Abstract: In the modern days Effective maintenance is essential to reduce the adverse effect of equipment failure. This can be achieved by accurately predicting the equipment failure such that appropriate actions can be planned and taken in order to minimize the impact of equipment failure to operation. This paper proposes a development of model based on Markov process for a rusk shaping system evaluate the system performance. The system comprises of continuous different four units. These units are sieving unit, mixing unit, divider unit and moulding unit. Analysis of reliability, long-run availability and mean time before failure of the rusk shaping system can help in increasing the production and quality of the rusk. The results obtained in the present work are considered to be very useful for devising the best possible maintenance strategies.

Keywords: Probabilistic study, Steady state probabilities, Markov approach.

I. INTRODUCTION

Today the industries are of high concern with the safety of their machines and also the uninterrupted working of the setup. Reliability engineering had gained its importance in recent years due to the results it had shown. Reliability, in general can be defined as the probability of a system/ device performing its anticipated purpose adequately for the intended period of time under the given operating conditions. Effective maintenance would certainly results in higher availability of the component and higher profits. Many engineering techniques are used in reliability risk assessments, such as reliability hazard analysis, failure mode and effects analysis (FMEA), fault tree analysis (FTA), Reliability Centered Maintenance, material stress and wear calculations, fatigue and creep analysis, human error analysis, reliability testing, etc. Because of the large number of reliability techniques, their expense, and the varying degrees of reliability required for different situations, most projects develop a reliability program plan to specify the reliability tasks that will be performed for that specific system. Recent studies by the researchers in the field of reliability/availability/maintainability [1]-[3] proposed several methods for industrial systems under maintenance. In [4] stochastic analysis of a repairable system with three dissimilar units and two repair facilities was introduced. The explicit expressions of the state probabilities of the system and then the explicit expressions were obtained. In [5] reliability characteristic of cold-standby redundant system was introduced considering two units. In [6] some reliability parameters of a three state repairable system with environmental failure were evaluated. Using [7] the Markovian approach, on three state systems, the formulae for steady state availability, the frequency of failure, mean time to failure and mean duration of down was derived. A model [8] on multi-state series, parallel and series parallel and parallel-series systems with regular reliability structures, considering the components that have exponential reliability functions with different transition rates between subsets of their states was studied expressions [9] for reliability and mean time to failure of k-out-of-n systems. A rusk manufacturing plant situated in Ludhiana, India is chosen for study. In this paper a subsystem of rusk making manufacturing system, which is a continuous production system is considered and the availability analysis of the complex mechanical system under preemptive resume priority repair is carried out. Laplace transform is used for solving differential equations to obtain state probabilities. Numerical results based on the true data collected from industry are presented to illustrate the steady state behavior of the system under different plant conditions.

II. SYSTEM DESCRIPTION

In Rusk shaping system, the rusk are moulded from dough sheets. Initially Flour or suji is sieved to remove any course particles and to aerate the floor in the sieving unit. Then Flour or suji, yeast, salt, sugar, fat and water are mixed in the required proportions in the mixing unit. In the divider unit, as a standard packing is in 800 g or 1 Kg the mixed material is divided into lumps. An extra 13% material is taken so as to compensate the weight losses during baking in the moulding unit, the rounded material come in unit where initially where sheets formed. Then the sheets curled and scaled and panned. Figure 1 represents the description of the process.
III. NOTATIONS AND ASSUMPTIONS

Sieving unit (S) : One unit subjected to major failure only.
Mixing unit (M): One unit subjected to major failure only.
Divider (D) : One unit subjected to major failure only.
Moulding unit (K) : One unit subjected to major failure only.

λₖ : Indicate failure rates of S, M, D, K (j=1,2,3,4).
µₖ : Indicate repair rates of S, M, D, K (j=1,2,3,4).
o : Indicate Component/Sub-system is operative.
q : Indicate component/Sub-system is in queue for repair.
r:Indicate component/Sub-system is under repair.

The following assumptions were taken into account:

- All the subsystems are initially operating.
- All the sub-systems are initially in good state.
- Each unit has two states viz., good and failed.
- It is also assumed that there is only one repair facility and priority will be given to sub-system S, M, D and K for repair activity.
- Each unit is as good as new after repair.
- The failure rates and repair rates of all units are taken constant.
- Failure and repair events are statistically independent.

IV. MATHEMATICAL ANALYSIS OF THE SYSTEM

Probability consideration gives the following first order differential-difference equations associated with the state transition diagram of the system.
Put the value of \( P_1(s), P_2(s), P_3(s) \) and \( P_4(s) \) in equation (1) and by using the normalizing condition,

\[
\begin{align*}
\sigma_1 P_1(s) + \sigma_2 P_2(s) + \mu_2 P_3(s) + \mu_3 P_4(s) + \mu_4 P_0(s) \\
(\sigma + \alpha_1) P_0(s) &= 1 + (\mu_1 K_1 + \mu_2 K_2 + \mu_3 K_3 + \mu_4 K_4) P_0(s)
\end{align*}
\]

\( (\sigma + \alpha_1) P_0(s) = 1 + (\mu_1 K_1 + \mu_2 K_2 + \mu_3 K_3 + \mu_4 K_4) P_0(s) \)

Availability function for \( A(s) \) system is given as

\[
A(s) = P_0(s)
\]

Inversion of \( A(s) \) gives the availability function \( A(t) \)

\[
A(t) = \frac{1}{s} \frac{\sigma_1}{\sigma + \alpha_1} P_0(s)
\]

Using normalizing condition

\[
\sum_{i=0}^{4} P_i = 1
\]

We get, \( [P_0 + P_1 + P_3 + P_4] = 1 \)

\[
P_0 = \frac{1}{[1 + \sum_{i=0}^{4} \frac{\lambda_i}{\mu_i}]}^{-1} \quad \text{..... (A)}
\]

V. AVAILABILITY ANALYSIS

The effect of various parameters on availability is studied. If the failure and repair rates are varied, the availability is affected. This effect is shown in following tables obtained for availability analysis of making system.

(a) Effect of failure rate of Sieving unit on availability \( A(\infty) \):

\[
\lambda_1 = 0.005, \lambda_2 = 0.006, \lambda_3 = 0.01, \mu_1 = 0.30, \mu_2 = 0.33, \mu_3 = 0.25, \mu_4 = 0.3
\]

Table 2. Steady state availability versus failure rate of sieving unit

(b) Effect of failure rate of Mixing unit on availability

\[
A(\infty): \lambda_1 = 0.005, \lambda_2 = 0.006, \lambda_3 = 0.01, \mu_1 = 0.30, \mu_2 = 0.33, \mu_3 = 0.25, \mu_4 = 0.3
\]

(c) Effect of failure rate of Divider on availability

\[
A(\infty): \lambda_1 = 0.005, \lambda_2 = 0.003, \lambda_3 = 0.006, \mu_1 = 0.30, \mu_2 = 0.33, \mu_3 = 0.25, \mu_4 = 0.3
\]

(d) Effect of failure rate of Moulding unit on availability

\[
A(\infty): \lambda_1 = 0.005, \lambda_2 = 0.003, \lambda_3 = 0.006, \mu_1 = 0.30, \mu_2 = 0.33, \mu_3 = 0.25, \mu_4 = 0.3
\]

(e) Effect of repair rate of Sieving unit on availability

\[
A(\infty): \mu_1 = 0.3, \mu_2 = 0.6, \mu_3 = 0.9, \mu_4 = 1.2
\]

(f) Effect of repair rate of Mixing unit on availability

\[
A(\infty): \mu_1 = 0.005, \lambda_2 = 0.003, \lambda_3 = 0.006, \lambda_4 = 0.01, \mu_1 = 0.3, \mu_3 = 0.25, \mu_4 = 0.3
\]
Table 7. Steady state availability versus repair rate of mixing unit

<table>
<thead>
<tr>
<th>$\mu_2$</th>
<th>0.33</th>
<th>0.66</th>
<th>0.99</th>
<th>1.32</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A (\infty)$</td>
<td>0.9232</td>
<td>0.9271</td>
<td>0.9284</td>
<td>0.9291</td>
</tr>
</tbody>
</table>

(g) Effect of repair rate of Divider unit on availability $A (\infty)$:

$\lambda_1 = 0.005$, $\lambda_2 = 0.003$, $\lambda_3 = 0.006$, $\lambda_4 = 0.01$, $\mu_1 = 0.3$, $\mu_2 = 0.33$, $\mu_3 = 0.3$

Table 8. Steady state availability versus repair rate of divider unit

<table>
<thead>
<tr>
<th>$\mu_3$</th>
<th>0.25</th>
<th>0.5</th>
<th>0.75</th>
<th>1.00</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A (\infty)$</td>
<td>0.9232</td>
<td>0.9336</td>
<td>0.9371</td>
<td>0.9388</td>
</tr>
</tbody>
</table>

(h) Effect of repair rate of Moulding unit on availability $A (\infty)$:

$\lambda_1 = 0.005$, $\lambda_2 = 0.003$, $\lambda_3 = 0.006$, $\lambda_4 = 0.01$, $\mu_1 = 0.3$, $\mu_2 = 0.33$, $\mu_3 = 0.25$

Table 9. Steady state availability versus repair rate of Moulding unit

<table>
<thead>
<tr>
<th>$\mu_4$</th>
<th>0.3</th>
<th>0.6</th>
<th>0.9</th>
<th>1.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>$A (\infty)$</td>
<td>0.9232</td>
<td>0.9377</td>
<td>0.9426</td>
<td>0.9450</td>
</tr>
</tbody>
</table>

VI. RESULTS AND DISCUSSION

From the analysis part it is being found that increase in the failure rate of sieving unit, mixing unit, dividing unit and moulding unit reduces the availability of the system. On the contrary increase in the repair rate increase the availability of the system. With increase in repair rate there had been increase of $1.08\%$, $0.41\%$, $1.56\%$ and $2.18\%$ respectively in sieving unit, mixing unit, dividing unit and moulding unit from 0.3 to 1.2, 0.33 to 1.32, 0.25 to 1.00 and 0.3 to 1.2 repairs per hour respectively.

REFERENCES


