

Применение методов логико-вероятностного исчисления профессора И.А.Рябина в программных комплексах

Теоретические разработки д.т.н. профессора **И.А.РЯБИНА**, представленные в данном электронном издании, применяются на практике специалистами ОАО «СПИК СЗМА» при выборе и обосновании структур сложных технических систем на основе сравнительного анализа надежности рассматриваемых вариантов.

ОАО «СПИК СЗМА» выполняет работы в области автоматизации технологических и производственных объектов на протяжении более 50 лет.

ОАО «СПИК СЗМА» с 1996 г. является базовой организацией Госстроя России по реализации научно-технической политики в области исследований, проектирования и наладки систем автоматизации технологических и производственных процессов и инженерного оборудования зданий и сооружений.

Начиная с 2001 г. в ОАО «СПИК СЗМА» ведутся работы по созданию, развитию и практическому применению «Программного комплекса автоматизированного структурно-логического моделирования и расчета надежности и безопасности систем «АРБИТР» Программный комплекс (ПК) «АРБИТР» разработан на основе общего логико-вероятностный метода (ОЛВМ) системного анализа, представляющего собой дальнейшее развитие логико-вероятностных методов оценки надежности структурно-сложных систем, основоположником которых является профессор **И.А.РЯБИН**.

ПК «АРБИТР» реализует новую информационную технологию автоматизированного структурно-логического моделирования и позволяет на основе заданной структурной схемы и вероятностных параметров элементов автоматически строить математические модели (логические и вероятностные) и выполнять расчеты различных показатели надежности, стойкости, живучести, устойчивости, технического риска, ожидаемого ущерба и реальной эффективности структурно-сложных высокоразмерных систем опасных производственных объектов. Логическая полнота ОЛВМ впервые позволила реализовать в одном ПК возможности существующих подходов (деревьев отказов и событий, блок-схем, графов связности и др.) к монотонному логико-вероятностному моделированию систем. Вместе с тем, ПК «АРБИТР» позволяет решать принципиально новый класс задач немонотонного логико-вероятностного моделирования структурно-сложных системных объектов и процессов.

В период с 2005 по 2007 год программный комплекс «АРБИТР» успешно прошел процедуру аттестации в "Совете по аттестации программных

средств" Научно-технического центра по ядерной и радиационной безопасности (НТЦ ЯРБ) Федеральной службы по экологическому, технологическому и атомному надзору (Ростехнадзор) РФ. На основании результатов экспертизы на программное средство "Программный комплекс АРБИТР (ПК АСМ СЗМА), базовая версия 1.0" выдан **Аттестационный паспорт Ростехнадзора РФ № 222 от 21 февраля 2007 г.** ПК «АРБИТР» стал первым аттестованным Ростехнадзором РФ отечественным программным средством анализа надежности и безопасности систем. ПК «АРБИТР» аттестован сроком на 10 лет и разрешен к применению на всех предприятиях, поднадзорных Ростехнадзору РФ

К настоящему времени накоплен значительный опыт практического применения ПК «АРБИТР» на предприятиях, в коммерческих и научно-исследовательских организациях, а также в высших учебных заведениях РФ. Работы по дальнейшему развитию теории ОЛВМ, технологии АСМ и совершенствованию ПК продолжаются.



АО «СПИК СЗМА» - производственно-инжиниринговая компания, основанная в 1961 г. Выполняет полный комплекс инжиниринговых услуг по автоматизации технологических процессов и производств, имеет собственное производство систем управления и электротехнического оборудования, центр продаж, сервисный и учебный центры.

Один из видов деятельности компании - **научная разработка методов и средств расчета надежности технически сложных систем на стадии проектирования, разработка специального программного обеспечения, обучение.**

Система менеджмента качества компании соответствует требованиям международного стандарта ISO 9001:2015

✉ **199106, 26-я линия В.О., дом 15, корп. 2, БЦ «Биржа»**

☎ **+7 (812)610-78-79**

@ **info@szma.com**

www.szma.com

RELIABILITY OF ENGINEERING SYSTEMS

I. Ryabinin

Principles
and Analysis



$$\sum_{k=1}^n \frac{1}{\bar{Y}_k}$$

Prof. I. Ryabinin, D. Sc. (Tech.), USSR, born 1925. He is a well-known scientist in the field of reliability theory and the author of several fundamental books on the modern reliability theory and its practical application in complex engineering systems.

The book deals with the theory of engineering system reliability. Covers basic concepts and quantitative characteristics of flows of events, statistical evaluation of reliability indices and testing of various hypotheses on the reliability of engineering systems. Also presented are analytical and statistical methods for calculating the reliability of restorable and redundant systems. Almost all theoretical reasonings are supported by examples, and calculations are brought to finite numerical results. The book is intended for engineers and scientific workers engaged in design and operation of engineering systems. May also interest teachers, postgraduates and students at engineering colleges.



Contents

Preface	9
Chapter One. Engineering System as an Object of Study	11
1. The Problem of Reliability of Engineering Systems	11
2. The Basic Concepts of the Theory of Reliability	13
3. The Complexity of Modern Engineering Systems	15
4. The Choice of the Model of System Functioning	19
5. Some Data from the Theory of Sets and the Algebra of Logic Necessary to Study the Problems of Reliability of Engineering Systems	24
Chapter Two. Quantitative Characteristics of Reliability	40
6. The Quantitative Estimation of Reliability of ES Elements	40
7. Accuracy and Confidence of Quantitative Estimation of Reliability	41
8. The Basic Random Variables Utilized in the Theory of Reliability	46
9. The Basic Characteristics of Reliability of a Product Operating up to the First Failure	48
10. The Basic Characteristics of Reliability of the Product Being Renewed	59
Chapter Three. The Basic Concepts and Characteristics of Fluxes of Events	67
11. The Process of Functioning of Renewable Products as a Flux of Events	67
12. The Basic Properties of the Flux of Failures	69
13. Ordinary Fluxes of Failures without Contagion	73
14. Ordinary Fluxes of Failures with a Limited Contagion	75
15. Analysis of the Basic Characteristics of Reliability with Various Laws of Distribution of Time of Unfailing Operation	85
Chapter Four. Statistical Estimation of Reliability Indices for ES Elements Operating in Actual Conditions	95
16. Methods of Obtaining Reliability Indices of ES Elements	95
17. Estimating the Probability of Failure by Frequency of its Occurrence. Confidence Intervals for the Probability of Failure	98
18. Tolerance Limits	118
19. Statistical Estimation of Numerical Characteristics of Continuous Random Variables Utilized in the Theory of Reliability	127
20. Estimating the Intensity of Ordinary Fluxes of Failures. Determining the Functions Which Characterize the Reliability of ES Elements	145
Chapter Five. Testing Various Hypotheses on Reliability of ES Elements	194
21. General Features of the Method	194
22. Comparing the Observed Frequency of Failures with the Hypothetical Probability of Failure	197

23. Testing the Hypothesis of the Equality of Two Probabilities of Failure	203
24. Testing the Hypothesis on the Homogeneity of Two Samples	224
25. Testing the Hypothesis on the Distribution Law	234
26. Determining the Distribution Laws on the Basis of a Small Number of Observations	260
Chapter Six. Analytical Methods of Calculating the Reliability of ES Without Regard for Renewal	
27. General	278
28. Mathematical Foundations of Logical Probability Methods for Calculating the Reliability of ES Without Regard for Renewal	282
29. The Method of Calculating the Reliability of ES with the Aid of Expansion Algorithm	288
30. The Method of Calculating the Reliability of ES with the Aid of Orthogonalization Algorithm	297
31. Tabular Method of Calculating the Reliability of ES	301
32. Logical Circuit Method of Calculating the Reliability of ES	305
33. The Method of Calculating the Reliability of ES with the Aid of Incompatible Hypotheses	317
34. Accuracy and Confidence in Estimating the Reliability of ES	324
Chapter Seven. Analytical Methods of Calculating the Reliability of ES with Regard for Renewal	
35. Renewal as a Means of Increasing the Reliability	337
36. Calculating the Reliability of a Renewable System Without Redundant Elements	338
37. Calculating the Availability of a Renewable Reserved System Consisting of Single-Type Elements	344
38. Calculating the Probability of Unfailing Operation of a Renewable Reserved System Consisting of Single-Type Elements	350
39. Approximate Logical Probability Method of Calculating the Reliability of ES with Regard for Renewal	359
40. Example of Calculating the Reliability of Renewable Marine Power Plant by the Approximate Logical Probability Method	371
Chapter Eight. Logical Statistical Method of Investigating the Reliability of ES with the Aid of Electronic Digital Computers	
41. Principles of Constructing Statistical Models for the Study of Reliability of Composite Engineering Systems	379
42. Formalization of the Process of Functioning of ES and Various Fundamental Approaches to the Solution of the Problem in Hand	383
43. Formation of Fluxes of Random Events	386
44. Formation of States of ES by an Electronic Digital Computer	391
45. Analysis of the State of a System with the Aid of an Electronic Digital Computer	393
46. Operator and Block Diagrams of the Algorithm for Determining the Probability of Unfailing Operation of ES	400
47. Description of Algorithm Operation	409
Chapter Nine. The Study of Reliability of Renewable ES by the Logical Statistical Method Using Electronic Digital Computers	
48. Selection of Problems for the Study of Reliability of ES	417
49. Effect of the Laws of Time Distribution of Unfailing Operation and Renewal on the Reserved System Reliability Characteristics	418

50. Effect of Contagion on the Reliability of ES	431
51. Study of Comparative Reliability of ES	438
52. Estimating the Absolute Reliability of ES from the Results of Observing the Failures of Its Elements	448
Chapter Ten. Some Additional Investigations into the Structural Reliability of ES	465
53. Formalized Method of Composing the Conditions of Capability of a System	465
54. The Study of the Structural Reliability of a System	474
55. Effect of Significance of Separate Elements on the Reliability of a System	483
Supplements	498
References	515
Index	530

Preface

The theory of reliability is a new branch of science which deals with the general regularities to be observed in the design, testing, manufacture, acceptance and use of products to obtain the maximum efficiency of the products.

The present-day theory of reliability has been developed during the last twenty years by engineers and mathematicians of various countries.

A valuable contribution has been made to the development of the general theory of reliability by Soviet scientists Sh. L. Bebiashvili, Yu. K. Belyaev, A. I. Berg, N. G. Bruevich, M. A. Gavrilov, B. V. Gnedenko, V. P. Grabovetsky, G. V. Druzhinin, I. N. Kovalenko, V. I. Nechiporenko, A. M. Polovko, Ya. B. Shor, V. I. Siforov, A. D. Solovyev, B. S. Sotskov, I. A. Ushakov et al.

The problem of reliability is tackled from a practical viewpoint in the Soviet Union and other countries in laboratories and design departments organized at enterprises and research centres. Special courses on the theory and calculation of reliability form today an integral part of the curricula of many technical colleges.

Despite an ever-growing number of publications on the problem of reliability almost all of them do not give sufficient attention to the statistical methods of investigation in the actual conditions of operation as well as to the methods of research into the reliability of structurally complex systems. All this makes it difficult to accumulate objective statistical data regarding the reliability of technical products and induces the researchers to resort to essential simplification of the problem dictated not by the physics of the process in question but by the requirements of the mathematical method. As a result, the theory of reliability is not applied in present-day practice on so wide a scale it unquestionably deserves.

Although rather intricate mathematical methods are utilized in the book, it is intended sooner for engineers than for mathematicians. All problems are discussed from the viewpoint of practical application.

It is presumed that the reader is acquainted with the fundamental concepts of the probability law and mathematical statistics. If not, it will be well advised to study first the symbols and terminology generally accepted in the theory of sets and in the algebra of logics in Section Five.

The author expresses his gratitude and appreciation to his colleagues for their invaluable assistance in preparation of this book.