

NDT Report

by Daniel Ward

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NDT TECHNEQUES

Advanced Stress Analysis & FEA

EXECUTIVE SUMMERY

This report looks at how NDT (Non-destructive Testing) is used in industry to ensure safety of mechanical structures. It explains what NDT is and how it differs from Traditional destructive testing and gives a brief explanation of how fatigue and corrosion affect the mechanical properties of materials.

It identifies and explains the basic principles and gives generalised examples of Ultrasonic Testing (UT), Radiographic Testing (RT) and Eddy Current Array Testing (ECA).

It gives an over view of how:



- Ultrasonic waves propagate through the material and are used to show subsurface defects and erosion of material is identified.
- Radiation is used to create 2D and 3D pictures of the interior of an object
- Eddy currents can be used to pick up surface defects and evaluated the quality of surface finishes and coatings.

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1. INTRODUCTION

It is widely appreciated that engineers need to understand the mechanical properties of a material so that designers can choose the correct materials for a given purpose. It's as equally important that those materials are of good quality, so that the mechanical properties don't fall beyond their ability to do the job they were designed to do. Traditionally destructive testing has been used to test materials strength and hardness which is still used today on batch materials. today we know that over time materials degrade through corrosion and fatigue. This means that a given materials mechanical properties deteriorate over time and certain components need to be tested to ensure they don't fail over time.

The American Society for Non-destructive Testing (ASNT) say that NDT is the testing, inspecting and evaluating of components in a way that does not impact its ability to remain in normal service. It is used in most industries whereby the machinery or equipment may succumb to material failure, essentially increasing the ability for engineers to guarantee the safety of working parts in operation (The American Society For Non-destructive Testing, n.d.).

NDT is commonly used in most industries aerospace, medical, and energy to reduce risk of mechanical failure of components while in operation, these industries rely on the fact that NDT tests the parts and materials being tested remain whole and serviceable after the testing.

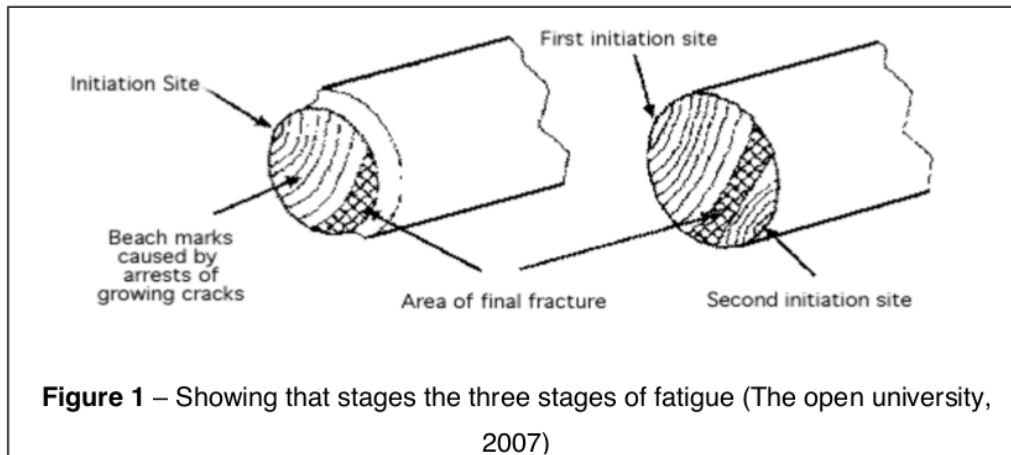
This is far removed from traditional destructive testing such as tensile or hardness testing, as these methods destroy the materials they test. Although destructive test methods are more accurate it is still much more suited to batch production parts. Destructive testing is not be beneficial as the parts being tested need to be replaced after its been tested.

Non-destructive testing types include ultra-sonics, radiography, magnetic particle, eddy current, dye penetrant and visual methods. Each of the essentially look for flaws in the materials, which are being tested, to ensure whether the part is mechanically capable of maintaining service.

2. MAIN BODY

Before looking at NDT its worth mentioning that material failure happens because a material or structure cannot withstand the load which it is designed to bare. This may happen for a few reasons, the main being poor design, fatigue and corrosion. As this report will be looking at NDT, poor design can be neglected as its not relevant for this paper.

Corrosion is defined as being the deterioration of a material due to its chemical composition within its surroundings. Corrosion of a material takes place at varied rate and there are 10 common types of corrosion, they are general attack, localised, galvanic, environmental, flow assisted, intergranular, de-alloying, fretting and high temperature (British Institute Of Non-destructive Testing, n.d.).



Fatigue takes place when a component is subjected to cyclic loading. This means that the part fails far below its static material strength it's also the most common reason for structural failure. This happens because a small initial defect slowly grows over time until the material can no longer withstand the stress/load applied. There are three stages to material fatigue they are:

- initiation, where the first crack appears,
- Crack propagation, where the crack slowly grows
- and failure, the material fails and splits into 2 parts.

We use NDT to ensure a component is safe to remain in operation. Using NDT, defects can be picked up before failure occurs, this makes NDT critical to the evaluation of structures to ensure safety is upheld (N.C. Bellinger, 2009).

There are five main methods of Non-destructive Tests, which each have their own varieties. They are Visual, Dye Penetration, Magnetic particle inspection, Ultrasonic, radiographic and Eddy current. The three that this report will be looking at in detail are Ultrasonic, Radiography and Eddy Current testing. Each of them has similarities and differences which will be explored in detail. 

As BINDT explain on their website, there is a relationship between NDT, Condition Monitoring (CM) and Structural Health Monitoring (SHM). It regards NDT as a vital tool to assist their analysis. It says that NDT is used in manufacturing to guarantee the quality of the materials, then again at CM where the data is used to input data into the SHM reports. It also specifies that regular NDT results can replace condition monitoring.

2.1. NDT & Stress analysis

Results of destructive testing are used to determine an array of material properties. During the design stages of a structure, a material will be chosen by comparing the material properties to the design specification. To ensure that the material is of good quality or to a specific standard it was be subject to testing, batch materials can be tested via destructive methods, in the case of customised or low production parts it can be deemed unfeasible to be destructively tested therefore NDT will be utilised to ensure there are no defects which could compromise its ability to withstand its loading conditions.

According to Haghani stress analysis tests should provide an accurate and reliable measure of the magnitude and distribution of stresses and strains of a structure under specified conditions (Haghani, 2014). Designers can use computational based FEA tools to design and test components at the design stage, but as time goes by the material properties of a component can change over its working life due to corrosion or fatigue (Venkataraman, 2001).

NDT ensures that structural components remain in safe working order by measuring material thickness or looking for initiation cracks with the components to foresee possible failure points within a structure. Operators and engineers can also track

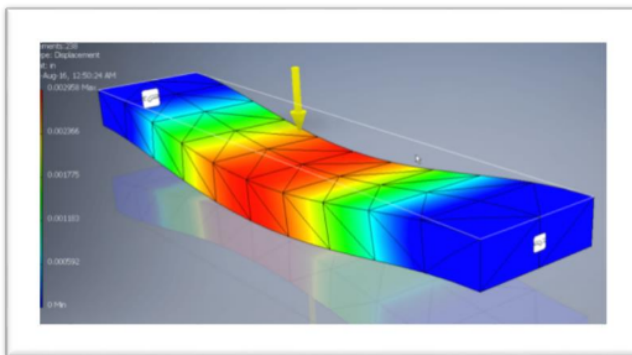


Figure 2. – Image of a typical computation model of stress analysis the Red area is of the model is where the highest concentration of stress occurs (cadsetterout.com, 2006).

crack propagation in parts that need less structural integrity such as an aeroplane fuselage. This improves safety at the workplace and saves money simultaneously as working parts don't need to be replaced until they're no longer capable of doing their job safely.

2.2. Ultrasonic testing (UT)

This family of methods use high frequency sound waves usually ranging from 0.1MHz-25MHz and as high as 50MHz on times, to measure and examine materials for internal cracks and defects as well as testing material thickness to determine material loss due to corrosion. A piezo-electric transducer is typically used to produce the wave energy, this is a piece of electrical equipment which transduces electrical energy into sound waves, the device is then introduced to the test piece, the sound energy propagates through the material until it relocates the receiver, often a fibre-optic sensor, where its acoustic emission is monitored projected on to a screen so that it can be read by an operator or computer processor.

At the point in which the wave energy hits a subsurface defect the waves return to the receiver quicker than they would if they had propagated through the entire test piece. As shown above in Figure 3. a shorter signal return time can be witnessed on a monitor. From this information a trained operator can assess the location, size and shape of the defect.

Ultrasonic inspection is one of the most versatile and useful family of

methods of NDT, as it can be utilised to find and assess surface and sub-surface defects with a high degree of accuracy at the point of inspection, thus results are

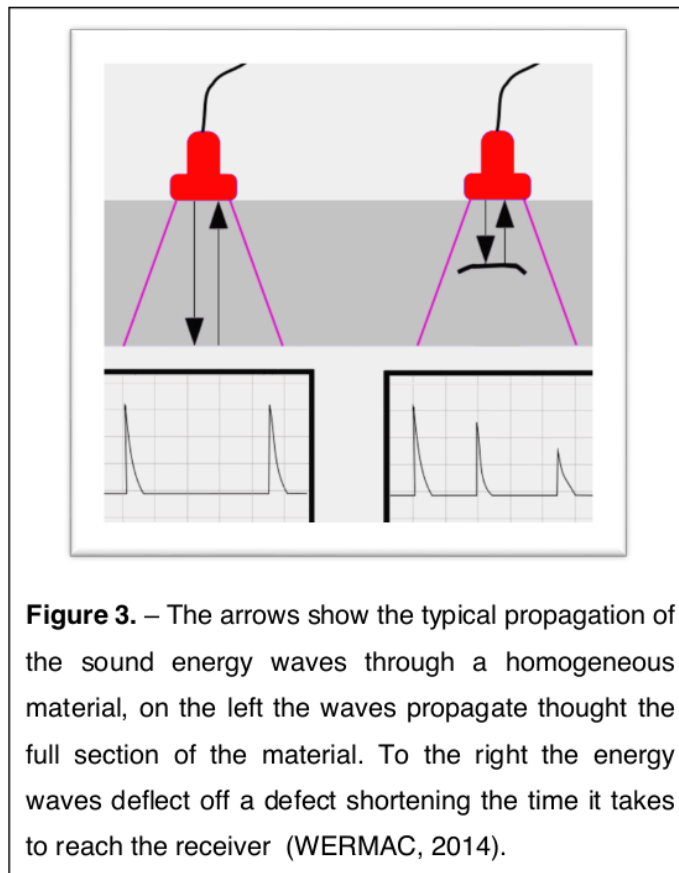




Figure 4. – Typical portable UT equipment being used to test extruded round bar for defects (Quality Mag, 2015).

instantaneous. The Pulse/Echo technique only requires one side of the test piece to be accessed which means large parts/components such as heavy pipe work can remain at its location while the test is carried out. In most cases very little to no preparation is required before testing. The information obtained can be

fed into a computer to make 3D Images of the defects which allow engineers to make informed decisions about whether the component needs replacing or can remain in service. UT can also be used measure material thickness.

Although UT is a very versatile method, it does come with limitations to its uses.

- Operators need to be highly trained to pick up defects on the monitor;
- Materials which are coarse grained, rough or objects which have irregular or fine topology can be difficult to test due to poor or high signal noise, this can sometimes be overcome by using a coupling medium which allows sound waves to be transferred into the material more efficiently, this also may not offer accurate test results;
- Defects in which run parallel to the direction of the sound waves may not be picked up;
- at least one surface must be suitable/accessible to the test equipment for the test to take place;
- Test equipment needs to be calibrated regularly to ensure validated results. Operators sometimes carry pieces of test material that used as a way of comparing results at the point of testing.

This test can be used to test a wide range of materials including metals, concrete, composites and more. almost all industries use this method as it does not produce any electromagnetic or static charges that can cause sparks and have very little adverse effects to its surroundings. (NDT Resource Center, 2007).

2.3. Radiography

Film Radiography, Real Time Radiography (RTR), Computed Tomography (CT), Digital Radiography (DR), and Computed Radiography (CR).

Possibly the most varied and complex method which can be used on most materials including metals, plastics and composites.

This group of tests use radiation such as x-rays or gamma rays to see through materials to highlight any internal flaws or defects, as well as determining internal features. The defects or feature can be seen either on a shadowgraph or on a screen/monitor. This type of test is often used in the petrochemical industry to detect defects in valves and pressure vessels and medical industry to determine injuries. It's also used for examining components for the aero industry and production mass production such as the car manufactures.

Direct Radiography, Computed Radiography, Real-Time Radiography and Computed Tomography are the most utilised in heavy industries.

Depending on which method is being utilised, an operator can create 2D images which is called projectional radiography or a 3D computer model of the subject called CT (Computed Tomography) Scanning (TWI, 2006).

It does this by introducing the subject to a source of electromagnetic radiation such as gamma or x-rays, some of the rays are absorbed by the subject or reflected away from the receiver, the rays that make it past the test piece are collected on either a film or an array of sensors to show the internals of the object. defects such as cracks are observable as there is

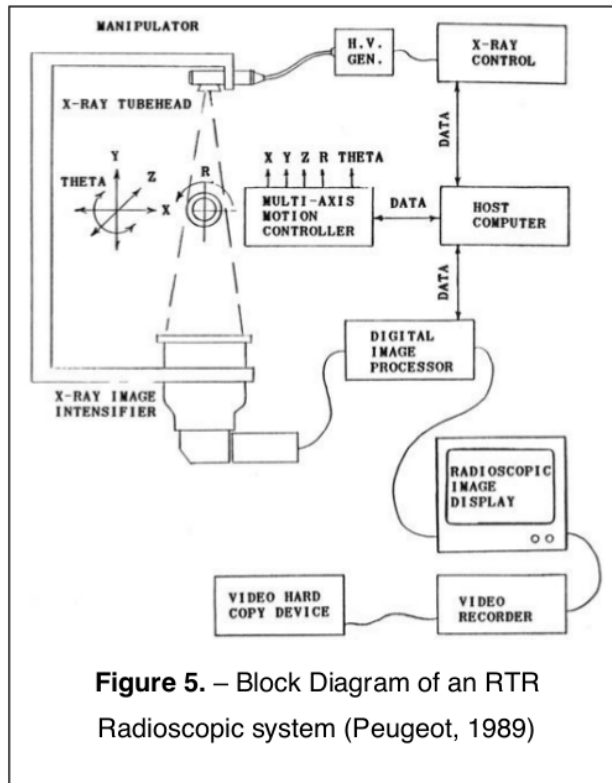
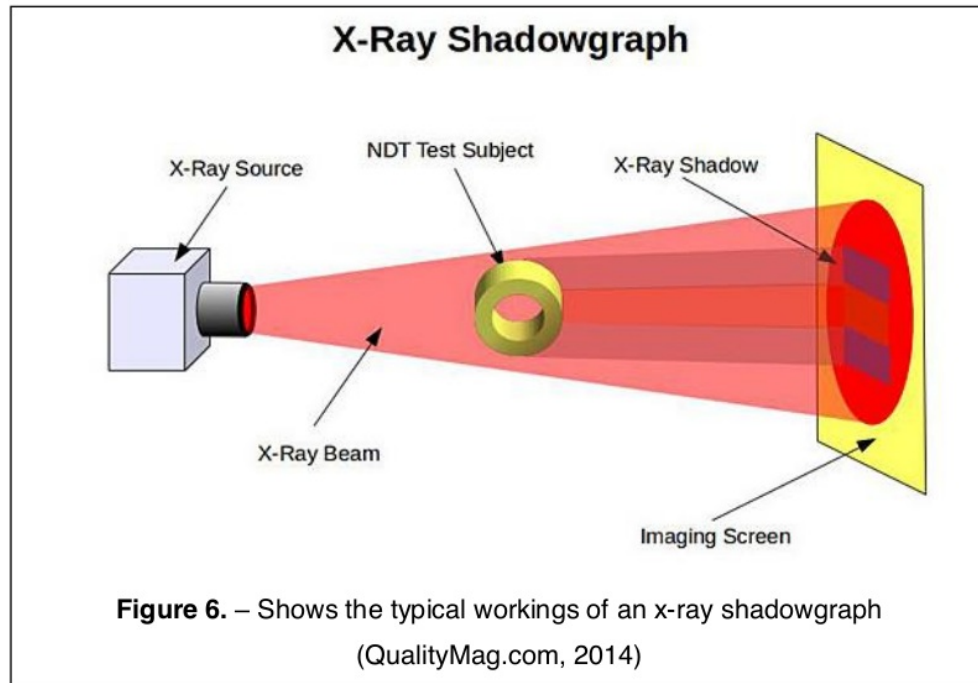


Figure 5. – Block Diagram of an RTR Radioscopic system (Peugeot, 1989)

less material to pass through in that area and more rays make it through to the film or receiver equipment.

This means that denser materials need more exposure and extremely thick parts are difficult to test, as not enough of the rays make it through.



As the text below the title shows, there are many different types of radiography, but they fall under two main categories, they are Conventional Radiography (CR), a projectional radiography. CR, the oldest method of RT, it uses a film to capture the rays, which develop much like a photograph and seen by holding the film to a bright light, commonly seen when having an x-ray in a hospital and Digital Radiography (DR) which uses highly sensitive equipment to capture the radiation. They all come with their own advantages and disadvantages.

On the whole radiography is very reproducible, it requires little to no surface preparation and can be used on site conditions making it very portable. With the correct set up its also able to detect defects under insulation or inside pressurised pipework.

The main risks associated with using radiography is to the operator and other workers in site conditions, the HSE say that these risks can be greatly reduced by

proper planning and using collimation which is a type of shielding device that reduces the leakage of radiation into its local environment (Health and Safety Executive, 2017).

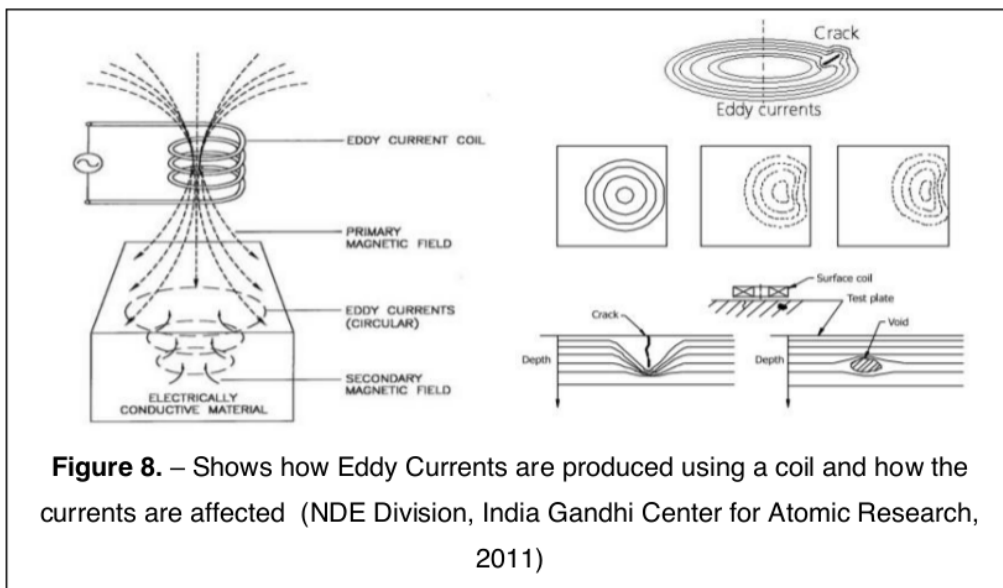
CR has the added disadvantage of the possibility of poor development of the film due to premature removal. This would cause the film to be undeveloped or worse, defects may not be detected and put back into use causing failure. More conventional CT overcomes this by feeding back real time digital images but carries the burden of having to remove the part from service while its being tested.



Figure 7 – An image of a shadowgraph (Swiss Saftey Center, 2016)

2.4. Eddy Current Array (ECA)

The Eddy current method has been used since the 1950's, its used to look for small surface cracks in test materials by introducing an electrical current through the material and monitoring differences in the eddy current flow (a-Martín, et al., 2011). The method is more diverse than MPI (Magnetic Particle Inspection) as it can be used to test all electro-conductive materials whether they are ferromagnetic or non-ferromagnetic materials. It's used to take thickness measurements of non-conductive surface coatings and inspect heat-treated metallic materials since magnetic permeability and conductivity of a material is affected by its micro-structure. It can also be used for material identification and characterisation, such as material conductivity with the correct test equipment (a-Martín, et al., 2011) (Yanhua Sun, 2016).

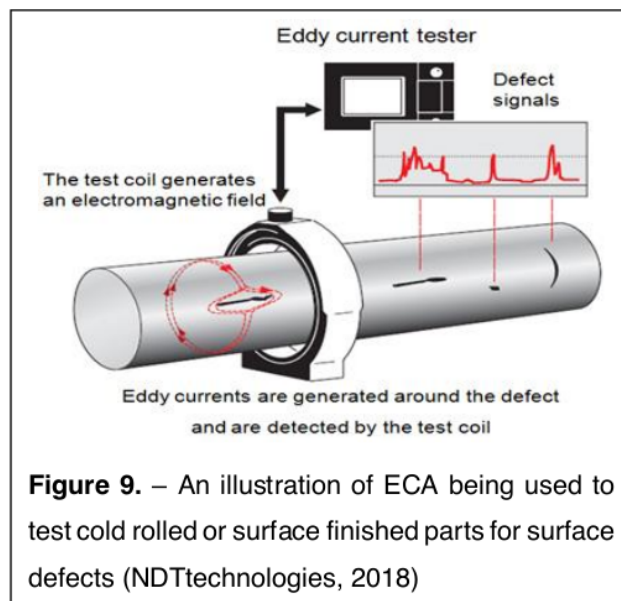


So, what is an eddy current and how can it be used to test materials? To answer that some principles of eddy current, need to be understood as well as a brief look at how electromagnetic induction (cadsetterout.com, 2006).

When a magnet is passed very near a conductor the magnetic forces of the magnet push the free electrons in the conductor to move in a direction inducing an electrical current. When that current is induced in the conductor it flows in small swirling patterns near the surface, much like little eddies that are created when you run your hand through water, when your hand stops, the swirls are no longer created. A more

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technical explanation would be; Eddy currents are created by changing magnetic fields, they flow perpendicular to the flow of the magnetic field and can be created by varying the flow of the current through the test specimen. The intensity of the eddy current is proportional to the magnitude of the magnetic field, the change rate in magnetic flux and area of the loop. It's also inversely proportional conductor's resistivity (MAGCRAFT, 2015).



This process is commonly used in the steel industry to ensure uniformed surface hardness, surface finishings and to identify residual stresses on the galvanising and annealing lines (Gerd Dobmann, 2008)

There are several factors that need to be considered when using this method of testing to get the most accurate readings. The electrical

conductivity of the materials being tested, the coil and specimen dimension, the frequency of the electrical current used, the distance between the test specimen and the coil and the magnetic permeability of the material. Highly trained operatives are needed to use the correct set up of the equipment and to read the results, because it can be difficult to distinguish between eddy currents and the induction currents produced.

The only real criteria for the test to take place is, the material being tested must conduct an electrical current and its most effective on bar or long slender components.

The main advantage of ECA testing is that its surroundings don't affect the ability to hold the test as they would with other NDT methods and debris such as oil, dust, dirt and humidity do not affect the test. This means that examination can proceed in site

conditions with very little preparation, saving time and money to the client. It's also been proven that ECA tests can be undertaken in a range of temperatures depending on the material of the test piece.

Other advantages are

- its ability to detect defects as small as 0.5mm in length (TWI, 2016),
- defects can be picked up through surface finishing's and layered materials.
- Automated equipment can be used to improve reliability and speed.
- Some variants of test equipment are very portable and can be used to gain access to hard to reach spaces.

Some of the disadvantages include:

- The inability to test non-metallic materials and fibrous materials such as carbon fibre unfeasibly, as the test relies on differences in electrical conduction and CFRP have layers of conductive materials placed in varied orientation,
- The test is very susceptible to changes in the magnetic permeability, this makes testing welding and other highly ferromagnetic materials difficult for less competent operatives.
- Testing complex geometries prove difficult because it becomes hard to tell the difference between material defects and the natural differentiating signals of the geometry.
- Large areas are difficult to test but this can be overcome with the help of more complex and expensive test equipment (Yong Li 1, 2019).
- Unless the system is automated there's no permanent record.
- Due to the way the eddy currents form, defects that run parallel are extremely difficult to detect and usually missed.



Figure 10. – Image of ECA being utilised to test pipework for defects while in operation with little to no preparation (Morgan Ward, 2019)

- The operator needs to interpret the signals from the currents and the geometry of the component, this means that flaws may be missed by less experienced operators. (Yong Li 1, 2019).

3. CONCLUSION

Stress analysis is a vital part of engineering, it allows engineers the opportunity to investigate how a structure or component may fail under specified conditions. Most components that we use today would have gone through some kind of Stress analysis, whether it's a child's toy or an aeroplane it would be tested to ensure its capable of being subjected to its working conditions. If a structure has well designed with a factor of safety and thorough non-destructive testing by highly qualified operators its highly unlikely that it will fail under normal working conditions.

Choosing which type of NDT to utilities depends on what information is needed, its condition, the component's geometry, what stage of production the component or material is at and whether the component can be easily relocated or needs to be tested on site. For example, heavy pipework carrying volatile gasses, that is fixed into the ground may need to be tested to ensure that the surface finish needs recoating or replacing. UT or RT would not give the best results but Eddy Current would be ideal, but UT is better at testing the same pipework for internal cracks in the pipe wall. This means that train engineers should be aware of what needs to be tested and what test need to be utilised for each situation.

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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DANIEL WARD

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RESEARCH-INFORMED LITERATURE



15.5

KNOWLEDGE AND UNDERSTANDING



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PRACTICAL APP



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