How Reliable is Reliability Function?

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Abstract

According to Knezevic [1] the purpose of the existence of any functional system is to do work. The work is done when the expected measurable function is performed through time. However, experience teaches us that expected work is frequently beset by failures, some of which result in hazardous consequences to: the users; the natural environment; the general population and businesses. During the last sixty years, Reliability Theory has been used to create failure predictions and try to identify where reductions in failures could be made throughout the life cycle phases of maintainable systems. However, mathematically and scientifically speaking, the accuracy of these predictions, at best, were only ever valid to the time of occurrence of the first failure, which is far from satisfactory in the respect of its expected life. Consequently, the main objective of this paper is to raise the question how reliable are reliability predictions of maintainable systems based on the Reliability Function.

1.0 Introduction

The necessity for the reduction in occurrences of operational failures started with the advanced developments of military, aviation and nuclear power industries, where the potential consequences could be significant. And so, during 1950s, Reliability Theory was "created". It was based on mathematical theorems rather then on scientific theories. Massive attempts where made to further the applications of the existing mathematical, statistical and analytical methods without a real understand of the mechanisms that caused the occurrences of in-service/operational failures.

Not surprisingly, deterministically educated engineers and mangers experienced fundamental difficulties in understanding Reliability Theory. The reason for that is very simple. Probability, unlike numerous measurable physical properties and as a main concept of reliability, cannot be seen or measured directly, For example: pressure: temperature: volume: weight of a component can be measured directly and by using appropriate mathematical manipulations, accurate predictions of the corresponding properties of a system constructed of these parts can be obtained. Moreover, the occurrence of a component failure is also clearly manifested and physically observed phenomena. And yet, the concept of reliability is abstract and immeasurable. It cannot be seen on the component/system. In fact, it serves as an abstract property of a component/system that obtains a physical meaning only when a large sample of components/systems is considered.

2. Reliability Function

To support the above presented conclusions regarding Reliability Theory, the fundamental definition of reliability will be used and analysed. It is widely accepted that Reliability is defined as the probability (P) that a considered entity (component, product, system) will operate without failure during a stated period of time (t), when operated in accordance with defined parameters. Mathematically, this statement is fully defined by the Reliability Function, *R(t).*

2.1 Reliability Function of a Component

For any component considered, the reliability function is defined in the following manner:

$$R(t) = P(TTF > t) = \int_t^{\infty} f(t)dt, \qquad t \geq 0 \qquad\qquad 1$$

where: *R(t)* is the reliability function, *f(t)* is the probability density function of the random variable known as the Time To Failure (*TTF*) of a component.

Reliability data regarding components can be fully defined through the numerous well-known probability distributions. However, in the vast majority of cases, current industry practices are premised on the reliability of components being defined by their manufacturers through a constant failure rate, λ, which forces all interested parties to express the reliability function in the form, $R(t) = e^{-\lambda t}$!

2.2 Reliability Function of a System

The Reliability function for a system, $R_s(t)$, is determined by the reliability functions of the constituent components and the way they impact the failure of the system. For example the reliability function for the system, whose reliability block diagram is presented in Figure 1, is fully defined by the following mathematical expression:

$$R_S(t) = P(TTF_S > t) = R_A(t) \times \{1 - [1 - R_B(t)][1 - R_C(t)]\}, \qquad t \geq 0 \qquad\qquad 2$$

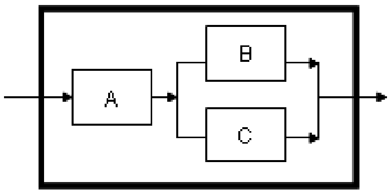

Figure 1: Reliability Block Diagram for a Hypothetical System whose failure will occur if a component A fails, or if components B and C fail

The above two equations briefly summarise the essence of the reliability function when the main concern is a prediction of the behaviour of the system until the first failure.

3. Mathematical Reality of a Reliability Function

Being educated to use mathematical expressions for all engineering predictions, which always have a single numerical outcome, the author has spent over a decade understanding the fundamental physical meanings of the mathematical definitions for the reliability of systems by the system reliability function. Thus, the realisation was that reliability mathematics dictates the following physical reality of the systems considered:

- One Hundred percent quality of components production and installation

- Zero percent of transportation, storage and installation tasks
- One Hundred percent of components are mutually independent
- No maintenance activities (inspections, repair, cleaning, etc.)
- Continuous operation of the system (24/7)
- First observable failure is a failure of the system
- Time counts from the “birth” of the system
- Fixed operational scenario (load, stress, temperature, pressure, etc.)
- Operational behavior is independent of the location in space (GPS or stellar coordinates)
- Reliability is independent of humans (operators, users, maintainers, managers, general public, law makers, etc.)
- Reliability is independent of calendar time (seasons do not exist)

4. Physical Reality of Reliability Function

Systematic research performed by the author during several decades of the observable physical realities of in-service/operational life of aerospace, military and nuclear power industries have clearly shown that the flowing physical reality determines the reliability of systems[1]:

- Quality of produced components and assemblies is less than 100%
- There are huge interactions between “independent” components
- Maintenance activities like: inspections, repair, cleaning, etc., have significant impact on the life of a system and impact reliability
- Neither all systems not all components operate continuously (24/7)
- First observable failure is not necessary the failure of a system (failure of components B or C alone, in the Figure 1, does not cause system failure)
- Components and a system have different “times”
- Variable operation scenarios (load, stress, temperature, pressure, etc.)
- Reliability is dependent of the location in space defined by GPS coordinates
- Reliability is dependent of humans, like: users, maintainers, general public
- Reliability is dependent of calendar time

5. Closing Question

The above list of physically observed and undeniable facts seriously impact the accuracy of the reliability predictions currently provided through reliability theory. Because, the first failure event and all subsequent ones generate physically observable changes in the reliability of a system that are impossible to embrace by the existing concepts used in the formulation of the Reliability Function.

The closing question for all reliability professionals is, “How can predictions of functional system reliability be “reliable” when lifelong physically observable events and associated human rules are totally excluded from the predictions?”

6. References

[1] Knezevic, J., The Origin of MIRCE Science, pp. 232. MIRCE Science, Exeter, UK, 2017, ISBN 978-1-904848-06-6

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