Applied Mathematical Modelling 34 (2010) 1672–1683

Contents lists available at ScienceDirect

Applied Mathematical Modelling

journal homepage: www.elsevier.com/locate/apm

Availability analysis of crank-case manufacturing in a two-wheeler automobile industry

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ARTICLE INFO

Article history:
Received 3 December 2008
Received in revised form 5 September 2009
Accepted 9 September 2009
Available online 17 September 2009

Keywords:
Availability
Preventive maintenance
Corrective maintenance
Runge–Kutta method

ABSTRACT

The paper describes the availability of crank-case manufacturing system in an automobile industry. The units discussed here fail either directly from normal working state or indirectly through partial failure state. The machines are subjected to both preventive and corrective maintenance. Failure and repair times of the units are independent. The problem is formulated using probability consideration and supplementary variable technique. The system of equations governing the working of system consists of ordinary as well as partial differential equations. Lagrange method and Runge–Kutta method is used to solve partial differential equation and ordinary differential equation respectively. The study reveals that successful program of preventive and routine maintenance will reduce equipment failures, extend the life of the equipment, and increase the system availability to considerable margin.

1. Introduction

Reliability, in general, can be defined as the ability of a system to perform its required functions under stated conditions for a specified period of time. Reliability technology is an important phenomenon of the existing era. This technology is widely used to increase the efficiency of the system. To overcome day-to-day problems, now a day, the system analysts and engineers are interested in the analysis of reliability models to implement them for practical utility. The paper consists of a brief discussion of method of calculating availability for idealized and faulty preventive maintenance. The problem is also reduced to the case when no preventive maintenance (PM) is done. The paper also presents the steady state and transient study of the system in evaluation of availability. The primary action of the preventive maintenance is to control the condition of the system and to ensure its availability. Efficiency of PM also affects the operational behavior of the system. Perfect and efficient PM means no damage and no error during maintenance operation. The faulty and inefficient PM means that either replaced component may not have worked properly or maintenance personal may have damaged the equipment. Corrective maintenance (CM) is the maintenance action carried out to restore a defective system or component to an operative condition. Many authors have studied preventive maintenance systems. Barlow and Hunter [1] studied the preventive maintenance models with minimal repairs. Singh [2] computed the state probabilities of a complex system having four types of components with preemptive repeat priority repairs. Zhang [3] studied the stochastic behavior of an (N+1)-unit standby system under preemptive priority repair rule and obtained the expressions for transient as well as steady states of the system using supplementary variable technique and Laplace transforms. Gandhi and Wani [4] evaluated maintainability index of mechanical system using digraph and matrix method. Grall et al. [5] presented a preventive maintenance structure for a

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doi:10.1016/j.apm.2009.09.016

gradually deteriorating single unit system. Kumar [6], Singh [7], Gupta et al. [8], Garg et al. [9] and some other workers applied reliability technology to various industrial systems obtaining important results.

In the present paper, the production of a crank-case in a two-wheeler automobile company has been discussed in detail. The raw material used is raw crank-case. The paper focuses on the system availability, and obtained the valuable expressions for availability under various conditions. The system availability has been discussed for two states: transient state and steady state. Numerical analysis of availability of the system for transient state and steady state has been done by using Runge–Kutta method and software package MATLAB 5.1 respectively. Based on the analysis of system, suggestions have been made to optimize the production of system.

2. System description and notations

2.1. System description

The crank-case assembly line, discussed in this paper consists of the following nine sub-systems. The units under study are specialized single purpose machines.

1. Module machine-1 (M_1).
2. Module SPM widma-1 (W_2).
3. Module machine-2 (M_3).
4. Module SPM widma-2 (W_4).
5. Module machine-3 (M_5).
6. Fine boring machine (B).
7. Horizontal milling machine (H).
8. Tapping machine-1 (T_8).
9. Tapping machine-2 (T_9).

All the sub-systems listed above are single units subjected to revealed as well as unrevealed failure. The first machine in the crank-case line is the module machine-1, is used to drill on the sides of the crank-case. Module SPM widma-1 machine is used to drill on the face of the raw crank-case. The module machine-2 is used for side tapping. The module SPM widma-2 is used for tapping. Module machine-3 is used for further tapping. Fine bores are drilled with the help of mico fine boring machine. Milling is done with the help of horizontal milling machine. Then tapping is done on tapping machine-1 and finally on tapping machine-2. Undergoing all these processes serially, we get a finished crank-case. Fig. 1 gives the schematic flow chart of the crank-case production process.

2.2. Notations

In addition to the notations used for sub-systems, we have also used the following notations.

-	the sub-system/unit is running without any failure
g	unit is in good state but not operative
m	unit is under preventive maintenance
r	unit is under repair or repair continued
A^z	($A = B, H$) indicates the working state of fine boring and horizontal milling machine w.r.t. z, (z = -, g, m, r)
$M_{i,j}^{x,y}$	indicates the working states of the sub-systems M_i and M_j w.r.t. x, y (x, y = -, g, r, m:: $i = 1, 3, 5$: $j = i + 2, i + 4$ if $i = 1$; $j = i - 2, i + 2$ if $i = 3$; $j = i - 2, i - 4$ if $i = 5$). The ordered pairs $\binom{x}{i}$ and $\binom{y}{j}$ refer the working status of the units M_i and M_j
$W_{k,l}^{x,y}$	indicates the working states of the sub-systems W_k, W_l w.r.t. x, y (x, y = -, g, r, m:: $k = 2, 4$: l = 4 if $k = 2$; l = 2 if $k = 4$)
$T_{u,v}^{x,y}$	indicates the working states of the sub-systems T_u, T_v w.r.t. x, y (x, y = -, g, r, m:: $u = 8, 9$: $v = 9$ if $u = 8$; $v = 8$ if $u = 9$)
λ_i	respective constant transition rate causing a unit of sub-systems M_1, W_2, M_3, W_4, M_5, B, H, T_8 and T_9 from normal to degraded state, ($i = 1, 2, \ldots, 9$)
pdf	probability density function
$\mu_i\ (x)$, $C(x)$	repair rate and pdf of PM time of the sub-systems M_1, W_2, M_3, W_4, M_5, B, H, T_8 and T_9 for its transition from degraded to normal state, and has an elapsed repair time 'x'; ($i = 1, 2, \ldots, 9$)
$\lambda_j\ (y)$	the first order probability that the sub-systems M_1, W_2, M_3, W_4, M_5, B, H, T_8 and T_9 transits from normal to failed state in the interval ($y, y + \Delta$), conditioned that it has not failed up to time y; ($j = 10, 11, \ldots, 18$)
$\mu_j(x), D(x)$	repair rate and pdf of repair time of the M_1, W_2, M_3, W_4, M_5, B, H, T_8 and T_9 to return it from failed to normal state, and has an elapsed repair time 'x'; ($j = 10, 11, \ldots, 18$)

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