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Editorial

Reliability Techniques in Industrial Design

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Reliability engineering focuses on the ability of physical equipment to function without failure. It describes the ability of a component or system to operate at design conditions for a specified period of time [1]. Reliability is closely related to availability, which is typically described as the ability of a component or system to function at a specified moment or interval of time [2].

Reliability is theoretically defined as the probability of success at time t and is estimated from previous data sets or by using specific tests [3]. Availability, testability, and maintainability are directly related to reliability [4].

High-quality engineering design requires planning for reliability from the earliest stages of a system's design [5]. The use of probabilistic design for reliability allows for a comparison of a component's strength against the stress that it will encounter in various environments [6]. Failures link hierarchically in terms of the system architecture, and in turn, a failure mode may cause failures in a higher-level subsystem or may be the result of a failure in a lower-level component [7].

Reliability and quality are closely related. Typically, quality focuses on the prevention of defects during the warranty phase, whereas reliability seeks to prevent failures during the lifetime of the product or system, from commissioning through operation to decommissioning [8]. Condition-based maintenance (CBM), known as predictive maintenance, monitors relevant variables to empirically determine the percentage of service life consumed (and, consequently, the remaining percentage as well) [6].

Reliability techniques in industrial design can substantially increase operational dependability through better system design and the selection of more suitable parts and materials. In addition, there are practices that can improve reliability with respect to manufacturing, assembly, shipping and handling, operation, maintenance, and repair [9].

Additionally, reliability is extremely design sensitive. A more reliable product needs less maintenance, and thus, a design trade-off between reliability and maintainability is required. Very slight changes to the design of a component can cause profound changes in operational dependability, which is why it is important to specify product reliability and maintainability targets before any design work is undertaken [10,11].

There are many tools that can be used in a comprehensive way to analyze the reliability of a system: Markov chains [12], machine learning [13], COX [14], and LCA [15], among others.

This Special Issue includes new research and the latest technologies related to reliability techniques in industrial design [16]. In particular, it includes a series of documents focused on: reliability, failure modes, design for reliability, maintenance, design for maintainability, building design, facility design, resilient design, reliability techniques, reliability-centered maintenance, a physics-of-failure-based approach, a reliability prediction and improvement statistics-based approach, reliability modeling, reliability testing, accelerated testing fail-safe design, detectability and common cause failures, maintenance 4.0, and built-in redundancy.

In the first of the contributions, Nordal and El-Thalji proposed a novel predictive maintenance assessment matrix, which they tested using a case study of a centrifugal

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compressor and validated using empirical data provided by the case study company. The paper also demonstrates the possible enhancements introduced by Industry 4.0 technologies. A failure mode and symptom analysis (FMSA) method was introduced to identify the critical symptoms and descriptors of failure mechanisms. FMSA is used to estimate monitoring priorities. Thanks to this work, it is possible to determine the critical monitoring specifications of a centrifugal compressor [17].

In the second contribution, Sokol et al. used a parametric study to evaluate the significance of the rotational components of Earth's motion in a seismic design. The first part of the paper is devoted to the derivation of a simple formula that can be used for expressing the importance of rotational components in comparison with the classic seismic design that does not use them. The quasistatic analysis, assuming inertial forces, is used. A crucial role is played by the shape of the fundamental mode of the vibration. Due to simplicity reasons, the well-known expression for the estimation of the first eigenmode as an exponential function with different power coefficients that vary for different types of buildings is used. The possibility of changing the soil parameters is, subsequently, included in the formula for the estimation of the fundamental frequency of tall buildings. The overall seismic analyses of complex FEM models of 3D buildings and chimneys were performed [18]. This research allows us to evaluate the rotational components of Earth's motion in a seismic design.

On the other hand, Gómez-Pau et al. studied the aging process of medium voltage power connectors and how it can lead to important power system faults. The electrical resistance of the connector is the most widely used health indicator for condition monitoring and RUL prediction, even though its measurement is a challenging task because of its low value, which typically falls in the range of a few micro-ohms. They developed an online method to solve this issue by predicting the RUL of medium voltage connectors based on the degradation trajectory of the electrical resistance, which is characterized through an analysis of the electrical resistance time-series data by means of the autoregressive integrated moving average (ARIMA) method. The approach proposed in this paper allows for applying predictive maintenance plans, since the RUL enables the determination of when the power connector must be replaced by a new one. As a result of this research, it is possible to obtain from several connectors an illustration of the feasibility and accuracy of the proposed approach for an online RUL prediction of power connectors [19].

Villa-Covarrubias et al. determined the actual reliability of a designed ball bearing that corresponds to the use conditions. The proposed method is based on the two parameters of the Weibull distribution, where the shape (β) and scale (η) parameters are both determined from the Hertz contact stress values, which are generated under the surface of the motionless outer race, and by the forces transmitted between the ball and the outer race. Therefore, the derived reliability is different from that offered by manufacturers [20]. The methodology proposed by these authors allows the reliability of a component or equipment to be calculated.

Jendzelovsky and Tvrda modeled the bearing structure of a hospital building as a reinforced concrete skeleton and selected a Boussinesque model, which is a model of the elastic half-space, for the subsoil under the plate foundation, where properties of individual layers of the subsoil were entered according to the geological survey. They analyzed the influence of the variance of input values on the resulting deflections, strain, and stress state of the plate foundation. Probability calculations confirmed the probability of failure, which was allowed for the second limit state [21]. The methodology developed in this research is appropriate because it allows for calculations related to the slab foundation of a hospital building through a probabilistic analysis.

Barraza-Contreras et al. formulated a fatigue-life Weibull method to predict the span of the Ni values, since applying Goodman, Gerber, Soderberg, and elliptical failure theories does not make it possible to determine the span of failure times (cycles to failure of Ni) of a mechanical element. The input's method is the equivalent stress (σ_{eq}) value given by the used failure theory; the expected Neq value determined by the Basquin equation;

and the Weibull shape β and scale η parameters that are fitted directly from the applied principal stress σ1 and σ2 values. In the performed application, the σ1 and σ2 values were determined via the finite element analysis (FEA) and from the static stress analysis [22]. This research can be applied to any mechanical analysis where the variable amplitude and cyclic load are known.

Sokol et al. presented the development of a SHM (structural health monitoring) strategy intended to confirm the improvement of the load-bearing capacity of a bridge over the Ružín Dam using static and dynamic load tests, as well as numerical simulations. A complex measuring system used for the tests consisted of two main parts: an interferometric IBIS-S (Image by Interferometric Survey-Structures) radar and a multichannel vibration and strain data logger. Next, structure–vehicle interactions were modelled, and nonlinear numerical dynamic analyses were performed. As a result, time histories of displacements of the structure from traffic effects were obtained [23]. This research is very useful and can be applied to calculate the stresses that bridges are subjected to due to dynamic loads from vehicular traffic.

González-Domínguez et al. proposed a tool to schedule preventive maintenance for healthcare centers using Markov chains. Markov chains proved useful in choosing the most suitable maintenance policies for each healthcare building without exceeding a specific degradation boundary, which enabled achieving an ideal maintenance frequency and reduced the use of resources. Markov chains have also proven useful in optimizing the periodicity of routine maintenance tasks, ensuring a suitable level of maintenance according to the frequency of the failures and reducing the cost and carbon footprint [24]. The advances achieved with this research represent a breakthrough in the optimization of the maintenance and management of healthcare buildings.

Finally, Calabrese et al. proposed a data-driven methodology for prognostic health management implementation, which has the following characteristics: it is unsupervised, i.e., it does not require any prior knowledge regarding fault behaviors, and it does not rely on pretrained classification models, i.e., it can be applied "from scratch"; additionally, it can be applied online due to its low computational effort and it includes all of the steps that are involved in a prognostic program, i.e., feature extraction, health indicator construction, health stage division, degradation modeling, and RUL prediction. The proposed methodology is applied in this study to a rotating component [25]. This work is novel and allows prognostic health management techniques to be implemented in components, which is very useful for edge computing.

With this Special Issue, published in *Applied Sciences*, we have tried to contribute to improving the overall efficiency of engineering design and helping to minimize design failures.

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