Maintenance Activity For Locomotive Crankshaft By Using FDBM Approach For Saving The Resources

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***Abstract*— This paper details the Modeling and Analysis of Crankshaft Maintenance activity for improving the productivity of Locomotive. Maintenance is the keyword in today's corporate strategy for survival in the global market. With a scheduled and cost-effective maintenance of the facility an organization can ensure its competitive edge in the market. Keeping this in mind a study is performed at Loco Shed. This shed is responsible for the maintenance of the Diesel Locomotive for the ZDM line. From the field survey ongoing maintenance schedule is obtained. The maintenance schedule is six parts program comprising of Trip, Fortnightly, Monthly, Quarterly, Half-Yearly and Yearly. After a detailed analysis of the schedule, critical f process was found in various schedules. From the analysis, the most common causes of failure in four major area of maintenance were detected. These failures were due to the misplaced steps in the present schedule i.e. steps which should have been performed in the earlier part of the schedule were delayed to the latter parts. Crankshaft is most maintenance intensive and expensive part of the engine and is the most vulnerable if proper maintenance is neglected. So overhauling of crankshaft is selected for modeling and analysis using FDBM approach to predict the performance of crankshaft maintenance activity.**

***Index Terms*— Maintenance, Crankshaft, Locomotive, FDB.**

I. INTRODUCTION

Since the beginning of time, humans have always felt the need for the maintenance of their equipment, machine, even the most rudimentary tools. Most of the failures experienced have been a result of abuse, as it sometimes still happens. First, they would do maintenance only when it was no longer possible to run it. That was called "Breakdown or Reactive Maintenance". It was until 1950's that some groups of Japanese engineers started a new concept in maintenance that consisted on performing the manufacturer's recommendations about the care that should be taken in the operation and maintenance of the machines and devices. That is called "Preventive Maintenance". To make it more effective proper scheduling can be done on the basis of history sheet of the system and past experience.

II. PROBLEM IN MAINTENANCE STRATEGY OF LOCOSHED

Railway is one of the organization in which schedule maintenance is mostly preferred along with the condition based maintenance for maintaining their diesel locomotives at various diesel maintenance workshops. They have the various schedules on the basis of running hours (days) such as Trip schedule – every after seven days, Fortnight schedule – every after fifteen days, monthly schedule – every after 30 days, Quarterly schedule – every after 90 days, Half yearly & yearly schedule. They also follow the major schedule such as three yearly and six yearly schedules called as periodic overhauling. It is observed that they are following conventionally framed scheduled maintenance system. Furthermore, this is a same repetitive laborious work which involves awkward posture of workers. It can be physically damaging on the neck, shoulder, back and forearms of the workers. Again such activity requires more human energy and time as compared to other activities carried out in loco shed .So it affects on productivity of maintenance of crankshaft. Thus it is necessary to formulate the model for such critical activity .With the help of this model, control on performance parameter and variables which help to improve productivity of crankshaft maintenance system can be obtained.

III. OBJECTIVE OF WORK

This work aims at detail study of present maintenance schedule for maintaining the ZDM loco and modeling and analysis of present maintenance activity of crankshaft using Field Data Base Modeling. It improves the personnel safety, system performance and availability of resources. It can be achieved by identifying the most critical components in the maintenance systems of the locomotive. Present practices of maintenance schedule, past failure data and their experiences can be taken into consideration for identifying the critical components.
FDBM have great importance for predicting the performance and for identifying potential failures in a system. It is an approach that complements the maintenance system & recommended that can be used for a more complete reliability study. FDBM is beneficial when it comes to improve the productivity of the present maintenance system.

IV. APPROACH OF FARMULATION OF MATHEMATICAL MODEL

The mathematical model can be established by an approach of experimental data based model formulation suggested by Schenck. H. Jr. [2], in a modified form is adopted for this purpose. The modification is to the extent of covering only and it is done by

(1) Identification of variables or parameter affecting the phenomenon.
(2) Establishment of dimension less pie terms

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(3) Direct data collection of crankshaft overhauling from loco shed workstation
(4) Rejection of absurd data
(5)Formulating the model

A. Need of formulation of model of Maintenance system

Maintenance is required for almost all types of machinery and applies also to the mechanical & automobile system. The type of maintenance that is performed can be defined as either preventive or corrective maintenance. Preventive maintenance is carried out at predetermined intervals or according to prescribed criteria and is intended to reduce the probability of a failure. Corrective maintenance is carried out after a failure and is intended to repair the system. In other words, preventive maintenance is performed before a failure and the corrective is preformed after the failure occurs. Consequently the challenge in planning the maintenance is to decide on when to perform preventive maintenance. Here two different types of system maintenance are exposed. One is corrective maintenance and another is preventive maintenance. Further it can be classified as scheduled maintenance and condition based maintenance.

However such maintenance policies may be quite inefficient to carry out proper overhauling of crankshaft. Thus it affect not only on productivity but also on human energy of workers. Thus it is necessary to formulate the model for such a critical activity by replacing the present approach with more flexible programs based on Field Data Base Modeling of needs and priorities in which the performance variable can be compared and helps to improve man machine system by deciding the strength and weakness of present method so that corrective actions can be planned for further improvement.

B. Chronicle sequence of maintenance activity of crankshaft

Various maintenance operations for overhauling of crank shaft can be enlisted chronologically as under.
1) Dismantling of big end nut by 41mm socket. 2) Decarbonizes of 6 liners in BDC position. 3) Lifting of piston and connecting Rod Assembly by crane. 4) Lifting of liner by crane using puller. 5) Removing old rubber ring, cleaning by kerosene and polishing it by emery paper. 6) Measuring Liner dia by Suito stand and checking inner piston ring gap by filler gauge. 7) Removing piston rings of piston by ring expander. 8) Taking out cerclip of piston pin by nose plyor. 9) Taking out piston pin. 10) Checking All Bearing Alignment And Resetting It Properly. 11) Tightening Of All Saddle Nuts. 12) Tightening Of Side Bolt By Spanner. 13) Fitting Of New Split Pin By Player.
classifications of Variables or factors of activity
The first step in this process is identification and classification of variables .The parameters of the phenomenon is called variables. Identification of all variables of the phenomenon is to be done based on known qualitative physics of the phenomenon. These variables are of three types
(1) Independent variables,
(2) Dependent variable, and
(3) Extraneous variable.
The independent variables are those which can be changed without changing other variables of the phenomenon. Whereas, the dependent variables are those, that can only change if any change in the independent variables. The extraneous variables change in a random and uncontrolled manner in the phenomenon. If the system involves a large number of independent variable, the experimentation becomes tedious, time consuming and costly. By deducing dimensional equation for the phenomenon, we can reduce the number of independent variable. The exact mathematical form of this equation will be targeted model. Upon getting the experimental results, adopting the appropriate method for test data checking and rejection, the erroneous data be identified and removed from the gathered data. Based on the purified data as mentioned above one has to formulate quantitative relationship between the dependant and independent Pi terms of the dimensional equation.
The crankshaft overhauling phenomenon is influenced by following variables

Table 1 - Independent and Dependent Variable

Description of Variables	Type of variable	Symbol	Dimension
Time required for activity	Dependent	Tm	T-1
Consumption of Human energy	Dependent	H E	M L2T-2
Productivity of crank shaft overhauling	Dependent	Pd	T-1
Age of worker	Independent	Aw	T-1
Experience of worker	Independent	Exw	T-1
Skill of worker	Independent	Skw	T-1
Enthusiasm of worker	Independent	Ew	
Description of Variables	**Type of variable**	**Symbol**	**Dimension**
Habbits of worker	Independent	Hw	
Health of worker	Independent	HlW	
Anthropometric data of worker	Independent	Ad	
Temperature of work station	Independent	Tws	
Humidity of workstation	Independent	Hws	
Noise of workstation	Independent	Nws	
Illumination of work station	Independent	IlWs	MT-3
Diameter of split pin	Independent	Dsp	
Length of split pin	Independent	Lsp	L
Diameter of saddle nut	Independent	Dsn	L
Length of saddle nut	Independent	Lsn	L
Diameter of saddle bolt	Independent	Dsb	L
Length of saddle bolt	Independent	Lsb	L
Diameter of small alen bolt	Independent	Dsmab	L
Length of small alen bolt	Independent	Lsmab	L
Diameter of side alen bolt	Independent	Dsiab	L
Length of side alen bolt	Independent	Lsiab	L
Diameter of saddle cap	Independent	Dsc	L
Length of saddle cap	Independent	Lsc	L
Diameter of main journal of crankshaft	Independent	Dmj	L
Length of main journal of crankshaft	Independent	Lmj	L
Diameter of crank pin journal of crankshaft	Independent	Dcpj	L
Length of crank pin journal of crankshaft	Independent	Lcpj	L
Diameter of bend ring	Independent	Dbr	L
Length of bend ring	Independent	Lbr	L
Diameter of small alen spanner	Independent	Dsms	L
Length of small alen spanner	Independent	Lsms	L
Diameter of side alen spanner	Independent	Dsis	L
Length of side alen spanner	Independent	Lsis	L

Diameter of barring rod	Independent	Dbrd	L
Length of barring rod	Independent	Lbrd	L
Diameter of main journal bearing	Independent	Dmjb	L
Thickness of main journal bearing	Independent	Tmjb	L
Length of main journal bearing	Independent	Lmjb	L
Diameter of crank pin journal bearing	Independent	Dcpjb	L
Length of frame	Independent	Lf	L
Length of crank pin journal bearing	Independent	Lcpjb	L
Thickness of crank pin journal bearing	Independent	Tcpjb	L
Width of frame	Independent	Wf	L
Height of frame	Independent	Hf	L
Kerosene (solvent) in kg	Independent	Ke	
Emery belt in kg	Independent	Eb	L
Lube oil	Independent		
Compressed air in kg	Independent	Ca	M
Axial clearance of main journal	Independent	Ax mj	L
Axial clearance of crank pin	Independent	Axcp	L
Saddle bolt elongation	Independent	El sb	L

C. Establishment of dimension less pi terms:

These Independent variables have been reduced into a group of pi terms. The Equation (1) shows the dimension less pie terms for the phenomenon.
List of Independent and dependent Pi term of crankshaft overhauling activity

Table 2 – Dimensionless Pi Terms

Description of Pi terms	**Establishment of dimensionless Equation of Pi term**
Pi term relating anthropometric data of worker	Π 1=[[(a*c*e*g)/(b*d*f*h)]
Pi term relating data of worker	$\Pi_{2=}$[(Ags/Exs),(sks/Ens),(hls/Hbs)]
Pi term relating specification of crankshaft	Π3=[(Dsps/Dsns)*(Lsps/Dsns)*(Dsmab/Dsns)*(Lsns/Dsns)*(Dsbs/Dsns)*(Lsbs/Dsns)*(Lsmab/Dsns)*(Dsiab/Dsns)*(Lsiab/Dsns)*(Dsc/Dsns)*(Lsc/Dsns)*(Dmj/Dsns)*(Lmj/Dsns)*(Dcpj/Dsns)*(Lcpj/Dsns)*(tmjb/Dsns)*(Dmjb/Dsns)*(Dcpjb/Dsns)*(tcpjb/Dsns)]
Pi term relating specification of tools	Π4=[(Dbr/Lbr),(Dsmsp/Lbr),(Lsmsp/Lbr),(Dsisp/Lbr),(Lsisp/Lbr),(Dbrr/Lbr),(Lbrr/Lbr)
Pi term relating specification of solvent ,lube oil and compressed air	Π 5= [(ker/l oil),(Ca/Eb)]
Pi term relating specification of Axial clearance of crank pin and Saddle bolt elongation	Π 6=[(Axcp/Elsb),(Axmj/Elsb)]
Pi term relating specification of workstation	Π 7=[(Hfrm/Lfrm),(wfrm/Lfrm)]
Pi term relating specification of temp.	Π 8= temp
Pi term relating specification of, humidity	Π 9= humidity in %
Pi term relating specification of illumination	Π10 = [(ilms* Ags/wt)]
Pi term relating specification of noise	Π 11=noise in db

Final Mathematical Model for crankshaft maintenance activity

Mathematical model For Time

$$(Y1) = 1.1798 *[(\pi_1)^{0.0873}*(\pi_2)^{0.102}*(\pi_3)^{0.6137} * (\pi_4)^{0.2115}*(\pi_5)^{-0.2101}*(\pi_6)^{-0.0025}*(\pi_7)^{1.5409} *((\pi_8)^{-0.4451}*(\pi_9)^{-0.125}*(\pi_{10})^{-0.0609} *(\pi_{11})^{0.1131}] \quad (1)$$

Mathematical model human energy

$$(Y2) = 1.2203 *[(\pi_1)^{0.2769}*(\pi_2)^{0.018}*(\pi_3)^{-0.2583} * (\pi_4)^{3.3045}*(\pi_5)^{0.0597}*(\pi_6)^{-0.0314} *(\pi_7)^{-1.3341} *((\pi_8)^{0.0415}*(\pi_9)^{0.0103}*(\pi_{10})^{0.002} *(\pi_{11})^{-0.3935}] \quad (2)$$

Mathematical model for productivity

$$(Y3) = 1.6837 *[(\pi_1)^{-0.0873}*(\pi_2)^{-0.1026}*(\pi_3)^{-0.1837} * (\pi_4)^{-1.2275}*(\pi_5)^{0.2101}*(\pi_6)^{0.0025} *(\pi_7)^{0.9916} *((\pi_8)^{0.4451}*(\pi_9)^{0.125}*(\pi_{10})^{j} *(\pi_{11})^{-0.1131}] \quad (3)$$

V. INTERPRETATION OF MODEL

Interpretation of model is being reported in terms of several aspects viz (1) order of influence of various inputs (causes) on outputs (effects) (2) the relative influence of causes on effect (3) Interpretation of curve fitting constant K (4) Sensitivity of causes (5) optimization (6) reliability

VI. ORDER OF INFLUENCE OF VARIOUS INPUTS AND THEIR RELATIVE INFLUENCE

Equation (1) is established based on field data for time The value of curve fitting constant in this model for (y1) is 1.1798, (y2) is 1.2203 and for (y3) is 1.6837 .This collectively represents the combined effect of all extraneous variables. Further, as it is positive, this indicates that, there are good numbers of causes, which have influence on increasing effect Analysis of the model for dependent pi term Y1:

1. The absolute index of π7 is the highest viz 1.5409 .thus the term related to frame of workstation is the most influencing π term in this model. The value of this index is positive indicating that time of crankshaft maintenance activity is directly proportional to workstation of activity
2. The absolute index of π8 is the lowest viz -0.4451 .thus the term related to temperature is the least influencing π term in this model. The value of this index is negative indicating that time of crankshaft maintenance activity is inversely proportional to temperature of workstation
3. The sequence of other independent π terms are π3, π4,π11 ,π2 ,π1 , π6 ,π10 ,π9 and, π5 having absolute indices as 0.6137,0.2115,0.1131, 0.1026, 0.0873, -0.0025, -0.0609, -0.125, -0.2101.
The time of crankshaft activity is directly proportional on crankshaft variable, tools, noise, workers data and anthropometric data of worker and indirectly proportional to clearance, illumination, humidity and solvent

Analysis of the model for dependent pi term Y2:

1. The absolute index of π4 is the highest viz 3.3045 .thus the term related to tools of crankshaft activity is the most influencing π term in this model. The value of this index is

positive indicating that time of crankshaft maintenance activity is directly proportional to tools of crankshaft activity
2. The absolute index of π7 is the lowest viz -0.4451.Thus the term related to frame of workstation is the least influencing π term in this model. The value of this index is negative indicating that time of crankshaft maintenance activity is inversely proportional to workstation of activity
3. The sequence of other independent π terms are π1, π5, π8, π9, π2, π10, π6, π3 and, π11 having absolute indices as 0.2769, 0.0597, 0.0415, 0.0103, 0.018, 0.0002,-0.0314, -0.2583.and -0.3935
The time of crankshaft activity is directly proportional on anthropometric data, solvent, temperature, humidity, workers data and illumination of workstation and indirectly proportional to clearance, crankshaft specification and noise
Analysis of the model for dependent pi term Y3:

1. The absolute index of π7 is the highest viz 0.9916 .thus the term related to frame of workstation is the most influencing π term in this model. The value of this index is positive indicating that time of crankshaft maintenance activity is directly proportional to workstation of activity
2. The absolute index of π8 is the lowest viz -1.2275. Thus the term related to temperature is the least influencing π term in this model. The value of this index is negative indicating that time of crankshaft maintenance activity is inversely proportional to tools required in an activity
3. The sequence of other independent π terms are π8, π5,π9 ,π10 ,π6 , π1 ,π2 ,π11 and, π3 having absolute indices as 0.4451,0.2101, 0.125,0.0609, 0.0025-0.0873,-0.1026, -0.1131, -0.1837The time of crankshaft activity is directly proportional temperature, solvent, humidity, illumination, clearance and indirectly proportional to anthropometric data, workers data, noise and crankshaft specification.

VII. ANN SIMULATION

The maximum reliability of the model can be established provided ANN Simulation of the gathered data is performed. ANN simulation will lead to simulation based model which will quantify appropriate non linear behavior of effect (responses) as influenced by causes (Inputs)

Following graphs for time ,human energy and productivity of crankshaft overhauling shows the comparison between practical data taken from field, equation based data obtained from modelling and neural based data obtained from ANN

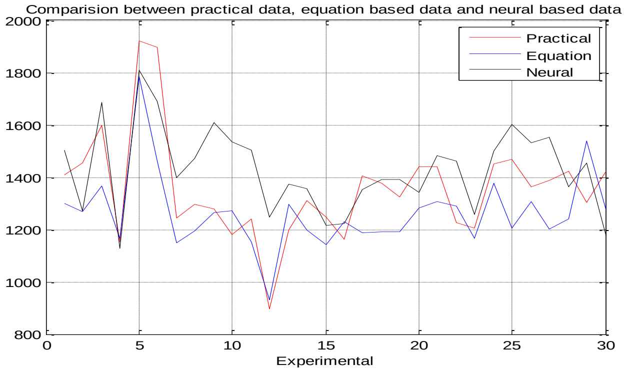

Fig-1: Graph of comparison with experimental data base, neural network prediction and equation base prediction for the network for Time

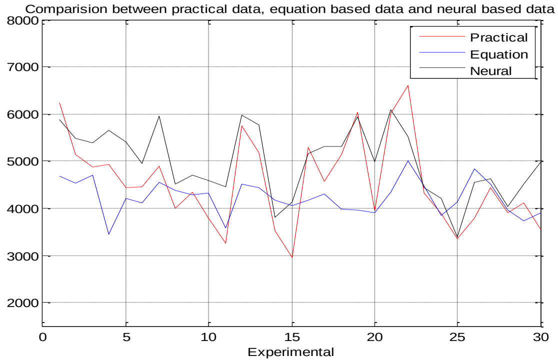

Fig-2: Graph of comparison with experimental data base, neural network prediction and equation base prediction for the network for Energy

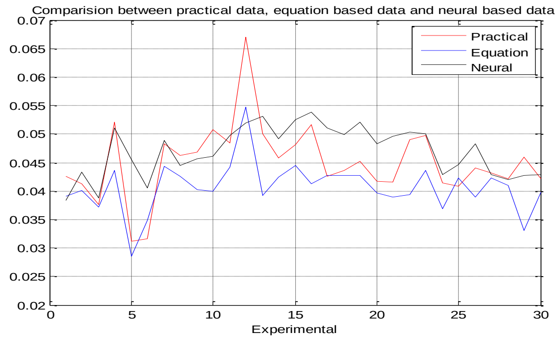

Fig-3: Graph of comparison with experimental data base, neural network prediction and equation base prediction for the network for Productivity

VIII. CONCLUSION

The postural discomfort experience of workers and saving available resources which involved in crankshaft overhauling became the cornerstone for this research work. They are not aware as to what extent ergonomic intervention can elevate their drudgery. Secondly the relationship between various inputs such as anthropometry of workers, specification of crankshaft, specification of tools, surrounding environmental conditions and their responses such as time to complete overhauling, human energy and productivity of crankshaft maintenance activity is not known to them quantitatively. Thus from these models "INTENSITY OF INTERACTION OF INPUTS ON DECIDING RESPONSE" can be predicted which will help to control variable for desired results

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