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Performance Analysis and Maintenance Planning of MAT Production System in MAT Making Industry

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Abstract
The paper discusses the performance modeling and maintenance planning for Mat Production Unit. The total plant is divided into many sections like cotton yarn section, coloring of yarn and mat production unit. Failure and repair rates are assumed constant. The mathematical model has been developed on the basis of probabilistic approach using Markov Birth – Death Process. The differential equations have been made using transition diagram which are further solved recursively by using normalizing conditions in order to develop the performance model using Steady State Availability. The critical subsystems are identified with the help of performance analysis in terms of various Availability levels for various combinations of failures and repair rates.

Keywords
Availability, Maintenance Planning, Performance Analysis

I. Introduction

The objective of utmost production and long run availability under the specified operative condition can be achieved by making the system failure free as far as possible by proper maintenance planning and control. Availability analysis helps us to obtain the necessary information about the control of various parameters The mechanical systems have attracted the attention of several researchers in the area of reliability theory. Dyal and Singh [1] studied reliability analysis of a system in a fluctuating environment. Deepika Garg et.al.[2] developed the mathematical model of a cattle feed plant using a birth-death Markov Process. Jorn Vatn and Terje Aven [3] touched the various techniques for maintenance optimization in Norwegian railways Dai et al. [4] developed an optimization model for the grid service allocation using Genetic Algorithm. Kiureghian and Ditlevson [5] analyzed the availability, reliability and downtime of system with repairable components. Rajiv Khanduja et. al [6] reported the availability analysis of the bleaching system of a paper plant. Tewari et.al. [7] analyzed the performance evaluation and optimization for urea crystallization system in a fertilizer plant using Genetic Algorithm. Kanduja et al. [8] developed a performance model for stock preparation unit of a paper plant using Markov approach and optimize the performance using genetic algorithm.

II. System Description

This system consists of three subsystems which are working in series. Subsystem (A) is a single unit subsystem and two subsystems (B & C) are multi-unit systems. Subsystem A shows the Ring Frame. Subsystem B denotes the ten tufting machines in parallel. Subsystem C denotes ten cutting machines in parallel.

III. Assumptions And Notations

A. Notations:

A : Operative state of Ring Frame
B : Operative state of tufting machines
C : Operative state of cutting machines
$\bar{B}$: Reduced state of tufting machines
$\bar{C}$: Reduced state of cutting machines
a : Failed state of Ring Frame
b : Failed state of tufting machines
c : Failed state of cutting machines
λ_1, μ_1 : Failure and Repair rates of Ring Frame
λ_2, μ_2 : Failure and Repair rates of tufting machine when it undergoes reduced state
λ_3, μ_3 : Failure and Repair rates of cutting machine when it undergoes reduced state
λ_4, μ_4 : Failure and Repair rates of tufting machine when it goes to a failed state
λ_5, μ_5 : Failure and Repair rates of cutting machine when it goes to a failed state
P_1 (t) : Probability that the system at time't is working in full capacity.
P_m (t) : State probability that the system is in mth state at time't'
' : Derivatives w.r.t. 't'

B. Assumptions:

1. All the units are initially operating and are in good state.
2. Each unit is as good as new after repair.
3. The failure and repair rates of all units are taken constant.
4. Failure and repair events are statistically independent.
5. All the units are good at time t=0 i.e. P_1 (0)=1 and equals zero otherwise.
6. Subsystem A has good and failed states only. Subsystem B and C have good, reduced and failed states.

P_i(t) : Probability at time 't' all units are good and the system is in ith state.
' : Derivatives w.r.t. 't'
Based on these assumptions and notations following state transition diagram is developed as shown in fig. 1

IV. Performance Modeling

The differential equations associated with the transition diagram shown in fig. 1, are developed on the basis of Markov birth-death process. Various probability considerations generate the following sets of differential equations:

$$P_0'(t)+ (\lambda_1+ \lambda_2+ \lambda_3)P_0(t)= \mu_1P_5(t)+ \mu_2P_2(t)+ \mu_3P_4(t) \quad (1)$$

$$P'_1(t)+(\lambda_1+ \mu_2+ \lambda_3+\lambda_4)P_1(t)= \lambda_2P_1(t)+ \mu_2P_{12}(t)+ \mu_4P_{11}(t)+ \mu_3 P_3(t) \quad (2)$$

$$P'_2(t)+(\lambda_1+ \lambda_2+ \mu_3+ \mu_4+ \lambda_5) P_2(t)= \mu_2P_4(t)+ \mu_3P_2(t)+ \mu_1P_8(t)+ \mu_4 P_9(t)+ \mu_5P_{10}(t) \quad (3)$$

$$P'_3(t)+(\lambda_1+\lambda_2+\lambda_3+\lambda_5)P_3(t)=\mu_1p_{14}(t)+\mu_1P_6(t)+\mu_3P_1(t)+\mu_2P_3(t)+ \lambda_5P_7(t) \quad (4)$$

$$P'_j(t)+\mu_iP_j(t)=\lambda_iP_k(t) \quad (5)$$

Where,
(for i=1, j=5,6 when k=1)
(for i=,2 j=7,8 when k=2)
(for i=1,2, j=9,10,11 when k=3)

Initial conditions at time t = 0 are Pi(t)=1 for i=0, Pi(t)=0 for i≠0 (6)

Steady State analysis i.e. when $t \to \infty$ and $d/dt \to 0$ applying on set of first order differential (1) to (6) we get:

$(\lambda_1+\lambda_2+\lambda_3)P_0=\mu_1P_5+\mu_2P_2+\mu_3P_4$ (1)

$(\lambda_1+\mu_2+\lambda_3+\lambda_4)P_1=\lambda_2P_1+\mu_2P_{12}+\mu_4P_{11}+\mu_3P_3$ (2)

$(\lambda_1+\lambda_2+\mu_3+\mu_4+\lambda_5)P_2=\mu_2P_4+\mu_3P_2+\mu_1P_8+\mu_4P_9+\mu_5P_{10}$ (3)

$(\lambda_1+\lambda_2+\lambda_3+\lambda_5)P_3(t)=\mu_1p_{14}+\mu_1P_6+\mu_3P_1+\mu_2P_3+\lambda_5P_7$ (4)

$\mu_iP_j=\lambda_iP_k$

Where,

(for i=1, j=5,6 when k=1)

(for i=,2 j=7,8 when k=2)

(for i=1,2,3,6,7 j=9,10,11 when k=3)

Solving these equations and using normalizing condition, we get:

$$\sum_{i=1}^{12} P_i = 1$$

$$P_1 = \left[1 + P_2 + P_3 + \cdots \ldots \ldots + P_{12}\right]^{-1}$$

The Steady State Availability of the system A_{ss} is given by

$A_{ss} = P_1 + P_2 + P_3 + P_4$

V. Performance Analysis

The effects of failure rates and repair rates of various subsystems/ machines comprising the system are examined and their effets on system availability is shown in the following tables:

A. Effect of Failure and Repair Rates of Ring Frames on Availability of the System

Table 1: Effect of Failure and Repair Rates of Ring Frames on Availability of the System:

λ_1/μ_1	0.004	0.005	0.006	0.007
0.04	0.8918	0.8723	0.8537	0.8359
0.08	0.9334	0.9226	0.9121	0.9018
0.12	0.9481	0.9407	0.9334	0.9262
0.16	0.9557	0.9500	0.9444	0.9388

B. Effect of Failure and Repair Rates of Tufting Machine on Availability of the System

Table 2: Effect of Failure and Repair Rates of Tufting Machine on Availability of the System:

λ_2/μ_2	0.003	0.006	0.009	0.012
0.07	0.8918	0.8843	0.8775	0.8713
0.08	0.8927	0.8861	0.8800	0.8743
0.09	0.8935	0.8875	0.8820	0.8768
0.10	0.8576	0.8467	0.8396	0.8223

C. Effect of Failure and Repair Rates of cutting machine on Availability of the System:

Table 3: Effect of Failure and Repair Rates of Cutting Machine on Availability of the System:

λ_3/μ_3	0.0002	0.0004	0.0006	0.0008
0.001	0.8918	0.8855	0.8808	0.8773
0.002	0.8958	0.8918	0.8884	0.8855
0.003	0.8973	0.8944	0.8918	0.8894
0.004	0.8981	0.8958	0.8937	0.8918

VI. Results and Discussion

From Table 1 to 3, it has been revealed that the increase in failure and repair rates of various subsystems affects the availability of the system and need to be control.

Table 1 depicts the effect of failure and repair rates of Ring Frame on the availability of the Cotton Yarn production system. It is observed that for some known values of failure/ repair rates of tufting machine and cutting machine as failure rates (λ_1) of Ring Frame increases from 0.004 to 0.008, the system availability decreases by 8.20%. Similarly, as the repair rates (μ_1) of Ring Frame increases from 0.04 to 0.20, the system availability increases by 7.68%.

Table 2 also reveals the variation of system availability with change in failure rates (λ_2) and repair rates (μ_2) of the Tufting Machine subsystem when it undergoes to a reduced state. As failure rates (λ_2) of Tufting machine increases from 0.003 to 0.015, the system availability decreases by 2.94%. Similarly, when repair rates (μ_2) of Tufting machine from 0.07 to 0.11, then the system availability increases by 0.33%.

Table 3 also reveals the variation of system availability with change in failure rates (λ_3) and repair rates (μ_3) of the Cutting Machine subsystem when it undergoes to a reduced state. As failure rates (λ_3) increases from 0.0002 to 0.0010, the system availability reduces by 1.95%. Similarly, when repair rate (μ_3) increases from 0.001 to 0.005, then the system availability increases by 0.76%.

VII. Conclusion

The performance analysis of MAT production unit has been done with the help of mathematical modeling using probabilistic approach. The results are shown in Tables 1 to 3 is derived to assists the maintenance decisions where repair priorities should be given to subsystem of mat production unit. From the analysis it is clearly seen that ring frame machine is the critical component of mat production unit.

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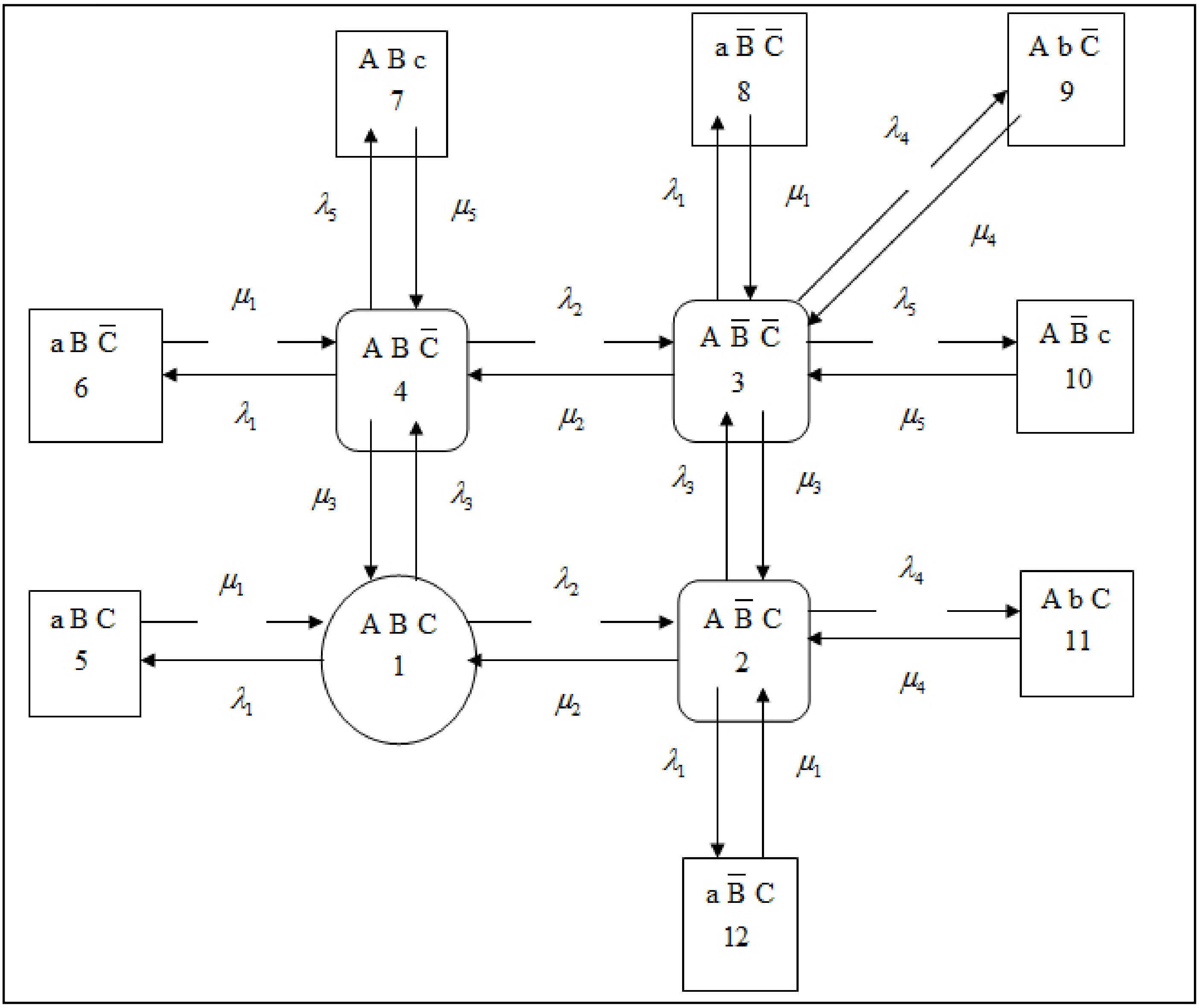

Fig. 1: State Transition Diagram for Mat Production System