

# Review of Theory and Technology of Mechanical Reliability for Dynamic and Gradual Systems

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**Abstract:** Along with the development of industry and modern science, the performance of the mechanical product increases continuously and the mechanical system and work environment become more complex. The problems for the performance and reliability of the product become more and more prominent. It is very important and urgent to research the area of reliability of the mechanical product. Based on the research of mathematics, mechanics, material science and mechanical engineering, the basic task of mechanical reliability design is to propose mathematical-mechanical models and methods for engineering practice in mechanical product design by integrating the reliability experiment and statistical analysis of the failure data. Dynamic and gradual changing over time are universal characteristics of mechanical systems during service lifetime. Structural dynamic and time-dependent reliability analyses needs theories and methodologies in terms of mechanical dynamics, strength deterioration mechanism, random processes, probability theory, reliability analysis and design, etc. With the developments during past decades, methods on dynamic and gradual reliability analysis of system are reviewed.

**Keywords:** Mechanical products; Dynamic reliability; Gradual reliability; Coupled and correlative mode; Incomplete probability information

## 1. Introduction

The purpose of mechanical reliability design is to estimate the operation capacity, state and service life of the product under the specified working conditions in the development stage of the mechanical products, and point out the weak links of the products. For mechanical products, the problem of reliability is closely related to personal safety, economic and social benefits. Therefore, the safety and reliability of mechanical products is one of the main purposes of engineering design. Reliability takes into account the quality of time factors, and more and more mechanical products are required to have reliability indicators. Therefore, deepening the overall understanding of conventional design and popularizing reliability technology is undoubtedly necessary for improving the quality of products. Therefore, it is imperative to study the reliability technology of mechanical products. There are many contents of reliability technology, which run through all aspects of product design, development, manufacturing, assembly, commissioning, testing, operation, transportation, storage, repair and maintenance. The experience of modern production shows that in the three stages of design, manufacture and use, the design determines the reliability level of the product. The task of manufacture and use is to ensure the realization of product reliability index. Therefore, we should vigorously

promote the reliability design method based on probability and statistics theory. It is the focus of the competition of mechanical products to ensure the safety and reliability of mechanical products in the process of operation, and this competition is mainly reflected in the competition of product reliability. Thus it can be seen that "material beauty and low price" must be supported by reliability engineering. Moreover, in order to achieve the function and performance of product requirements, we should ensure the reliability of design and ensure that the components of products are assembled according to the design requirements in the process of product design. It can be asserted that only products with high reliability can win in the fierce competition in the international market. Therefore, it is an urgent and important task to popularize and carry out the reliability technology in the field of machinery industry.

## 2. The Connotation of Mechanical Reliability

Mechanical reliability refers to the ability of a mechanical product to complete the prescribed functions within the prescribed conditions and time. Because of the influence of engineering material characteristics, the system parameters of mechanical products are inherently uncertain, so the reliability design technology considering this inherent randomness is very important. According to the

relevant statistics, the contribution rate of product design to product quality can reach 70% to 80%. It can be seen that the design determines the quality of the product and gives the inherent nature of the product. The relationship between the mechanical reliability can be seen, the mechanical reliability mainly should include the content of the study for the first time overrun, dynamic reliability, reliability of the gradient, and these areas have formed reliability modeling, qualitative analysis, quantitative analysis and experimental research. Accordingly, the mechanical reliability of the technology can be divided into: the reliability of data collection and statistical analysis, analysis and design, manufacture and assembly reliability, maintenance reliability, reliability growth and reliability prediction and allocation, reliability, reliability test and reliability management disciplines. The mechanical reliability relationship can be seen that mechanical

reliability is closely related to reliability, mathematics, reliability physics, failure analysis, material strength, fault diagnosis, maintenance support, quality engineering and other disciplines. As shown in Figure 1, a frame diagram of mechanical reliability is shown.

Mechanical products are mostly the achievements of many disciplines. Their performance requirements are high-speed, high-power, precision, lightweight, intelligent, extreme, high reliability, pleasant and friendly environment. Mechanical reliability is closely related to the performance requirements of mechanical products. These performances will determine their winning and losing in the fierce market competition and the social and economic benefits. The relationship between mechanical product performance requirements and mechanical reliability is shown in Table 1.

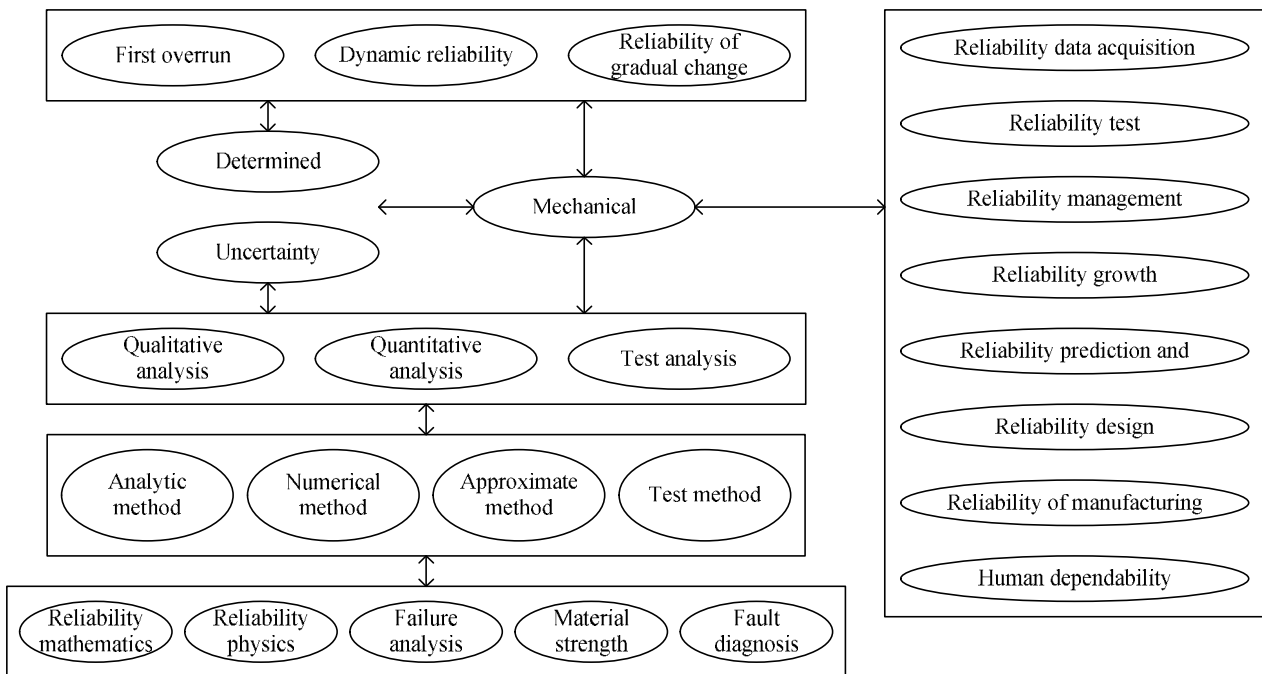


Figure.1. System Block Diagram of Mechanical Reliability

Table.1. The Relationship Between Mechanical Product Performance Requirements and Mechanical Reliability.

Number	Product performance	The relationship between product performance and reliability
1	High speed	High speed need feasibility analysis and dynamic analysis
2	High power	The importance of high power needs to highlight the importance of reliability research
3	Precision	A dynamic study of the need for reliability related to precision
4	Lightweight	Lightweight requirements for dynamic and gradual reliability design
5	Intelligentization	Intelligentization involves the study of the reliability of electrohydraulic fusion

### 3. Research Status of Dynamic and Gradual Reliability

#### 3.1. Dynamic Reliability Analysis Based on First Crossing Theory

The research on the dynamic reliability theory of structural systems can be traced back to 1940s. RICE[1] studied the problem of dynamic response intersecting with a fixed boundary, and first put forward the famous first passage probability formula, which laid the foundation

for the first time to surmount the dynamic reliability theory of failure. Subsequently, SIEGER[2] proposed the first transcendental probability calculation method when the structural response is a continuous Markov process. HELSTROM[3] derives the analytical solution of the first transcendental moment of time in the envelope process. COLEMAN[4] proposed a Poisson process method for the first time to surpass the frequency calculation. CRANDALL[5] introduces the numerical simulation method to the first transcendence problem, which further develops the theory of dynamic reliability analysis based on the first crossing model.

### **3.2. Stochastic Dynamic Analysis and Reliability Analysis Based on Stochastic Simulation Method, Random Perturbation Technique And Orthogonal Expansion Theory**

After 1980s, the problem of response analysis for random structures mainly includes random simulation, random perturbation and orthogonal expansion theory, etc. [6] The initial simulation method is mainly based on large sample MonteCarlo [7]simulation. Although Carlo method can solve almost all dynamic reliability analysis problems, but due to the limitation of computational efficiency, the results are mostly used to verify other methods, such as statistical moments, probability density and dynamic failure probability of random response.

## **4. Research Prospect of Dynamic And Gradual Reliability**

Based on the major needs of the country and aiming at the frontier of international academia. Aiming at the key reliability problems in localization and self-development of mechanical products, the reliability theory and technology system provide theoretical basis and technical method for solving the key reliability problems in the development and localization of mechanical products.[8]This provides a perfect theoretical method and technical specification for the development of mechanical reliability. Therefore, the key is to break through the bottleneck of restricting the reliability development of mechanical products, and apply theoretical and technological achievements to design and manufacture, so as to provide solid theoretical support for machine design. Therefore, we should strengthen the research on the bottleneck of reliability theory and application which is consistent with engineering practice and must break through. These researches are also the inevitable trend of the development of mechanical reliability.

### **4.1. Reliability Design and Manufacture of Nonlinear Stochastic Dynamic and Gradual Mechanical Systems**

In reliability design, the dynamic behavior and gradual failure of a multi degree of freedom nonlinear stochastic system should be considered at the same time, which is one of the international problems. The deterioration of some parameters of a mechanical product not only leads to failure, but also affects its dynamic behavior. Therefore, the dynamic behavior of mechanical products also affects the deterioration process of parameters. How to properly consider these two kinds of coupling factors in the construction of reliability model is one of the key and difficult points of the problem.

### **4.2. Reliability Design And Manufacturing Problem of Coupling Failure Mode of Dynamic And Gradual Mechanical System**

In the first development direction, we mainly study the reliability design problem of mechanical products with dynamic coupling and gradual coupling, but there are no problems related to vibration failure, gradual failure and static failure. The coupling correlation of each type of failure type, and the reliability design and manufacturing problem of the coupling related to the dynamic stochastic process and the gradual random process.

### **4.3. The Reliability Design And Manufacturing Problem of The Dynamic And Gradual Mechanical System With The Absence of Probability Information**

In the process of mechanical reliability design and manufacture, the probability distribution information of the random parameters of the mechanical system and its components needs to be mastered. But in engineering practice, it is often difficult to have enough data and data to determine the probability distribution of the random parameters. At present, the reliability design and manufacture method of mechanical products has been greatly developed, but most of these methods assume that the design parameters are subject to normal distribution. However, due to the complexity of engineering and the relative lack of statistical data, the design parameters are subject to various forms of probability distribution, and some even do not obey normal distribution. It can be seen that the reliability design and manufacturing method that simply uses normal distribution will bring some errors, and even can not get the ideal design results sometimes.

## **5. Conclusion**

The research of mechanical dynamic and gradual reliability should take mechanical products as the research object. The vibration and impact environment are related to the performance and reliability requirements of the mechanical products. The impact of the deterioration of the performance of the mechanical product on the reliability is the characteristic model. The bottleneck and challenge in many aspects of the theory and technology of facing

the reliability of mechanical products, mechanical products and dynamic gradient reliability design theory and method based on the stochastic process and probability statistics, mechanical dynamics, degradation mechanism, reliability design and so on. Finally, the author applies the obtained theoretical and technological achievements to the design of actual mechanical products, so as to provide reasonable and necessary theoretical and technological support for the design, manufacture, use and evaluation of mechanical products in China.

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