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Introduction to Reliability of Mechanical Systems

03 5018

Syllabus: Probabilistic, statistical and info-gap robustness concepts of reliability. Reliability of static and dynamic mechanical components and systems. Reliable design. Probabilistic failure models. Quality control. Statistical acceptance testing.

Course website:

http://yakovbh.net.technion.ac.il/courses/introduction-to-reliability-of-mechanical-systems

Prerequisites:

Linear Systems (03 4032)

Statistical Methods (09 4431)

Time and place of lectures: Wednesdays, 15:30–18:30. Lady Davis, room 371.

Office hours. Sundays 13:00–14:00. Thursdays 10:00–11:00. Other times by appointment. Kahn 308.

Outline of Lectures

Part I: Info-Gap Analysis of Mechanical Reliability

1. Info-gap robustness analysis of a statically loaded beam with load uncertainty.[1]
2. Lecture 1 continued.
3. Info-gap robustness analysis of the design of a vibrating cantilever with load uncertainty: damping and stiffness design concepts.[2]
4. Lecture 3 continued.
5. Info-gap robustness and opportuneness analysis of mass, strength, and safety factors in the design of a beam.[3]
6. Info-gap robustness analysis of heat conduction with uncertain spatially distributed heat source.[4]
7. Info-gap robustness analysis of two coupled harmonic oscillators: modal behavior with uncertain load.[5]

Part II: Statistical Analysis of Reliability

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[1] ○ *Robust Reliability in the Mechanical Sciences,* section 3.2.
○ Lecture Notes on Robustness and Opportuneness, sections 1 and 2 (file ro02.pdf).

[2] ○ *Info-Gap Decision Theory,* section 3.2.1.
○ Lecture Notes on Robustness and Opportuneness, section 6 (file ro02.pdf).

[3] Lecture Notes on Performance vs Robustness of a Cantilever (file beam-op001.pdf).

[4] Problem Set on Robustness and Opportuneness, #14 (file: ps2-02.pdf).

[5] ○ Problem Set on Robustness and Opportuneness, #16 (file: ps2-02.pdf).
○ Related material in *Robust Reliability in the Mechanical Sciences,* section 4.3.

8. Statistical failure models: Reliability function, failure rate function, mean time to failure, Poisson process.[6]
9. Statistical failure models: Exponential, Gamma, Pareto, Weibull, normal, lognormal.[7]
10. Probabilistic reliability analysis with info-gap-uncertain probability distributions.[8]
11. Statistical hypothesis testing applied to acceptance testing. Testing sample means with t tests. Sequential sampling.[9]
12. χ^2 test for acceptance testing and reliability analysis.[10]
13. Acceptance sampling of a large population. Threshold tests for detecting a change.[11]

Course Requirements

1. **Homework.** Highly recommended. Homework problems will be put on the course website each week. The exercise session will be done in "reverse" mode: students will work in small groups, guided by the instructor, rather than frontal presentation of the solutions. Solutions will be posted on the website afterwards. Solving homework problems each week will enable mastery of the material.

2. **Review exercises.** The Lecture Notes contain review exercises that will assist the student to master the material in the lecture and are highly recommended for review and self-study. The student is directed to the review exercises at selected places in the notes. They are not homework problems, and they do not entitle the student to extra credit.

3. **Mid-term exam.** Optional ("magen"). One optional mid-term exam will be given after completing Part I. It will be 1 hour duration and will have a weight of 40% in the final grade. The weight of the mid-term is moved to the final exam if the mid-term grade does not improve the final grade. Each student is allowed one 2-sided page of notes and a hand calculator. Date: to be determined.

4. **Final Exam.** Required. 60% in the final grade (plus weight of the mid-term exam as necessary). A grade of less than 50 on the final exam will be recorded as the final grade in the course. Each student is allowed two 2-sided page of notes and a hand calculator. Moed Alef: 14.7.2019. Moed Bet: 26.9.2019. If a student takes the exam more than once, it is the last grade that is recorded.

[6] ○ Høyland and Rausand, sections 2.1–2.5.
○ Lecture Notes on Probabilistic Failure Models, sections 1–5 (file: pfm.pdf).
[7] ○ Høyland and Rausand, sections 2.6–2.11.
○ Lecture Notes on Probabilistic Failure Models, sections 6–13 (file: pfm.pdf).
[8] ○ *Info-Gap Decision Theory,* section 3.2.3.
○ Lecture Notes on Probabilistic Failure Models, section 14 (file: pfm.pdf).
[9] ○ Hines and Montgomery, chap. 11.
○ Lecture Notes on Acceptance Testing, sections 1–3 (file: acctes.pdf).
[10] ○ Hines and Montgomery, chap. 11.
○ Lecture Notes on Acceptance Testing, sections 4–6 (file: acctes.pdf).
[11] Lecture Notes on Acceptance Testing, sections 7–8 (file: acctes.pdf).

Books and Other Sources

Books 2, 3, 13 and 14 are the main texts. The other books are useful supplementary sources.

1. J.I. Ansell, 1994, *Practical Methods for Reliability Data Analysis,* Oxford.
2. Ben-Haim, Yakov, 1996, *Robust Reliability in the Mechanical Sciences,* Springer.
3. Ben-Haim, Yakov, 2006, *Info-Gap Decision Theory: Decisions Under Severe Uncertainty,* 2nd edition, Academic Press.
4. Ben-Haim, Yakov, Lecture Notes on Acceptance Testing, course website, acctes.pdf.
5. Ben-Haim, Yakov, Lecture Notes on Performance vs Robustness of a Cantilever, course website, beam-op001.pdf.
6. Ben-Haim, Yakov, Lecture Notes on Probabilistic Failure Models, course website, pfm.pdf.
7. Ben-Haim, Yakov, Lecture Notes on Robustness and Opportuneness, course website, ro02.pdf.
8. O. Ditlevsen and H.O. Madsen, 1996, *Structural Reliability Methods,* John Wiley, New York.
9. G.W.A. Dummer and R.C. Winton, 1990, *An Elementary Guide to Reliability,* Pergamon Press, 4th ed.
10. C.E. Ebeling, 1997, *An Introduction to Reliability and Maintainability Engineering,* McGraw-Hill.
11. I. Elishakoff, 1983, *Probabilistic Methods in the Theory of Structures,* Wiley, New York.
12. E.A. Elsayed, 1996, *Reliability Engineering,* Addison Wesley, Reading, Massachusetts.
13. Hines, William W. and Douglas C. Montgomery, 1990, *Probability and Statistics in Engineering and Management Science,* 3rd ed, Wiley, New York.
14. A. Høyland and M. Rausand, 1994, *System Reliability Theory: Models and Statistical Methods,* Wiley, New York.
15. R.D. Leitch, *Reliability Analysis for Engineers: An Introduction,* Oxford, 1995.
16. E.E. Lewis, 1994, *Introduction to Reliability Engineering,* Wiley, New York.
17. J.D. Robson, *An Introduction to Random Vibration,* Edinburgh University Press, 1963.
18. A. Villemeur, 1992 *Reliability, Availability, Maintainability and Safety Assessment,* Vol. 1: Methods and Techniques, Vol. 2: Assessment, Hardware, Software and Human Factors. John Wiley, New York.