Chapter

Introductory Chapter: Failures Analysis

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1. Introduction

Failure of a material or structure represents a multidiscipline characteristic of it. There is no universally applicable definition on the failure. In a broad sense, failure represents a behavior at which the material or structure is no longer able to fulfill its function. In a narrow sense, however, failure is defined as that given in an elementary strength of materials textbook. Namely, the narrow sense failure of a material or structure is related to its load sustaining ability. When the stresses sustained by the material or structure exceed their ultimate values, which are generally the strengths of the material, the material or the structure is said to have attained a failure status. Thus, a failure criterion in which the critical parameters are the ultimate values must be provided to assess the failure.

Mechanical failures, as a result of improper design, corrosion, surface fracture, and other material defects, are described in the context of real world. Case studies involve steam generators, boiler tubes, gas turbine blades, welded structures, chemical conversion reactors, and more.

Nondestructive testing (NDT) methods are important tools to help us assure the safety, quality, and reliability of materials and structures. Finding defects, whether they are flaws or imperfections, during the manufacturing, and construction process or before, are the first step in any "postmortem" failure analysis.

The most common types of NDT methods are:

- Visual inspection
- Dye (liquid) penetrant
- Magnetic particle inspection
- Radiographic (X-ray) testing
- Eddy current
- Ultrasonics
- Leak detection
- Acoustic emission
- Infrared thermography

Each of these methods has its advantages and limitations, and often more than one technique is needed to identify the root cause and quantify the extent of the problem.

2. Highlight on failure analysis

The broadest sense failure is concerned with an accident of a pipeline used for oil or gas transportation. A leakage of the pipeline is a most often occurred accident, which will cause the pipeline to cease its transportation function and hence is defined as a failure of the pipeline. Based on the accident survey and management practice, a list of characteristics and quantitative descriptions of the pipeline accidents or failures are summarized in the book. A probable model from statistical analysis for the accident is provided. Fragility, anti-fragility, and integrity are used as indexes to describe the state of an accident.

A stress corrosion cracking represents a narrower sense of failures. Three factors are necessary for the occurrence of such a failure. They are a sensitized material, a corrosive environment, and a tensile stress applied on the material. A stress intensity based failure criterion has been widely used to detect the failure. However, the measured fracture toughness of a material must take the effects of corrosive environments into account, and a significant cutting down on the fracture toughness can be seen.

The failure of a unidirectional composite is a typical example of the narrowest failure cases. The composite is anisotropic and its failure behavior is generally different at a different point as well as along a different direction. This makes the analysis of composite failures a great challenge. There are essentially two kinds of approaches to a composite failure, that is, phenomenological and micromechanical. Hardly any a composite failure can be efficiently addressed only through a phenomenological approach, since it does not care for any stresses induced in the constituent fiber and matrix of the composite. For instance, an interface debonding between the fiber and matrix, which frequently initiates the composite failure, cannot be practically dealt with without knowing the stress states in the fiber and matrix.

While most failure analyses are performed with deterministic methods, there are probabilistic techniques to theoretically characterize a failure of a material or structure as well. In a deterministic method, the critical parameters such as strengths of the material or structure are provided, without considering any variability and uncertainty involved in the determination of these parameters. On the other hands, the variability and uncertainties have been incorporated in a probabilistic technique to quantify a material's or structure's failure. A probabilistic technique is described in the book to determine a material failure.

3. Non-destructive characterization

The non-destructive testing (NDT) methods to test FRP-concrete on RC structures use an impulse excitation principle. In an impact-echo NDT method, a light mobile impact machine with multiple hammer impacts across the length of an FRP (CFRP) plate bonded to a concrete structure generates specific frequencies and waveforms. The frequencies and waveforms are unique as a function of the FRP-concrete bond condition. Detecting changes in frequencies and waveforms indicate a change in bond condition, that is, from a bonded to a de-bonded state. The NDT method used to evaluate FRP-concrete bond on RC bridges in the field is explained.

The impulse excitation theory and the mathematics of a signal analysis to measure the impact signal frequencies and waveforms are highlighted. Examples of NDT testing on several bridges in Missouri are presented.

Electromagnetic methods have been developed to do nondestructive evaluation of the steel reinforcing bar (rebar) in concrete. AC current flew in an excitation coil and AC magnetic field is produced, and eddy current is induced in the steel rebar. A detection coil is then used to measure the magnetic field produced by the eddy current and the magnetization effect.

A temperature diffusivity measurement and nondestructive testing using non-stationary local heating and IR thermography for analysis of some engineering failures are also outlined in the book.

The coverage of failures is very broad. Hardly any a single book is able to describe failure mechanisms or to provide diagnoses or detections on failures occurred in all kinds of materials and structures. In fact, the existing literature on the failure related topics is extensive. Some of them can be recommended for the readers to obtain more information. They include monographs or edited books by Holm and Tomasz [1], Velázquez and Luis [2], Makhlouf and Aliofkhazraei [3], Greuter and Zima [4], and Hinton et al. [5], and review papers by Blandford [6], Orifici et al. [7], Ossai et al. [8], Liu and Zheng [9], Breitenstein and Sturm [10], Louis [11], Hellier [12], Hemeda and Pitilakis [13], Hemeda [14], Giovanni [15], and among others. Even so, we believe the present book is useful to the readers.

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