Abstract

In many industrial applications, machines tend to experience random failure. As more and more people are becoming dependent on machines, they have become a part of our daily lives, providing comfort in all walks of life. It leads to an immense need of scientific research to develop a systematic approach for studying the phenomena of machining systems. Reliability theory as a mathematical and physical science has been widely used to understand the laws of occurrence of failures in machining systems. The reliability theory plays an important role in the prediction and improvement of industrial system operating in a machining environment. Queuing theory, a modern mathematical technique, is often used as a potent tool to solve the blocking and delay problems of complex machining systems. A “Finite Source Queuing Model” which is also called as “Machine Repair Model” or often named as “Machine Interference Model” has a lot of significant applications of practical nature in many organizations which are working in the environments of machining. The finite source or population queues constitute one major branch of all queues having its applications in several fields like production and manufacturing systems, power supply, manufacturing processes, computer & communication systems and distribution plants.

With the advancement in technology and over utility, the machining systems are becoming more complicated and sophisticated because of which, it becomes quite difficult for the system designers and the technologists to maintain their efficiencies. We know pretty well that during the operation of a machining system, the major aim of the industrial organization is to increase the quantity and quality of production by minimizing its total cost. Sometimes the working of the machining system is disrupted due to the improper functioning of some machining components. In such a situation, to avoid the possibility of stoppage of services and production loss, an efficient repair facility, and/or maintenance policy is usually provided to repair the improperly working machines or to maintain service threshold as per requirement respectively. Standby redundancy is the alternative means of continuing the function of machining system when it becomes inoperative due to failure and is one of the basic methods to increase reliability. Another method to increase the system reliability is to perform preventive maintenance on the system according to some schedule and policies depending upon associated cost and
other characteristics such as the number of permanent and additional repairmen, phase repair, increased service rate, vacation, etc. The maintenance action can be performed while the system is in operation without degrading its operation or by stopping the system for some time to avoid the un-pleasure consequences.

The objective of this thesis is to model repairable redundant machines which will be helpful for strategic implementation of such system in complex environment and will enable the system engineers and decision makers to use the machining system in a more efficient way to achieve desired reliability and availability of the system. Our findings will be of great importance in improving the availability and many reliability attributes associated with the machines which will lead to high cost saving strategies in service rendering by the concerned system. The thesis comprises of six chapters and bibliography.

In chapter 1, we illustrate the chronological development of research on reliability and maintainability analysis of redundant repairable systems (RRS). A brief review of the queueing theory, reliability, availability, maintainability and machine repairable systems has been presented. Some fundamental concepts and related literature have been given to provide insights into various issues related to machine repairable systems which may be useful for the system designers to plan effective strategies for an efficient machining system. Some important factors such as standby’s, discouragement, N-policy, F-policy, vacation, switching failure, common cause failure, degraded failure, multi-mode of failure have also been discussed. The analytical, as well as the numerical methods for solving the repairable systems, have been elaborated.

Chapter 2, deals with the transient analysis of repairable machining system having multi identical online and warm standby machines. There is a facility of repair of failed machines rendered by an unreliable server who is prone to failure and follows the threshold policy in rendering the service and being repaired. The failed machines waiting in the queue may renege and opt sequentially whether to leave the queue or remain in the queue in geometric fashion at the epochs of availability of the secondary server. By constructing the transient differential-difference equations, the probabilities associated
with the system states are determined using the numerical method based on Runge-Kutta method. Various queueing and reliability indices viz. expected number of failed machines in the system, throughput, reliability, mean time to failure, failure frequency etc., are established and numerically computed by taking an illustration. The sensitivity analysis and numerical simulation are performed for exploring the effects of parameters on some performance measures.

Chapter 3, is devoted to the performance modeling and reliability analysis of a redundant machining system composed of several functional machines. To analyze the more realistic scenarios, the concepts of switching failure and geometric reneging are also included. The time-to-breakdown and repair time of operating and standby machines are assumed to follow the exponential distribution. For the quantitative assessment of the machine interference problem, various performance measures such as mean-time-to-failure, reliability, reneging rate, etc., have been formulated. To show the practicability of the developed model, a numerical illustration has been presented. For the practical justification and validity of the results established, the sensitivity analysis of reliability indices have been presented by varying different system descriptors.

Chapter 4, deals with the maintainability issues and standby workstations provisioning which are the key concerns of the system designers in manufacturing system to overcome the unpredictable interruptions due to workstation failures. An optimal \( F \)-policy is proposed to control the admission of jobs in the case when the capacity of the system is full. By using queue-theoretic approach, the performance of manufacturing system consisting of finite identical workstations in parallel is explored. Various realistic features including minor and major breakdowns of the service facility, degraded failure rate of workstations, controlled admission of failed workstations, etc., are also taken into account for modeling the repairable manufacturing system. The spectral method is employed to compute the transient state probabilities for the governing model. Greedy-selection and Newton-quasi methods are used to determine the optimal parameter/threshold by minimizing the total cost associated with different activities.
Chapter 5, is devoted to realistic redundant machining system which is applicable in various systems like computer and communication system, manufacturing and production system, etc. In the present model, the system consists of $M$ identical active operating machines which function in parallel and prone to breakdown. The operating machines are under the care of one permanent repair facility that provides time-sharing repair services. Under maintenance policy, we facilitate the studied model with the advantage of standby machines of mixed type and additional repair facility. From an economic point of view, we also consider $N$-policy and $F$-policy to control service and arrival of failed machines effectively. For analysis purpose for a long period, we compute steady-state probabilities using product-type method recursively. Sensitivity analysis is done for various parameters numerically by developing code in MATLAB. All analysis is tabulated in tables and depicted in graphs.

Chapter 6, elaborates the reliability analysis of fault tolerant multi-component machining system having multi-warm spares and reboot provisioning. The time-to-breakdown and repair of active/inactive units and server are assumed to be exponentially distributed. The reboot process and recovery delay is also counterfeited exponentially distributed. The spectral method is adapted to compute the transient state probabilities of the system states. In order to predict the transient behavior of the system, various performance measures such as reliability function, mean-time-to-failure, etc., have been established. To show the practicability of the developed model, we present numerical results by taking an illustration. The sensitivity of various system parameters on the reliability function and MTTF have also been examined.

The thesis contains a comprehensive and up-to-date bibliography.