MODELS IN MECHANICAL RELIABILITY DATA

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Abstract *The mechanical reliability uses many statistical models to fit experimental data. The state-of-the-art in the domain implies extended use of specialised software, from simple freeware to complex, expensive ones; the paper proposes an investigation of the capabilities of some useful software, mainly applying the regression analysis of experimental data and some numerical examples and extends the discussion to dependability and performability.*

Keywords: robotics, regression, reliability.

1.Introduction

Today, billions of dollars are being spent annually world wide to develop reliable and good quality products and services. Global competition and other factors are forcing manufacturers and others to produce highly reliable and good-quality products and services.

Needless to say, nowadays reliability and quality principles are being applied across many diverse sectors of economy and each of these sectors has tailored reliability and quality principles, methods, and procedures to satisfy its specific need. Some examples of these sectors are robotics, health care, electric power generation, Internet, textile, food, and software [1]..

There is a definite need for reliability and quality professionals working in diverse areas to know about each other's work activities because this may help them, directly or indirectly, to perform their tasks more effectively [1].

Reliability is an important and challenging subject, which involves the disciplines of science and engineering. Researchers in both these fields have been working on reliability problems for several decades, to summarize various ageing and dependence concepts of the lifetimes that have been widely studied in the field of reliability [6]. Many efforts was made to reliability applications for manufacturing systems [10; 14; 15; 16; 17; 18].

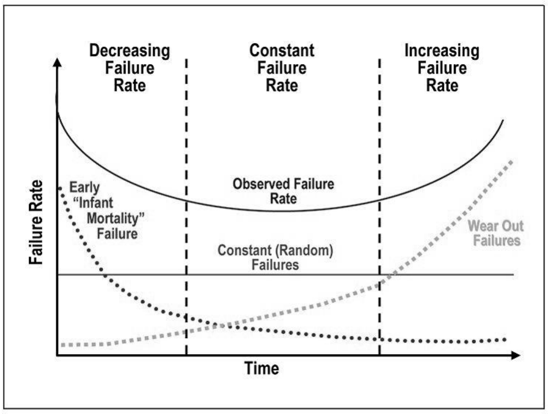
2. Hazard-rate function, models and software

A common method of analyzing the lifetime of the products, systems, etc. is to used distributional models, which describe the process under the study. Based on the concept from probability theory, hazard-rate function, h(t):

$$h(t) = f(t) / R(t) \qquad (1)$$

where f (t) denotes the probability density function, and R(t) the reliability function, which is also called the survivorship function. The quantity h(t), named the hazard function, represents the probability that a device of age t will fail in the small interval of time [t; t+dt], known that in the time interval [0;t] it did not fail.

The bathtub curve does not depict the failure rate of a single item: it depicts the relative failure rate of the entire population of items over time [10]. The name bathtub suggests the cross-sectional shape of the eponymous device and comprises three time periods (fig.1) [3; 1]. Many products reflect the bathtub curve, fig.1 [3;23], but not any product follows a bathtub curve hazard function [9; 24].



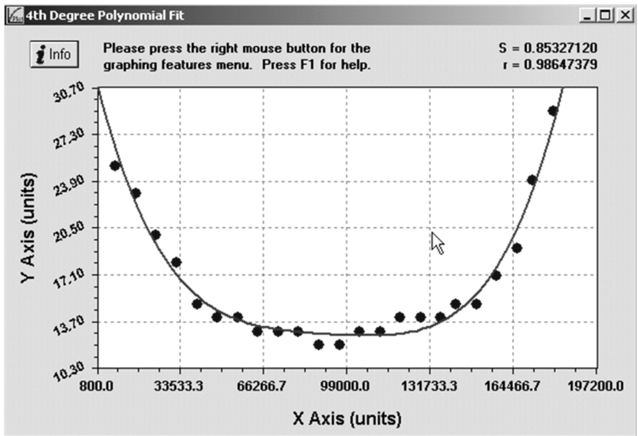


Fig.1 The Bathtub Curve (Hypothetical Failure Rate vs.time)

Fig.2 Polynomial hazard-rate function: $y(x) = 31.3 - 7.3 * 10^{-4}x + 1.1 * 10^{-8}x^2 - 8 * 10^{-14}x^3$

A first opportunity to calculate the regression curve for the reliability field data is the software CurveExpert (version 1.3 or 1.4), a comprehensive curve fitting system for Windows. It employs a large number of regression models (both linear and nonlinear) as well as various interpolation schemes to represent data. In addition, the user may define any customized model desired for use in a regression analysis [2]. An illustrative example is presented in fig. 2, for the polinomial model:

$$h(x) = a + bx + cx^2 + dx^3 \qquad (2)$$

Another easy way for reliability regressions is LAB Fit, with the main application **Curve Fitting** (nonlinear regression - least squares method, Levenberg-Marquardt algorithm - , almost 500 functions at the library with one and two independent variables, functions finder, option: write fitting function with up to 150 characters, 6 independent variables and 10 parameters) [5]. An example for an adapted beta model is presented in fig. 3:

$$h(x) = a[(x - 9.3)^b(10.7 - x)^c - 0.7^{bc}] \qquad (2)$$

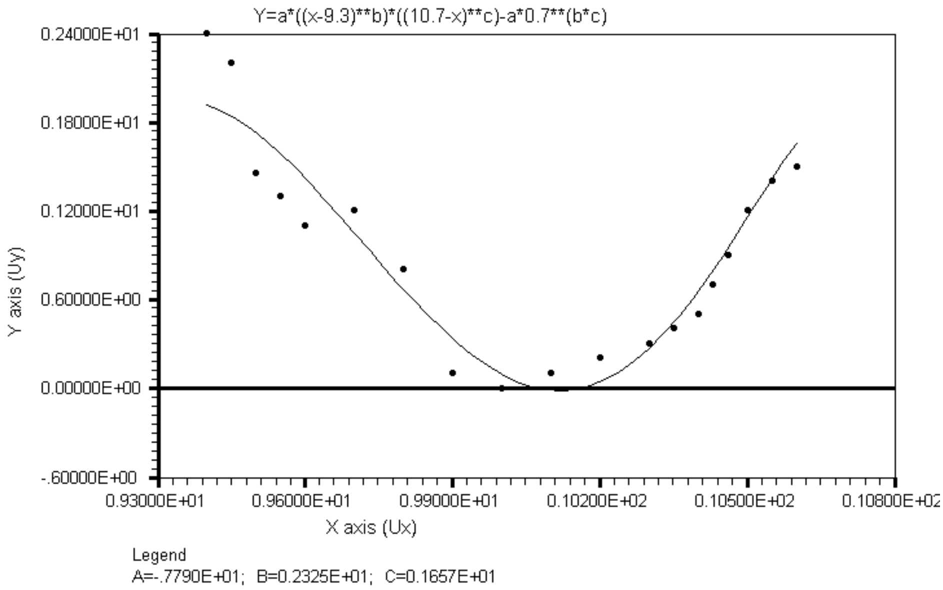


Fig.3. Adapted beta hazard-rate function

A more sophisticated reliability data analysis is offer by OriginPro8.1; produced by **OriginLab,** is a professional data analysis and graphing software for scientists and engineers; it offers peak-analysis and curve-fitting capabilities, over 60 customizable graph types, and analysis templates [5]. An example for a eulerian model is presented in fig. 4:

$$h(x) = ax^{b}(60 - x)^{c} \qquad (3)$$

Equation	y = a*(x^b)*((60-x)^c)
Report Status	New Analysis Report

Input Data

Parameters

		Value	Standard Error
B	a	168,88481	46,35949
	b	-0,46066	0,0501
	c	-0,433	0,05231

Iterations Performed = 24
Total Iterations in Session = 24
Fit converged - tolerance criterion satisfied.

Statistics

	B
Number of Points	60
Degrees of Freedom	57
Reduced Chi-Sqr	17,39088
Residual Sum of Squares	991,2801
Adj. R-Square	0,41534
Fit Status	Succeeded(100)

Fit Status Code :
100 : Fit converged

Summary

	a		b		c		Statistics	
	Value	Error	Value	Error	Value	Error	Reduced Chi-Sqr	Adj. R-Square
B	168,88481	46,35949	-0,46066	0,0501	-0,433	0,05231	17,39088	0,41534

ANOVA

		DF	Sum of Squares	Mean Square	F Value	Prob>F
B	Regression	3	8045,7199	2681,90663	154,2134	0
	Residual	57	991,2801	17,39088		
	Uncorrected Total	60	9037			
	Corrected Total	59	1754,98333			

Fitted Curves Plot

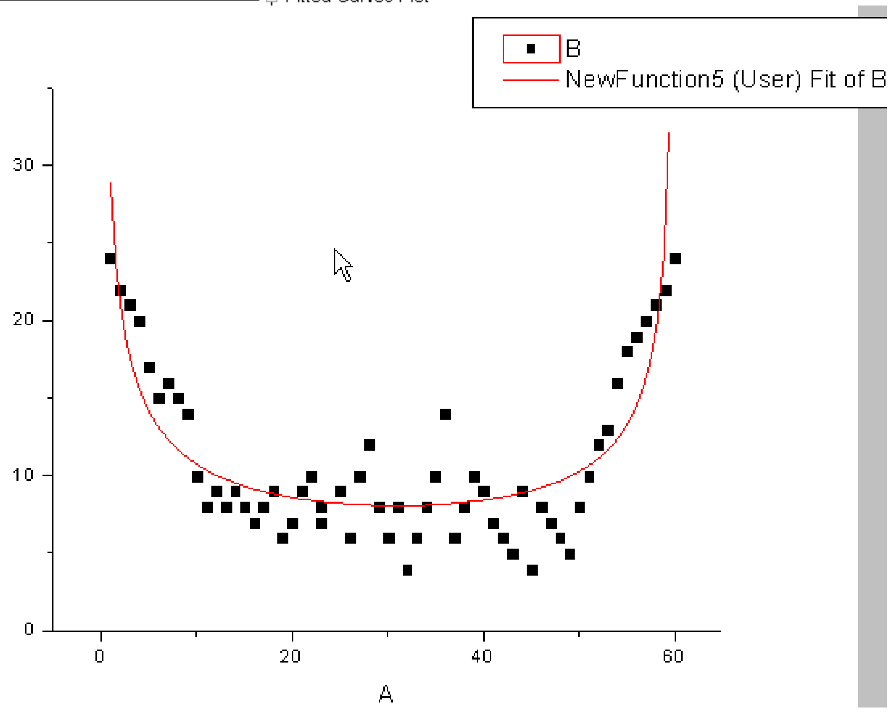


Fig.4. The eulerian model [20]

The software offers here an extensive evaluation of the fitting results, including ANOVA evaluation.

3. Dependability and performability

In determining the complexity and consequent frequent failure of the critical combination and complex integration of large engineering processes and systems, both in their level of technology as well as in their integration, the integrity of their design needs to be determined. This includes *reliability*, *availability*, *maintainability* and *safety* of the inherent process and system functions and their related equipment. Determining engineering design integrity implies determining reliability, availability, maintainability and safety *design criteria* of the design's inherent systems and related equipment [13].

For a wider covering of these notions it was introduced the term of dependability [21;32;33].. *Dependability*, according to current use of this term, is that property of a system which allows "reliance to be justifiably placed on the the service it delivers." Such service is *proper* if it is delivered as specified; otherwise it is *improper*. System *failure* is identified with a transition from proper service to improper service. Dependability thus includes attributes of reliability and availability as special cases. Specifically, a reliability measure quantifies the "continuous delivery of proper service"; an availability measure quantities the "alternation between deliveries of proper and improper service" [7]. A detailed presentation of the dependability
Structure [11;12] is illustrated in fig.5.

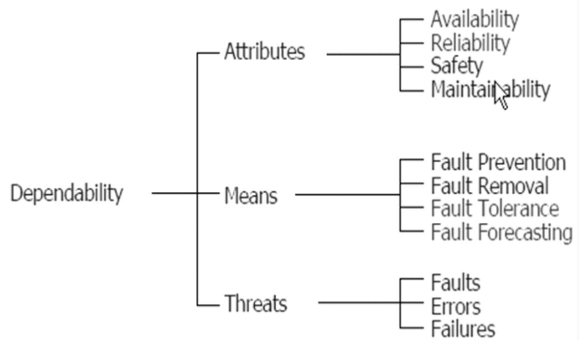


Fig.5 Dependability detailed structure [22]

Fig.6 Implications of performability [8]

A new generalisation of the entire problem was formulated as *performability*, a new term introduced in l980 by John Meyer [7]; Originally he used this term mainly to reflect attributes like reliability and other associated performance attributes like availability, maintainability, etc. However, this reflected only partially the performance measures that we now would like the word to mean. Also. since that time dependability has been used to include more attributes related to performance. Therefore, it was considered logical and appropriate to extend the meaning of performability to include attributes like dependability and sustainability. Thus. the definition of the term performability has been widened to include sustainability in the context of the changed scenario of the 21st century in order to reflect a holistic view of designing, producing and using products, systems or services, which will satisfy the performance requirements of a customer to the best possible extent and are not only dependable (implying survivability and safety) but are also sustainable [8].

Performance engineering can be defined as the entire engineering effort that goes into improving the performance of a system that not only ensures high quality, reliability, maintainability and safety but is also sustainable. Implicit with this definition is not only the high performance of a system but also its minimum life-eyele costs. Performance engineering addresses sustainability along with other factors like quality, reliability, maintainability and safety reflect the entire engineering effort of a producer to achieve the performability of a product, system or service, which in fact can be called improving 3-S, namely, survivability, safety and sustainability. This concept is depicted in fig l.6. [8].

4. Conclusions

In the above hazard-rate reliability exemples it was used the regression curve, which has the property that the sum of the squared vertical distances from it to point on the cutter diagram is the minimum. The analysed models are convenient for the goodness of fit. From the analysis of values of residual sum of squares and reduced Chi-square coefficients, results the graphs closed to experimental data. [19].It may be emphasized here that the usual definition of dependability ignores the accompanying environmental consequences while creating products, systems and services. It is evident that in order to produce a truly optimal design economically, consideration sustainability should not be overlooked. These attributes are very much influenced by the design, raw materials, fabrication techniques and manufacturing processes [8]

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