ACADEMIA NDT INTERNATIONAL

Science, Technology and Diagnostics in Non-Destructive Testing

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A new discipline: NDT integrity engineering

Recommendation of the Academia NDT International

The Academia NDT International would like to draw your attention to the emergence of the **NDT Integrity Engineering** discipline, which serves to safeguard the integrity of materials and structures through the use of advanced and appropriate NDT practices. The Nondestructive Testing (NDT) profession belongs to STEM (Science, Technology, Engineering and Mathematics), which is a family of disciplines collecting the most important areas in emerging technologies. It is necessary for NDT to join other professions that are also aiming to adjust their educational programs to the needs of those requiring advanced knowledge, skills and the correct disposition.

NDT Integrity Engineering is a discipline to develop nondestructive testing and evaluation involving materials science, fracture mechanics, and other sciences that would guarantee and enhance the reliability and safety by ensuring integrity of structures in everyday life.

Nondestructive Testing – Nondestructive Evaluation

In broad sense, NDT has two fundamental objectives:

- **The social objective** is to save the general public as well as the natural and built environment in case a structure or component fails due to a non-detection of a failure. A failed structure or component can often jeopardize its environment and human life.
- **The commercial objective** is to optimize the productivity of assets (i.e. components or structures of a facility) being inspected.

Initially, NDT was used in industry as a quality control tool: **Quality Control NDT (QC-NDT)**. Performance details and requirements were usually set out in standards. The flaw detection capacity of a procedure was mainly unknown. Despite this, the application of various NDT methods was widely accepted because they demonstrated their effectiveness in practice. Their success might also be supported by the fact that substantial design margins were applied to address many uncertainties in the design, manufacturing and operation processes. The NDT result was mainly expressed as “go / no-go” and was strongly dependent on the skills of the NDT personnel.

Over time the technological development required quality improvement in the production and in the operation. New structural materials were applied and new methods in design were introduced as a consequence of the development of fatigue and fracture theories. Risk assessment, condition monitoring and life management as new technical areas were developed. These changes were revolutionary in the overall engineering practice, and they had a similar revolutionary impact on NDT. The acceptance criteria moved the QC-NDT practice into a new world of reliable detection and sizing of flaws. The concept of **Quantitative Nondestructive Evaluation (Q-NDE)** was born.

We can distinguish between two types of NDT/NDE: the QC type NDT and the fitness for service (FFS) type NDE. In recent decades, the relative importance of the latter has been continuously increasing.

- In **QC type NDT** the basic task is a decision on compliance or non-compliance with the quality requirements. The deviation is usually expressed as analog signal because the requirements are also given in this form. For example, in ultrasonic testing, the signal is compared with the signal originating from an artificial reference reflector. The accuracy of this comparison depends strongly on the closeness of the reflecting surface morphology (e.g. crack) to that of the artificial reflector.

- With **FFS type NDE** of an operating structure or component, the most important information is the encompassing rectangle or square, i.e. the size and the location of a flaw present in the structure. The encompassing flaw sizes have to be compared with the allowable flaw sizes defined in FFS standards, usually as a function of flaw geometry and surface vicinity.

Need for NDT Integrity Engineering

Basically, the following factors establish the necessity of NDT Integrity Engineering:

- **Economic factors:** In recent decades one of the fundamental goals of economy is to increase the productivity of engineering structures, which leads to their better utilization. Increased productivity is often associated with significant reductions in the weight of structure. This overall trend, increases the requirements against NDT on the one hand, and defines new NDT tasks on the other. New NDT developments are a natural response toward the appearance of novel materials, e.g. light metal alloys, composites, and ceramics; or new technologies, e.g. additive manufacturing.
  High-value and high-risk engineering assets are ageing, yet there is a need for their further use beyond their design life. Materials ageing may lead to the gradual degradation of safety margins of structures and components. For example, the average age for oil refineries and associated pipelines in the USA is more than 40 years; these assets are required to run at high capacities. Another example: the age of 65% of operating nuclear power reactors worldwide exceed 30 years approaching or, in some cases, reaching design life. Life extension of nuclear power plants became a worldwide trend, with the key condition to ensure the plant components' structural integrity until the end of the extended lifetime. In the case of both industrial segments, the critical and increasing urgency of the role of NDT is more than obvious.

- **Safety factors:** Parallel with the aforementioned economic motivations, the way the world understands safety is continuously changing. Risk accepted by the society is decreasing forcing regulators to render safety regulations progressively more rigorous. This again puts NDT in the foreground. On the other hand, regulators tend to take risk into consideration, which means that NDT efforts are focused on the higher risk areas. Components to be tested are prioritized according to their risk. This could result in a reduction in NDT burden or demand. However, for the examination of high-risk areas, the conventional NDT procedures and equipment are not adequate for the task, bringing to question the issue of quality not quantity. Consequently, risk-based or risk-informed, inspection brings new requirements for NDT.

- **Managerial factor:** According to industrial practice, in many areas during in-service inspection of operating components, when a flaw that exceeds the acceptance standard is detected, the operation manager routinely asks the NDT staff whether the operation with the given component can be continued. The reason is that operation managers typically do not have the detailed knowledge on stability and growth of crack-like flaws. Even an NDT person with extensive experience can rarely answer the question. Obviously, there exists a gap between the NDT personnel who provide inspection results and the managers who are responsible for making decisions with regard to the fitness for continued service of a structure or component with detected flaws. The NDT integrity engineer is the best solution to bridge this gap.

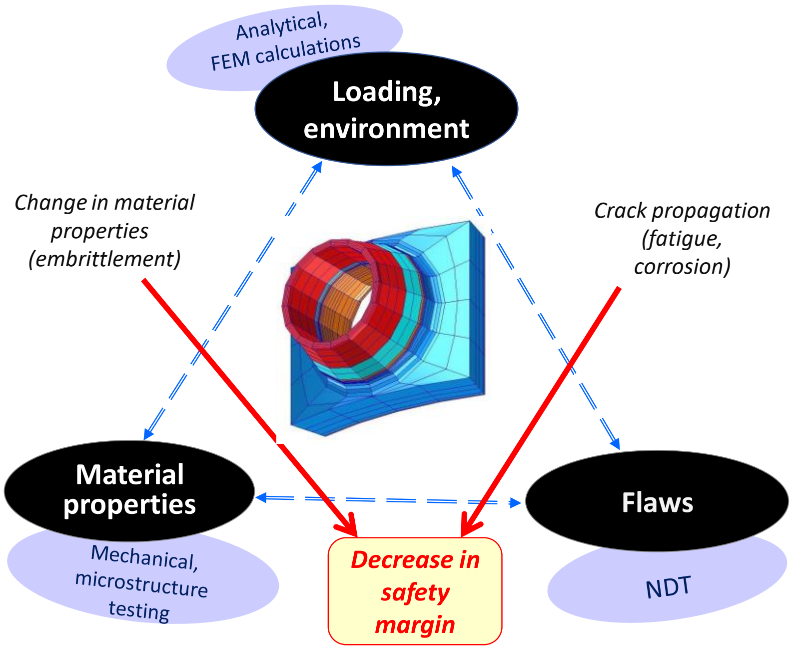
Structural integrity assessment

Structural integrity assessment of engineering structures and components is the evaluation of their resistance to strength and fracture. This assessment is based on three fundamental inputs, as listed below and shown in the schematic that follows.

- awareness of the loading environment (mechanical, chemical, thermal, magnetic, electric, electromagnetic) arising in the component during operation;
- properties of the structural material (such as, tensile properties and fracture toughness);
- parameters of existing flaws (cracks, delamination, corrosion).

All of these inputs may be subject to changes during component use (i.e. operation) due to the detrimental effects of materials ageing. Ageing can affect the material properties such as embrittlement (loss of toughness) and can contribute to the propagation of cracks due to fatigue and / or corrosion. Consequently, the true assessment of structural integrity should take into consideration a continuous decrease in safety margins. This decrease will compromise the component's integrity and put its safety at risk. For a reliable assessment, all three inputs are equally important.

Since the energy requirement for ductile failure is far greater than required for fracture in the brittle mode, the basic tool of structural integrity assessment is fracture mechanics (either deterministic or probabilistic). Fracture mechanics allows the calculation of the limit of loading conditions for the material, complete with its mechanical properties and intrinsic flaws (e.g. cracks, lack-of-fusions), such that these flaws remain stable and not propagate.



NDT Integrity Engineer competences

NDT Integrity Engineering is a discipline to develop nondestructive testing and evaluation involving materials science, fracture mechanics, and other sciences that would guarantee and enhance the reliability and safety by ensuring integrity of structures in everyday life.

We are strongly convinced that this subject matter expertise can and must be added to the NDT / structural integrity assessment quality process and most importantly to the safe and reliable operation of high-risk facility structures and components. The specific position of the NDT Integrity Engineer is expressed by joining both the “NDT” and “Integrity” words in its name. NDT Integrity Engineering primarily focuses on NDT methods with a knowledge base that encompasses all disciplines which contribute to establish any integrity related decision.

The NDT Integrity Engineer must understand and speak the entire “NDT language”. It is based on a firm grasp of the principles behind nondestructive testing and nondestructive characterization, and some practical experience in some of the major NDT methods.

The most important **NDT related competences** are the following:

- the physical basis, the possibilities and limitations of the major NDT methods;
- the evolution of NDT including the current tendency to provide early detection of materials degradation;
- the structural health monitoring strategies and techniques;
- the impact of the development of information technology and micro- and nanoelectronics on NDT and technical diagnostics;
- the globalization of NDT.

In the area of **loading and environment** the knowledge should cover the following:

- the awareness of the physical fields arising in the component during operation, including the basics of analytical and numerical methods of their calculations;

- the calculation of stress / strain status, stress intensity factors and other operational conditions associated with the operating environment including any accidental loading.

The most important **materials related items** are the following:

- properties of structural materials;
- the “material’s response” to loading and environment, i.e. the materials ageing effects;
- the potential ageing processes such as embrittlement, loss of toughness, fatigue, corrosion, creep, wear and other like factors, and their effect on the integrity of the component.

Beside the specific competencies described above, the NDT integrity engineer should be in possession of **general engineering competencies** such as:

- awareness of a broad multidisciplinary context of engineering;
- general ability to solve engineering problems in the field of activity;
- ability to apply codes of practice and safety regulations;
- awareness of economic, organizational and managerial issues;
- ability to effectively communicate information and solutions with engineering community and society at large;
- ability to function effectively in a national and international context, as an individual and a member of a team, and to cooperate with engineers and non-engineers effectively.

The main intention of this paper was to draw attention to the emergence of the profession of NDT integrity engineer to ensure the correct and needed applications of so powerful NDT methods in materials and components integrity assessment and safety. The economic development tendency, the severity of safety requirements as well as the apparent gap between the knowledge of NDT personnel and decision-maker contributed to develop the competencies of the NDT integrity engineer.