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***Research Article***

# OPTIMIZATION OF MODELS OF LINER PISTON MAINTENANCE ACTIVITY OF LOCO SHED

**K Borkar[1], J.P. Modak[1] and *P.N. Belkhode[2]**

*[1]PCE, Nagpur, India*

*[2] LIT Nagpur, India*

**Author for Correspondence*

## ABSTRACT

In this paper field data based model is proposed to reduce the overhauling time and human energy consumed in liner piston maintenance activity so as to increase the productivity of liner piston maintenance activity. The independent variables affecting the phenomenon such as anthropometric parameters of workers, specification of liner piston data, specification of tools used in liner piston maintenance activity, specification of solvents, axial clearance of big end bearing and bolt elongation, workstation data and extraneous variables viz. temperature, humidity at workplace, illumination at workplace and noise at workplace Eastman Kodak Company Ltd. (1983) are taken into account. The model is formulated for dependent variables of liner piston maintenance activity to minimize the overhauling time and human energy consumption and to improve the productivity of liner piston maintenance activity. The developed model can predict the performance of liner piston maintenance activity which involves man and machine system (Muwell, 1956). The model is then optimized by optimization technique and the sensitivity analysis of the model has also been estimated.

***Keywords:*** *Mathematical Modelling, Liner Piston, Maintenance Activity, Sensitivity, Optimization*

## INTRODUCTION

Loco shed workers have to work in humid, poorly illuminated and noisy environment. During the liner piston maintenance activity, the body posture of loco shed workers experienced a postural discomfort. The interactions of workers with engine block during the liner piston maintenance operations lead to awkward postures which create muscular discomfort. Therefore, it is felt necessary to study the specifications of liner piston maintenance operations from postural comfort point of view. For this, the inputs as well as corresponding responses are measured and the relationship is established between the responses and inputs using theories of experimentation (Schenck, 1961) for liner piston maintenance activity in loco shed (Vidyasagar and Belkhode, 2014). Thus, the factors influencing the liner piston maintenance activity have been identified, so as to minimize the overhauling time of liner piston maintenance activity and to optimize the productivity and conserving human energy in this activity (Sonde and Belkhode, 2013).

### *The Model Formulation*

Theory of experimentation as suggested by Hilbert is an appropriate approach for representing the response of any phenomenon in terms of proper interaction of various inputs of the phenomenon has been proposed in the present investigation which involves following steps

- Identification of variables or parameter affecting the phenomenon
- Reduction of variables through dimensionless analysis
- Test planning
- Rejection of absurd data
- Formulation of model

*Identification of Variables*

Identification of variables is to be done based on known qualitative physics of the phenomenon. These variables are of three types

1) Independent variables
2) Dependent variables

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3) Extraneous variables

The term variable is used in a general sense to imply any physical quantity that undergoes change. Any aspect or a physical quantity, due to variation in it, which influences the final outcome of an activity (largely man machine system) or a phenomenon are known as input or independent variable of the activity. If a physical quantity can be changed independent of other quantities, then, it is also an independent variable. If a physical quantity can be changes in response to the variation of one or more number of variables, then it is termed as dependent or response variable. If a physical quantity that affects our test is changing in random and in uncontrolled manner in the phenomenon, then it is called as an extraneous variable.

***Models Developed for Dependent Variables of Liner Piston Maintenance Activity***

The exact forms of models for dependent variables, of liner piston maintenance activity are as under.

$Z_1 = \pi_{D1} = 1.0122\ (\pi_1)^{-0.0973}\ (\pi_2)^{-0.1917} (\pi_3)^{0.8772}\ (\pi_4)^{-6.0098}\ (\pi_5)^{0.0896} (\pi_6)^{0.378} (\pi_7)^{0.6869}\ (\pi_8)^{-0.5615}\ (\pi_9)^{-0.2282}\ (\pi_{10})^{0.0887}\ (\pi_{11})^{0.0838}$

(1)

$Z_2 = \pi_{D2} = 1.7874\ (\pi_1)^{0.355} (\pi_2)^{0.3448} (\pi_3)^{0.1681}\ (\pi_4)^{4.4021}\ (\pi_5)^{-0.0249}\ (\pi_6)^{-0.131} (\pi_7)^{-0.3313}\ (\pi_8)^{-0.1018}\ (\pi_9)^{-0.1479}\ (\pi_{10})^{0.0643}\ (\pi_{11})^{0.2221}$

(2)

$Z_3 = \pi_{D3} = 1.1148\ (\pi_1)^{0.0973}\ (\pi_2)^{0.1917}\ (\pi_3)^{0.0188}\ (\pi_4)^{-2.5291}\ (\pi_5)^{-0.0896}\ (\pi_6)^{-0.378}\ (\pi_7)^{2.971} (\pi_8)^{0.5615}\ (\pi_9)^{0.2282}\ (\pi_{10})^{-0.0887}\ (\pi_{11})^{-0.0838}$

(3)

In the above equations ($z_1$) is relating to response variable for overhauling time of liner piston maintenance activity, ($z_2$) is relating to response variable for human energy consumed in liner piston maintenance activity and ($z_3$) is relating to response variable for productivity of liner piston maintenance activity.

***ANN Simulation***

The liner piston maintenance activity involving non-linear system where in the validation of field data based models is not in close proximity, it becomes necessary to formulate Artificial Neural Network (ANN) simulation of the observed data (Kartalopous, 2004; Belkhode *et al.*, 2013). The output of this network can be evaluated by comparing it with observed data and the calculated data of mathematical model (Vidyasagar, 2013, 14).

The various output and graphs obtained by ANN program for overhauling time of liner piston maintenance activity are shown as below

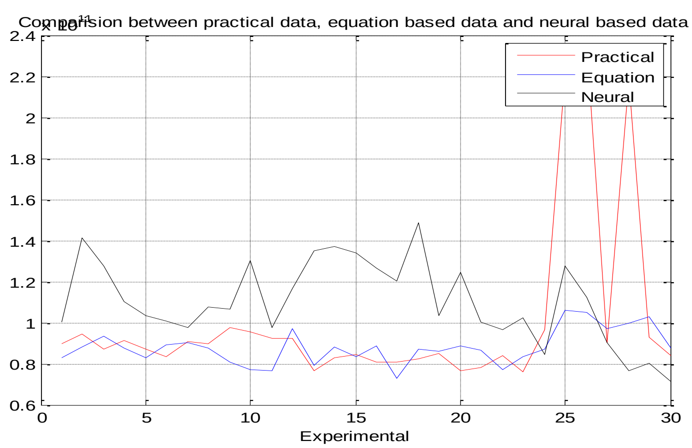


**Figure 1: Graph of Comparison with Experimental Data Base, Neural Network Prediction and Equation Base Prediction for the Network for Overhauling Time-Liner Piston Maintenance Activity (z1)**

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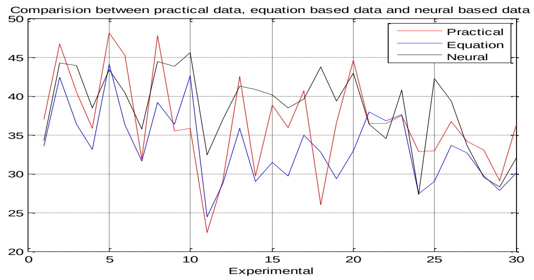


**Figure 2: Graph of Comparison with Experimental Data Base, Neural Network Prediction and Equation Base Prediction for the Network for Human Energy Consumed in Liner Piston Maintenance Activity ($z_2$)**

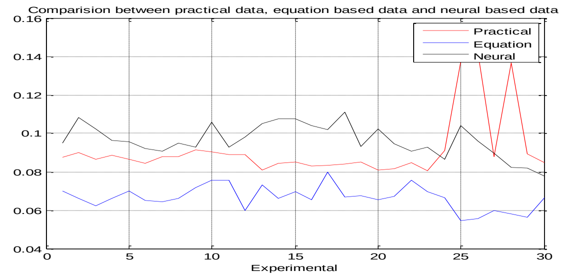


**Figure 3: Graph of Comparison with Experimental Data Base, Neural Network Prediction and Equation Base Prediction for the Network for Productivity of Liner Piston Maintenance Activity ($z_3$)**

From the above comparison of phenomenal response by a conventional approach and ANN simulation, it seems to be that the curve obtained by dependent pi terms for liner piston maintenance activity for overhauling time (z1), human energy consumed (z2), and productivity (z3) of liner piston are overlapping due to less percentage of error which is on positive side and gives an accurate relationship between ANN simulation and field data.

***Optimization of Models for Liner Piston Maintenance Activity***

The ultimate objective of this work is not merely developing models but also to find out the best set of independent variables, which will result in maximization/minimization of the objective function (Vidyasagar and Belkhode, 2013).

There will be three objective functions corresponding to this model. The model for the productivity of liner piston maintenance activity ($z_3$) needs to be maximized where as model for overhauling time of liner piston maintenance activity ($z_1$) and human energy consumed in liner piston maintenance activity($z_2$) needs to be minimized.

To maximize the linear function, linear programming technique is used as shown below. Let, the linear model in the form of first degree of polynomial can be written as,

$Z=K_1+ a *X_1+b*X_2+c*X_3 +d*X_4+e*X_5 \quad +f*X_6+g*X_7 +h*X_8+i*X_9 +j*X_{10} +k*X_{11}$

Thus the equation will be objective function for the optimization or to be very specific for minimization for the purpose of formulation of the linear programming problems and constraints for the problem can be defined as $C_1$ and $C_2$ (i.e. $C_1$= Log $\pi_{1\ max}$), (i.e. $C_2$= Log $\pi_{1\ min}$).

Hence the equations of constraints will be as under:

$.1x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_1$

$.1x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_2$

The other constraints can be like wise found as under.

$0x_1 + 1x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_3$

$.0x_1 + 1x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_4$

$.0x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_5$

$0x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_6$

$.0x_1 + 0x_2 + 0x_3 + 1x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_7$

$0x_1 + 0x_2 + 0x_3 + 1x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_8$

$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 1x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_9$

$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 1x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_{10}$

$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 1x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_{11}$

$0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 1x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_{12}$

$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 1x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_{13}$

$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 1x_7 + 0x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_{14}$

$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 1x_8 + 0x_9 + 0x_{10} + 0x_{11} \leq C_{15}$

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$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 1x_8 + 0x_9 + 0x_{10} + 0x_{11} \geq C_{16}$
$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 1x_9 + 0x_{10} + 0x_{11} \leq C_{17}$
$0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 1x_9 + 0x_{10} + 0x_{11} \geq C_{18}$
$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 1x_{10} + 0x_{11} \leq C_{19}$
$.0x_1 + 0x_2 + 0x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 1x_{10} + 0x_{11} \geq C_{20}$
$.0x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 1x_{11} \leq C_{21}$
$0x_1 + 0x_2 + 1x_3 + 0x_4 + 0x_5 + 0x_6 + 0x_7 + 0x_8 + 0x_9 + 0x_{10} + 1x_{11} \geq C_{22}$

After solving this linear programming problem, we get the minimum value of the Z and the set of values of the variables to achieve this minimum value.

$Z_{1min}$ =antilog=(11.03516044)=1.084327x$10^{11}$ and corresponding to this ,the values of $z_{1min}$ the independent pi terms are obtained by taking the antilog of $x_1$, $x_2$, $x_3$, $x_4$, $x_5$, $x_6$, $x_7$, $x_8$, $x_9$, $x_{10}$ and $x_{11}$. These values are 0.531259, 1.630555, 22886690834, 0.459878, 38.90476, 0.117284, 0.213848, 0.26,24,89100 and 70 respectively.

Similar procedure has been adopted optimize of dependent variables z2 and z3 of liner piston mentioned as below,

$Z_{2min}$ =antilog=(3.2113)=1626.6720 and corresponding to this ,the values of $z_{2min}$ the independent pi terms are obtained by taking the antilog of $x_1$, $x_2$, $x_3$, $x_4$, $x_5$, $x_6$, $x_7$, $x_8$, $x_9$, $x_{10}$ and $x_{11}$.These values are 0.531259, 1.630555, 22886690834, 0.459878,38.90476,0.117284, 0.213848, 0.26, 24,89100 and 70 respectively.

$Z_{3max}$=antilog=(-1.0893106)=0.0814121 and corresponding to this ,the values of $z_{3max}$ the independent pi terms are obtained by taking the antilog $x_1$, $x_2$, $x_3$, $x_4$, $x_5$, $x_6$, $x_7$, $x_8$, $x_9$, $x_{10}$ and $x_{11}$. These values are 1.6587, 5.17005, 22886690834, 0.459878, 116.143, 0.182479, 0.213848, 0.458, 80, 400697.7 and 89 respectively.

## DISCUSSION

The awkward postures adopted by loco shed workers during the liner piston maintenance activity create a muscular discomfort, became the motivation for this work. Perhaps, the present investigation will be useful to identify the main variable on which one can work and conversely the productivity of liner piston maintenance activity can be improved.

Analysis of mathematical models showed that the influence of specification of liner piston ($\pi_3$) on overhauling time ($z_1$) is significant and a tool used for liner piston maintenance ($\pi_4$) is significant for human energy consumed in liner piston maintenance activity ($z_2$) while workstation of liner piston maintenance activity ($\pi_7$) is significant on productivity of liner piston maintenance activity ($z_3$). Response variable overhauling time of liner piston maintenance activity ($z_1$) increases significantly, response variable human energy consumed in liner piston maintenance activity ($z_2$) and productivity of liner piston maintenance activity ($z_3$) increases moderately.

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