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Editorial

Analytical Modeling Occupies a Special Place in Reliability-Physics Predictive Modeling Efforts

E Suhir*

Bell Laboratories, Murray Hill, NJ (ret), Portland State University, Portland, OR, and ERS Co., Los Altos, CA, USA and Bordeaux Univ., Bordeaux, France

***Corresponding Author:** E Suhir, Bell Laboratories, Murray Hill, NJ (ret), Portland State University, Portland, OR, and ERS Co., Los Altos, CA, USA and Bordeaux Univ., Bordeaux, France.

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“There are things in this world, far more important than the most splendid discoveries – it is the methods by which they were m made”. Gottfried Wilhelm Leibnitz (1646-1716), German mathematician and philosopher.

"Give thanks to God, who made necessary things simple, and complicated things unnecessary". Gregory Skovoroda (1722-1794), Ukrainian philosopher.

Analytical ("mathematical") predictive modeling [1-4] occupies a special place in the reliability-physics modeling effort. Such modeling enables obtaining relationships that clearly indicate “what affects what”, but, more importantly, can often explain the physics of phenomena and particularly various paradoxical situations better than the finite-element-analysis (FEA), or even experimentation, can [3,4]. FEA modeling, initially implemented in the mid-1950s of the last century in the areas of engineering where structures of complicated geometry were employed (aerospace, maritime, some civil engineering structures), has become shortly the major modeling tool in electronics and photonics engineering and reliability physics as well: powerful and flexible FEA computer programs enable obtaining, within a reasonable time, a solution to almost any stress-strain related problem. Analytical solutions in reliability physics problems are, however, still important: simple, easy-to-use and physically meaningful analytical relationships provide clear and compact information of the role of various factors affecting the phenomenon or the behavior and performance of a material or a device of interest.

A crucial requirement for an effective analytical model is simplicity and clear physical meaning, and, as Einstein has put it, should meet the requirements of "external justification and internal perfection". A good analytical model should be based on physically meaningful considerations and produce simple and easy-to-use relationships, clearly indicating the role of the major factors affecting the phenomenon, the object or the structure of interest. One authority in applied physics remarked, perhaps only partly in jest, that the degree of understanding a physical phenomenon is inversely proportional to the number of variables used for its description and that "a formula longer than two inches is most likely wrong". Hooke's law (1678) in structural analysis, Newton's second law (1687) in mechanics, Lorentz's factor (1892) in the relativity theory (establishing the transformation from a coordinate frame in space-time to another frame moving at a constant velocity relative to the former one) and Einstein's famous relationship (1905) in physics are, probably, the best illustrations to this statement. Empirical relationships, such as, e.g., the Coffin-Manson's one in the reliability of solder-joint interconnections in electronic and photonic packaging, are useful, but their structure and particularly their non-integer exponents clearly indicate on the lack of understanding of the underlying physics of failure.

It is imperative that predictive modeling is always conducted prior to and often even during the actual accelerated testing, particularly of the failure-oriented-accelerated-testing (FOAT) type [5], which is the experimental foundation of the probabilistic design-for-reliability (PDfR) effort at the design stage (see, e.g. [6]) of an electronic or a photonic product, and that analytical ("mathematical") modeling complements computer simulations. These modeling tools are based on different basic assumptions and use different computation techniques, and if the output data obtained using these tools are in agreement, then there is a good reason to believe that these data are accurate and, hence, trustworthy.

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