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Methodology for extracting reliability from the qualification tests ISO 23936-2

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In the O&G production chain, the presence of non-metalic materials is widely spread in several applications, often as a critical component. In this context, the equipment manufacturers are claimed to standard-proof their products and systems relative to material requirements. This process is mandatorily ruled by the qualification standard ISO-23936, which establishes the baseline procedures for testing non-metalic materials for use in O&G production. The standard determines pressure, temperature, loads, and number of specimens required for the qualification process of the material, and as a result, presents a procedure for the lifetime estimation under operating conditions. However, the ISO-23936 does not present guidelines to extract a reliability measure from the samples tested in many different conditions. In this work, a methodology to use the data coming from the tests of ISO-23936 with the aim of obtaining reliability estimation is presented and an O&G industry case study is performed. Additionally, the discussion about ISO 23936 lifetime traditional approach and reliability methods is carried out, emphasizing the difference between them.

Keywords: O&G industry, reliability estimation, qualification tests, elastomers properties, ISO standards.

1. Introduction to ISO 23936

Non-metallic materials are used in the petroleum and natural gas industries for pipelines, liners, seals, gaskets, and washers, among others. ISO 23936 describes the requirements and procedures for the qualification and selection of non-metallic material used in those equipments (ISO 23936-1, 2022). The standard proposes a series of component requirements to be considered and evaluated when qualifying and selecting the material, for which it provides test procedures and/or normative references (ISO 23936-1, 2022; ISO 23936-2, 2011). Specifically, a test and analysis procedure for qualifying the material against the ageing resistance reliability requirement is mainly presented in the documents.

2. The ISO 23936 aging (reliability) qualification test

In the ISO 23936 aging test, material specimens are exposed to test fluids and soaked at three different elevated temperatures above the operating one, to thermally accelerate chemical reaction (if this occurs), along different time intervals. Then, physical/mechanical properties are measured for each unit. Let $x_{t,k}$ be the value of some mechanical property (e.g.: tensile strength) for the item submitted to temperature k, during t time units. An aging curve over time is got for each of the three temperature levels by fitting a parametric function to the subset of $x_{t,k}$ related to the specific temperature level.

Thus, three different service times are defined (one for each temperature level) by finding the point in the aging curve for which the material property will reach an acceptance boundary previously defined (e.g.: a change of 50% in the original tensile strength). By applying the plotting method (Modarres et al, 2017), the Arrhenius equation is obtained enabling the estimate of service time at the operating temperature. Limits of acceptability are defined as failure criteria, and the material is considered to have “failed” when this limit is attained. Then, this method is supposed to forecast material service life, providing a tool for selecting competing materials for a component design.

3. The limitations of the ISO 23936 aging test

There are two main limitations to the method presented in section 2:

1) ***There is no proven relationship between the acceptance criteria and the component failure***: For example, will the 50% change in tensile strength cause the component to fail? It is not possible to relate service times with service life nor to claim that materials with longer service time up to reach the acceptance boundary will fail later.
2) ***There is no reliability quantification:*** Even though it is possible to relate the acceptance criterion to failure occurrence, it does not mean the material will have exactly that service life when used in the same application. There is uncertainty not captured in the section 2 method. It is more useful to assess reliability performance (i.e., the probability of operating without failure during the mission time) than to estimate an imprecise and improbable service lifetime.

This work does not propose a change in the aging test procedure defined in ISO 23936, but rather a different way of analyzing the data, to overcome the presented limitations.

4. The method for extracting reliability analysis from ISO 23936 aging test

The method proposed in this work advocates running exposure tests with test fluids at 3 different elevated temperatures, during different time intervals, exactly as described in ISO 23936. From this point the following steps must be performed:

1. Define the actual acceptance criteria for relevant properties through a simulation model.
2. Find the service life in each of the three temperature levels such as in ISO 23936 but for acceptance criteria defined in step 1.
3. Build a likelihood function for the 3 service lifetimes found in step 2 from Eq. (1), where t_k is the service life at temperature k, and $\{a, b, \beta\}$ are the AW model parameters (Modarres et al, 2017)
4. Estimate the Arrhenius-Weibull parameters (a^*, b^*, β^*) via maximum likelihood estimators (MLE) or Bayesian methodology, and quantify the reliability for the mission time (T) and operating temperature (k_0) from the AW reliability function (see Eq. (2))

$$L = \prod_k \frac{\beta t_k^{\beta-1}}{\left(be^{\frac{a}{k}}\right)^{\beta}} e^{-\left(\frac{t_k}{be^{\frac{a}{k}}}\right)^{\beta}} \quad (1)$$

$$R(T,\, k_0|a^*,\, b^*,\, \beta^*) = e^{-\left(\frac{T}{b^* e^{\frac{a^*}{k_0}}}\right)^{\beta^*}} \quad (2)$$

If step 1 is unfeasible, try to label each specimen as pass/fail by assembling them in the component and verifying if the component fails to perform some function with the aged material (or by measuring their properties and verifying if the component fails to perform some function via simulation model), and built the likelihood function by using the CDF AW function for the failure data and the reliability AW function for the non-failure data. If none is possible, use the ISO 23936 acceptance criteria in step 1, and perform the next ones.

5. Conclusions

This work proposed a method to better define failure criteria and to assess the uncertainty about the service lifetime estimated according to ISO 23936 aging test. The approach doesn't modify the setup and physical requirements of the test but only proposes a different way to define acceptance criteria and the use of the probabilistic physic of failure model (PPoF) AW to treat the data statistically. Then it comprises a simple tool to qualify non-metallic materials for use in Oil & Gas production based on quantitative reliability analysis.

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