Implementation Of Taguchi Technique On Heat Treatment Process Of Pinion Gear.

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Abstract:

Surface engineering and surface engineered materials find wide applications in engineering industries in recent years. Inconsistency in hardness and case depth has resulted in the further optimization of the process variables involved in surface hardening. In the present study, the following operating parameters viz. preheating, carbon potential, holding position, furnace temperature, carburising time, quenching medium, quenching temperature, quenching time and tempering temperature were taken for optimization using the Taguchi and Factorial design of experiment concepts. From the experiments and optimization analysis conducted on pinion gear materials M353, it was observed that furnace temperature and quenching time had equal influence in obtaining a better surface integrity of the case hardened components using gas carburizing furnace. Preheating before gas carburizing furnace further enhanced the surface hardness.

Keywords: Pinion, Hardness, Taguchi Techniques, Optimization, Process Variables.

1) INTRODUCTION

Changing demands of dynamic market place have improved and increased the commitment to quality Consciousness. All over the world, companies are developing quality management systems like ISO 9001-2000 and investing in total quality. One of the critical requirements for the ISO 9001-2000 is adequate control over process parameters. An auditing report of the ISO indicates that the majority of the heat treatment processes in industries present improper application of process variables and inadequate control over the process parameters Adequate control of process variables is possible if the level at which each of the parameters has to be maintained. Optimization is one of the approaches that help in finding out the right level or value of the parameters that have to be maintained for obtaining quality output. Determination of optimum parameters lies in the proper selection and introduction of suitable design of experiment at the earliest stage of the process and product development cycles so as to result in the quality and productivity improvement with cost effectiveness

Investigations indicate that in surface hardening processes. Heat treatment temperature, rate of heating and cooling, heat treatment period, Quenching media and temperature, Post heat treatment and pre-heat treatment processes are the major influential parameters, which affect the quality of the part surface hardened. This deals with the optimization studies conducted to evaluate the effect of various process variables in Gas Carburizing furnace.

In this study, Taguchi's Design of Experiment concept has been used for the optimization of the process variables of Gas Carburizing process and Factorial design of Experiment for the optimization of process variables of Induction Hardening process. Taguchi's L9 orthogonal array and 3^4 Factorial arrays have been adopted to conduct experiments in Gas Carburizing.

2) GAS CARBURIZING PROCESS VARIABLES USING TAGUCHI'S METHOD

In this study, Taguchi's L9 orthogonal array of Design of Experiment is used for the optimization of process Variables of Gas carburizing process to improve the surface hardness of hardened component. All these experiments were carried out by Repetition Method. Two different optimization analyses (Response Graph Analysis and Signal to noise Ratio analysis) have been done on the materials selected for the study. The low carbon steel materials M353 used were Experiments have been conducted on the machined component pinion of steering wheel assembly. Figure1 shows the gas carburizing furnace of heat treatment on pinion gear.

Figure 1 GAS CARBURIZING FURNACE

3) HARDNESS OF PINION GEAR

Hardness of a material is generally defined as resistance to permanent indentation under static or dynamic loads. Engineering materials are subjected to various applications where the load conditions and functional requirements may vary widely in automobiles; power steering is an important assembly in which pinion are the major components subjected to twisting load. In order to improve the wear resistance characteristics and have high reliability, the Components (Pinion) are subjected to case hardening. The major problem in case hardening is inconsistency in hardness. The magnitude of hardness depends on the process variables of any surface hardening process. Hence, in the present research, process variable optimization study has been carried for obtaining higher surface hardness on the pinion material M353 used in the power steering assembly of the automobile.

Figure 2

4) GAS CARBURIZING-OPERATING CONDITIONS

Gas Carburizing Process is a surface chemistry process, which improves the case depth hardness of a component by diffusing carbon into the surface layer to improve wear and fatigue resistance. The work pieces are pre-heated and then held for a period of time at an elevated temperature in the austenitic region of the specific alloy, typically between 870° C and 940°C.

The conditions under which gas carburizing experiments have conducted are given in table.

SR.NO.	PARAMETER	NOTATION	LEVEL 1	LEVEL-2	LEVEL -3
1	FURNACE TEMPERATURE	A	870° C	910° C	940° C
2	QUENCHING TIME	B	60 min	90 min	120 min
3	TEMPERING TEMPERATURE	C	150 ° C	200° C	250° C
4	TEMPERING TIME	D	80 min	100 min	120 min

Table: 1

5) SELECTION OF AN ORTHOGONAL ARRAY

We Have Four Variables (Parameter) In Our Case with Three Levels

Hence, Degree Of Freedom = 1+4(3-1) =9

So, Minimum 9 Experiments are to be conducted .In this case array that can be used is L9 Orthogonal Array. The naming of array means the there are 9 runs for 4 factors, Contain 3 Levels. Our problem happens to fit inside of this array

Assigning Orthogonal Array for L9 Array

Experiment	Furnace Temp (Celsius)	Quenching Time (min)	Tempering Temp (Celsius)	Tempering Time (min)
1	870	60	150	80
2	870	90	200	100
3	870	120	150	120
4	910	60	200	120
5	910	90	150	80
6	910	120	250	100
7	940	60	150	100
8	940	90	250	120
9	940	120	200	80

Table:2

6) HARDNESS TESTING:

The heat treated specimens hardness was measured by means of Rockwell hardness tester. The procedure adopted can be listed as follows:

1. First the brale indenter was inserted in the machine; the load is adjusted to100kg.
2. The minor load of a 10 kg was first applied to seat of the specimen.
3. Now the major load applied and the depth of indentation is automatically recorded on a dial gage in terms of arbitrary hardness numbers. The dial contains 100 divisions. Each division corresponds to a penetration of .002 mm. The dial is reversed so that a high hardness, which results in small penetration, results in a high hardness number. The hardness value thus obtained was converted into C scale b y using the standard converter chart.

Figure3- Rockwell Hardness Tester

7) RESULT & DISCUSSION

A) Signals to Noise Ratio Method

Signal noise (S/N) ratio analysis estimates the effect of noise factors on the performance characteristics. It was developed as a proactive equivalent to the reactive loss function. Signal factors are set by the designer to obtain the intended value of the response variable

. Noise factors are not controlled or are very expensive or difficult to control. The Gas carbonizing conditions adopted in the experimentation are given in table, and the test results with S/N ratios are reported in the table.

S/N ratio for maximizing the response factor as the objective (Maximizing the surface hardness) is determined from the equation

$$S/N = -10 \text{ Log10 } [1/\sum yi^2 * n]$$

Where, yi - the experimental response values for the trials,

n - Number of trials.

Optimum condition for surface hardness are found by adopting the higher the **S/N** ratio is better as the strategy and results are given in the table. The optimum condition result obtained in S/N method matches with the optimum result obtained from the response graph analysis.

B) ORTHOGONAL ARRAY FOR GAS CARBURIZING WITH TEST RESULTS AND S/N RATIO MATERIAL CALULATIONS.

EXPERIMENT	Maximum Hardness							Calculation for Larger the Better				
	T1	$T1^2$	T2	$T2^2$	SM1	ST1	SE1	Ve1=Se1/1	Standard Deviation	Mean	(Mean*Mean)+variance	S/N=-10*Log(1/(Mean*Mean)+variance)
1	77	5929	77	5929	11858	11858	0	0.00	0.00	77.0	5929.00	37.73
2	77	5929	78	6084	6006.25	12013	6006.75	2002.25	44.74	77.5	8008.50	39.04
3	77	5929	80	6400	6162.25	12329	6166.75	2055.58	45.33	78.5	8217.83	39.15
4	78	6084	81	6561	6320.25	12645	6324.75	2108.25	45.91	79.5	8428.50	39.26
5	79	6241	82	6724	6480.25	12965	6484.75	2161.58	46.49	80.5	8641.83	39.37
6	77	5929	77	5929	5929	11858	5929	1976.33	44.45	77.0	7905.33	38.98
7	79	6241	80	6400	6320.25	12641	6320.75	2106.92	45.90	79.5	8427.16	39.26
8	78	6084	79	6241	6162.25	12325	6162.75	2054.25	45.32	39.3	3594.81	35.56
9	77	5929	78	6084	6006.25	12013	6006.75	2002.25	44.74	38.8	3503.81	35.45

Table:-3

From the experimental result, the average effects of process variables under consideration on the obtainable surface hardness have been calculated and the same are presented in the table 3.

C) CALCULATION FOR RESPONSE TABLE, FIRST PARAMETER & FIRST LEVEL:-

$$SP1,1 = \frac{37.73 + 39.04 + 39.15}{3} = 38.64$$

$$SP2,1 = \frac{37.73 + 39.26 + 39.26}{3} = 38.75$$

$$SP3,1 = \frac{39.15 + 39.37 + 39.26}{3} = 39.26$$

$$SP4,1 = \frac{37.73 + 39.37 + 35.45}{3} = 37.52$$

Response Table:-

Level	Furnace Temp (Celsius) **A**	Quenching Time(min) **B**	Tempering Temp (Celsius) **C**	Tempering Time (min) **D**
1	38.64	**38.75**	**39.26**	37.52
2	**39.20**	37.88	37.91	**39.09**
3	36.75	37.99	37.42	37.99
Δ	2.45	0.87	1.84	1.58
RANK	**1**	**4**	**2**	**3**

Table: 4

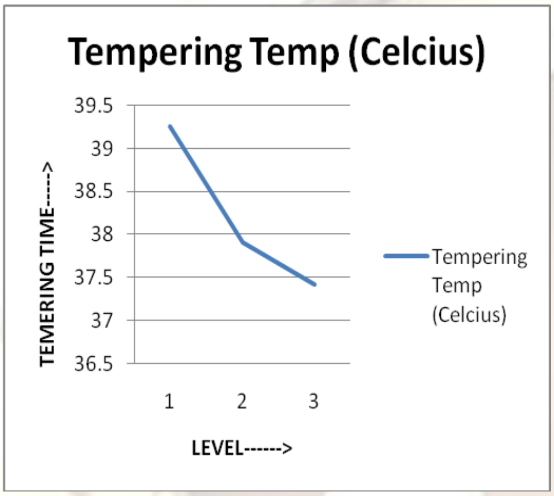
From this we can say for obtaining Maximum Hardness Furnace temp is the most influential parameter
Table of the average SN value for each factor:-
Δ = Max – Min

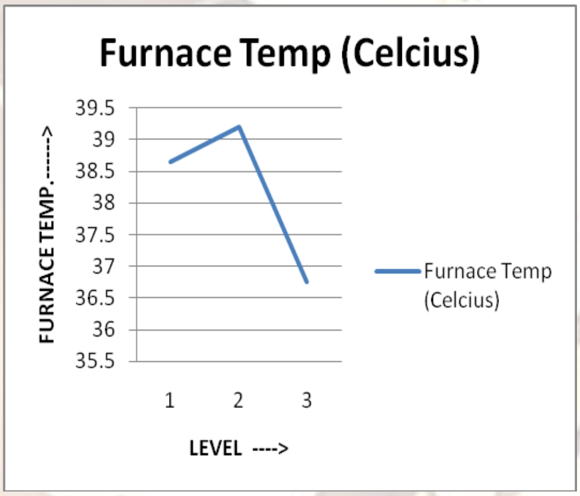
$$\Delta = 39.20 - 36.75$$
$$\mathbf{\Delta = 2.45}$$

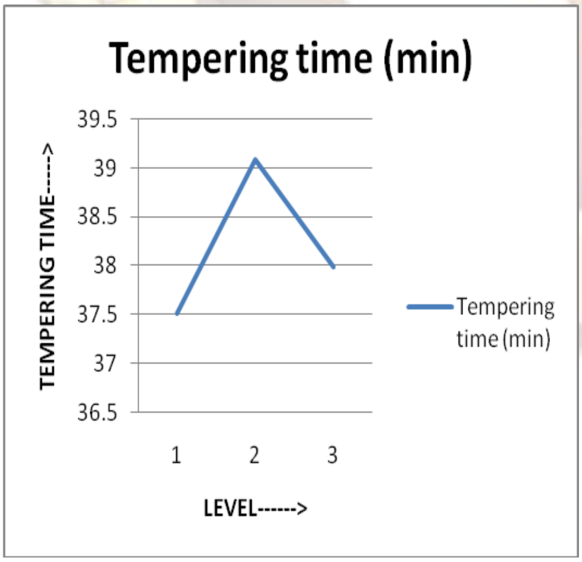
D) RESPONSE GRAPH METHOD

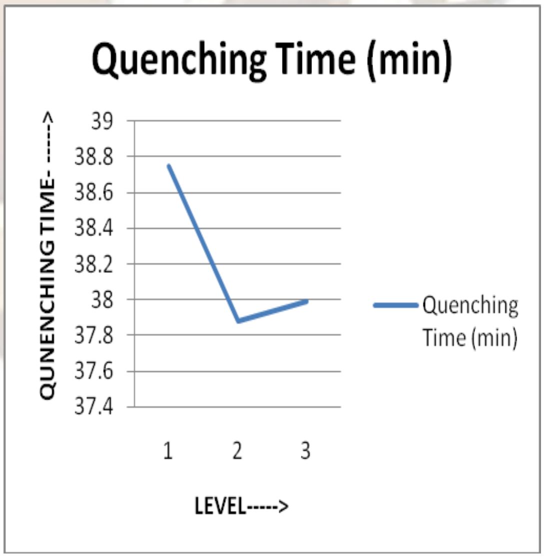
Response graph method gives the output of interest to be optimized i.e., minimize, maximize, targeted, etc. The output can be more that one and also it can be quantitative or qualitative

For getting maximum hardness following is the setting done A2B1C1D2
Furnace temp- 910 Celsius
Quenching Time- 60 min
Tempering Temp- 150
Tempering Time- 100 min









B) PERCENTAGE OF CONTRIBUTION OF EACH PARAMETER ON SURFACE HARDNESS

Level	Furnace Temp (Celsius)	Quenching Time(min)	Tempering Temp (Celsius)	Tempering Time (min)
1	38.64	38.75	39.26	37.51
2	39.20	37.88	37.91	39.09
3	36.75	37.99	37.42	37.99
Δ	2.45	0.87	1.84	1.58
Contributions	**36.35**	**12.9**	**27.29**	**23.44**

Table: 5

7) CONCLUSION

1) In the present analysis, Furnace temperature (910°C) gives high hardness
2) Taguchi experimentation predicts best setting for best hardness of pinion gear M353 material. i.e.

Optimum Gas Carburising Process Condition

Sr.No.	Process Variables	Values with unit
01	Furnace Temp(Celsius)	910° C
02	Quenching Time(min)	60 Min
03	Tempering Temp(Celsius)	150 ° C
04	Tempering Time (min)	100 Min

Table: 6

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