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Investigation of Significant Process Parameter in Manganese Phosphating of Piston Pin Material by Using ANOVA

Hemant V Chavan*, Milind s Yadav**
*(Department of Mechanical Engg, Mumbai University, Maharashtra – 415639, India)
** (Department of Mechanical Engg, Mumbai University, Maharahstra – 415639, India)

ABSTRACT
The aim of this study is to determine the most significant parameter such as phosphating bath temperature, phosphating time,accelerator level on the fatigue life of piston pin material such as 40NiCr4Mo3 by analysis of variance (ANOVA).The selected three imput parameters were studied at three different level by conducting nine experiments based on L9 orthogonal array of Taguchi's methodology.Phosphating bath temperature has significant effect on fatigue strength followed by phosphating time and accelerator level.
Keywords – Fatigue strength, Phosphating process, piston pin material, Taguchi, ANOVA

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. The use of non-metallic surfaces with new additives leads to investigations into the interaction between these protective over layers and the base material. Surface treatments play a major role in the performance of the piston pin.. 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 material is studied by using design of experiments. The taguchi method uses the orthogonal arrays to optimize the process parameters.

Valdas kvedaras[02] and et al conducted rotating bending fatigue test results have shown that after pyrolytic chromium. He shows that plating the fatigue strength of steel can be improved as well as considerably worsened. It is due to the fact that depending on operating temperature of pyrolytic chromium plating process chromium coating of different microstructures can be found C.Marikkanu [04] and et al shown that corrosion resistance of phosphate coating are much superior than conventional coating. He shows that addition of accelerators resulted in better phosphate coating within reasonable time (30 min) and temperature (353K).

II. METHODOLOGY

In view of extensive applications of low alloy steel for making automotive component, SAE4340 material which is commonly used selected for the present study.Subsequent to procurement, the chemical composition of each grade of steel was evaluated through the spectroscopic analysis, the result of which are given in table 1

Table .1 .chemcial Composition of base material

Element	% weight
C	0.47
Mn	0.59
Si	0.24
S	0.022
P	0.034
Cr	1.1
Ni	1.430
Mo	0.250

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.

The coating unit comprised of a number of modular, tube-shaped component holders for accommodating the components to be coated. In order to achieve a uniform deposit over the entire surface of the components during the coating process, the component holders are given complex spinning motion by means of gear-arrangements.The coating unit comprised of a number of modular, tube-shaped component holders for accommodating the components to be coated. In order to achieve a uniform deposit over the entire surface of the components during the coating process, the component holders are given complex spinning motion by means of gear-arrangements.

Figure 1 .Phosphating bath

In general, phosphating sequence comprises of seven operations, as indicated in the flow chart figure 2. However, depending upon the surface conditions of the base metal, some of these operations may be omitted or additional operations may be incorporated into the system.

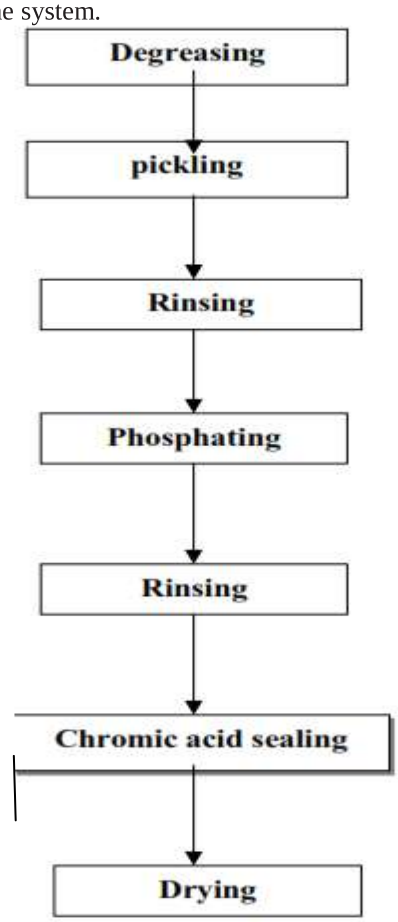

Figure 2. Operating sequence involved in phosphating process

2.2 Design of Experiment

The three factors temperature, phosphate time, accelerator were considered as the control factors affecting the fatigue life. A review of the current literature revealed that the testing parameters such as temperature, phosphating time and accelerator are easier to control. Hence these three factors are used as the main design factor in the present study

Table 2.operating parameters and their levels

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

In the present case since each of the main factors is associated with three levels, the dof of each of the factor is two. It is important to notice that the number of experimental trial in the OAs must be greater than the total dof required for studying the effects. Hence L_9 OA, requiring nine experimental trials is suitably chosen for the present case. L9 OA together with column assignments is shown in table 3

Table 3.L9 orthogonal array

Trials	Temperature	Phosphating time	Accelerator
1	92	5	1
2	92	10	1.5
3	92	15	2
4	93.5	5	1.5
5	93.5	10	2
6	93.5	15	1
7	95	5	2
8	95	10	1
9	95	15	1.5

Optimum setting of process parameter is a crucial aspect to improve phosphate ability of specimen. The investigation of effects of phosphate coating parameters on fatigue life of piston pin material is desirable. Fatigue strength is calculated experimentally for rache level of experiment.

Table 4.Experimental results

Trials	**Temp**	**Time**	**Accel. level**	**Fatigue life**
1	92	5	1	272340
2	92	10	1.5	271356
3	92	15	2	271437
4	93.5	5	1.5	271706
5	93.5	10	2	271304
6	93.5	15	1	272837
7	95	5	2	272565
8	95	10	1	272907
9	95	15	1.5	272639

In the present study S/N ratio analysis is done with fatigue life as the performance index and all the calculation are conducted in Minitab 16. As fatigue life is to be maximized, S/N ratio is calculated using larger the better criterion and is given by

$$\frac{S}{N} = -10 \log\left(\frac{1}{r}\sum_{i=1}^{r}\frac{1}{{y_i}^2}\right)$$

Where y is the observed data and r is the number of tests in a trial.

3.1Main effect plots

The analysis of the result from the plots, lead to establish the optimal setting levels of process of parameter.Hence the combination of process parameters is 95 – 15 – 1 gives the maximum fatigue life when coated with phosphating.

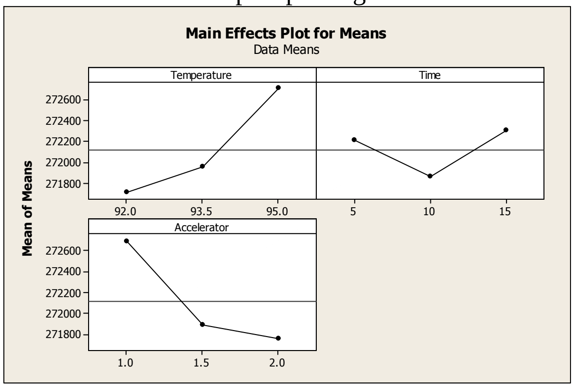

Figure 3.Main effect plot for means

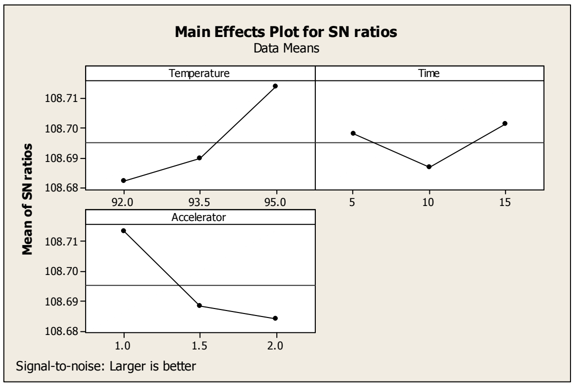

Figure 4.Main effect plot for S/N ratios

3.2 ANOVA analysis

In the present study, ANOVA is performed using S/N ratio as the response and the ANOVA table also consists of the F values and p value and percent contributions. By comparing evaluated F values of a parameter with the tabulated ones, the significance of the factors and their interactions can be easily understood. If the obtained F value of a parameter is greater than the tabulated one, then that particular parameter has a significance influence over the process response.

Table 5.ANOVA table

Source	Seq SS	Adj SS	Adj MS	F	P	% contribution
Temperature	1611553	1611553	805776	18.57[b]	0.051	69.91
Phosphating time	332540	332540	166270	3.83	0.207	10.96
Accelerator	1505778	150778	752889	17.35	0.055	14.83
Residual error	86798	86798	43399			4.3
Total	3536668					

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,. But parameter accelerator also have significance on the fatigue life.

III. CONCLUSION

1) The combination of process parameters is 95 – 15 – 1 gives the maximum fatigue life when coated with phosphating.
2) From main effect plot it is also cleared that temperature and accelerator is having greater inclination hence both are having higher influence.
3) The levels that have highest value of S/N ratio are the best factor levels. Third level of temperature gives the best result whereas third level of time and first level of accelerator gives the satisfactory result.
4) 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 69 % ratio. As seen from the graph the percent contribution due to error is low i.e. 5 %, then it is assumed that no important factors were omitted from the experiment and the opportunity for further improvement is not very great.

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