Destructive Testing Methods: Overview

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Abstract

Destructive Testing (DT) of welded joints is a common procedure that uses different types of methods focused on understanding materials' behaviour and performance under specific conditions, allowing to understand their breaking point.

DT is connected to the quality of the material and, as such, it is used in several industrial sectors.

Thus, it is important to understand what Destructive Testing is, what its different methods are and how they are applied by several technicians/professionals who work in DT and are the main focus of **TRUST – Destructive Testing Technician**[1] project.

This paper presents an overview of Destructive Testing and of its methods as a way to understand its importance to industry and why is it important to qualify professionals to implement DT.

Keywords: Destructive Testing, material, specimen, industry, methods, procedures, technicians

Introduction

Destructive Testing (DT) is a procedure that tests at which moment a component, asset or material breaks. For this end, the material being tested is submitted to multiple destructive testing approaches in order to understand which will deform or destroy it entirely. The reason behind this procedure is to know and understand how the material will behave under pressure.

DT allows for the identification of physical properties of a component such as resilience, toughness, flexibility and strength. As such, it is an essential testing method that contributes to the identification of the limits of components to support correct operational, upkeep and replacement recommendations. Therefore, DT is applied before a part is mass produced or used in its actual application.

Typically, DT is either performed by technicians who work at industrial laboratories (e.g., chemists, electrochemical process experts, failure analysis experts, material scientists, metallurgical and polymer engineers, quality control analysts and regulatory compliance experts), or by a third party that provides testing in a lab using specific equipment.

Destructive Testing: Applicability

The methods used in DT are usually applied for failure analysis, process validation and materials classification. A very common example of DT is in crash simulations since automakers and aerospace industries recur to DT to test the capability of their safety equipment by determining their perform limits when other components fail.

[1] TRUST project aims to design a new European Destructive Testing Technician qualification standard (aligned with EQF level 4), to reply to the urgent need for qualifying personnel in this specific field.

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Many industries resort to DT, including aerospace, automotive, chemical, construction, defence, electrical engineering, fabrication, infrastructure, manufacturing, oil and gas, petrochemical, pipeline, power generation and software. So naturally, there are an assortment of types of DT procedures that can replicate environmental factors to mimic the exposure, materials which may undergo once they are in use, as well as different types of pressure to test the strength of the materials. For example, in aerospace, high temperature and pressure are applied to the cabin in order to guarantee that safety features (e.g., air respirator release) will perform under such conditions.

Destructive Testing: Methods

Destructive Testing comprise an array of methods that can be implemented by professionals working in industrial laboratories, depending on their purpose.

As such, it is very important to understand what those methods are, how they can be used and under which conditions, to ensure their proper implementation and the quality of the materials tested.

Some of these methods will be addressed by the European Destructive Testing Technician qualification standards, designed and developed in TRUST project, which targets young people and professionals already working in the field of DT but are in search for a formal recognition of their competences and skills, or are in search for up/reskilling opportunities.

Table 1 Brief definition of different Destructive Testing methods

DT Method	Description
Aggressive Environment Testing	Includes fracture and fatigue tests in corrosive environments (e.g., containing salinity, humidity, hydrogen sulphide, carbon dioxide, among other natural elements), involving different temperatures and pressures. These tests allow for the assessment of the impact of these conditions on materials and on their performance.
Corrosion Testing	This testing covers non-toxic, small-scale and aqueous corrosion tests in various environments, such as fresh and sea water.
Fracture and Mechanical Testing	They can be carried out on several materials and consist of different types of DT methods, like: ¬ Tension tests, bend tests (which ensure quality control by bending materials in a guided or free way to uncover embrittlement); ¬ Charpy impact tests (that determine the sum of energy absorbed by a material in a fracture by subjecting it to high strain); ¬ Pellini drop weight tests (which defines the nil-ductility transition temperature, that consists in the temperature explosion bulge tests where the plate remains flat after a fracture and crack spread while in the presence of elastic strains); ¬ Peel tests (they determine weld size and failure type); ¬ Crush tests (also known as compressive strength test, that determine the strength of concrete bearing loads); ¬ Pressure tests (they apply proportional pressure to a material being strained revealing micro structurally strains within a material's elasticity, through hydrostatic pressure); ¬ Fracture tests (which expose imperfections like cracking (owed to inadequate width to height ratio), incomplete penetration, lack of fusion, porosity and slag inclusion).

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DT Method	Description
Fatigue Testing	It is used to test the strength of welded joints under frequent or variable amplitude loading, as well as fatigue crack growth testing of welds, base metals and heat affected zones, usually conducted in salt water or open-air environments.
Hydrogen Testing	It can be conducted at a range of different temperatures and strain rates, in substances that have a risk of corrosion from being exposed to hydrogen.
Residual Stress Measurement	Allows designers and engineers to define aspects such as near-surface and through-thickness residual stress distribution. These aspects can then be applied in engineering critical evaluations since this test measures internal stress of a part and its repercussions on the surface stress. Residual stresses can be created intentionally (e.g., scratch-resistant glass on smartphones) or unintentionally (e.g., premature failure of a structure) and remain in a solid material even once the original causes that created the stresses have been removed. It includes three methods to measure residual stress: 1. Neutron diffraction, 2. Synchrotron diffraction, 3. X-ray diffraction.
Tensile Testing	Also referred to as *elongation*, it is employed in construction materials to test their weld-strength in order to certify the structural integrity of a weld and the building itself. It is a type of stress testing accomplished by elongating or condensing a part to ascertain the strength of the material. Thus, calculating the physical properties and determining which materials can withstand a great amount of force (e.g., a skyscraper that is subjected to environmental factors will use materials and components that are deemed safe to use by DT methods to endure circumstances under expected limits).
Hardness Testing	It asserts how well and how long a part will perform and last over time, by showing the resistance of the material to indentation, that determines hardness. This test establishes if a component experiences permanent deformation while undergoing stress, resorting to the use of the Rockwell scale
Torsion Testing	Another type of stress testing resulting from twisting forces applied to determine shearing of the material before it becomes deformed. Naturally, the failure point occurs when the material succumbs to the twisting.

DT focused on the welding field, also known as Destructive Weld Testing, requires the physical destruction of a finished weld to assess its strength and qualities. It is commonly used for applications such as, welding procedure qualification, sampling inspection, research inspection, welder performance qualification testing, failure analysis work, methods of destructive weld testing (typically involving sectioning or breaking the welded component) and evaluating various mechanical and physical characteristics. Some methods for performing this test include:

Table 2 Brief description of Destructive Weld Testing methods

Method	Description
Macro Etch Testing	It is a method that requires the removal of little samples from the welded joint, to be polished at their cross section and etched using a mild acid mixture, varying on the material used as a base. Thus, providing a clear visual of the weld's internal structure such as depth of penetration and, if applicable, evidence of lack of fusion, inadequate root penetration, internal porosity and cracking at the fusion line (where the transition between the weld and the base material occur).

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Method	Description
Fillet Weld Break Test	A testing method that involves breaking a sample fillet weld that is welded on one side, by applying a load onto its unwelded side, typically in a press, and increasing it until the weld fails. In order to establish the existence and scope of any welding discontinuities, the failed sample is inspected. Thus, providing an accurate indication of discontinuities within the entire length of the weld tested (normally 6 to 12 inches) in oppose to a cross-sectional snapshot, as in the macro etch test. Through the use of this type of weld inspection items such as lack of fusion, internal porosity and slag inclusions can be detected. Even though this test is usually used on its own, it can also be used as a complement to the macro etch test, as it provides data on similar traits but with different detail.
Transverse Tension Test	It consists of verifying that the tensile properties of the base metal, the weld metal, the bond between the base and the weld, and the heat-affected zone are in accordance with the design requirements since a big part of design is based on tensile properties in the welded joint. This test is performed by pulling specimens to failure and then dividing the maximum load required during testing by the cross-sectional area, resulting in units of tension per cross-sectional area
Guided Bend Test	It involves bending a specimen to a specified bend radius. This type of test is typically needed as transversal to the weld axis and may be bent in plunger-type test machines or in wraparound bend test jigs, as it is most commonly used in welding procedures and welder performance qualification tests. This type of testing is particularly good at finding liner fusion defects, which will often open up in the plate surface during testing

Conclusion

This paper aims to provide to its readers a brief overview of what Destructive Testing (DT) is and what the main implemented methods are in the scope of this procedure, more specifically in Destructive Testing of welded joints, some of which addressed by the new European Destructive Testing Technician (EDTT) qualification, under design and development in TRUST project.

The implementation of such methods rely in the guidance provided by specific ISO[2] standards, which are also considered by the EDTT qualification to ensure the alignment of its contents with industry's requirements, allowing for a much better prepared workforce.

Each method has its own procedures and purposes, hence the need to know them to understand how and in what contexts they can be applied by the professionals working in DT.

References

ESAB (n.d.) "Introduction to destructive welding testing". Retrieved from https://www.esabna.com/us/en/education/blog/destructive-testing-of-welds.cfm (accessed on January 2022)

Flyability (n.d). "Destructive Testing: A Guide". Retrieved from https://www.flyability.com/destructive-testing (accessed on January 2022)

TWI (n.d.). "What is Destructive Testing? – Methods, definition and examples". Retrieved from https://www.twi-global.com/technical-knowledge/faqs/what-is-destructive-testing (accessed on January 2022)

[2] International Organization for Standardization (https://www.iso.org/home.html)

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