RELIABILITY IN A SEA OF RISK (RIASOR)

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INTRODUCTION

The Reliability in a Sea of Risk project (RiaSoR) addresses the strategic need for the ocean energy industry to focus on the key engineering challenges that underpin the reliability and survivability of emerging wave and tidal energy technology [1].

RiaSoR project

The RiaSoR project will establish industry best practices in reliability testing for wave and tidal devices through improved load measurements and verification, standardising design guidelines for marine energy systems, and increasing safety in marine energy operations.

In today's uncertain investment environment, the perception of technical risk is dependent on how confident the investors are that the ocean energy devices will perform reliably and produce the expected output from their devices. As the industry is approaching a pre-commercial stage, in-sea testing and demonstration at various scales will be a primary focus for the sector over the next three to five years.

This places a key role on the test houses to put in place a rigorous testing programme whereby the reliability of these emerging technologies can be tested and independently verified before the systems move onto large-scale array deployments.

RiaSoR consortium

RiaSoR brings together three leading European research and testing sites from the north of Scotland, England and Sweden in order to develop industry approved reliability testing practices. These practices will be applied by the research and testing sites, ensuring consistency and robustness of testing to demonstrate reliability across wave and tidal technologies.

The overall technical approach will be driven by SP Research, who bring their experience in reliability testing from the automotive industry [2]. They will focus on developing framework methodologies that will be deployed at the onshore Offshore Renewable Energy Catapult test site in Blyth (England) and the European Marine Energy Centre's offshore test sites in Orkney (Scotland).

METHODOLOGY

Variation Mode and Effect Analysis (VMEA)

The Variation Mode and Effect Analysis (VMEA) methodology used in other more mature sectors such as automotive and aerospace industry will be adapted in this project for the ocean energy sector [3].

For reliability regarding mechanical failure we use the concept of load-strength interaction. This means that we study separately a) the outer load acting on the structure to be designed and b) the strength, or resistance, of the structure. The aim is to design the structure to assure that the strength exceeds the load for future usage.

Statistical methods provide useful tools for describing and quantifying the variability in load and strength. For this purpose the concept of VMEA will be used, which is a method aimed at guiding engineers to find critical areas in terms of the effects of unwanted variation.

Mathematical principles of VMEA

The method is based on characterising each source by a statistical standard deviation and calculating its sensitivity with respect to the target function, e.g. fatigue life of maximum stress. The VMEA method combines these into the total prediction uncertainty, denoted τ , which is obtained by the root sum of squares (RSS) of the uncertainties:

$$\tau = \sqrt{\tau_1^2 + \tau_2^2 + \tau_3^2 + \cdots} = \sqrt{c_1^2\sigma_1^2 + c_2^2\sigma_2^2 + c_3^2\sigma_3^2 + \cdots}$$

where τ_i is the resulting uncertainty from source i and is calculated as the product of the sensitivity coefficient c_i and the uncertainty σ_i of source i.

Note: VMEA is a so-called second-moment method since it uses only the standard deviation to characterize the distribution of the uncertainty sources.

VMEA DEVELOPMENT PHASES

The VMEA method can be used as a reliability tool throughout the product development process.

In the early design stage when only vague knowledge about the variation is available, the basic VMEA is used to compare different design concepts. Further in the design process, when better judgements of the sources of variation are available, the enhanced VMEA is used. This is then further developed into the probabilistic VMEA in the later design stages where more detailed information becomes available. The goal is to assess the reliability and safety factors.

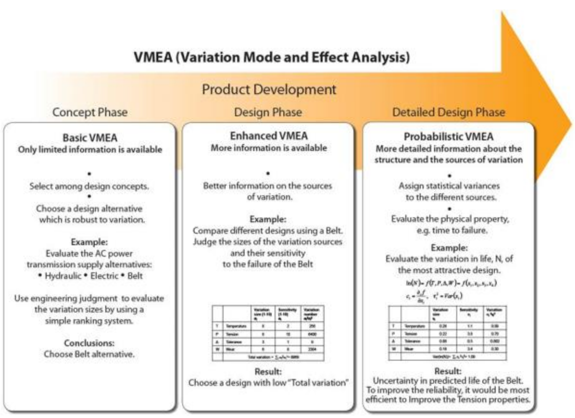

FIGURE 1. VMEA (VARIATION MODE AND EFFECT ANALYSIS).

Basic VMEA

In a basic VMEA the goal is to identify the most important sources of variation, for example when different design solutions are evaluated. The sizes of the sources of variation as well as their sensitivities to the studied product property are evaluated on a scale from 1 to 10. The robustness of the product is characterised by summing the square of the product of sensitivity and variation size.

To conduct an adequate VMEA that incorporates different views and competences, a cross-functional team of experts should be formed. Such an analysis will indicate which sub-systems or components are most critical, and thus need to be studied in more detail.

Enhanced VMEA

The enhanced VMEA is a refinement of the basic VMEA with the aim to understand and quantify the uncertainty sources in more detail. The main difference is that the sensitivities and variation sizes are assessed in real physical units instead of the 1 to 10 scale. The assessment uncertainties can be based on engineering judgement, but can also be supported by initial testing, literature and data sheets from manufacturers.

Probabilistic VMEA

The probabilistic VMEA is well suited in the later design phases, for example, when there is a need to predict the life of the product and to determine proper safety factors or tolerances.

The general procedure of the probabilistic VMEA is the same as for the basic VMEA. The main difference compared to the basic VMEA is that here we make use of a model for the prediction and thus we need to include both statistical uncertainties and model uncertainties, together with the random variation.

Further, as in the enhanced VMEA, we assess the magnitude of the uncertainties by standard deviations, instead of using a ranking scale.

Different types of uncertainties are analysed, such as:

- ***Scatter*** or physical uncertainty which is identified with the inherent random nature of the phenomenon, e.g. the variation in strength between different components.
- ***Statistical uncertainty*** which is that associated with the uncertainty due to statistical estimation of physical model parameters based on available data, e.g. estimation of parameters in the Coffin-Manson model for life based on fatigue tests.
- ***Model uncertainty*** which is that associated with the use of one (or more) simplified relationship to represent the 'real' relationship or phenomenon of interest, e.g. a finite element model for the relation between outer loads and local stresses.

Scatter cannot be avoided, but needs to be handled by using safety factors, while the last two types of uncertainties can be decreased by gaining more data or by building better models.

In the operation of wave or tidal devices, the VMEA can be updated by condition monitoring data and be used for operations and maintenance planning.

OUTCOME

The goal of the RiaSoR project is to consistently learn from the physical interactions between the devices and their environments, while embedding this understanding and building robustness into marine energy technology designs.

RiaSoR II is currently in development with the aim to implement the VMEA methodologies with a condition monitoring framework whereby more data from onshore and offshore testing of wave energy devices validates VMEA analysis, and ultimately improves OPEX costs for wave and tidal developers.

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