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# THE ANALYSIS OF NECK RING MECHANISM SYSTEM

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***Abstract:*** The study and analysis of the neck ring mechanism system is an important topic in reliability. Analytical techniques become very complicated and unrealistic, especially for modern complex systems. There have been attempts in the literature to evolve more realistic techniques and failure rate and repair rate using a simulation approach for reliability analysis of systems. This work proposes a hybrid approach called Markov system dynamics (MSD), which combines the Markov approach with the system dynamics simulation approach for reliability analysis and to study the dynamic behavior of systems. This approach has the advantages of both Markov and system dynamics methodologies. The proposed framework is for a standby mechanism system that has two components one on a standby mode another one online mode with repair. The results of the simulation when compared with that obtained by traditional Markov analysis, clearly validates the MSD approach as an alternative approach for reliability analysis.

***Keywords:*** *Simulation approach, reliability analysis, dynamic implications of standby systems, Markov system dynamics approach, complex systems.*

## INTRODUCTION

Mechanism is a device which transfer motion to some desirable pattern any typically develops very low forces and transmit little power [1].
Neck Ring Mechanism is one of the most important components of an individual section machine (I.S. machine), it functions as the major component in I.S. machine and which form the neck of the bottle .it operate with high pressure of air. A neck ring mechanism for use in an I.S. glass forming machine comprising [2]:

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A rock member adapted to be supported horizontally, A pair of spaced cylinders reciprocable on rock member for movement in opposite directions, gear means coupled to said member for oscillating said member and cylinders about the longitudinal axis of said member, longitudinal grooves on the periphery of member ,a follower in each groove, each follower being supported by one of cylinders, means for adjusting at least one of followers so that the follower contacts a wall of an associated groove, and followers and grooves being arranged such that at least one pair of radically adjacent followers contact radically adjacent groove side walls of a cylinder so as to lock the cylinder on rock member whereby backlash between cylinder and rock member is eliminated [3].
In today's technological world, almost every person depends upon the continued carrying out of a broad array of compound machinery, equipment's and services for our everyday safety, security, mobility and economic welfare [4]. The concept of failure rate is vital in reliability and survival analysis. Nevertheless, obtaining the failure rate in numerous practical situations is regularly not so simple, as the structure of the system to be considered, for instance, can be rather complex or the process of the failure development cannot be explained in the simple way [6]. In these cases, an appropriate model can help a lot in deriving reliability characteristics. Time domain modeling is concerned with the behavior of system reliability over time. The simplest time-dependent failure model assumes that failures arrive randomly with inter-arrival times exponentially distributed with constant rate. Generally, researchers organize their reliability analysis via using exponential cumulative distribution function when failure rate has a constant rate [12].
The study and analysis of neck ring mechanism systems is an important topic in reliability. Analytical techniques become very complicated and unrealistic especially for modern complex systems. Traditional techniques cannot effectively deal with the uncertainties of the risk response development. Moreover, decision making process often involves the experts' subjective judgments and preferences regarding qualitative/quantitative criteria for mega projects. This problem may result in imprecise and indefinite data being present, which makes the decision-making process complex and challenging. To mitigate these difficulties,
[11] introduced a new multiple criteria decision-making approach with interval computations to conquer these difficulties for mega projects. The complexity of the modern engineering systems besides the need for realistic considerations when modeling their availability/reliability renders analytical methods very difficult to be used. Conventional neck ring mechanisms such as those disclosed in U.S.Pat. No.3.233.999 and U.S.Pat. No.3.024.571., includes a horizontal shaft which is oscillated 180° by a rack and pinion assembly. A pair of neck ring holder arms is attached to cylinders which surround the shaft and which slide telescopically along the shaft between open (apart) and closed (together) positions.
The cylinders are moved between the open and closed positions by piston assemblies which are coaxial with and integrally operable with the horizontal shaft. Both the horizontal shaft and the surrounding cylinders are splined for mutual engagement and rotation as a unit about the axis of the shaft. Neck mechanism system has attracted the attention of several authors and designers in the field of reliability theory and designer.

**Controlling the Temperature of a Glass Neck Ring Mechanism**
This patent was filed by [23] and assigned to Emhart Industries. This invention has focused upon controlling the temperature of a glass neck ring mechanism.

This method involves the formation of a passage in the neck ring mechanism wall, extending from external surface to a position adjacent to the cavity.

Controlling the Temperature Inflow Neck Ring Mechanism

This patent, relating to controlling the temperature of a neck ring mechanism was filed in 1984 by [23] and assigned to Emhart Industries Inc. It appears to be very close in concept to the U.S. Patent Number 4.519.827 granted to Stanley Jones the same year. In this invention an infrared, radiation transmitting device and an infrared radiation detection device are used to detect the temperature of the neck ring mechanism during the manufacture of neck ring mechanism articles. An infrared radiation transmitting device is inserted in a passage in the neck ring mechanism portion adjacent to the neck ring mechanism cavity.

Glassware neck ring mechanism machine with unitary axis

This patent was filed by Wilbur Orland Doud in 1987 and was assigned to Ball Corporation. Doud designed a glassware neck ring mechanism machine with a plunger and neck ring mechanism assembly that works in conjunction with a carriage and a parison blank neck ring mechanism. The assembly also acts to suspend the completed parison by the neck ring portion.

Glass container forming machine including neck ring mechanism cooling

This patent, relating to Glass container forming machine including neck ring mechanism cooling, was filed in 1992. by Robert S. Johnson & Robert D. Hall and was assigned to American National Can Company. It is an object of the invention to provide a simple low cost way of providing adequate cooling to a neck ring mechanism of a parison forming machine. Reduction in neck ring mechanism temperature allows increased speed of operation.

**Apparatus for forming glass articles with treating mean**

This patent, relating to the apparatus for forming glass articles with treating means, was filed in 1965 by John E. Cook and was assigned to Owens. The invention relates to a method and apparatus for controlling the cooling air on a Westlake glass blowing machine. In this method, a gather of glass is placed on the upper end of a spindle. When the spindle rotates, end for end, about its axis, a small amount of air is introduced to the interior of the gather to form an initial cavity.

Reliability analysis and model of neck ring mechanism

Neck ring mechanism systems have attracted the attention of several authors in the field of reliability theory. Various researchers including.

[2] has analyzed two-unit cold neck ring mechanism system models if the repair of the failed unit continues until the unit becomes as good as new.

[3] analyzed a two-unit (one priority and other ordinary) cold neck ring mechanism system model if each unit has no independent and non-identical components.

It is also assumed that, if the repair of the ordinary unit is not complete within a specified time, known as the maximum repair time, then the ordinary unit is discarded. They have assumed that failure and repair times are uncorrelated.

[4] analyzed a two-identical unit cold neck ring mechanism system model, assuming that an order is placed to replace the failed unit by a new one if the unit is not repaired during the specified time limit. Many papers in the field of reliability theory have investigated system models assuming that upon failure of a unit, it is replaced by its standby unit.

[9] presented a comparison of two models of a system that has two non-identical active series units with identical cold standbys.
[10] have studied the two-unit cold neck ring mechanism redundant system where the repairman is always available to inspect and repair the failed unit and replace the failed unit with the standby unit if it is available instantaneously. There is extensive literature on availability characteristics of neck ring mechanism systems with two or three components under varying assumptions on the failures and repairs [15,8]. Methods used in the existing literature deals with non-Markov systems involving analytical techniques such as regenerative point technique and the supplementary variables techniques which contain many differential equations. However, it is still not easy to solve these differential equations. Therefore, the issues of how to formulate and solve the system of Markov renewal equations and how to specify those undetermined functions are gradually becoming interesting and important in the analysis of stochastic models. Several research papers and books have been published that discuss various facts of reliability technology. Traditional statistical methods for recognizing and evaluating systems are not always appropriate, especially when enough data are not available. In the real world, the static mathematical models have resulted from a system full of non-deterministic nature; their parameters become non-unique uncertainties and a chain of uncertainties. There are many approaches for accounting for uncertainty and deviation, for example, mathematics models and simulation tools [7]. Many researchers have been searching for alternate methodologies for more practical and realistic reliability analysis. Simulation has been used as a powerful tool for modeling and analysis of system reliability. It is used to represent the dynamic behavior of systems in the most realistic.This work is focused on the development of a system dynamics simulation methodology for the reliability analysis of a standby system with repair. (1). The prior art neck ring mechanisms that involved a splined connection between the invert shaft and the neck ring arm elements is that the reciprocation of the arm elements relative to the invert shaft typically is primarily spring actuated, pneumatic actuation not being reliable due to air leakage in use because of the inability to properly seal a splined shaft against such leakage. (2). The Pitch line misalignment of the cylinders is a recurring problem due to backlash between the cylinders and the shaft. (3). Adjustment too tight causes increased wear which results in backlash and further misalignment of the neck molds. (4). Adjustment too loose also results in backlash. Further, the splined shaft and splined cylinders are ineffective at sealing the pneumatic piston assemblies from air leakage which may result in the neck molds not opening completely.
Interchangeable with existing mechanism and simple installation.

1. A radial ball bearing is used to ensure smooth rotation and a simplified maintenance routine
2. A shaft end seal reduces air leakage and improves operational efficiency.
3. Extremely low back-lash in the mechanism provides consistency to help improve ware quality and reduce defects.
4. A fully hardened and ground shaft with superior wear resistance qualities extends the service life and maintains accuracy throughout its life.

## METHODS AND MATERIALS

### Operation of the neck-ring mechanism

A neck ring mechanism for transporting, rotating and releasing a glass article which comprises, a neck ring housing, a neck ring rotatably mounted within housing and comprising a plurality of neck ring segments, an inner bearing ring mounted for rotation within housing, mean slid ably mounted, with respect to inner bearing 'ring' and operatively retaining neck ring segments' for opening and closing the segments of neck ring, rotatable cam means for actuating slid ably mounted means, and means for rotating cam 'means and clamming slid ably mounted means inwardly for closing neck ring segments and for rotating neck ring.
wherein means for rotating cam means includes a main drive gear secured to cam means for unitary rotation therewith, first sprocket and gear means for rotating main drive gear and cam means in one direction for closing neck ring' segments. Including second sprocket and gear means cooperating with first sprocket and gear means so as to rotate main drive gear in an opposite direction for opening neck ring segments. Main drive gear in an opposite direction for opening neck ring segments. Including means for limiting relative rotation between inner bearing ring and cam means to a degree sufficient for opening and closing neck ring segments. Including latch means for periodically locking inner ' bearing ring stationary with respect to housing and preventing the simultaneous rotation of inner bear ring and cam means for effecting' the opening and closing of neck ring segments. Wherein slid ably mounted means are mounted to be rotationally fixed with respect to 'inner bearing ring. for simultaneous rotation with the rotation of inner bearing ring and for 'remaining' rotationally stationary when inner bearing ring is locked in a Stationary position.

### Modeling aims and approach

In fact, whereas the problem of determining long run availability of the system has been extensively studied in the literature, the problem of finding the reliability of the system has not satisfactorily been tackled till now. However, among several available methods, Markov method is widely used for reliability analysis. This has motivated us to propose a novel system dynamics simulation technique for reliability analysis. This technique is used to study and analyze the dynamic behavior of systems in the most realistic sense. The present work proposes a hybrid approach called as Markov system dynamic (MSD) approach which combines the Markov approach with system dynamics simulation approach to overcome some of the limitations of Markov process in a simple and efficient way for reliability analysis and to study the dynamic behavior of systems. Initially it has been proved that the stationary, continuous-time Markov models are algebraically equivalent to linear system dynamics models as shown below.

### The continuous-time Markov process

A continuous-time Markov process is completely described by its transition probability function $p_{ij}(t)$ which is the probability that the system is in state j at time t if it was in state i at time 0.

And also $p_{ij}(t + \Delta t) = p\{x(t + \Delta t) = j \mid x(0) = I\} = \sum_{k}^{s}{}_{=1} p\{x(t + \Delta t) = j \,.\, x(t) = k \mid x(0) = i\}$

Where,
S is the total number of states that the system can occupy at any time.

Using the Baye's theorem, the above equation can be obtained according to [12] is summarized in eqn. (1).

$$pij\ (\mathrm{t} + \Delta\mathrm{t}) = \sum_{\mathrm{k=1}}^{\mathrm{s}} P\{X\ (t + \Delta t) = j, X(t) = k, K(0) = i\} \times \mathrm{P}\{\mathrm{X(t) = k} \mid \mathrm{X}(0) = i$$

Using the Markov's assumption of forgetfulness, the above equation can be obtained as follows:

$$pij\ (\mathrm{t} + \Delta\mathrm{t}) = \sum_{k=1}^{s} P\{X\ (t + \Delta t) = j \mid X(t) = k\}\ \mathrm{P}\{\mathrm{X(t) = k} \mid \mathrm{X}(0) = i$$

Defining $\lambda_{kj}(t) = P\{X\ (t + \Delta t) = j \mid X(t) = k\}$.
And noting that $P\{X\ (t) = k \mid X(0) = i\} = p_{ik}\ (\mathrm{t})$ .

$$pij\ (\mathrm{t} + \Delta\mathrm{t}) = \textstyle\sum_{k=1}^{s} P_{ik}\ (t) \times \lambda_{kj}\ (t) \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (1)$$

This equation is called as the Chapman–Kolmogorov equation.
$\lambda_{kj}(t)$ called the transfer rate from state k to state j at time t.
Theoretically, the transfer rates can be time varying or even state-dependent, but in general, they are assumed to be constant. This is the stationary assumption. Most of the literature on Markov process makes this stationary assumption and such models are termed as homogeneous (or stationary) Markov models.
A stationary, continuous-time Markov model is then given by [Eq. (1) becomes as follows],

$$pij\ (\mathrm{t} + \Delta\mathrm{t}) = \textstyle\sum_{k=1}^{s} P_{ik}\ (t) \times \lambda_{kj} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Transition probabilities are continuous functions of time with the following properties:

$0 \leq P_{ij} \leq 1$ for i, j and t

$\sum_{j=1}^{s} P_{ik}\ (t) = 1$ for $\mathrm{i} = 1, 2 \ldots\ldots\ldots\ldots \mathrm{S}$ ……… (3)

$\lambda_{kj} \geq$ for k $\neq$ j

$\lambda_{kj} \geq$ for k $=$ j

$\sum_{j=1}^{s} P_{ik}\ (t) = 0$ for $\mathrm{k} = 1, 2 \ldots\ldots\ldots\ldots \mathrm{S}$ ……….(4)

The rate of change for p(t), where p(t) is a square matrix of transition probabilities, can be written in the form of the following differential equation:

$$\frac{d}{dt}\ pi(t) = p\ (t)R, \qquad \ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where R is a square matrix of the transfer rates.
It can be shown that for such a Markov process, the time spent in state I before making a transition to state j is negative exponentially distributed with mean $1/\lambda_{ij}$.

It may be noted that negative exponential distribution has the same forgetfulness as the Markovian assumption.
A system with S possible states will have $S^2$ differential equations which are too large a number to solve easily.

**One therefore works with state probabilities.**
A state probability $P_j(t)$ is defined as the probability that the system is in state j at time t (no matter in what state it was Δt time back). Thus it is the sum of the probabilities of transition from state I to j over all states ij.

$$P_{ij}(t) = \sum_{i=1}^{s} P_{ij}\ (t) \qquad \text{………...(6)}$$

The instantaneous rate of change of state probabilities can be derived as,

$$\frac{d}{dt}\ pi(t) = \sum_{i=1}^{s} P_i\ (t)\ \lambda_{ij} \qquad \text{……….....(7)}$$

Defining P (t) as the row vector of state probabilities, these state equations can be obtained in the following vector matrix form:

$$\frac{d}{dt}\ P(t) = \ P\ (t)\ \times R \qquad \text{…………………..(8)}$$

Taking transpose of both sides Eq. (8) and defining

$$\underset{\sim}{Z}(t) = \ P^T(t),$$

And R = $R^{T,}$ Eq. (8) becomes

$$\dot{\underset{\sim}{Z}} = R\underset{\sim}{Z}\ (t) \qquad \text{…………………………… (9)}$$

This is the familiar vector matrix state differential equation of an autonomous linear system. Thus it can be concluded that stationary, continuous-time Markov processes are representatives of autonomous linear systems.

**Development of equivalent system dynamics model**
In this section, a system dynamics model has been developed which is equivalent to continuous-time Markov process as described below.
Equation (7) shows that the instantaneous rate of change of *j*th state probability,

$$\frac{d}{dt}\ pj(t) = \sum_{i=1}^{s} P_i\ (t)\ \lambda_{ij} \qquad \text{……………(10)}$$

This can be written as

$$\frac{d}{dt}\ P_j(t) = \ P_j(t)\,\lambda_{kj} + \sum_{i=1, i\neq j}^{s} P_i\ (t)\ \lambda_{ij} \qquad \text{.....................(11)}$$

Making use of Eq. (4), the above equation can be written as follows

$$\frac{d}{dt}\ P_j(t) = \ P_j(t)\left\{-\ \sum_{k=1,\mathrm{i}\neq\mathrm{j}}^{S} \lambda_{kj}\right\} + \sum_{i=1,\mathrm{i}\neq\mathrm{j}}^{S} P_j\ (t)\ \lambda_{kj} \qquad \text{………….. (12)}$$

$$\frac{d}{dt}\ P_j(t) = \sum_{i=1, i\neq j}^{s} P_i\ (t)\ \lambda_{ij} - \sum_{i=1, i\neq j}^{s} P_j\ (t)\ \lambda_{ik} \qquad \text{…….…………..... (13)}$$

s

Immediately the above Eq. (13) can be recognized as a level equation with $P_j$ as a level variable, and $\sum_{k=1,\mathrm{i}\neq\mathrm{j}}^{S}\ P_i\ (t)\lambda_{kj}$ as the total inflow into the level during the period $t\ and\ t\ +\ \Delta t$

$\sum_{k=1,i\neq j}^{S} P_j(t)\lambda_{kj}$ is the total flow out of the level.

The inflow increases the probability $P_j(t)$ due to transitions to state j, while the outflow reduces $P_j(t)$ due to transitions out of the state j. The transfer rates $\lambda_{ij}$ and $\lambda_{jk}$ are the constants associated with the input and output rates. It can be observed that rates are linearly dependent on level variables from which they emerge. Thus stationary, continuous-time Markov models are algebraically equivalent to linear system dynamics models.

**A Markov system dynamic approach to system reliability/availability assessment**

The procedure that we propose in this paper [16-21], develop the availability/reliability study using continuous-time system dynamics simulation is described in Table 1, where I distinguished a total of five steps.

Step 1: (System's states description). The first step of the study is the identification of the states of the system that means the selection/determination of the systems or components within the system functional or up and down states blocks, and how they relate to each other. As a result of this step, we will obtain a state transition diagram of the system that contains the relations among its components' states and their reliability features.

Step 2: (Data collection). Before starting to build the simulation model in step 3, I take note to know the design, the complete taxonomy of components of the system, and I try to find out full reliability and maintainability information of each item in terms of components' failure rate and repair date data information. I use several sources to find this information such as performance data from the actual production, expert judgments and laboratory testing.

Step 3: (Building the system dynamics simulation model). In this step, the state transition diagram of the system will be converted into equivalent MSD model. The resulting model is called as system dynamics model.

Step 4: (MSD simulation): In simulating the MSD model, an algorithm written in C was developed and it is used on a digital computer for developing various scenarios and to obtain the required simulation replications and the results.

Step 5: (Results and analysis). This step will include the presentation of result for the availability and reliability parameters corresponding to the functions of our interest in the different configurations. This step implies explaining the results obtained with the simulation, and the factors that may lead to those results, and also providing possible actions to improve system's availability or reliability to meet system's functional requirements.

Table 1. Steps in the availability/reliability assessment

| Step name | Descriptions | Result |
|---|---|---|
| System's states description | Determination of the basic functional states for the system configuration and for the every function to analyze | List of all functional states transition diagram of the system that contains the relations among state and their reliability features |
| Data collection | Complication of the necessary reliability and maintenance data (and information) for each one of the considered states | Reliability and maintenance data form one state to another; failure rate, repair rate, MTTR, MTBF, MFTM, preventive schedule, time etc |
| Model building | Continuous-time system dynamics simulation model building | Markov system dynamics model |
| System dynamics simulation | Simulation scenarios and experiments design | Scenario listings, required simulation replications and the results etc. |
| | Simulation scenarios and experience design | Result of the parameters of availability and reliability of the functions of our interest in the different configurations |
| Results and analysis | Simulation results calculation | |
| | Simulation results calculation | interpretation of results and their discussion |

**Reliability assessment of a neck ring mechanism system with repair**

The approach of system dynamics was created and developed in the late 1950s by a group of researchers led by Forrester at the Massachusetts Institute of Technology (MIT), Cambridge, MA [1]. It is a methodology for modeling and redesigning manufacturing, business, and similar systems that are part man, part machine [13]. It builds on information feedback theory, which provides symbols for mapping systems in terms of diagrams and equations, and a programming language for conducting computer simulations.

Another advantage of system dynamics modeling is that it is easy to experiment with alternative values of parameters.

Finally, the steady state solutions for these problems can be obtained easily by the inspection of the flow diagrams. The present work proposes MSD approach for reliability modeling of a neck ring mechanism system with repair as described in the following sections

**Assumptions to analyze the system**

Step 1. System's states description and assumptions

In this system, I use the following assumptions to analyze the system through Markov analysis.

The system consists of two components such that one is in online, and another is in standby mode.

The standby unit will have a reduced failure rate while in its standby mode.

Once active, the standby (backup) unit may experience the same failure rate as the online (primary) system (if they are identical units) or may have a different failure rate.

The dependency arises because the failure rate of the standby unit depends on the state of the primary unit.
Repair of the primary unit is feasible when it is in a failed state, and the system will continue to operate as long as the backup unit has not failed.
If the primary unit is restored before the backup has failed, then the system's perspective no failure has occurred, and the system returns to its initial state.
The primary unit has a failure rate λ1 and constant repair rate 'μ' whereas the standby unit is having a failure rate $\lambda_1$ when it is in online and a failure rate $\lambda_2$ when it is in standby mode.
The failure of the secondary unit while in standby remains undetected and therefore no repair is possible.
The rate diagram for Markov analysis is shown in Fig.1. In this diagram, state 1 indicates that the primary unit is in operating mode and the second (backup) unit is in standby mode, state 2 indicates that the backup unit is in operating mode and the primary unit under repair and state 4 indicates that backup unit is in the failed state. And the state 3 represents a failure (perhaps undetected) of the standby unit while in standby with $\lambda_2$ being the corresponding failure rate.
In the Markov analysis, the system reliability is established from system state probabilities which are evaluated using a rigorous mathematical treatment as discussed by several authors. However, in the proposed model, the system state probabilities are established by observing the dynamic behavior of the system over its entire simulated mission period using the system dynamics approach. This approach is as discussed in the following section.

Step 2. Data collection
The proposed MSD methodology starts after identification of the system states as mentioned in the previous section. To illustrate the above system, i consider the required data for further analysis.
I take an active component which has a failure rate (failures per day) of 0.01 and a repair rate of 0.10. An older standby component has a failure rate of 0.001 while in standby and a failure rate of 0.10 when online. Now it is required to solve for the system reliability for a planned 30-day use. This solution takes place as follows. This illustrative example is as like the system under study, i.e., a neck ring mechanism system with repair. The data regarding the constant failure and repair rates of this illustrative example have been used in the proposed MSD simulation model.

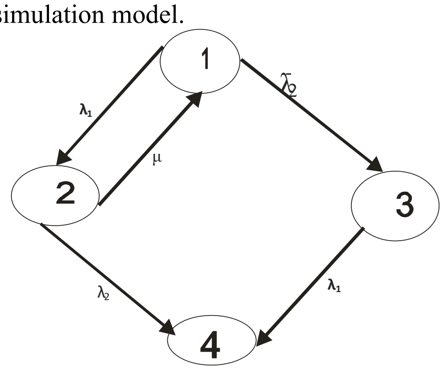


Fig.1. The Rate diagram for a standby system with repair of neck ring mechanism

Step 3. Building the system dynamics simulation model

The next step in the modeling process is to convert the rate diagram of system into the rate and level diagrams. The rate diagram (Fig.1) of the standby system with repair is now converted into a comprehensive system dynamic model. This is presented in Fig.2.

In the model depicted in Fig.2, the four states of the standby system with repair are indicated with level variables S1, S2, S3, S4 and the state transitions are indicated with rate variables (R12, R21, R13, R34, R24) with the corresponding transition rates ($\lambda_1$, $\lambda_2$, $\mu$, $\bar{\lambda}_2$)($\lambda_1$ indicates failure rate of primary unit and $\mu$ indicates its repair rate,$\lambda 2$indicates failure rate of the standby unit when it is in on line and $\lambda_2$ indicates failure rate of the standby unit when it is in standby mode).

The initial value of system reliability (as indicated at the level variable S1) is assumed as unity. The level of system reliability will be decreased by the rate of failures of either the primary unit or standby unit and it will be recovered with the repair of the primary unit before the standby unit has failed. These are measured as probability density functions (pdfs) of the system. The rate variables are influenced by the respective auxiliary variables, i.e., failure rate and repair rates of the primary unit and the failure rate of the standby unit along the entire mission or operating time. In addition, the level of failure state of the system (i.e., level variable S4) is increased by these rate variables of the primary and standby units, leading to the declining reliability of system. Figure 1 depicts the basic structure of the standby system with repair reliability model.

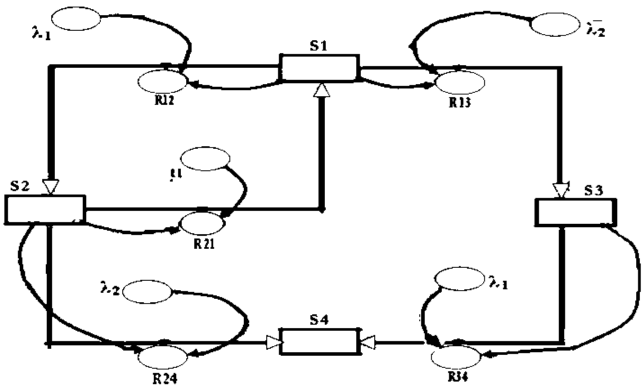


Fig. 2. A comprehensive system dynamic model of neck ring mechanism

Form figure 2 above show the comprehension system dynamic model of figure 1 above.

In the model depicted in Fig. 3.2, the four states of the standby system with repair are indicated with level variables S1, S2, S3, S4 and the state transitions are indicated with rate variables (R12, R21, R13, R34, R24) with the corresponding transition rates ($\lambda_1$, $\lambda_2$, $\mu$, $\bar{\lambda}_2$) . ($\lambda_1$ indicates failure rate of primary unit and $\mu$ indicates its repair rate, $\lambda 2$ indicates failure rate of the standby unit when it is in on line and $\lambda_2$ indicates failure rate of the standby unit when it is in standby mode).

## RESULTS AND DISCUSSION

The analysis of neck ring mechanism system has been completed, and the results were captured in the Figs. (3-7).

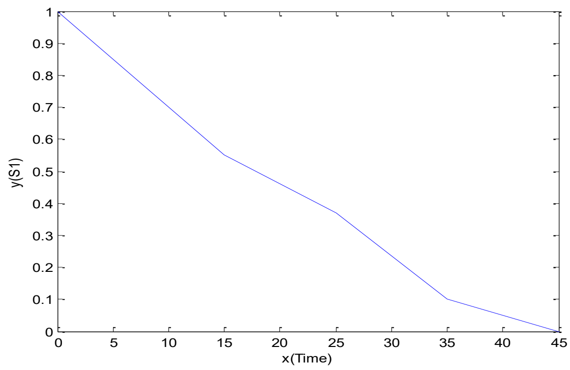


Fig.3. (S1 vs. Time) performance graph

From figure 3 above show the performance graph (state S1 vs time) its indicate that system reach its minimum level with increase in time. The system S1 decreased to it minimum level 1.0 as Time increased to the highest level of 45.

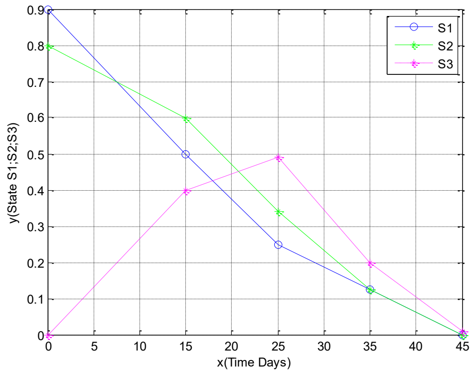


Fig.4. (State S1, S2, S3 vs. Time) performance graph

From Fig. 4 above show performance graph (state S1, S2, S3, vs time) of the system went there is increase in failure and decrease in time.

As S1 decreased to 0.9, the Time Days increased to 45. The graph of S2 decreased to 0.8 with increase in Time Days of 45. It was only S3 graph that increased to maximum of 0.5 and maintained a downward trend to 45 Time Days.

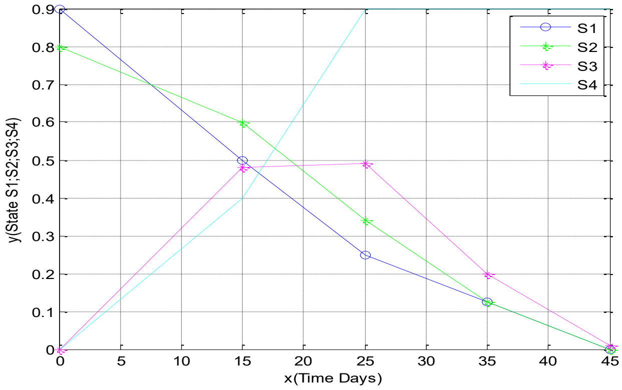

Fig.5. (State S1, S2, S3, S4, vs. Time) performance graph

From Fig. 5 above show the performance graph of the system (State S1, S2, S3, S4, vs Time) when the system simulated simultaneously by considering all its state to analyze its reliability.

It is shown in the graph of Fig.5 that the system states S1 and S2 have similar graph trend while S3 and S4 maintained a particular graph trend. The graph of system S1 decreased to 0.9, as the Time Days increased to 45. The graph of S2 decreased to 0.8 with increase in Time Days of 45. The graph of S3 increased to maximum of 0.5 at 15 to 25 Time Days and maintained a downward trend to 45 Time Days. The graph of S4 increased to 0.9 at 25 Time Days and maintained a horizontal line to 45 Time Days.

Step 4. System dynamics simulation

The next stage of MSD approach is to simulate the comprehensive MSD model of the system using the proposed algorithm. Using this, the state probabilities of the system have been calculated for reliability analysis and also the required simulation can be performed to study the dynamic behavior of the system as follow.

Proposed algorithm;

Step 1: The values of transition rates ($\lambda_1$ $\lambda_2$ $\mu$, $\bar{\lambda}_2$) and the time interval dt are taken as inputs. Also the total time T is taken as input, i.e., the time for which the system has to be simulated.

Step 2: Initially set S1 equal to one.

Step 3: Set $S_i$ equal to zero for i =2, 3, 4.

Step 4: A conditional loop is formed with the condition, t<T.

Step 5: In each execution of the loop, the time is increased by dt, i.e., t =t + dt. So, the loop will continue till time T with each step taken at time difference dt.

Step 6: As assumed S1 initially has probability unity, and the system fails when it becomes zero. Run a conditional loop as long as the condition, i.e., the probability of S1 > 0 is satisfied.

Step 7: Within the loop all the rate variables are calculated. The probabilities of the states are calculated first and the outflow rates are calculated according to the logic as follows:

S1 (t) = S1 (t – dt ) + (R21 -R12 – R13) * dt …...(a)
S2 (t) = S2 (t – dt) + (R12 –R21 –R24) *dt ……(b)
S3 (t) = S3 (t – dt ) + (R13 – R34) * dt ……..(c)
S4 (t) = S4 (t – dt ) + (R34 + R24) * dt …….(d)

Step 8: Then all the required values are displayed and the required graphs can be drawn using these values to study the dynamic behavior.

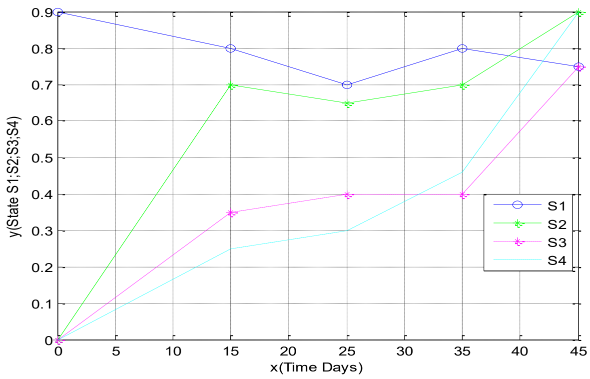


Fig. 6. Performance graph of the States against Time

From figure 6 above show performance graph at state S1, S2, S3, S4, against Time (days) as the system simulate for 45-days. The reliability of the system state S1 decreased from 0.9 with increase in Time to 45 Days. The reliability of the system state S2, S3 and S4 increased from origine to 45 Time (Days) respectively.

Table 2. The Reliability by Proposed and conventional method

| Time (Days) | Reliability by Proposed model (Rs) | Reliability by Conventional method (Rc) |
|---|---|---|
| 0 | 1.0 | 1.0 |
| 5 | 0.9520 | 0.9496 |
| 10 | 0.9290 | 0.9318 |
| 15 | 0.9050 | 0.9060 |
| 20 | 0.8810 | 0.8811 |
| 25 | 0.8570 | 0.8580 |
| 30 | 0.8090 | 0.8094 |

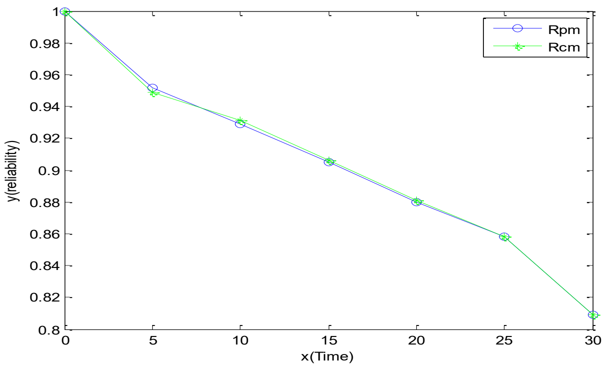


Fig.7. Comparison of results of reliability

From figure 7 above show the comparison of results: graph of reliability by proposed model (Rs) and reliability by conventional method by (Rc) from table 1.

**The model experimentation**

By implementing this algorithm, the model experimentation is performed as follows.
The simulation of the proposed model confirms that the operating state (reliability) of the standby system with repair decreases with increase in hazard rates as shown in Fig.3. The following experiments has been performed in this study:

Experiment 1. Test simulation run the system was first simulated with a test simulation run with an assumption that initially it is having maximum reliability, i.e., unity and the primary and standby units of the system are in operating state (i.e., at level variable S1). And the operating state of the system reaches its minimum level with increase in time.

Experiment 2. Second simulation run In a second simulation run, the system has been simulated (for 45 days) with the given values of failure rate and repair rates of the primary unit and the failure rates of the standby unit when it is in online as well as in standby mode. In this, the operating state (i.e., reliability as indicated with level variable S1) of the system reaches its minimum level with increase in time as shown in Fig.3.

Experiment 3. Third simulation run In a third run, the proposed model for the standby system with repair has been simulated (for 45 days) by considering the state 2(i.e., S2) which indicates that the backup unit is in operating mode and the primary unit under repair and also the state 3 (i.e., S3) which represents a failure (perhaps undetected) of the standby unit while in standby with $\bar{\lambda}_2$ being the corresponding failure rate as shown in Fig. 3.
Finally, the system has been simulated simultaneously by considering all of its states to analyze its reliability.
Figure 4. depicts the dynamic behavior of the standby system with repair in its all states. The simulation results in Fig.4. Clearly indicate that the operating state of the system decreases with increase in time due to primary and standby unit's failures.

And, the system will be in operating state if one of its units is in operating state (S2, S3 curves indicate this in Fig. 4.). The system reaches its failed state when both of its units fail. And the sum of S1, S2, and S3 state probabilities will give the system reliability.

## RESULTS AND DISCUSSION

The results of failure rate analysis, repair analysis, replacement analysis and reliability analysis are show in Table 1 and Table 2. The failure of the component depends on the performance of the system. From the analysis show that not all the components fail due to the function of it.

From the Table 1, illustrate the replacement analysis from the analysis I observe that not all the components can be replaced.

System reliability is established from system state possibility as show in Fig.2, so to simplify this analysis, the same system has been considered.

In this work and solved using the proposed model as described earlier to calculate the reliability and the dynamic behavior of the system. The obtained results are presented in table 3 and fig. 5 which clearly indicate that the simulate results very closely match with computed value.

From Fig 3 is failure rate diagram for a standby system with repair. During the analysis of the data collection I assume that the system has an invention and older one. They have failure rate and repair rate; the new invention has a failure rate (failure per day) of 0.01 and repair rate of 0.10. An older standby system has a failure of 0.00l while in standby and a failure rate of 0.10 when online. Now it is require solving for the system reliability for a planned 30-days use. This solution takes place as follows. This illustrative example is as like the system under study, i.e., a standby system with repair. The data regarding the constant failure and repair rates of this illustrative example have been used in the proposed MSD simulation model.

From the above analysis the productivity time increment has possibility with replacement instead of repairs.

It is clear from the results; the proposed system dynamics modeling framework can be used as an alternative approach to analyze the reliability of systems instead of using the Markov methodology alone which requires too many mathematical equations and calculates with unrealistic assumptions. It is worth mentioning here that the MSD modeling is much easier compared to the traditional approaches to study the reliability of complex systems.

Conclusively, for analyzing the dynamic behavior of systems, MSD simulation seems to be useful and also to understand the functioning and interaction of the different facets of reliability of systems. It can be stated that a switch from conventional methods to simulation seems to be the most promising reliability modeling and analysis strategy for systems.

## CONCLUSIONS

In this work, a hybrid approach called as (Markov System Dynamic) MSD approach has been proposed for reliability analysis and to study the dynamic behavior of systems.

The proposed framework is illustrated in (Fig 1) for a standby system with repair. The results of the simulation when compared with those obtained by traditional Markov analysis clearly validate the proposed approach as an alternative approach for reliability analysis.

The procedure for the development of the MSD approach for this system is explained and the model is run to observe all its states. The proposed methodology is applicable for all types of failure rates and repair rates, and it is much simpler compared to traditional approaches. Further, this methodology can be used for studying various scenarios having managerial implications of system reliability. It is important to note that reliability declining of component or system has to be observed carefully to achieve the desired results. From the analysis of the component, i observe that not all the components can replace, and the reliability of some components is zero due to the failure rate. And also, the productivity time increment has possibility with replacement instead of repairs.

From this my work, I recommend managers must beware of the existing interdependencies within the component or system.

Accordingly, the model can be used as a simulation tool. Based on simulation analyses, managers can learn how to deal with such a comprehensive approach like the one investigated in this work. And, the different parties, i.e., engineers and machine operators, can jointly work with the model to understand the dynamic behavior of systems.

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## ANALIZA SISTEMA MEHANIZMA SA ROTACIONIM PRSTENOM

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***Apstrakt:*** Proučavanje i analiza sistema mehanizma sa kružnim prstenom je važna tema u pouzdanosti. Analitičke tehnike postaju veoma komplikovane i nerealne, posebno za moderne složene sisteme.
U literaturi je bilo pokušaja da se razviju realnije tehnike i stopa otkaza i stopa popravke koristeći simulacioni pristup za analizu pouzdanosti sistema.
Ovaj rad predlaže hibridni pristup nazvan Markov sistemska dinamika (Eng. Markov system dynamics-MSD), koji kombinuje Markov system kao pristup, sa simulacionim pristupom sistemske dinamike za analizu pouzdanosti i za proučavanje dinamičkog ponašanja sistema.
Prikazani pristup ima prednosti i Markov sistemske metodologije. Predloženi okvir je za sistem mehanizma u stanju pripravnosti koji ima dve komponente, jednu u režimu pripravnosti, drugu u online režimu sa mogućnosti popravke.
Rezultati simulacije, u poređenju sa rezultatima dobijenim tradicionalnom Markov analizom, jasno potvrđuju pristup, Markov sistemsku dinamiku-MSD kao alternativni pristup za analizu pouzdanosti.

***Ključne reči:*** *Simulacioni pristup, analiza pouzdanosti, dinamičke implikacije rezervnih sistema, Markov sistemski dinamički pristup, složeni sistemi.*

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