# Investigation of Optimal Process Parameters for Mechanical and Wear Properties of Carburized Mild Steel using Taguchi Approach

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***Abstract*- The properties of metals and alloys can be changed by heating followed by cooling under definite conditions to make them suitable for specific applications. Carburization is a method of producing mild steel having tough inner core and hard outer surface. In this paper, carburized mild steel developed by applying carburization process. After this we carried out different tests for mechanical and wear properties at different parameters. The parameters are considers as carburization temperature, carburization sock time, tempering temperature and tempering sock time. In present paper we optimize the process parameter by which we can produce best properties in carburized mild steel. For optimizing parameters we use Taguchi method. In Taguchi method $L_9$ ($3^4$) orthogonal array is using for experiment purpose. The mathematical values for heating and socking parameters are obtained by different experiments. We also apply ANOVA analysis for further Mathematical calculations, which gives significant parameters influencing mechanical and wear properties.**

***Keywords: Carburization process, Taguchi method, Process parameters, ANOVA analysis, Mechanical and wear properties.***

## I. INTRODUCTION

Changing demands of dynamic market place have improved and increased the commitment to quality conscious- ness. All over the world, companies are developing quality management systems like ISO 9001-2000 and investing in total quality [1]. 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 Indus-tries present improper application of process variables and inadequate control over the process parameters [2].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 [3].

Machine components are subjected to surface damages like wear and corrosion in addition to static and dynamic loads. Therefore, apart from material strength, surface hardness is also an equally important property for the reliability of components against failures [15-17].

Carburizing is the addition of carbon to the surface of low-carbon steels at temperatures within the austenitic region of the steel concern, which generally is between 850°C and 950°C for mild steels. Within this temperature range austenite, which has high solubility for carbon, is the stable crystal structure. Hardening is accomplished when the subsequent high-carbon surface layer is quenched to form martensite so that a high-carbon martensitic case with good wear and fatigue resistance is superimposed on a tough, low carbon steel core [4].

Carbon diffusivity in austenite varies both with carbon concentration and carburizing temperature [5-8]. The study of process parameters in metals during heat treatment has been of considerable interest for some years [9-12] but there has been relatively little work on process variables during the surface hardening process [13] since controlling parameters in carburization is a complex problem. The major influencing parameters in carburization are the holding time, carburizing temperature, carbon potential and the quench time in oil [14].

In this study, Taguchi's Design of Experiment concept has been used for the optimization of the process variables of pack carburizing process. Taguchi's $L_9$ orthogonal array and $3^4$ Factorial arrays have been adopted to conduct experiments in pack carburizing [18].

## II. ANOVA (ANALYSIS OF VARIANCE)

For the analysis of experimental data, Analysis of variance (ANOVA) and F-test (standard analysis) method are used, which are based on the Taguchi method given below:

$$C.F. = \{T^2 / N\},$$

C.F. = Correction factor,
T = Total of all result,

N = Total no. of experiments

$$S_T = \{\sum_{I=1 \text{ to } 18} Z_I^2 - C.F\},$$

$S_T$ = Total sum of squares to total variation.
$Z_I$ = Value of results of each experiments (I=1to18),

$$S_X = \{(Z_{X1}^2 / M_{X1} + Z_{X2}^2 / M_{X2} + Z_{X3}^2 / M_{X3}) - C.F\},$$

$S_X$ = Sum of the squares of due to parameter X (X=A, B, C, D),
$M_{X1}, M_{X2}, M_{X3}$ = Repeating number of each level (1, 2, 3) of parameter X,
$Z_{X1}, Z_{X2}, Z_{X3}$ = Values of result of each level (1, 2, 3) of parameter X,

$$F_E = \{F_T - \sum F_X\},$$

$F_E$ = Degree of freedom (D.O.F.) of error terms,
$F_X$ = Degree of freedom (D.O.F.) of parameter of X,
$F_X$ = (Number of levels of parameter X) – 1,
$F_T$ = Total degree of freedom (D.O.F.),
$F_T$ = (Total number of results)-1,

$$V_X = \{S_X / F_X\},$$

$V_X$ = Variance of parameter X,

$$S_E = \{S_T - \sum S_X\},$$

$S_E$ = Sum of square of error terms,

$$V_E = \{S_E / F_E\},$$

$V_E$ = Variance of error terms,

$$D_X = \{V_X / V_E\},$$

$D_X$ = F-ratio of parameter of X,

$$S_X' = \{S_X - (V_E * F_X)\},$$

$S_X'$ = Pure sum of square,

$$C_X = \{(S_X' / S_T) * 100\%\},$$

$C_X$= Percentage of contribution of parameter X,

## III. CONCLUSIONS

From the above studies on carburized mild steels samples the following conclusions have been drawn.

1. The mechanical and wear properties of mild steels were found to be strongly influenced by the process parameters.
2. Hardness and tensile strength increases with increase in the carburization temperature.
3. Wear rate and toughness decreases with increase in the carburization temperature.
4. Finally the net conclusion is that the mild steel carburized under the different temperature range and investigates suitable temperature at which the mild steel giving the best results for the mechanical and wear properties like tensile strength, hardness and wear rate.

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