Influence of Phosphating Parameters on Fatigue Strength of EN 19 Materials

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Abstract - The influence of phosphating parameters including phosphating bath temperature, phosphating time and accelerator level on the fatigue performance of EN24 was studied. The taguchi method was used to investigate the relationship between the fatigue performance and phosphating parameters. The results shows that phosphating bath temperature is the most significant factor among the three parameters.Accelertaor level is less influential on the fatigue life.

Keywords – EN19,Fatigue strength, Manganese Phosphating, Phosphating parameters, Taguchi Method

I. INTRODUCTION

In the automotive and machinery industry, there is a great deal of interest in improving environmental friendliness, reliability, durability and efficiency. The reduction of wear and friction is a key element in decreasing the energy losses, particularly in engines and drive trains. Surface treatments and coatings contribute to a better lubrication with oils and can participate significantly in achieving these goals. Among protective coatings, the class of carbon-based materials shows interesting properties, combining low friction with a good wear resistance. For these reasons, they are increasingly being used as protective films for moving parts. The use of such non-metallic surfaces with new additives leads to investigations into the interaction between these protective over layers and the base material. Literature shows that phosphating is one of the surface coating method which will improve friction properties and wear properties thus increases fatigue life. In this work , the investigation effect of phosphating surface coating on piston pin of different material is studied by using design of experiments. The taguchi method uses the orthogonal arrays to optimize the process parameters. In the present work, improvement in fatigue life is obtained by optimizing process parameters such as operating temperature, phosphating time and accelerator. The experimental result analysis showed that the combination of higher levels of operating temperature, phosphating time and accelerator is essential to achieve improvement in fatigue life. The effect of phosphating on the piston pin fatigue life, which is most important criterion, in determining the life in cycles, was optimized with the higher the best control characteristics of the Taguchi method and the results were analyzed with graphical methods.

II. EXPERIMENTAL

2.1 phosphating process

Phosphating process can be defined as the treatment of a metal surface so as to give a reasonably hard, electrically non-conducting surface coating of insoluble phosphate which is contiguous and highly adherent to the underlying metal and is considerably more absorptive than the metal. The coating is formed as a result of a topochemical reaction, which causes the surface of the base metal to integrate itself as a part of the corrosion resistant film. Phosphate deposition can be achieved through the use of both spray and immersion processes and the choice of the appropriate method depends upon the size and shape of the substrate to be coated and based on the end use for which the coating is made. Spray process is preferred where shorter processing times are required. This method, however, requires more factory floor space and special equipment for their application. Immersion process though slower, produce uniform coatings and they require less factory floor space as the process tanks can be arranged in a compact manner. But, immersion processes are more susceptible to contamination during continuous operation than are spray processes. Smaller parts can be effectively and economically phosphated by immersion process whereas spray process is more suitable for larger work pieces. Phosphating may be carried out at temperatures ranging from 30-99 °C and processing time can be varied from

a few seconds to several minutes. Suitable choice of these parameters is determined by factors such as nature of the metal to be coated, thickness and weight of the coating required and bath composition.
Phosphating procedure is as follow.

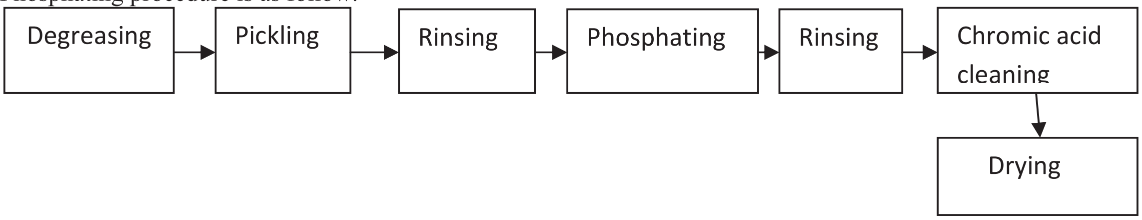

Figure 3 .Phosphating procedure

III. DESIGN OF EXPERIMENT

The experiments were designed to establish the effects of phosphating parameters on fatigue strength of EN 24 as a piston pin material Optimum setting of process parameter is a crucial aspect to improve phosphate ability of specimen.a generic signal to noise (S/N) ratio is used to quantify the present variation.The common principle of Taguchi method is to develop an understanding of the individual and combined effects of a variety of parameters from a minimum number of experiments. A generic signal to noise ratio(S/N) ratio is used to quantify the present variation. Because the value of fatigue strength is vital in this experiment, the S/N ratio for " Larger the Better" is related to the present study which is given by

$$R_{S/N} = -10 \times \ln\left(\frac{1}{N}\left(\sum_{i=1}^{N}\frac{1}{y_i}\right)\right) \quad (1)$$

Where n is the number of repetition in a trial under the same design condition, yi represents the measured values and subscript I represents the number of design parameters in the orthogonal array.

3.1 Materials

In view of extensive application of low alloy steel for making piston pin, we selected EN 24 as a material for experiments which having chemical composition as done by Spectroscopic Test as follow.

Table 1 chemical composition of EN 19

Steel Grade	**Weight Percentage of elements**							
	C	**Mn**	**Si**	**S**	**P**	**Cr**	**Ni**	**Mo**
EN 19	0.41	0.61	0.26	0.023	0.032	0.920	0	0.270

For determining the mechanical properties, tensile tests were conducted within the elastic limit of the steel.

Table 2 Mechanical properties of EN19

Steel grade	**Yield load**	**Ultimate load**	**Yiels Strength**	**Ultimate Tensile strength**	**% Elongation**	**Hardness**
EN 19	11320 N	11760 N	577 MPa	599 MPa	18.64	41 HRC

3.2 Specimen preparation for fatigue test specimen

Based on the recommendations provided in standards, dumbbell shaped round test specimens having nominal neck diameter of 6 mm and 18 mm transition fillets were prepared for carrying out fatigue tests. The drawing of the specimen is given in figure 1.

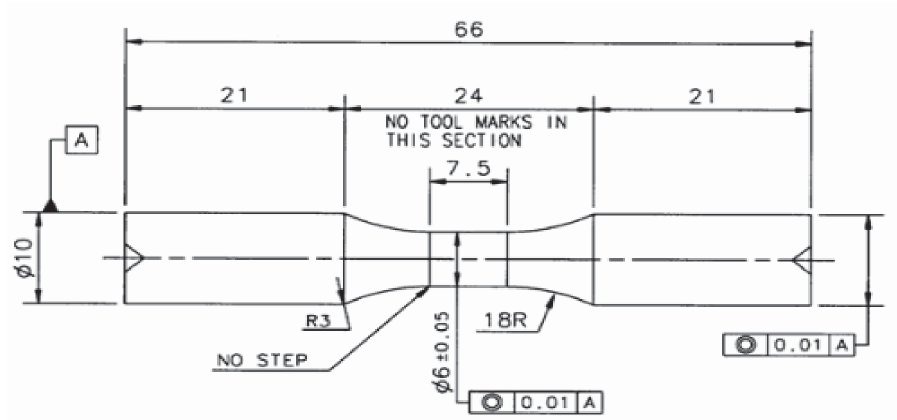

Figure 1 .Fatigue specimen

The specimens were case carburized at 920°C for three hours, followed by soaking at 850°C for 30 minutes and quenching in oil at 120°C. Finally, the quenched specimens were tempered at 180°C for 2 hours, followed by cooling in still air, so as to achieve a final hardness in the range of 40-50 HRc.

IV. RESULTS AND DISCUSSION

In the present study, increase in fatigue life of piston pin of manganese phosphate coated is the main objective. Hence the response variable used is to accomplish this study is to increase fatigue life of piston pin in number of cycles by using L9 orthogonal array ,since each of the main factors is associated with three levels, the dof of each of the factor is two.

The three factors temperature, phosphate time, accelerator were considered as the control factors affecting the fatigue life..Design parameters are the controllable factors that are the testing parameters such as temperature, phosphating time and accelerator are easier to control. The levels are chosen keeping in mind the low thickness of the coating otherwise wear may occur through the coating.

Table 3 . design parameter level

Factors	Unit	levels		
		1	2	3
Temperature	Deg C	92	93.5	95
Phophating time	Minute	5	10	15
Accelerator	mL / L	1	1.5	2

Table 4 shows that the experimental results with calculated S/N ratio for fatigue strength. According to the principles of Taguchi method, using the values given in table 4, the corresponding S/N responses were divided, which are shown in table 5 and figure 2. For a set up factor,the present study defines high influence on fatigue strength as the maximum S/N ratio. Consequently, as shown in figure2 and table 5, both of them indicate that the combination of optimal design parameters is temperature 92 degree c,phosphating time is 15 minutes and accelerator level as 1(low).

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Table 4.experimental lay out and results with calculated S/N ratio for fatigue strength

Trials	Temperature	Phosphating time	Accelerator	S/N ratio	Fatigue life
1	92	5	1	95.95	62703
2	92	10	1.5	95.88	62819
3	92	15	2	95.92	62769
4	93.5	5	1.5	95.87	61995
5	93.5	10	2	95.90	61883
6	93.5	15	1	95.90	62533
7	95	5	2	95.88	62022
8	95	10	1	95.92	62382
9	95	15	1.5	95.88	62234

Table 5 Response for S/N ratios

Level	Temperature	Phosphating time	Accelerator
1	95.95	95.88	95.92
2	95.87	95.90	95.90
3	95.88	95.92	95.88
Delta	0.09	0.04	0.04
Rank	1	3	2

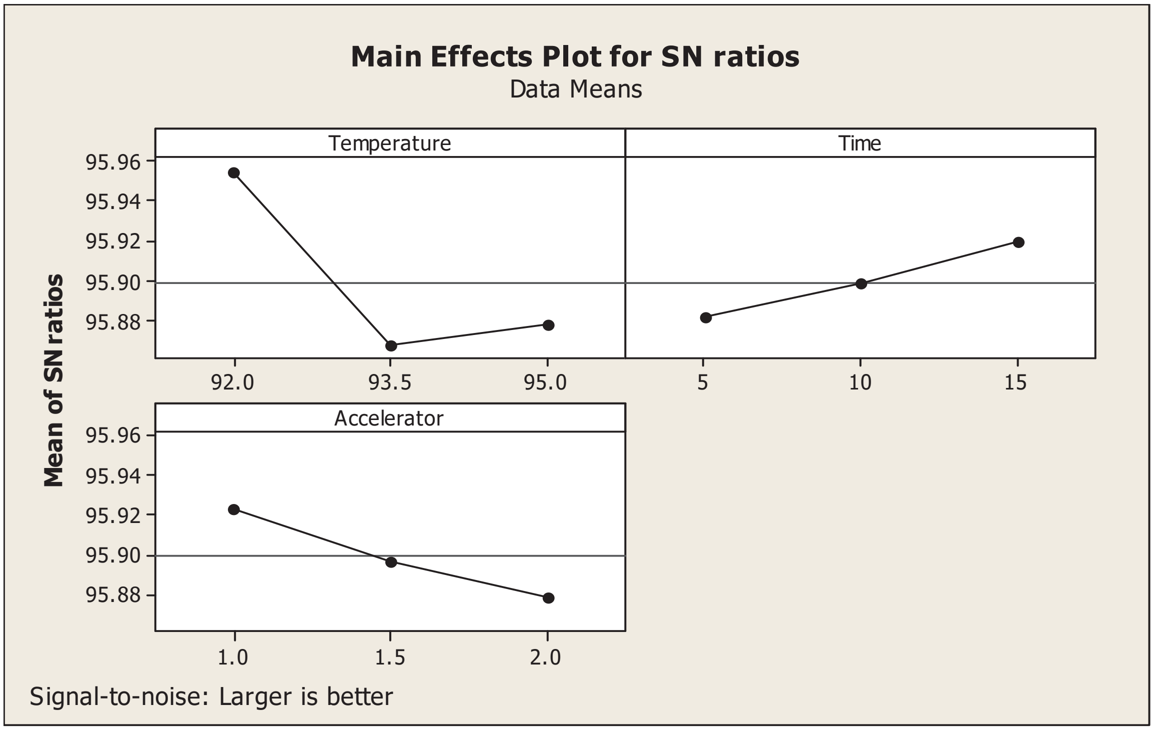

Figure 2. Main effect plot for S/N ratios

The value of delta and rank in table 5can assess which factor has the greatest effect on the response characteristics of intrest.Delta measures the size of the effect by taking the difference between the highest and lowest values for each response characteristic. The value of delta shows that the effect of phosphating bath temperature on the fatigue strength is the most significant, followed by phosphating time , accelerator level. Phosphating solution temperature is very important parameter, which is to be maintained within specified range for better results.

3.1 anova analysis

The most important statistic in the analysis of variance table is the p-value (P), which exists for each term in the model (except for the error term). The p-value for a term indicates whether the effect for that term is significant.

Table 6.ANOVA table

Source	DF	Seq SS	Adj SS	Adj MS	F	P	% contribution
Temperature	2	702038	702038	351019	13.58[b]	0.069	45.46
Phosphating time	2	111406	111406	55703	2.16	0.317	9.40
Accelerator	2	150657	150657	75328	2.91	0.255	42.57
Residual error	2	51686	51686	25843			2.45
Total	8	1015787					

b – significant parameter ($F_{0.1,2,8}$ = 3.11: $F_{0.05,2,8}$=4.46: $F_{0.01,2,8}$ = 8.65)

It can be seen that parameter temperature has got the most significant influence on fatigue life at the confidence level 90% , 95% ,99 % within the specific test range. The effects of control factors on the fatigue life in percentage and the error percentage are shown graphically. When the graphic is investigated, it is seen that all factors are effective on the result. temperature has the biggest effect with 46 % ratio. As seen from the graph the percent contribution due to error is low i.e 2 %, then it is assumed that no important factors were omitted from the experiment and the opportunity for further improvement is not great.

V. CONCLUSION

1) Taguchi orthogonal array design is suitably applied to maximize the fatigue life of phosphate coated specimen by optimizing three factors temperature, time and accelerator levels. The optimum testing condition obtained from the analysis yields about 15.19 % increase in life compared to uncoated specimen.
2) In the performed experimental trials using Taguchi orthogonal arrays, it was found that the Temperature (69%) had a significant effect on the fatigue life and followed by temperature (11%) and time (15%).
3) The presence of alloying elements and their chemical nature can cause distinct difference on phosphatability. This may be one of the reason for improvement in fatigue life.

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