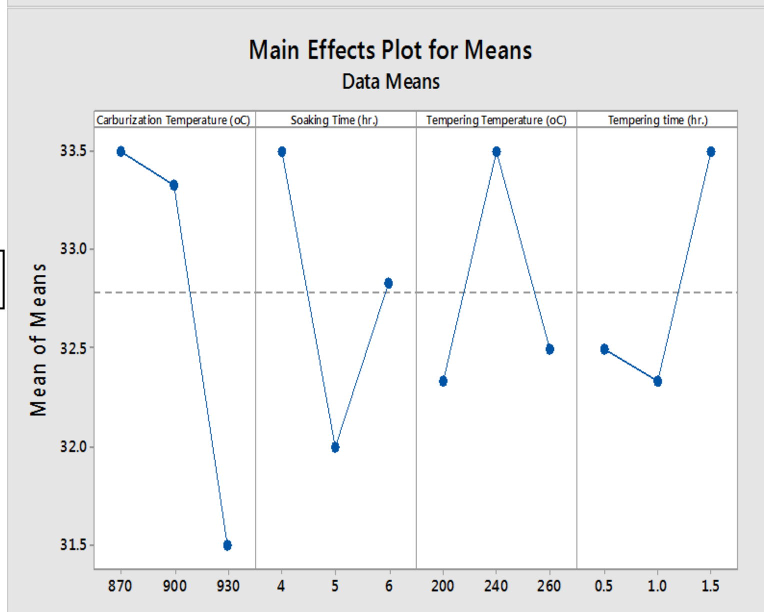
Figure 2 (a) and (b) Main effects plot for Mean and S/N ratio for Hardness.

Table 3.2, 3.3, 3.4 and Figure 3.1 and 3.2 showsthat input parameter Carburization temperature at level-3 contribute tremendously in order to obtain maximum hardness (Larger is better) of AISI 1020 steel. After carburization temperature second factor effected most is tempering time at level-2, then carburizing soaking time at level-3 tempering time followed by tempering temperature at level-2.

(a)



(b)



Figures 3 (a) and (b) Main effects plot for Mean and S/N ration for impact strength.

Table 4, 5 and Figure 3 (a) and (b) shows that minimum output parameter (smaller is better) wear rate was obtained at carburizing temperature at level-3 followed by carburizing soaking time at level-3 then tempering time at level-2 then tempering temperature at level-3.

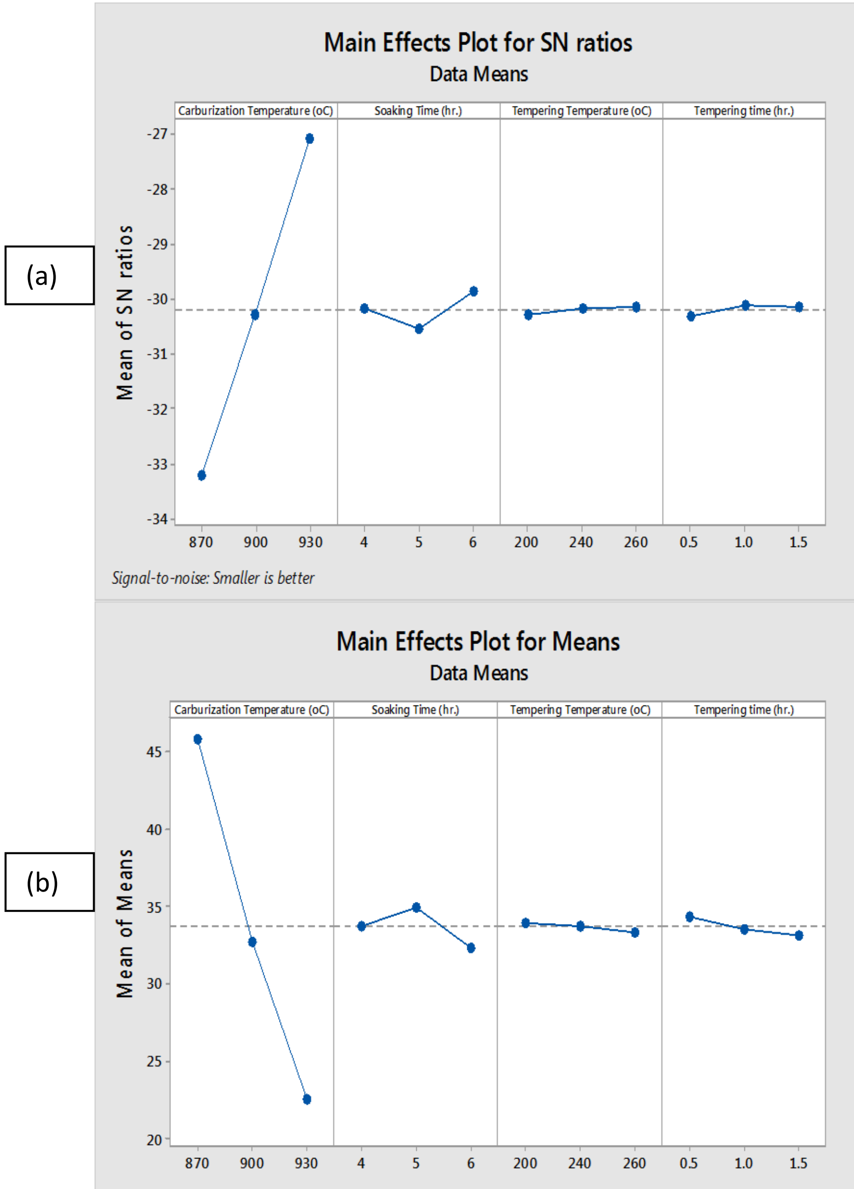


Figure 4 (a) and (b) Main effects plot for Mean and S/N ratio for wear.

Table 3.3, 3.4 and Figure 3.5 and 3.6 shows that minimum wear (smaller is better) was obtained at carburizing temperature at level-3 followed by carburizing soaking time at level-3 ten tempering time at level-2 then tempering temperature at level-3.

IV. CONFIRMATION TEST

When whole optimization of process parameters take place it is easy to predict improvement in process parameters. The Carburizing temperature (°C) Level-3, Soaking time (hr.) Level-3, Tempering temperature (°C) Level-2 and Tempering time (hr.) Level-3 were used for confirmation test. It is observed that when Carburizing temperature at 930 °C, Soaking time 6 hr., Tempering temperature 240°C and Tempering time 1.5 hr., the final result obtained as hardness 62.5 Rc, impact strength 35.7 J, and wear rate 16.2 Micron. It is observed that L9 Taguchi technique improve multi responses in carburization process for AISI 1020 Steel.

V. CONCLUSIONS

Whole experiments were conducted in batch furnace and AISI 1020 used as work piece in order to determine to optimize input parameters. L9 Taguchi techniques were used in order to conclude different results are discussed below:

It is observed from Taguchi L9 analysis that hardness and wear rate improves with increase in most influence factor that is carburizing temperature. While impact strength goes on decrease with increase in carburizing temperature.

After carburizing temperature most influence factor is carburizing soaking time. Maximum hardness and minimum wear obtained with increase in carburizing soaking time.

Tempering time was more influence parameter than that of tempering temperature.

After carburizing temperature, tempering time shows maximum influence in order to improve hardness.

Tempering temperature has minimum influence on carburizing process.

.Confirmation result shows most suitable identical optical parameters for carburization of AISI 1020 steel.

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