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A RELIABILITY APPROACH TO NEW PRODUCT DEVELOPMENT PROCESS

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Abstract: This study aims to overview the reliability analysis process at the stage of product's development. Based on the reliability theory and practice, a methodology for components' parameters definition is developed, through contemporary solution instruments. The goal is to raise the possibility for reliability prediction of complex electromechanical systems by defining their components' parameters. Reliability prediction needs to be involved in product design at an early point to identify reliability issues and concerns and begin assessing reliability implications as the design concept emerges. Use of computer-aided engineering (CAE) analysis and simulation tools at an early stage in the design can improve product reliability more inexpensively and in a shorter time than building and testing physical prototypes. Tools such as finite element analysis, fluid flow, thermal analysis, integrated reliability prediction models, etc., are becoming more widely used, more user friendly and less expensive.

Key words: Reliability, CAD, CAE, Design, Approach

1. INTRODUCTION

The reliability has many definitions and aspects. Generally, this is the ability or probability of failure-free performance of required functions under stated conditions for a stated period of time. The main reason enhancing reliability is to satisfy the customers and to reduce the warranty costs. As reliability is one of the key factors in product quality, which is closely linked to customer satisfaction, the ability to design products which will be "reliable" is a key to future market success. Reliability is designed into the product by engineering, launched on its course by best installation practices by project engineering, demonstrated by operations in careful use and it is only sustained by maintenance. It is generally accepted that 80% of product reliability is achieved in the design stage [3, 7]. The reliability assessment could be performed at different stages of product life cycle. The respective approaches for reliability assessment could be divided in four types [7] as it is shown on fig.1.

Reactive approach – the maintenance goal is to restore the product to proper condition as failures occur. It is a "fix-when-broken" strategy. Proficiency is demonstrated and profit is assured when repairs are accomplished in the minimum amount of time using minimum resources.

Preventive approach – the goal is to control the planned maintenance activities rather than allowing unplanned breakdowns. The expected outcome is reducing unanticipated expenses. A key metric is the ratio of planned work to unplanned work and all the efforts are concentrated on best maintenance practices to reduce failures and improve availability by performing correct maintenance to avoid failures.

Predictive approach – the goal is to eliminate the machinery outages by use of technology to measure machine condition, assess machinery problems, and decide on the corrective actions. Reliability techniques are used to predict product failures and forecast remaining life. A key metric is the ratio of predicted problems found compared to the number of observations. These types of actions are a state of determining problems rather than excluding probable ones.

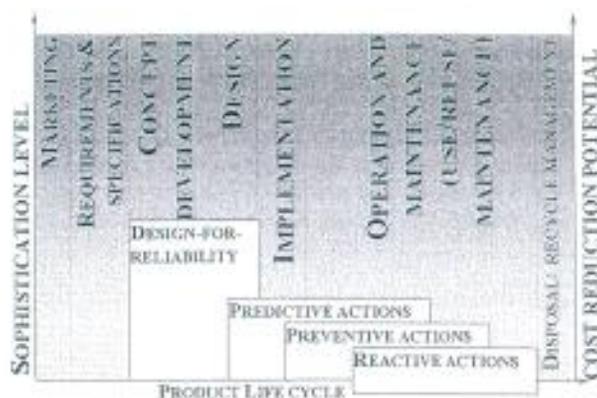


Fig.1. Reliability approaches and actions

Design-for-reliability approach – the benefits of performing earlier reliability assessment, at the stage of concept and design development, include target product operating life, improved probability and severity of failure, and reduced cost of support and maintenance. In fact, the product reliability requires the deployment of inherently reliable technologies. The quantitative methods that have been developed to increase reliability have great impact on products reliability and success.

Design for Reliability means systematic approach to the design process that is focused on reliability and based on the Physics of Failure (PoF). Applicable from the idea phase of the product development cycle through product obsolescence, Design for Reliability concepts integrated with reliability verification and analytical physics form a coherent stage gate/phase design process that helps ensure that a product will meet customers' reliability objectives. Specific Design for Reliability guidelines includes the following:

- Design based on the expected range of the operating environment;

- Design to minimize or balance stresses and loads and/or reduce sensitivity to these stresses or loads;
- De-rate components for added margin;
- Provide subsystem redundancy;
- Use proven component parts & materials with well-characterized reliability;
- Reduce parts count & interconnections (and their failure opportunities);
- Improve process capabilities to deliver more reliable components and assemblies.

Generally, three internal properties of technical systems are identified as significant factors of the external properties of *performance, economy and reliability* – namely *simplicity, clarity and unity*. These properties are mainly typical for the conceptual design of the product and could be used to obtain quantitative assessment at this stage [3].

2. APPROACH FOR RELIABILITY ASSESSMENT AT DESIGN STAGE (DESIGN-FOR-RELIABILITY)

The modeling and the analysis of the reliability parameters give the possibility to evaluate and to optimize the construction through their balance at design stage [4, 7]. Different steps of this process are formulated and shown in general on fig.2 [9, 10].

The activities could be summarized in two general groups – Physics-of-Failure (PoF) assessment and Reliability assessment (RA), where each group is divided in two levels with proper activities contained.

2.1 Physics-of-Failure assessment

The PoF is the first stage of performing reliability assessment of the examined product. This initial assessment uses a PoF methodology, which is founded on the conviction that failures are governed by fundamental processes that are mechanical, chemical, electrical, thermal or radiation in nature. These processes initiate failures when the accumulated damage caused by the applied stress exceeds the product's endurance.

The *inputs* for initial assessment are all the data available from the initial product technical description and specifications. All the operational (types of loads applied) and environmental (temperatures, humidity, shock and their cyclic ranges, etc. ambient parameters) conditions as well as product design specifics are used further [10].

Life cycle environmental profiles are composed, based on the preliminary defined as input operational and environmental conditions. These profiles are used during the performed stress analyses as well as input data for the subsequent RA. They should include the complete information about the exploitation conditions of the product.

The purpose of performing *Stress analyses* is to provide sufficient information about the quantitative parameters of the potential mechanisms of failure. Use of computer-aided engineering (CAE) analysis and simulation tools at an early stage in the design can improve product reliability more inexpensively and in a shorter time than building and testing physical prototypes. Tools such as

finite element analysis, fluid flow, thermal analysis, integrated reliability prediction models, etc., are becoming more widely used, more user friendly and less expensive.

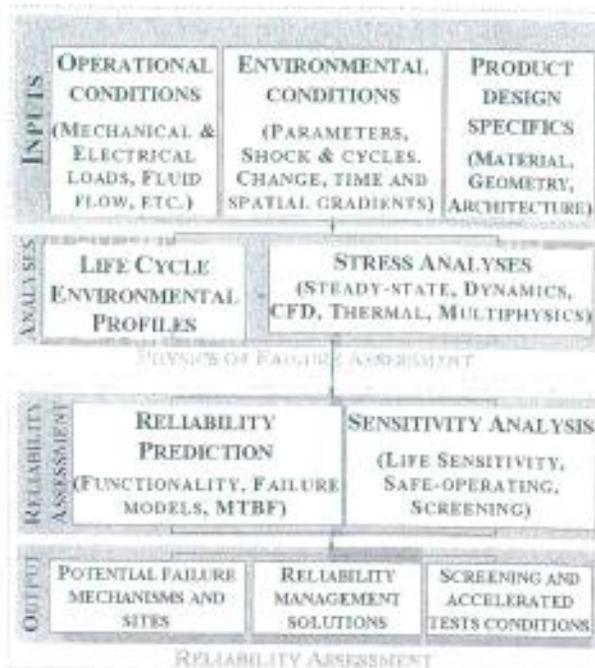


Fig.2. Physics of Failure and Reliability Assessment

2.2 Reliability assessment

Several steps are performed during the reliability assessment stage. The quantitative *reliability prediction* needs defined structure of the product that contains all the connections and dependencies of its components as well as definition of different functionalities. The result is a reliability prediction functional model created which one makes possible to evaluate products reliability as well as its failure modes. This functional model includes all components whose failure models are defined on the next step. Results from the preceding stress analyses are used as input data for components reliability models definition. Each component is included in the complex system parameters evaluation according to its functionality connections. Finally, the necessary reliability quantitative parameters are determined (Mean Time Between Failures – MTBF, system failure rate, reliability distribution function over time, etc.). These parameters could also be used in further Failure Modes, Effects and Criticality Analysis (FMECA) to complement reliability data for the product.

Sensitivity analysis is performed in parallel, using the previously defined life cycle environmental profiles. It is used to ascertain how a given model output depends upon the input parameters. This is an important method for checking the quality of a given model, as well as a powerful tool for checking the robustness and reliability of its analysis.

The *outputs* of this process are a ranked list of potential failure mechanisms and sites. Previewing its distribution in detail and using already known stress distributions

could lead to balanced design of the product and offers suitable solutions for *reliability management* [2]. The reliability balance of the components leads to achieved optimization of the price/performance index that is of great importance for products market realization. This optimization is an expert decision based on quantitative assessed reliability, technical and economical parameters.

3. PRACTICE EXAMPLES

3.1 Complex product

Reliability assessment at design stage of a new power tool – rotary hammer – is used as an example. The steps of the reliability assessment and optimization process are illustrated on fig.3 below.

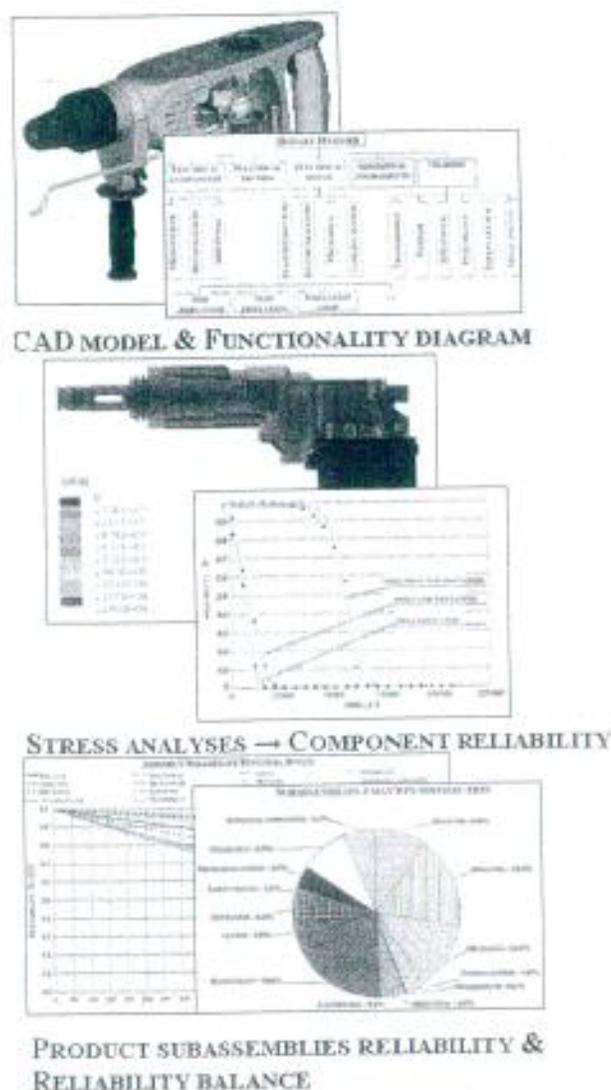


Fig. 3 Reliability assessment at design stage of new complex product

The prediction is performed after the preliminary design is finished. The structure of the product is built to reproduce the functionality of the machine and internal connections [5]. Several multiphysics stress analyses are

performed and separate components physics of failure are examined under proper operational and environmental conditions [8]. Techniques used vary from statistical based (data available for parts used in other power tools) through commonly used (reliability models for bearings, insulations, etc.) to specific finite element analysis (housings, spindle loads, etc.). The result is used as input data for component reliability parameters evaluation. A complete reliability model is calculated, based on the built structure and already known components reliability parameters. Reliability distribution over time is achieved as well as the failure distribution at subassemblies level is obtained. Revising the balance of failures, corrective actions over the design are performed to obtain balanced and reasonable reliability of the system.

The output data from the performed analysis is used also in a subsequent Failure Modes and Effects Analysis and evaluation of product's life cycle cost.

Final result is a product with reasonable cost at sufficient reliability that is competitive for its class.

3.2 Product sensitivity verification

A critical part of complete product is examined – combustion chamber of a gas heat exchanger – during its design, due to the existing service data of similar products (fig.4). The sealing of the chamber and its sensitivity to different work, environmental and geometry dimensions deviation is determined. The most critical point is the deflection of the flat seal, placed near the chamber cover. The difference in thermal expansion coefficients causes appearance of gap and worsens the seal of the unit. Sensitivity (probabilistic) analysis is performed in order to predict the reliability of the parts. Input parameters are: thermal load deviation; material properties deviation and dimension deviation. The output data is expressed of data for new stress management solution that decreases the probability of failure due to some of the input parameters deviation.

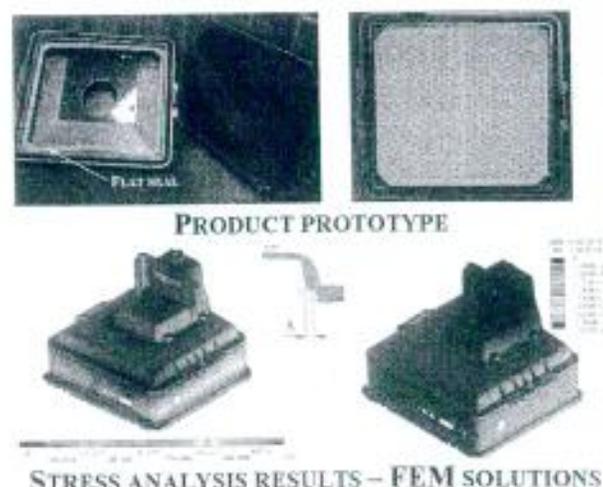


Fig. 4 Combustion chamber simulation

The analysis is performed in parallel with the prototype testing that made possible additional test data to be included in the evaluation and the model to be verified.

In fact, the possibility of CAE to simulate variable loads and conditions is used to prevent future failures in serial manufacturing. Using CAE techniques also speeds up the design process, i.e. decreases time-to-market value, and decreases expenses for making a lot of prototypes. A great feature is the possibility to investigate the eventual failure cause in detail and to observe its genesis. The parallelism to the prototype tests makes possible to return in the design the observed disadvantages as well as the simulated possible failures.

4. CONCLUSION

Design for Reliability provides a systematic approach to the design process that is sharply focused on reliability and firmly based on the physics of failure. Applicable from the idea phase of the product development cycle through product obsolescence, Design for Reliability concepts integrated with reliability verification and analytical physics form a coherent stage gate/phase design process that helps ensure that a product will meet customers' reliability objectives. The semi-quantitative approach of an initial assessment can help reduce costs and save time by identifying potential reliability issues during the design phase and helping the OEM focus their reliability efforts.

However, the aspect how reliable the product should be remains. It cannot be considered generally, because different products, different utilities and different customers all have differing requirements and expectations. Some of the factors that should be considered are: product component balance and the benefits gained by the reliability improvements [1, 9].

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