RELIABILITY EXAMINATION OF STOCHASTIC MODEL OF A SEED PROCESSING PLANT HAVING THREE TYPES OF FAULTS

[1]Deepal, [2]Pooja Bhatia

[1]Research scholar,[2]Professor

Department of Mathematics

Baba Mastnath University, Rohtak, 124021, Haryana, India.

Abstract - The paper deals with a model of a seed processing plant which has centrifuge system situated at Yunick Agro, Hisar, Haryana (India) on the basis of real data collected. The system goes for inspection whenever there is any fault. Depending on time of repair and cost of repairs, faults are classified as minor, major or neglected faults.The occurrence of a minor/neglected fault leads to degradation whereas occurrence of a major fault leads to failure of the system. Some neglected faults are not repairable on-line and may lead to failure of the system. After inspection, repair being carry out according to fault is repairable or non repairable. Replacement or labour redundancy is used in case of non-repairable faults. Considering all these aspects and using the real data collected from the plant, various measures of system effectiveness such as MTSF, Reliability, Availability and Busy period etc. are derived by using Semi-Markov process and Regenerative Point technique. The functioning of the plant's machine is examined using numerical results and graphs derived thereof. From the plots so obtained, we get cut-off points of profit for different values of rates of major faults/ revenue of per unit Uptime.

Index Terms - Reliability, Labour redundancy, Semi-Markov Process, Mean Time To System Failure(MTSF), Availability, Regenerative Point technique

I. INTRODUCTION

In field of agriculture, seed processing is crucial process for superior quality of seed I.e higher genetically purity,possession of good shape, size, colour, etc.,higher physical soundness and weight, higher germination,higher physiological vigour and stamina. The fundamental aim of seed processing is to achieve the greatest percentage of perfect seed with maximum germination potential.Sequence of operations in seed processing are based on characteristics of seed such as shape, size, weight, length, surface structure, colour and moisture content.The primary functioning in a seed processing plant are receiving; pre-cleaning; conditioning; drying; cleaning and grading; treatment; and weighing, packaging and storage.Using good quality seed, development of root system will be more efficient that helps absorption of nutrients efficiently and result in higher yield. The principal function of the seed industry in India is to improve in the expansion of agriculture, providing access to superior quality seeds and planting materials for the farmers in India. In the present scenario of competitive market, improvement in performance of the machines with minimum operating cost is the main objective of each industry. In the present paper, actual data relating to a seed processing plant machine, situated in Yunick Agro Seed, Hisar(Haryana) has been gathered personally by visiting the said plant premises from time to time and a stochastic model is developed considering its various types of faults using Semi-Markov Process and Regenerative Point Technique. The plant machine is a single unit complex system with various sub systems wherein different faults occur during operation. The faults are categorized as minor, major and neglected faults on the basis of down time and cost which are repairable as well as non-repairable. Since the machine is operative round the clock, therefore, power failures/ degradation are also considered as faults. It is observed that on occurrence of a minor/neglected fault, machine partially stopped and can be corrected by preventive maintenance/repair, whereas in case of major fault,when system goes to failure labour redundancy and replacement is used. Some neglected faults are not repairable on-line and may lead to failure of the system. Inspection is being done by a single repairman who visits the plant in negligible time and inspects whether the fault is repairable or non-repairable. In case of repairable fault, the defective part is repaired whereas in case of non-repairable fault, the defective part of the machine is replaced or work is done manually by labour. For numerical calculations, inspection rates, repair rates and replacement rates are assumed to follow Exponential Distributions. On the basis of so collected real data, by using Semi-Markov Process and Regenerative Point Technique, various measures of system effectiveness such as MTSF, Reliability, Availability (with full and reduced capacity) and Busy Period of repairman are obtained. Finally, numerical calculations and graphs drawn on the basis thereof have been used for evaluation of performance of the machine which is useful for smooth and better functioning of the seed Industry.

II. LITERATURE SURVEY

Researchers and Scientists are trying to improve the performance of industries using various reliability techniques. Kumar et al. (1989) analyzed the reliability and availability behaviour of subsystems of paper industry by using probabilistic approach [1]. Gupta et al. (2005) worked on the system reliability and availability in butter oil processing plant by using Markov Process and R-K method [2]. Kumar and Bhatia (2011) discussed reliability and cost analysis of a one unit centrifuge system with single repairman and Inspection [3]. Bhatia and Kumar (2013) studied Performance and Profit Evaluations of a Stochastic Model on Centrifuge System Working in

Thermal Power Plant Considering Neglected Faults [4]. Sharma and Vishwakarma (2014) applied Markov Process in performance analysis of feeding system of sugar industry [5]. Renu and Bhatia (2017) dealt with reliability analysis for removing shortcomings using stochastic processes and applied for maintenance in industries [6]. A few of the Researchers have worked for real data of paper machine and footwear machine. Veena Rani and Pooja Bhatia discussed about Performance Evaluation of Stochastic Model of a Paper Machine Having Three Types of Faults [7]. Bhatia P. and Rani Veena, (2021) analyzed a study on Comparative Analysis of two Stochastic Models for Single Unit Paper Machine Considering Repairable/ Non-Repairable Minor and Major Faults[8]. Rinku and Pooja Bhatia, (2022) analyzed a study on a Study on Comparative Analysis of Two Stochastic Models for Single Unit footwear Machine[9].

For the purpose of performance evaluation, a stochastic model is developed by using Regenerative Point Technique and following measures of system effectiveness are obtained

- Transition Probabilities
- Mean Sojourn Time
- Mean Time to System Failure (MTSF)
- Expected up time/Expected down time
- Busy Period of repairman (Repair and Replacement time)
- Profit analysis

III. MODEL DESCRIPTIONS

(1) *ASSUMPTIONS*

- The system consists of a single unit.
- The system works with full efficiency after each repair and replacement.
- The Repair man reaches the system in negligible time.
- A single Repair man facility is provided to the system for repair and replacement of the components.
- Time distribution of various faults i.e. minor/major/neglected are Exponential while other distributions are general.
- A minor fault leads to partial failure whereas major fault leads to complete failure.
- Some neglected faults are not repairable on-line and may lead to failure of the system.
- Due to power failure/degradation the machine stops temporarily for few minutes.

(2) *NOTATIONS*

- λ_1/ λ_2 : Rate of occurrence of minor/major faults.
- λ_3: Rate of occurrence of neglected faults.
- a_1/b_1 : Probability that a minor fault is replaceable or repairable.
- $a_2/b_2/c_2$: Probability that a major fault is replaceable or repairable or work is done manually by labour.
- $i_1(t)/i_2(t)$: p.d.f of time to inspection of the unit at down state/failed state
- $I_1(t)/I_2(t)$: c.d.f of time to inspection of the unit at down state/failed state
- $h_1(t)/h_2(t)$: p.d.f of time to replacement of the unit at down state/failed state.
- $H_1(t)/H_2(t)$: c.d.f of time to replacement of the unit at down state/failed state.
- $k_1(t)/k_2(t)$: p.d.f of time to maintenance of the unit at down state/failed state.
- K3(t)/k3(t):c.d.f/p.d.f of time to maintenance of the unit at down state.
- $K_1(t)/K_2(t)$: c.d.f of time to maintenance of the unit at down state/failed state.
- $l_1(t)$:p.d.f of time to labour redundancy of the unit at failed state.
- $L_1(t)$: c.d.f of time to labour redundancy of the unit at failed state.
- ©: Laplace covolution
- */**: Laplace transformation/Laplace stieltjes transformation.
- Q_{ij}/q_{ij}: cdf/pdf for the transition of the system from one regenerative state S_i to another regenerative state S_j or to a failed state S_j.

(3) *TRANSITION STATES*

Different states of the system model according to Semi Markov process and Regenerative Point Technique are as follows:
State 0: Initially state is operative.
State 1: Operative unit temporarily failed due to some minor faults.
State 2: Unit completely failed due to some major faults.
State 3: Operative unit temporarily failed due to some neglected faults.
State 4: Minor fault identified in inspection which is rectified by replacement of components/ parts and after this system is operative.
State 5: Minor fault identified in inspection which is rectified by repair/maintenance of components/ parts and after this system is operative.
State 6: Major fault identified in inspection which is rectified by replacement of components/ parts and after this system is operative.
State 7: Major fault identified in inspection which is rectified by repair/maintenance of components/ parts and after this system is operative.
State 8: Major fault identified in inspection which is rectified by labour redundancy and after this system is operative.
Here, state 0 is operative state with full capacity whereas 1,3,4,5 are operative states with reduced capacity,states 2,6,7,8 are failed states.

(4) TRANSITION DIAGRAM

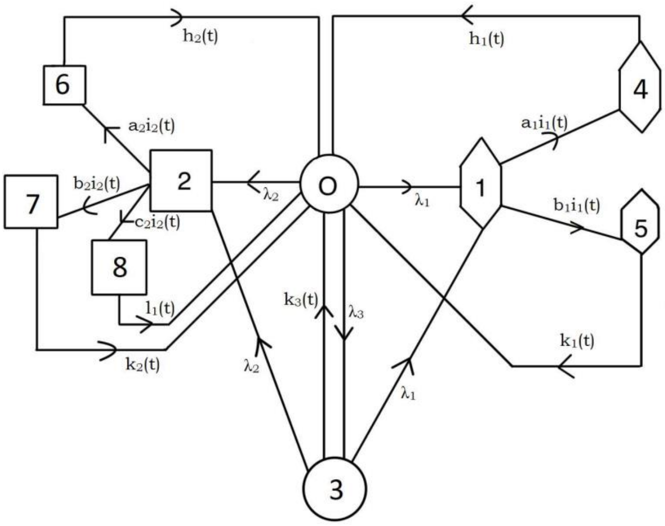

Fig 3.1

IV. RELIABILITY INDICATOR

(1) Transition probability

we can find transition probabilities by using simple probabilistic arguments and these are given by:

$p_{ij}= \lim_{s\to 0}\int_0^{\infty} \exp(-st)dQijdt$

$p_{01}=\lambda_1/\lambda_1+\lambda_{2+}\lambda_3$ $p_{02}=\lambda_2/\lambda_1+\lambda_{2+}\lambda_3$ $p_{03}=\lambda_3/\lambda_1+\lambda_{2+}\lambda_3$ $p_{14}=a_1i_1^*(0)$ $p_{15}=b_1i_1^*(0)$ $p_{40}=h_1^*(0)$

$p_{50}=k_1^*(0)$ $p_{26}=a_2i_2^*(0)$ $p_{27}=b_2i_2^*(0)$ $p_{28}=c_2i_2^*(0)$ $p_{60}=h_2^{*(}0)$ $p_{70}=k_2^*(0)$

$p_{80}=l_1^*(0)$ $p_{30}=k_3{}^*(\lambda_1+\lambda_2)$ $p_{31}=\lambda_1(1-k_3^*(\lambda_1+\lambda_2))/\lambda_1+\lambda_2$ $p_{32}=\lambda_2(1-k_3^*(\lambda_1+\lambda_2))/\lambda_1+\lambda_2$

It can be verified that

$p_{01}+p_{02}+p_{03}=1,$ $p_{14}+p_{15}=1,$ $p_{26}+p_{27}+p_{28}=1,$ $p_{40}=p_{50}=p_{60}=p_{70}=p_{80}=1,$ $p_{30}+p_{31}+p_{32}=1$

(2) Mean sojourn times

The unconditional mean time taken by the system to transit for any regenerative state j, when it is counted from epoch of entrance into that state i', is mathematically, stated as

$mij=\int_0^{\infty} tdQ_{ij}(t)=-Q_{ij}^{*'}(s)$

$m_{01}+m_{02}+m03=\mu_0$, $m_{14}+m_{15}=\mu_{1,}$ $m_{26}+m_{27}+m_{28}=\mu_2,$ $m_{30}+m_{31}+m_{32}=\mu_3,$ $m_{40}=\mu_4$

$m_{50}=\mu_5,$ $m_{60}=\mu_6,$ $m_{70}=\mu_7$ $m_{80}=\mu_8$

and the mean sojourn time in the regenerative states i are obtained as

$\mu_0=1/(\lambda_1+\lambda_{2+}\lambda_3),$ $\mu_1=-i_1^{*'}(0),$ $\mu_2=-i_2^{*'}(0),$ $\mu_3=(1-k_3^*(\lambda_1+\lambda_2))/\lambda_1+\lambda_2,$ $\mu_4=-h_1^{*'}(0),$

$\mu_5=-k_1^{*'}(0),$ $\mu_6=-h_2^{*'}(0),$ $\mu_7=k_2^{*'}(0),$ $\mu_8=-l_1^{*'}(0)$

(3) Measures of system Effectiveness

Using probabilistic arguments for regenerative processes, various recursive relations are obtained and are solved to find different measures of system effectiveness, which are as follows:

Mean Time to System Failure(MTSF) $T_{11}=N/D$

Where $N=p_{03}(1+\mu_1p_{31}+p_{31})+\mu_0+p_{01}(\mu_1+p_{14}\mu_4+p_{15})$ $D=1-p_{03}p_{30}+(p_{01}+p_{31}p_{03})(p_{14}p_{40}+p_{15}p_{50})$

Expected Uptime of the system $UT_1=N_1/D_1$

Expected Downtime of the system $DT_1=N_2/D_1$

Busy Period of Repairman(Repair time only) $BR_1=N_4/D_1$

Busy Period of Repairman(Replacement time only) $BRP_1=N_5/D_1$

Where

$N_1=\mu_0+p_{03}\mu_3$

$D_1=p_{02}(\mu_2+\mu_6p_{26}+\mu_7p_{27}+\mu_8p_{28})+p_{03}(\mu_3+\mu_2p_{32}+p_{26}p_{32}\mu_6+p_{31}\mu_1+p_{27}\mu_7p_{32}+\mu_8p_{28}p_{32}+p_{31}p_{15}\mu_5+p_{31}p_{14}\mu_4)+p_{01}(\mu_1+p_{14}\mu_4+p_{15}\mu_5)+\mu_0$

$N_2=(p_{01}+p_{03}p_{31})\mu_1$ $N_3=(p_{01}+p_{03}p_{31})\mu_1+p_{02}\mu_2$ $N_4=p_{15}\mu_5(p_{01}+p_{03}p_{31})+\mu_7p_{02}p_{27}$ $N_5=\mu_4(p_{01}+p_{03}p_{31})p_{14}+\mu_6p_{02}p_{26}$

(4) Profit Analysis

The expected profit incurred of the system is given by
$P_3 = C_0UT_1 - C_1DT_1 - C_2BI_1 - C_3BR_1 - C_4BRP_1 - C_5$
C_o = revenue per unit up time of the system
C_1 = revenue per unit down time of the system
C_2 = cost per unit time of inspection
C_4 = cost per unit time of replacement
C_5 = other fixed costs
Here other fixed costs (C_5) includes cost of installation of the system, wages of the repairman/operator etc.

(5) Numerical study

Giving particular values to the parameters and considering
$i_1(t)=\alpha_1 e^{-\alpha 1t}$ $i_2(t)=\alpha_2 e^{-\alpha 2t}$ $h_1(t)=\gamma_1 e^{-\gamma 1t}$ $h_2(t)=\gamma_2 e^{-\gamma 2t}$ $k_1(t)=\beta_1 e^{-\beta 1t}$
$k_2(t)=\beta_2 e^{-\beta 2t}$ $k_3(t)=\beta_3 e^{-\beta 3t}$ $l_1(t)=\eta_1 e^{-\eta 1t}$
We get
$p_{01}= \lambda_1/(\lambda_1+\lambda_2+\lambda_3)$ $p_{02}=\lambda_2/(\lambda_1+\lambda_2+\lambda_3)$ $p_{03}=\lambda_3/(\lambda_1+\lambda_2+\lambda_3)$ $p_{14}=a_1$ $p_{15}=b_1$
$p_{30}=p_{40}=p_{50}=p_{60}=p_{70}=1$ $p_{26}=a_2$ $p_{27}=b_2$ $p_{28}=c_2$ $\mu_0=1/(\lambda_1+\lambda_2+\lambda_3)$
$\mu_1=1/\alpha_1$ $\mu_2=1/\alpha_2$ $\mu_3=1/ \lambda_1+\lambda_2+\lambda_3+\beta_3$ $\mu_4=1/\gamma_1$ $\mu_5=1/\beta_1$
$\mu_6=1/\gamma_2$ $\mu_7=1/\beta_2$ $\mu_8=1/ \eta_1$
For the particular cases, taking values from the collected data and assuming the values

(6) Mean time to system failure(T_{32})=195.319
(7) Expected Uptime of the system (UT0)=0.989
(8) Busy period of repairman(Inspection time only)BI0=0.00246
(9) Busy period of repairman(Repair time only)BR0=0.0037
(10) Busy period of repairman(Replacement time only)BRP0=0.00276
(11) Expected profit P_{32}=332.376

(12) Graphical analysis

Using above numerical values, various graphs are drawn for MTSF(T_{32}) and profit(P_{32}) of the system for different values of rates of minor and major faults(λ_1,λ_2), Repair rates(β_1,β2),replacement rates(γ_1.γ_2) ,inspection rates(α_1,α_2) and labour redundancy rate (η_1). From the plotted graphs following conclusion are drawn
Fig. 3.2 presents the graph between mean time to system failure (T_{32}) and the rate of occurrence of minor faults (λ_1) for the different values of rate of occurrence of major faults (λ_2). It can be concluded from the graph that the MTSF decreases with increase in the values of rate of occurrence of minor faults and has lower values for higher values of rate of occurrence of major faults.

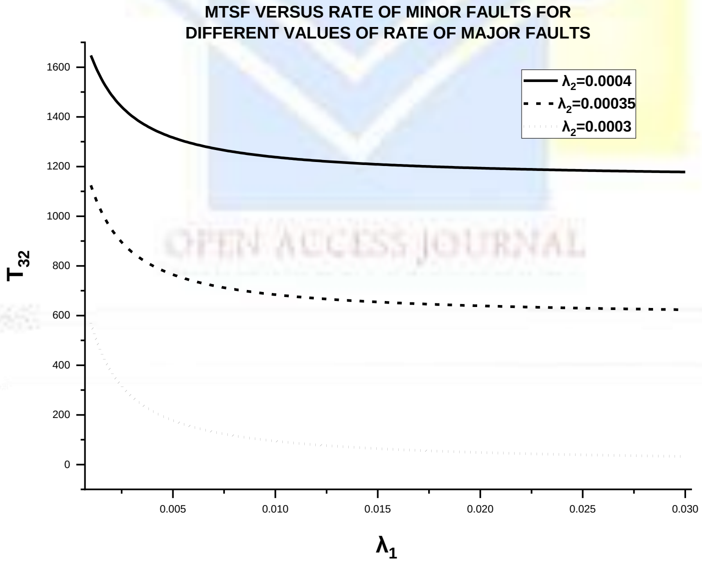

Fig 3.2

Fig 3.3 shows the graph between MTSF (T_{32}) and the rate of occurrence of neglected faults that are not repairable online (λ_3) for the different values of rate of occurrence of major faults (λ_2). It is observed from the graph that the MTSF decreases with increase in the values of rate of occurrence of neglected faults that are not repairable on-line and has lower values for higher values of rate of occurrence of major faults.

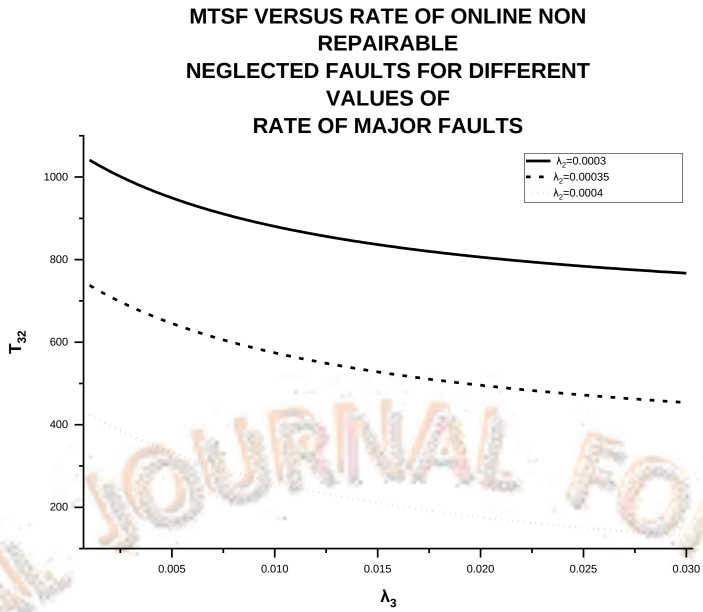

Fig 3.3

Fig 3.4 represents the graph pattern of profit (P_{32}) with respect to the rate of occurrence of minor faults (λ_1) for different values of rate of occurrence of major faults(λ_2). From the graph,we observe that the profit of the system decreases with the increase in the values of the rate of occurrence of minor faults and has lower values for higher values of the rate of occurrence of major faults.

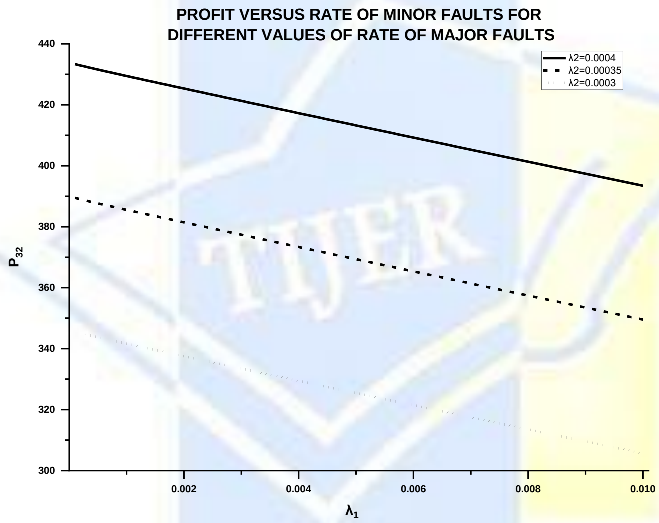

Fig 3.4

Fig. 3.5 represents the graph of profit (P_{32}) with respect to revenue per unit up time (Co) of the system for the different values of rate of occurrence of major faults (λ_2). We conclude that:

(i) The profit increases with the increase in the values of revenue per unit up time and has lower values for higher values of rate of occurrence of major faults.

(ii)For $\lambda 2 = 0.0003$, the profit is negative or zero or positive according as Co is < or = or > 659.061 and hence, in this case, for the system to be profitable, the revenue per unit up time of the system should be fixed greater than Rs.659.061.

(iii)For $\lambda_2 = 0.0083$, the profit is negative or zero or positive according as C0 is < or = or > 692.148 and hence, in this case, for the system to be profitable, the revenue per unit up time of the system should be fixed greater than Rs. 692.148.

(iv)For $\lambda_2 = 0.0163$, the profit is negative or zero or positive according as C0 is< or = or > 726.775 and hence, in this case, for the system to be profitable, the revenue per unit up time of the system should be fixed greater than Rs. 726.775.

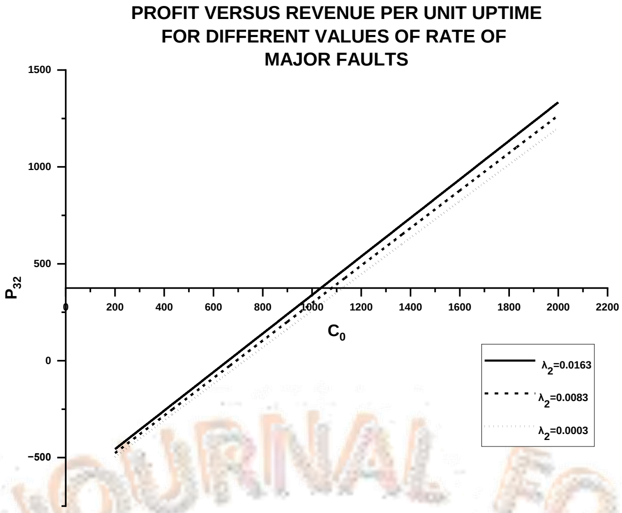

Fig 3.5

V. CONCLUSION

From the graphical analysis done above, we conclude that mean time to system failure and the profit per unit time of the seed processing plant decreases with the increase in the values of the rate of minor as well as major faults and mean time to system failure decreases with increase in the values of rate of occurrence of minor faults that are not repairable on-line and has lower values for higher values of rate of occurrence of major faults. Further, we obtained cut off points of profit for different values of revenue per unit Uptime. We found that, for specific value of rate of minor/major fault what should be the greater value of revenue of per unit Uptime or lower value of miscellaneous costs to get positive profit. On the basis of these values, several suggestions can be given to the management team of the seed processing plant to make the overall profit.

VI. REFERENCES

[1] D. Kumar, J. Singh, and P.C. Pandey. (1998). "Availability of a Washing System in the Paper Industry", Microelectronics Reliability, 29(5),775-778.
[2] P. Gupta, A.K. Lal, R.K. Sharma, and J. Singh(2005). "Numerical Analysis of Reliability and Availability of the Serial Processes in Butter-oil Processing Plant," International Journal of Quality and Reliability Management, 22(3), 303-316.
[3] R. Kumar and P Bhatia (2011). "Reliability and Cost Analysis of a One Unit Centrifuge System with Single Repairman and Inspection", Pure and Applied Mathematics Sciences, 74(1- 2),113-121.
[4] Kumar, R. and Bhatia, P. 2013. "Performance and Profit Evaluations of a Stochastic Model on Centrifuge System working in Thermal Power Plant Considering Neglected Faults." International Journal of Scientific and Statistical Computing, Malasia, ISSN: 2180-1339,4(1), 10-18.
[5] S.P.Sharma and Y. Vishwakarma(2014). "Application of Markov Process in Performance Analysis of Feeding System of Sugar Industry", Journal of Industrial Mathematics, Article ID 593176.
[6] Renu, and Bhatia, P. (2017). "Reliability Analysis for Removing Shortcoming Using StochasticProcess and Apply for Maintenance in Industry", Special Issue of International Journal of Engineering Science and Technology, 62-66.
[7] Rani, V. and Bhatia, P. (2020). "Performance Evaluation Of Stochastic Model of a Paper machine Having Three Types of Faults" International Journal of Science and Engineering, 91-102.
[8] Bhatia P. and Rani Veena, (2021) "A Study on Comparative Analysis of two Stochastic Models for Single Unit Paper Machine Considering Repairable/ Non-Repairable Minor and Major Faults" International Journal of All Research Educational and Scientific Method
[9] Rinku and Bhatia, P.(2022)"A Study on Comparative Analysis of Two Stochastic Models for Single Unit footwear Machine" Mathematical Statistician and Engineering Applications,5614-5626.