International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Volume 4, Issue 2 (March-April, 2016), PP. 38-44

OPTIMIZATION OF HEAT TREATMENT PROCESSES OF STEEL USED IN AUTOMOTIVE BEARINGS

Sushil Kumar [1], Rakesh[2] , Amit kumar Singh[3]
[1]Research scholar, Department of Production Enginneering
[2]Assistant Professor, Department of Production Engineering
[3]SNL Bearing Limited, Ranchi
[1]kumarsushil.in.co@gmail.com

Abstract— ***The purpose of the present work is to obtain the most effective controlling parameters for heat treatment of needle bearing steel , the effect of controlling parameters such as Holding Time, Carburizing temperature, Carbon Potential and Quenching temperature on hardness value of bearing steel. In this case, 9 combinations of the above mentioned 4 parameters were set and Taguchi's method was followed accordingly. Signal to noise ratio (S/N) analysis showed that effective hardness value was obtained when the parameters were chosen on the basis of "Smaller the better" category which were Holding Time: 40 min., Carbon Potential: 1.2 m^3/hr., Carburizing Temperature: 890^{0}C and Quenching Time:4 min.***

Keywords: Carburizing Temperature, Carbon Potential Needle Bearing

I. INTRODUCTION

Steel is an alloy whose main constituents are iron and carbon. Carbon steel (plain-low) is graded by its carbon content as 0.1% to 0.3% it is called mild steel, which cannot be hardened by direct heat treatment method because of low strength of carbon content . Thermo chemical carburizing –case hardening and heat treatments of atoms in metals and alloys and a corresponding marked variation in physical, chemical and mechanical properties. Out of these , the more important of treatments are heat treatments such as immersion hardening, induction and case hardening by carburizing [child, 1980(1)]. Carburizing and case hardening are " thermo chemical" treatments , usually conducted at temperatures in the range 800-920 ^{0}C in the first stage of "case hardening". Quenching is followed by a low –tempering. The heat treatment involves a variety of processing factors to achieve these objectives, including controlled gaseous atmospheres to a predetermined temperature. The furnace is filled with a suitable gas as methane, butane or propane. In carburizing, controlled level of carbon is introduced at the surface and allowed to diffuse to a controlled depth. Carburizing and case-hardening is applied to near –finished components and its enhancing to high-hardness, strength and wear resistant properties on surface in sufficient depth, and fatigue strength(2). In the gas carburizing process is that the original toughness and difficulty remain unaffected even after the heat treatment [Rajan et.al, 1943(3)]

II. TAGUCHI METHOD

Optimization is a key step to improve the performance and to find the optimal process parameters based on the responses .There are a few optimization tools such as the gradient search method, the FEM neutral, network method and Taguchi method(4). There is a unique statistical experimental design technique known as Taguchi's Robust Design method .The design of parameters using Taguchi's method is an off-line Quality control method. Offline Quality control methods are Quality and cost control activities conducted at the product and process design stages to improve product manufacturability and reliability and to reduce the product development and life time cost (Philip, 1988(5)).This method has also seen wide application in engineering analysis to optimize performance characteristics through design parameter settings. Parameter design can be used to make a process most effective against available sources of variation and hence to improve field performance. The Taguchi method uses a special design of orthogonal array to study the entire process parameter space with a small number of experiments. The Taguchi method is based on orthogonal arrays to minimize the number of experiments and to improve product quality (6-8).

The Taguchi method is a powerful tool for designing high quality systems based on orthogonal array experiments that provide much-reduced variance for experiments within optimum setting of process control parameters (9-11). Many of the researches have attempted to analyze and optimize. Single and multi performance responses of heat treatment process using Taguchi methodology. Among them multiple progressive tool (surnace (2010)) and utility concept (zhizharg (2008(12)) are used. This method is a combination of experimental and analytical concepts to determine the most influential parameter on the result response for the significant improvement in the overall performance. It employs signal-to-noise (S/N) ratio to analyze experiment data and conclude more information .The current study considered hardness as optimization criteria which was achieved after analyzing the influence of each heat treatment parameter on the quality of the research specimen. The optimal levels of process parameters can be estimated. In order to achieve carburizing steel components, a parameter optimization study is to be carried out in a gas-carburizing furnace by verification of results.

III. SPECIMEN SPECIFICATION

The first and foremost job for the experiment is the specimen selection. The specimen chosen for this purpose is a Shell or journal SCE188 which is already a drawn piece. It is a large grain sized carbon-chromium steel in competence with ASTM standard. It ensures higher hardness ,medium ductility and high strength. The chemical composition of this steel alloy is specified as below:

HT-8 Heating Furnace in SNL Bearing

ASTM STD.	Si%	Mn%	P%	Cr%	Al%	Ni%	S%	C%	Fe%
	0.1	0.5-0.7	0.03	1.3-1.6	0.07-0.12	0.2-0.4	0.025	0.13-0.18	Balance

Samples of SCE-188

The process variables were noted as holding time, carbon potential, carburizing temperature and quenching time which affect the hardness were selected for the Taguchi design. A L9 (3^4) orthogonal array design was adopted for experimentation the bearing sample chosen. Nine experiments were conducted by varying all these parameters, the details of which are given below:

S. No	Parameters	Notations	Unit	Value with Range
1	Holding Time	HT	min	40-50
2	Carbon Potential	CP	M^3/kg	1.05-1.35
3	Carburizing Temperature	CT	0C(degree centigrade)	860-900
4	Quenching Time	QT	min	4-6

The influence of these parameters (for low, medium and high) on surface hardness, case depth, and the case hardened component was taken to measure the surface hardness and
case depth. The results of the L9 Orthogonal array of gas carburizing process parameters and test results for SCE188 are noted below:

Experiment	Holding Time	Carbon Potential	Carburizing Temperature	Quenching Time	HVN
1	**40**	**1.1**	**860**	**4**	**780**

2	**40**	**1.2**	**875**	**5**	**810**
3	**40**	**1.3**	**890**	**6**	**795**
4	**45**	**1.1**	**875**	**6**	**845**
5	**45**	**1.2**	**890**	**4**	**830**
6	**45**	**1.3**	**860**	**5**	**865**
7	**50**	**1.1**	**890**	**5**	**850**
8	**50**	**1.2**	**860**	**6**	**895**
9	**50**	**1.3**	**875**	**4**	**840**

Process Parameters and Hardness (HV)

Parameter	**Low**	**Medium**	**High**
Carbon Potential	**816.66**	**845**	**833.33**
Carburizing Temp.	**846.66**	**831.66**	**825**
Holding Time	**795**	**846.66**	**861.66**
Quenching Time	**816.66**	**841.66**	**845**

The above table indicates that average effect of main parameters at a 3 factor level (Low Medium and High) on surface hardness (HVN) and also carburizing temperature has an effect on surface hardness.

IV. RESULTS AND DISCUSSION

We have already obtained a table(showing value of hardness) on the basis of influence of different process parameters namely Holding Time, Carbon Potential, Carburizing temperature and Quenching Time on the response namely hardness was analyzed in this section. In **Taguchi methodology** signal to noise ratio plays a vital role in determining influence of process parameters. As hardness to be maximized keeping the process parameters optimized so accordingly signal to noise ratio was calculated by considering "larger is better" criterion. S/N ratio was calculated by following Equation 1.

$$\frac{S}{N} = -10log_{10}\left(\frac{1}{n}\sum_{i=1}^{n}\frac{1}{Y_i^2}\right) \qquad (1)$$

Where S/N is performance statistics, n is the number of repetitions for an experimental combination; and "Yi" is performance value of the *i*th experiment. In the current work , for any given experimental combination only one trial was carried out hence n=1 and the equation can be rewritten as.

$$\frac{S}{N} = -10log_{10}\left(\frac{1}{Y_i^2}\right) \qquad (2)$$

The S/N ratio corresponding to L9 orthogonal array are also included in Table 3. Then the mean S/N ratios at each level for various factors have been calculated. The optimum levels were selected as the largest S/N ratio among all the levels of the factors. In order to evaluate the influence of each factor on the hardness value, the S/N ratio for each factor was computed. The S/N ratio for single factor can be calculated by averaging the values of S/N ratios at different levels.

Calculation

1. Hardness value (Yi)=780 (H.T=40 C.P=1.1 C.T=860 Q.T=4)
n=1 (Since we have considered only one hardness value for the given values)
S/N= -10*log10(1/7802)
= -10*log10(1.643*10-6)
= -10*(-5.784)
= 57.8418

Similarily other values are obtained as:

2. Yi=810 (H.T=40 C.P=1.2 C.T=875 Q.T=5)
S/N=58.1697

3. Yi=795 (H.T=40 C.P=1.3 C.T=860 Q.T=4)
S/N=58.0073

4. Yi=845 (H.T=45 C.P=1110 C.T=875 Q.T= 6)
S/N=58.5371

5. Yi=830 (H.T=45 C.P=1115 C.T=890 Q.T=4)
S/N=58.3815

6. Yi=865 (H.T=45 C.P=1120 C.T=860 Q.T=5)
S/N=58.7403

7. Yi=850 (H.T=50 C.P=1.10 C.T=890 Q.T=5)
S/N=58.5883

8. Yi=895 (H.T=50 C.P=1.20 C.T=875 Q.T=6)
S/N=59.0361

9. Yi=840 (H.T=50 C.P=1.30 C.T=860 Q.T=4)
S/N=58.4855

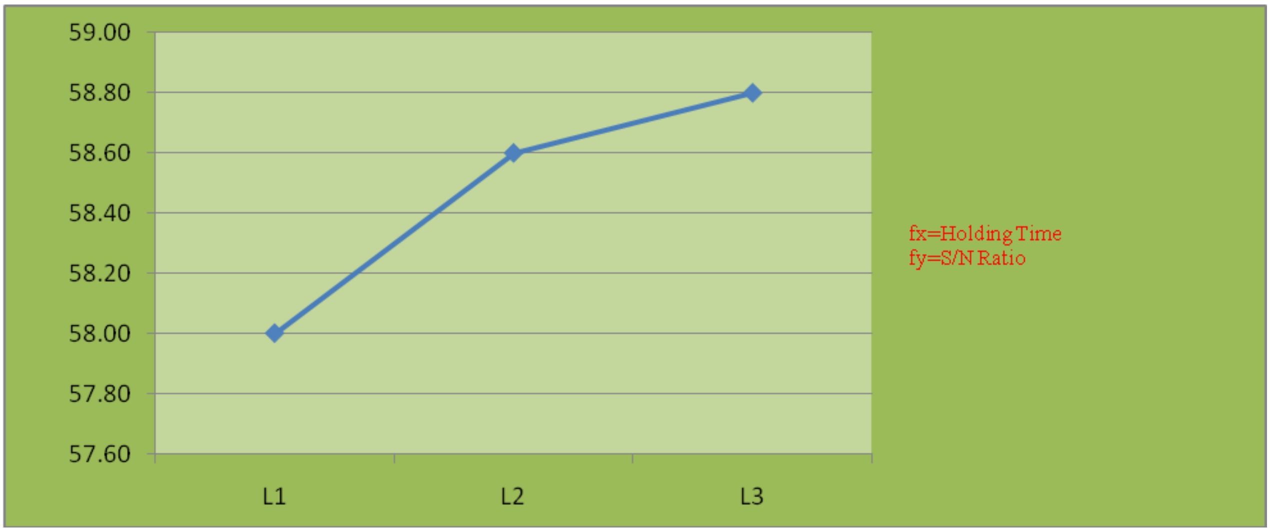
On the basis of the calculations the following table is obtained:

SN ratio with corresponding factor combinations

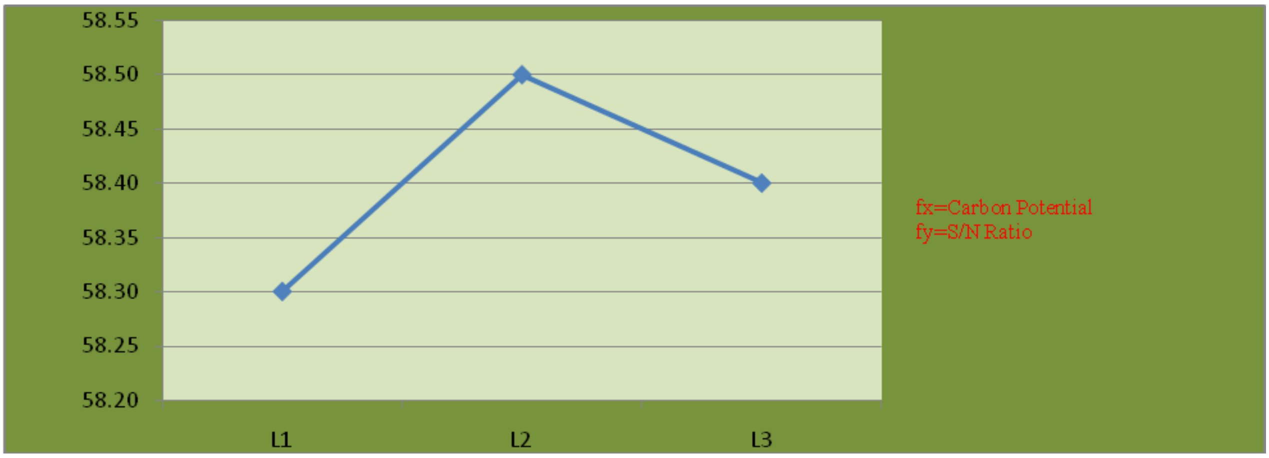
Experiment	Holding Time	Carbon Potential	Carburizing Temp.	Quenching Time	HVN	S/N ratio
1	40	1.1	860	4	780	57.8418
2	40	1.2	875	5	810	58.1697
3	40	1.3	890	6	795	58.0073
4	45	1.1	875	6	845	58.5371
5	45	1.2	890	4	830	58.3815
6	45	1.3	860	5	865	58.7403
7	50	1.1	890	5	850	58.5883
8	50	1.2	875	6	895	59.0361
9	50	1.3	860	4	840	58.4855

Charts (S/N Ratios vs various Parameters)

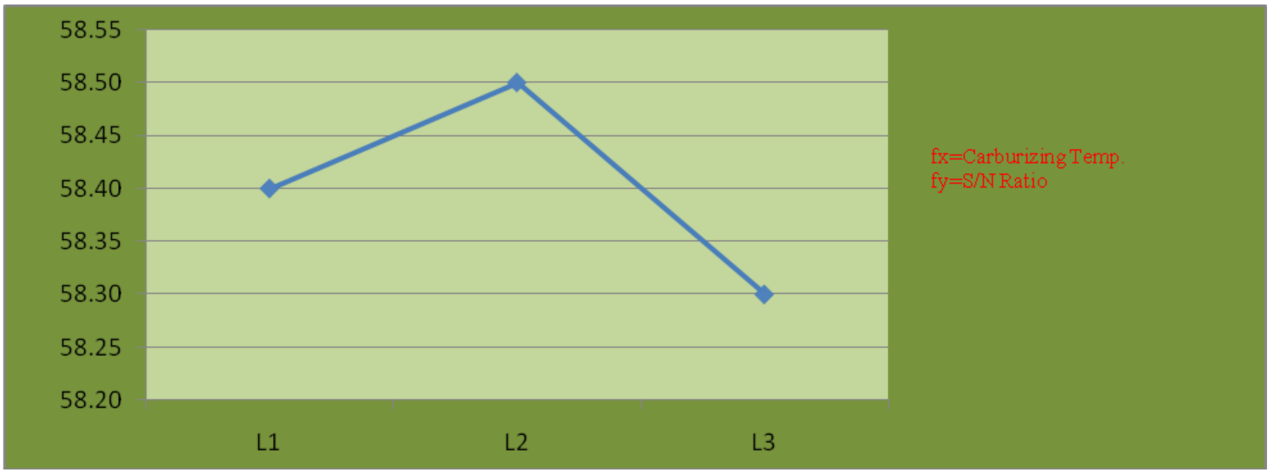
(1.) S/N Ratio vs Holding Time



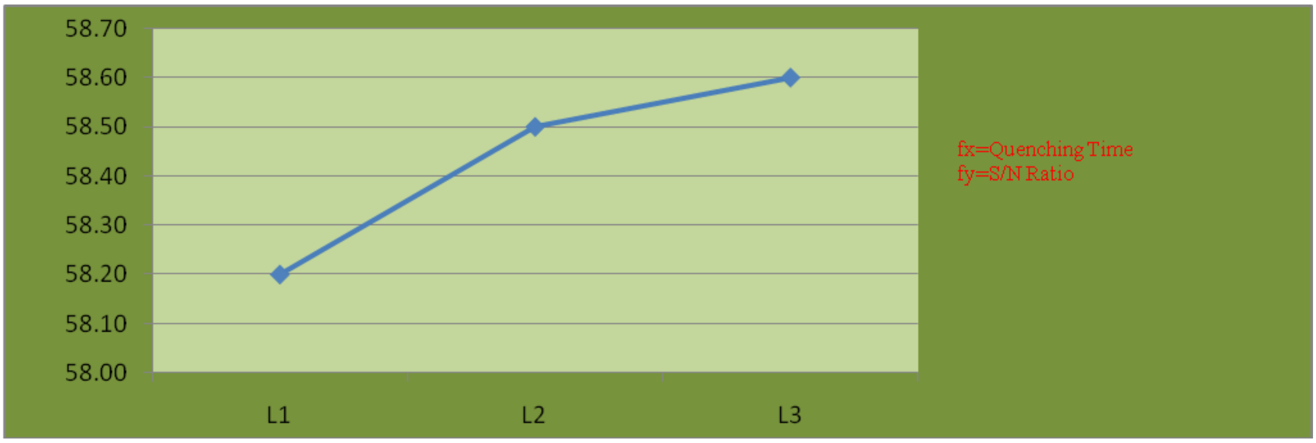
(2.) S/N Ratio vs Carbon Potential



(3) S/N Ratio vs Carburizing Temperature



(4) S/N Ratio vs Quenching Time



SN RATIOS vs VARIOUS PARAMETERS

Since optimized process parameters for hardness are obtained for 3 different approaches of Taguchi.

(A) Larger the better

Main effect plot in the Fig indicates that Holding Time at 3rd level, Carbon Potential at 2nd leve,l Carburizing Temperature at 2nd level and Quenching Temperature at 3rd level are optimized levels for maximizing hardness of bearing.

1. Holding Time: 50 min.
2. Carbon Potential: 1.2 m^3/hr.
3. Carburizing Temperature: 875 ^oC

(C) Moderate the best

Main effect plot in the fig. indicates that Holding time at 1st level, Carbon Potential at 1st level , Carburizing temp. at 3rd level and Quenching temperature at 1st level are optimized levels for maximizing hardness for bearing

1. Holding Time: 45 min.
2. Carbon Potential: 1.3 m^3/hr.
3. Carburizing Temperature: 875 ^oC
4. Quenching Time : 5 min.

V. CONCLUSION

4. Quenching Time : 6 min.

(B) Smaller the better

Main effect plot in the fig. indicates that Holding time at 1st level, Carbon Potential at 1st level , Carburizing temp. at 3rd level and Quenching temperature at 1st level are optimized levels for maximizing hardness for bearing

1. Holding Time: 40 min.
2. Carbon Potential: 1.2 m^3/hr.
3. Carburizing Temperature: 890 ^oC
4. Quenching Time : 4 min.

The optimized Taguchi result was predicted and it was illustrated that Bearing steel heat treated under various Holding Time, Carbon Potential, Carburizing Temperature and Quenching Time shows maximum hardness which are equally applicable to get a result. A comparison is thus made for the 3 results of Taguchi Approaches to get 3 optimized values.

Factor levels for predictions

Serial no.	Taguchi Approach	H.T	C.P	C.T	Q.T
1	Larger	50	1.2	875	6

	the better				
2	**Smaller the better**	**40**	**1.2**	**890**	**4**
3	**Moderate the best**	**45**	**1.3**	**875**	**5**

The respective hardness values for the three levels is obtained as per the Vickers hardness test and are:

1. 903 HV
2 .890 HV
3. 910 HV

Thus the conclusion derived considering the utilization of various parameters and desired Hardness value, the best value chosen is **Taguchi Approach for "Smaller the better" which is 890 HV**

The following conclusions can be extracted from this study.

- Taguchi method is used to provide an efficient design of experiment technique to obtain simple, systematic and efficient methodology for the optimization of the process parameters.
- Taguchi's robust design method can be used to analyze optimal heat treatment parameters for the carburizing and case hardened steel described in the paper. The Taguchi method efficiently, obtains optimal heat treatment parameters for the plain- low carbon steel, minimizes the number of experiments, and analyzes the influence of each of the parameter on the experiment results and the contribution of individual parameters.

REFERENCE

[1] .Honeycombe R.W.K. and Bhadeshia H.K.D.H., Steels, 2nd ed., Butterworth-Heinemann Publishing Ltd. Oxford, U.K. 2000.
[2]. Rajan T.V; Sharma C.P. and Sharma, A., Heat Treatment Principles and Techniques. Prentice Hall of India Private Limited, New Delhi, 1989.
[3]. Krauss G., Steels: Heat Treatment and Processing Principles, ASM International, OH, USA, 1989.
[4]. Jahazi M. and Egbali B., The influence of hot rolling parameters on the microstructure and mechanical properties of anultra-high strength steel. J Mat Pro Tech., vol.103, 2000, pp.276-9.
[5]. Korda A., Miyashita Y., Mutoh Y. and Sadasue T., Fatigue crack growth behavior in ferritic-pearlitic steels with networked and distributed pearlite structures. Int J Fat., vol.29, 2007, pp. 1140-8.
[6-7]. Song P.S., Shieh Y.L., Fracture lifetime of hydrogen-charged AISI 4130 alloy steel under intermittent sustained overloads, Eng Frac. Mech., vol.71, 2004, pp.1577-84. 17. http://www.efunda.com and M. Silverman, personal communication, February 15th, 2007.
[8]. Dowling N.E., Mechanical behavior of materials, Prentice-hall, 1999. 80
[9]. Metals handbook 9th ed., American society for metals, vol.9, 1985.
[10]. Mamoru O., Yukito T; Hitoshi K. and Yuji F., Development of New Steel Plates for building structural use, Nippon Steel Technical Report, vol.44, 1990. pp.8-15.
[11]. Kempester M.H.A., Materials for engineers, 3rd ed., Hooder and Stonghton., 1984.
[12]. Raymond A. and Higgins B., Properties of Engineering Materials. Hooder and Stonghton.

[1] J. Clerk Maxwell, A Treatise on Electricity and Magnetism, 3rd ed., vol. 2. Oxford: Clarendon, 1892, pp.68–73.
[2] I. S. Jacobs and C. P. Bean, "Fine particles, thin films and exchange anisotropy," in Magnetism, vol. III, G. T. Rado and H. Suhl, Eds. New York: Academic, 1963, pp. 271–350.
[3] K. Elissa, "Title of paper if known," unpublished.
[4] R. Nicole, "Title of paper with only first word capitalized," J. Name Stand. Abbrev., in press.
[5] Y. Yorozu, M. Hirano, K. Oka, and Y. Tagawa, "Electron spectroscopy studies on magneto-optical media and plastic substrate interface," IEEE Transl. J. Magn. Japan, vol. 2, pp. 740–741, August 1987 [Digests 9th Annual Conf. Magnetics Japan, p. 301, 1982].
[6] M. Young, The Technical Writer's Handbook. Mill Valley, CA: University Science,