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Mathematical modeling and performance analysis of combed yarn production system: Based on few data

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ABSTRACT

The paper describes the availability of combed sliver production system, a part of yarn production plant. The units under study are specialized single purpose machines. Performance analysis of the system is carried out to identify the key factors. The optimum value of 'r', where 'r' represent the number of repairman to repair the twelve carding machines ($r \prec 12$), is calculated to maximizing the steady state availability of the system. The problem is formulated using probability consideration and supplementary variable technique. Probability considerations at various stages give differential-difference equations, which are solved using Lagrange method to obtain the state probabilities. The numerical analysis carried out helps in increasing the production rate by controlling the factors affecting the system i.e. availability optimization.

1. Introduction

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. Reliability is an important consideration in the planning, design and operation of the system. The process industries are the backbone of a country for its development. The process industries must provide continuous and long-term production to meet the ever-increasing demand at lower costs. The reliability and availability analysis of process industries can benefit in terms of higher production and lower maintenance. The need and application of reliability technology in the process industries is well understood by many researchers. Singh [1] analyzed the problem of system reliability with identical units having statically independent and dependent (common cause) failures. Singh [2] computed the state probabilities of a complex system with preemptive repeat priority repairs and failure of non-failed components. Subramanian and Anantharaman [3] carried out reliability analysis of a complex standby redundant system and estimated the comprehensive cost function. Dijkhuizen and Heijden [4] have given a series of mathematical models and optimization techniques, with which the optimal preventive maintenance intervals can be determined from an interval availability point of view. Kumar [5,6], Gupta et al. [7], Garg and Singh [8] and some other workers applied reliability technology to various industrial systems obtaining important results. Todinav [9] is proposed a new method for optimization of the topology of engineering systems based on reliability allocation by minimizing the total cost.

The present paper consists of a brief discussion of method of calculating some important reliability characteristic such as reliability function, failure frequency and renewal frequency. A yarn production plant situated in Himachal Pradesh (India) is chosen for study. Here, the production of combed sliver, a part of a yarn production system has been discussed in detail. The

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combed sliver production system further consists of four sub-systems blow room (B), carding machine (C), unilap machine (U) and comber machine (M), all working in series. Sub-system M is having multiple units working in parallel. The sub-system C is a 5-out-of-12: G system i.e. there are 12 carding machines working in parallel and the system works till there are at least 5 carding machines in good and operating state. Combed sliver production sliver fails either when there remain only four carding machines in working position, or sub-system B or U comes to failed state. When there remain only four carding machines are in working state, the system is under breakdown and the collective repair (including corrective and preventive maintenance) of all the carding machines is performed. In routine, normally eight or ten units remain in working states. The twelve carding machines are repaired with the help of 'r' repairmen where ($r < 12$). The optimum value for 'r' is calculated which maximizes the steady state availability of the system operating with ten or more carding machines. The production capacity of the plant is 34.56 tones combed yarn per day at optimum level. The target of the management to produce 29 tones combed yarn per day. This target can be achieved if at least ten carding machines remain in operative state. With this consideration, the performance of the system is examined. Numerical analysis is carried out making use of software package MATLAB.

2. The system

2.1. System description

There are four machines in the combed sliver production system. The first machine is the blow room. The raw cotton that arrives in the mill is in the form of hard pressed bales contains a lot of impurities. This cotton is fed manually into the blow room where opening, cleaning and removal of heavy particles, dust etc. of cotton is done. Cleaned fiber in sheet form, from the blow room is fed to the carding machines. Carding machine once again individualize and cleans the cotton fiber laps, remove neaps, short fiber ends and delivers compact carded sliver. Then unilap machine is used for processing the carded sliver transforming it into laps. This process helps in getting a good quality of comber material. Finally these laps are loaded on comber machine which further removes short fibers and remaining neaps, thus giving a fine combed sliver. Undergoing all these processes serially, we get a combed sliver. Fig. 1 gives the schematic flow chart of the combed sliver production process. The mathematical modeling is carried out for these machines that are prone to failure.

(1) *Blow room* (B):	consists of one unit which is subjected to major failure only
(2) *Carding machine* (C):	consists of twelve identical units(C_1, C_2, ..., C_{12}) which are working in parallel. This sub-system keeps the system operative if at least five carding machines remain in working states
(3) *Unilap machine* (U):	consists of one unit which is subjected to major failure only
(4) *Comber machine* (M):	consists of five identical units which are working in parallel and is subjected to minor failure only (assumed equivalent to no failure)

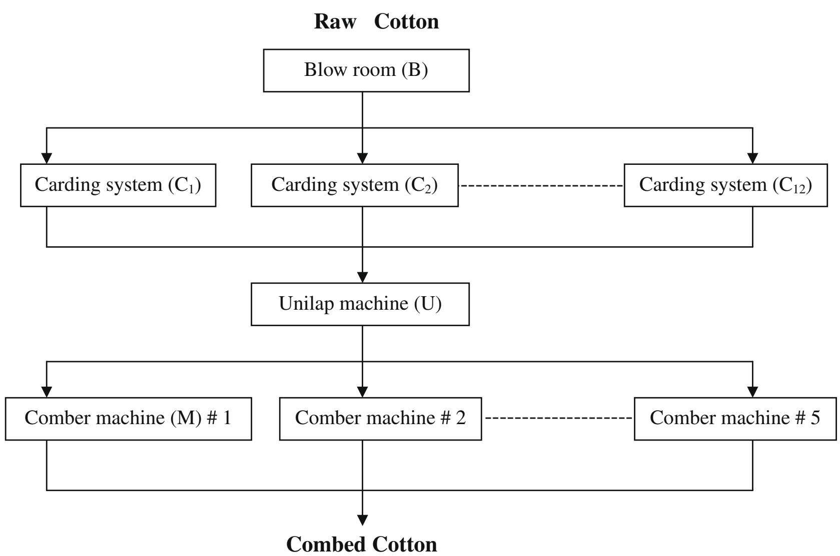

Fig. 1. Flow diagram of combed sliver production system.