Vol. XIV & Issue No. 05 May - 2021
INDUSTRIAL ENGINEERING JOURNAL

FIELD DATA BASED MODELLING TO IMPROVE THE PRODUCTIVITY AND MAINTENANCE OF AIR COMPRESSOR

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Abstract

These days we are more interested in automation, but there is still a need for ergonomically designed tools in the modern consumer and industrial environment. Ergonomics refers to designing for human use. The term "human factor" or 'ergonomics" are now in news even in developing countries like India. According to scholars, ergonomics deals with man and his working environment, tools, materials and process. Ergonomics tries to achieve comfort to the man and accomplish the work efficiently. Various disciplines contribute for development and implementation of the knowledge of ergonomics in practice .Members of various professional societies like engineers, psychologists and medical practitioners contribute for development of ergonomics of course, it is advantageous to be an engineer for successful implementation of ergonomics in manufacturing, design and planning. Paper details the improvement in productivity and quality of maintenance of air compressor. There are two types of maintenance attended here periodical and breakdown. Air compressors are used in these locos to maintain 10 kg/cm^2 air which is used for loco breaking and loco running systems like fuel supply control through governor and hydraulic transmission system. The improvement in overhauling of air compressor improves the periodical maintenance schedules which save precious time and increase efficiency. Further paper details the field investigation carried out in regard to air compressor overhauling operation. An approximate generalized field data based model is evolved for Improving Productivity and Maintenance Quality.

Keyword: Maintenance, Compressor, Mathematical, Model, productivity

1. INTRODUCTION

The maintenance work consists of periodical (Preventive) and breakdown maintenance. The periodical one is called as schedule repair which is attended after a certain time period it is divided from 10 days gap to 720 days for locomotive. Breakdown maintenance is called as trouble repair which are attended after sudden failure of locomotive on run. The improvement in overhauling of air compressor improves the periodical maintenance schedules which save precious time and increase efficiency. In the present method, the productivity is less and requirement of human energy is substantial. Therefore, the factors influencing the overhauling of air compressor have been identified, so as to optimize the productivity and conserving human energy in this activity. The generalized mathematical model has been formulated using theories of experimentation for the overhauling of air compressor. Field data based model for a man machine system will decide strengths and weaknesses of present method of performing any maintenance activity. Once weaknesses are known corrective action can be decided. Strength characteristics of the maintenance operator including back, shoulder, arm, sitting leg strength and standing leg strength are poor when compared with other industrial workers. The physiological and biomechanical demands of doing maintenance work in such an environment are much greater, with the above constraint. Further, they have to work in humid, less airy, poor illumination & noisy environment along with vibrations. So, due to the present overhauling method the productivity is less & requirement of human energy and time required is substantial. Hence, it is required to identify the factors influencing the overhauling activity to formulate the Field data based model for this activity for decreasing the time required for overhauling the air compressor and conserving human energy.

2. OVERHAULING ACTIVITY

A question arises before the production in-charge that in spite of the hard work done by the worker, why he fails to give the adequate productivity for complete shift of 8 hours, which reduces the efficiency of operation. Hence, this aspect in general stimulates to investigate a mathematical model, which can predict the air compressor overhauling activity performance which involves man-machine system. Indeed the model will be useful for both workers as well as for the production in-charge to work on prominent variables by which they can improve the performance of worker by deciding the strength and weakness of present method. Once weaknesses are known corrective action can be decided.

The maintenance of various engine parts carried out as per prescribed schedule. Out of these maintenance activities, maintenance of air compressor consumed more time and human energy with less productivity. Data is collected based on sequence of maintenance activity by direct measurement from this data input and output variables are decided and model is formed by forming dimensionless equation using regression analysis.

Strength characteristics of the maintenance operation including back, shoulder and sitting leg strength and standing leg strength are poor when compared with other industrial workers. Most

studies agree that maintenance operators are bound to have lower than average aerobic capacity. Further, they have to work in open environmental and noisy environment. So, due to the present maintenance techniques of air compressor overhauling productivity is less and requirement of human energy and the time required is substantial. The generalized mathematical model has been formulated using theories of experimentation for overhauling techniques activities. Therefore, the present approach could be replaced with optimized techniques based on field data based modeling in which dependent and independent variables of an activity can be compared and the one most effective method for improving the present method can be evolved. Hence, it is required to identify the factors influencing the air compressor overhauling techniques which necessitates formulating the Field Data based Models for these activities so as to increase the productivity besides reducing the time required and conserving human energy.

It can be seen from the literature review and cursory survey that the effectiveness of maintenance techniques not only depends on the specifications of process parameters, but also on the anthropometric dimensions of the operators including his attitude and aptitude to do work. It also depends on specifications of operator's tools, ambient temperature, relative humidity and Illumination (environment). Therefore, it was decided to study effect of these inputs (independent variables) on the outputs. i.e., time of maintenance, human energy consumed (dependent variables) in this activity. Once, the model is formulated for any phenomenon, one gets a clear idea about variation of dependent variables in terms of interaction of various independent variables.

2.1 Ergonomics issues in Maintenance Field

According to PC Schutte and JR Smith (2001) the major objective of the ergonomics is to enhance the effectiveness and efficiency with which human task are carried out to improve desirable human values. enhancing safety, reducing fatigue, increasing comfort with improved job satisfaction while enhancing effectiveness in carrying out the tasks

2.2 Scheduling a maintenance activity

Hussain, S.and. Naikan V. N. A (2010), analyzed the maintenance of the industrial repairable systems. The future issues were addressed in the mathematical modeling for maintenance. They attempted to review the models which are available in the research literatures to deploy appropriate model for effective maintenance planning and implementation.

Endrenyi J. (1999) and other members were found that the impact of maintenance strategy on reliability. The author suggested that the optimized probabilistic maintenance models would provide the highest savings and also the highest flexibility in exploring and utilizing the effects of changes in any of the parameters.

Narkhede B.E., (2014) studied the implications of manufacturing strategy practices on manufacturing and business performance. Author details the action plan composed of decisions in improvement activities. The author further suggest to assess the implications of organizational knowledge, source of information and functional orientation, resource based view of the manufacturing and global orientation, on manufacturing practices which include advanced manufacturing technology.

Kulkarni S D, Dhake R J, Raut R D, Narkhede B E, (2014) details the procedure for achieving operational excellence through Integrated Approach of Lean Manufacturing and TPM Methodology in Mechanical Cluster Line through the case study.

Many researchers have given recommendations for ergonomics design and mechanization of maintenance activities. The problems of scheduling maintenance are also investigated by some researchers. Therefore establishment of scientific, comprehensive maintenance system are faced with today's challenges.

3. DATA COLLECTIONS:

The air compressor overhauling phenomenon is influenced by following variables.

Table 1: Independent and Dependent Variables

Sr. No.	Description	Type of variables	Symbol
1	Stature	Independent	a
2	Shoulder Height	Independent	b
3	Elbow Height	Independent	c
4	Eye Height	Independent	d
5	Finger tip Height	Independent	e
6	Shoulder Breadth	Independent	f
7	Hip Breadth	Independent	g
8	Hand Breadth across thumb	Independent	h
9	Skill of worker	Independent	W_s
10	Habits of worker	Independent	W_h
11	Anthropometric data	Independent	A_n
12	Age	Independent	A_g
13	Experience	Independent	Exp
14	Enthusiasm	Independent	En
15	Ambient temperature	Independent	θ
16	Relative Humidity	Independent	ø
17	Illumination	Independent	I
18	Spanner	Independent	Sp

19	Pipe wrench	Independent	Pw
20	Screw Driver	Independent	Sd
21	Pressure	Independent	P
22	Time for overhauling	Dependent	T
23	Human energy consumption for overhauling	Dependent	He

4. ANALYSIS OF DATA (ESTABLISHMENT OF DIMENSIONLESS π TERMS):

These independent variables have been reduced into group of π terms.

List of the Independent & Dependent π terms of the overhauling activity are:

Table 3: Independent dimensionless π terms

Sr. No.	Independent Dimensionless ratios	Nature of basic Physical Quantities
01	π1	Anthropometric dimensions of the worker
02	π2	Specifications of maintenance tools
03	π3	Specifications of process parameters
04	π4	Ambient temperature
05	π5	Relative humidity
06	π6	Illumination

Table 4: Dependent dimensionless ratios

Sr. No.	Dependent Dimensionless ratios or π terms	Nature of basic Physical Quantities
01	πD1	Time of overhauling
02	πD2	Human Energy Consumption for overhauling

Six independent π terms ($\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6$) and two dependent π terms (π_{D1}, π_{D2}) have been identified for field study model formulation.

Each dependent π term is a function of the available independent π terms,

$Td = f(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6)$

$He = f(\pi_1, \pi_2, \pi_3, \pi_4, \pi_5, \pi_6)$

Where,

$Td = \pi_{D1}$, First dependent π term= Td

$He = \pi_{D2}$, Second dependent π term= He

f stands for "function of " . The probable exact mathematical form for the dimensional equations of the phenomenon could be relationships assumed to be of exponential form.

4.1 Model formulation by identifying the curve fitting constant & various indices of π terms:

The multiple regression analysis helps to identify the indices of the different π terms in the model aimed at, by considering six independent π terms and one dependent π term. Let model aimed at be of the form,

The exact forms of models obtained are as under:

$T = K\{[(P1)]^{a1},[P2]^{b1},[P3]^{c1}[P4]^{d1},[P5]^{e1}[P6]^{f1}\}$

$He = K\{[(P1)]^{a2},[P2]^{b2},[P3]^{c21}[P4]^{d2},[P5]^{e2}[P6]^{f2}\}$

To determine the a_1, b_1, c_1, d_1, $e_1$and f_1 in equation, so that:

$$T=K_1*[(\pi_1)^{a1}*(\pi_2)^{b1}*(\pi_3)^{c1}*(\pi_4)^{d1}*(\pi_5)^{e1}*(\pi_6)^{f1}] \quad (1)$$

$$He=K_2*[(\pi_1)^{a2}*(\pi_2)^{b2}*(\pi_3)^{c2}*(\pi_4)^{d2}*(\pi_5)^{e2}*(\pi_6)^{f2}] \quad (2)$$

To determination of K_1, a_1, b_1, c_1, d_1, $e_1$and f_1 in the above equations, so that:

$$\Sigma T = nK_1 + a_1*\Sigma A + b_1*\Sigma B + c_1*\Sigma C + d_1*\Sigma D + e_1*\Sigma E + f_1*\Sigma F$$

$$\Sigma T*A = K_1*\Sigma A + a_1*\Sigma A*A + b_1*\Sigma B*A + c_1*\Sigma C*A + d_1*\Sigma D*A + e_1*\Sigma E*A + f_1*\Sigma F*A$$

$$\Sigma T*B = K_1*\Sigma B + a_1*\Sigma A*B + b_1*\Sigma B*B + c_1*\Sigma C*B + d_1*\Sigma D*B + e_1*\Sigma E*B + f_1*\Sigma F*B$$

$$\Sigma T*C = K_1*\Sigma C + a_1*\Sigma A*C + b_1*\Sigma B*C + c_1*\Sigma C*C + d_1*\Sigma D*C + e_1*\Sigma E*C + f_1*\Sigma F*C$$

$$\Sigma T*D = K_1*\Sigma D + a_1*\Sigma A*D + b_1*\Sigma B*D + c_1*\Sigma C*D + d_1*\Sigma D*D + e_1*\Sigma E*D + f_1*\Sigma F*D$$

$$\Sigma T*E = K_1*\Sigma E + a_1*\Sigma A*E + b_1*\Sigma B*E + c_1*\Sigma C*E + d_1*\Sigma D*E + e_1*\Sigma E*E + f_1*\Sigma F*E$$

$$\Sigma T*F = K_1*\Sigma F + a_1*\Sigma A*F + b_1*\Sigma B*F + c_1*\Sigma C*F + d_1*\Sigma D*F + e_1*\Sigma E*F + f_1*\Sigma F*F$$

In the above set of equations, the values of the multipliers K_1, a_1, b_1, c_1, d_1, $e_1$and f_1 are substituted to compute the values of the unknowns (viz. K_1, a_1, b_1, c_1, d_1, e_1 and f_1). The values of the terms on L.H.S and the multipliers of K_1, a_1, b_1, c_1, d_1, e_1 and f_1 in the set of equations are calculated and tabulated. After substituting these values in the equations, one will get a set of 5 equations, which are to be solved simultaneously to get the values of K_1, a_1, b_1, c_1, d_1, $e_1$and f_1.The above equations can be verified in the matrix form and further values of K_1, a_1, b_1, c_1,

d_1, $e_1$and f_1 can be obtained by using matrix analysis.

$$\mathbf{X_1 = inv\ (W)\ x\ P_1}$$

The matrix method of solving these equations using 'MATLAB' is given below.

W = 7 x 7 matrix of the multipliers of K_1, a_1, b_1, c_1, d_1, e_1 and f1

P_1 = 7x 1 matrix of the terms on L H S and

X_1 = 7 x 1 matrix of solutions of values of K_1, a_1, b_1, c_1, d_1, e_1 and f1

Then, the matrix obtained is given by,

X1 matrix with K1 and indices a1, b1, c1, d1, e1 and f1 are evaluated:

K1=1.98, a = 2.23 , b = 1.12, c = 1.98 , d = 0.70, e = 0.72 , f = 0.53

X_1 matrix with K_1 and indices a_1, b_1, c_1, d_1, e_1 and f_1 are evaluated and substituted in the given equation:

$$\mathbf{T= 1.98*(\pi_1)^{2.23}*(\pi_2)^{1.12}*(\pi_3)^{1.98}*(\pi_4)^{0.70}*(\pi_5)^{0.72}*(\pi_6)^{0.53}}$$

Similarly, based on the same approach the unknown for Human Energy Consumption is calculated and equation is presented in the given form

$$\mathbf{He = 1.58*(\pi_1)^{1.42}*(\pi_2)^{0.54}*(\pi_3)^{0.14}*(\pi_4)^{0.85}*(\pi_5)^{0.27}*(\pi_6)^{1.47}}$$

In the above equations (T) is relating to response variable for time of overhauling activity and (He) is relating to response variable for human energy consumed in the overhauling of air compressor activity

4.2 Models Developed For Dependent Variables

The Readings have been collected at work stations with a team of different workers at each location at different timings.

The exact forms of models obtained are as under:

$$\mathbf{T= 1.98*(\pi_1)^{2.23}*(\pi_2)^{1.12}*(\pi_3)^{1.98}*(\pi_4)^{0.70}*(\pi_5)^{0.72}*(\pi_6)^{0.53}}$$

$$\mathbf{He = 1.58*(\pi_1)^{1.42}*(\pi_2)^{0.54}*(\pi_3)^{0.14}*(\pi_4)^{0.85}*(\pi_5)^{0.27}*(\pi_6)^{1.47}}$$

In the above equations (T) is relating to response variable for time of overhauling activity and (He) is relating to response variable for human energy consumed in the overhauling activity.

5. RESULT AND DISCUSSION

Interpretation of Time of Overhauling (T)

The value of curve fitting constant in this model for (T) is 1.98. This collectively represents the combined effect of all extraneous variables such as lower aerobic capacity of worker, physiological and biomechanical demands of doing overhauling in vertical space restrictions, working in noisy environment along with heat stress and less oxygen uptake etc. Further, as it is positive, this indicates that these causes have increasing influence on the time of overhauling activity (T). The absolute index of π_1 is the highest Viz. 2.23. Thus, the term related to anthropometric data is the most influencing π term in this model. With age, enthusiasm, general health the status of Miner deteriorates making the time for overhauling increase as $[\pi_1]$ increases.

Interpretation of Human Energy (He)

The value of curve fitting constant in this model for (He) is 1.58. This collectively represents the combined effect of all extraneous variables such as lower aerobic capacity of miners, physiological and biomechanical demands of doing work in vertical space restrictions, working in noisy environment along with heat stress and less oxygen uptake etc. Further, as it is positive, this indicates that these causes have influence on the Human energy consumed in overhauling activity (He). The absolute index of π_1 is the highest Viz. 1.42. Thus, the term related to anthropometric data is the most influencing π term in this model. With the age, enthusiasm, general health status of worker deteriorates making the Human energy for overhauling also increase as $[\pi_1]$ increases.

Analysis of the Mathematical models showed that the influence of Anthropometric data of the worker and ambient temperature on the time of overhauling is significant and increases with increase in ambient temperature. The response variable time of overhauling decreases with improvement in Illumination, ambient air velocity in the work station. The response variable Productivity increases significantly with reduction in ambient temperature and relative humidity. The response variable Human Energy Consumed in overhauling operation is significantly dependent upon Anthropometric data of worker.

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