

Assignment 1

by Aimee Davies

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Assignment 1

University of Wales Trinity Saint David

School of Engineering

A report to compare three methods of Non-Destructive Testing in Industrial Applications

Aimee Gore

1302416

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Advanced Stress Analysis and FEA M6X00420

Kelvin Lake

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5. Structure (+)

5. Presentation(+)

Abstract

This report will outline 3 methods of Non-Destructive Testing; Visual Inspection, Ultrasonic Testing and Dye Penetrant Inspection. It will give an overview of the scientific principles of the technique as well as explaining the advantages, disadvantages, sources of error and assumptions for each method. Applications for each method and how useful these are in helping industry to understand stress analysis is analysed and concluded.

It also compares Non-Destructive Testing against Destructive Testing as a means of material data analysis and how these methods are used in industry to help understand how stress affects material and components.

In conclusion, NDT is a useful method to help engineers to understand the process of stress on a component. However, to gain an in-depth understanding, multiple methods should be employed simultaneously.

1 Introduction

Non-Destructive Testing is a method used to test the material structure strength without compromising the component or part. Non-Destructive Testing can highlight potential weaknesses that can arise in materials and components with which the early identification can help engineers to plan maintenance schedules, spending and critically, to avoid catastrophic failure in parts, as supported below;

“Non-Destructive Testing relates to the examination of materials for flaws without harming the object being tested. Non-Destructive Testing provides a cost-effective means of testing while protecting the objects usability for its designed purpose” (PRNewswire, 2019)

Non-Destructive Testing is a vital part of structural maintenance. A small defect can cause dramatic failures if not identified early enough, it can propagate and eventually a force or load will be applied that will cause sudden total failure (Moore, 1981.) By conducting a thorough inspection, of which NDT is one type of inspection, these weaknesses can be managed, and measures put in place to minimise the likelihood of failure, or if necessary, the part can be replaced, preventing a potential catastrophic failure.

1.1 Destructive Testing Methods

Non-Destructive Testing is the process in which material is inspected and sampled while in service. Comparatively, there is Destructive Testing, where a part is tested to its operating limit. By exerting stresses, loads and forces on a part the catastrophic failure point can be determined for a set of operating parameters. It is important to understand what and where total part failure happens because it can then be prevented from occurring in the field.

Destructive testing can replicate a variety of conditions that a part can be exposed to in a controlled situation. The tests carried out can measure the exact operating parameters for failure of a part to occur, the information is recorded and widely communicated to industry and end users of the part. With the available information the end user can decide the suitability of the part and material. Destructive Testing is carried out on components that are not used in service, and as such they can only replicate predicted conditions and assume material properties are all the same. However, it can be difficult to create exact operating parameters that the part is exposed to. It assumes that there are no defects created in the manufacturing of the component, it also assumes that the material being tested in the laboratory and the component used in service are exactly the same. (Aire and Chimezie, 2016)

Advantages of Destructive Testing include:

- Rough identification of the mechanical properties of an adhesive joint
- Mechanical properties of a component are identified
- Many standards of testing
- Low cost of equipment
- Ability to compare adhesives  1
- Verification of surface preparation required, curing conditions and working conditions
- Tests are low cost to carry out

There are also disadvantages associated with Destructive Testing:

- No internal defects can be detected
- Manufacture of the part is necessary for the tests (Adhesive and Glue, 2019)

Destructive Testing is an important process as it helps to determine material property and how a component will react to conditions imposed on it. However, once a part has been manufactured for purpose it is not a practical testing method to help engineers analyse its practicality and life span. NDT allows engineers to understand how a component is performing while it is in the field and if any measures need to be undertaken to prevent the part from failing.

1.2 Application within Industry

Inspection starts during manufacture of the part and an examination schedule is determined by the application or process that the component is a part of. There are often standards that need to be adhered to for the fabrication of the part. These will depend on where the installation is and relate to the industry of the application.

Inspections need to examine the material used and how these are affected by external factors. These include:

- Exposure; e.g. water, heat or a combination of elements
- Location of part (above or below ground) and what exposure this will lead too.
- Application
- Material carried (if pipe work)
- Stresses and Supports
- Rate of corrosion and measures that need to be put in place to limit this e.g. corrosive-resistant paint

Maintenance and inspection plans can be built to manage any risks that can be foreseen, and it is the responsibility of the asset owner to ensure they conduct thorough testing as far as reasonably practicable to prevent major accidents occurring.

It is critical for an engineer to have an effective process surrounding Non-Destructive Testing. All parties involved should be familiar with the process and happy with the chosen inspection method. The process should start with data collection, the inspector should be

familiar with the component and material, and the use of resources like drawings, sketches and photographs should be utilised as necessary. Phase two of the process includes analysis and evaluation of the data collected. All stakeholders should be involved in this stage to understand the results of the inspection. Finally, the engineer/s can make an informed action plan from the results. This could include another method of NDT, a more robust maintenance schedule or simply nothing at this stage. NDT testing can be used for HSE purposes, to aid in the Management of Change Process, to comply with audits and HAZOP's, all of which are critical to ensure safety of all involved and assess asset integrity. (HSE.gov.uk, 2019)

There are many factors affecting the choice of NDT method that is suitable and most effective for the purpose. This includes:

- Cost
- Ease of access for inspection
- Risk and consequence of component failure
- Material of component.

There are also a range of methods available within each branch of NDT depending on priority, costs and depth of inspection required. As so many options are available, it is important for the engineer to fully understand the importance of thorough NDT schedule and what is required from the inspection.

2 Visual Inspection

Visual Inspection (VI) is the most common approach of inspection although it is sometimes considered the most simplistic. It is, however, an important method of NDT and has many uses, applications and benefits. Visual Inspection in its most basic form, can be done on an ad hoc basis without the need for any other equipment or tools. When carried out effectively it can reduce the need for any other form of inspection, so can save both time and money for engineers and companies (Gholizadeh, 2016).

2.1 Scientific Principles of the Technique

Visual Inspection is the process of an engineer viewing the surface of the material on a part. Any imperfections are highlighted, and further testing can be requested if, and when required. Although the most elementary interpretation of Visual Inspection is by using line of sight, this can be enhanced using magnifying glasses, borescopes and remote viewing (ASNT.org, 2019).

2.2 Advantages and Disadvantages

The obvious advantage of using Visual Inspection as a form of NDT is the low cost, it can be undertaken with very little equipment, tools and resources. It is relatively easy to carry out if access and lighting is sufficient for the inspector. Visual Inspection is a simple and low-cost form of NDT and any type of material can be inspected if the engineer is adequately trained and experienced. A variety of issues can be highlighted and visually seen as opposed to other methods where a deformity is seen as an error reading, this helps identify the causing issue. Training and experience are low cost and relatively short as most is completed 'on the job'. Visual Inspection is available to any component if the inspector has access (Guidance Document, 2015). Information can be collected and stored for further analysis away from the field (Forsyth et al., 1999), allowing for this information to be recalled later for comparative purposes.

The most important disadvantage with this method is the inspection can only be as thorough and reliable as the inspector conducting it. This, however, can be overcome by using advanced visual techniques which include remote viewing, to increase the reliability of the inspection. The ability for several inspectors and engineers to inspect a part will enable a more detailed and thorough inspection.

2.3 Sources of Error and Assumptions

For Visual Inspection to be effective there are several factors that contribute to a successful inspection.

- The engineer must be adequately trained in what they are inspecting.
- They must have the relevant competencies and experience to conduct a knowledgeable inspection.
- They must be familiar with the material being inspected and the potential deformities that are common to the material.
- The inspector must have knowledge of what potential deformities might occur
- They must know the early signs of possible deformities and failures.
- The inspector must be comfortable to carry out the inspection to the depth and level required by the schedule
- They must be trained and competent to use any extra equipment should it be required. (Guidance Document, 2015)

Unfortunately, the inspection is carried out by a human and so errors can be "Human-Nature", especially where repetition or exhaustion can start to affect reliability (Drury and Watson, 2002). Assumptions can be made by the inspectors as to what the material is used. The inspector can also assume what stresses the component is exposed too. To try and eliminate these assumptions, component familiarity, history and application should be known.

2.4 Typical Applications

As previously stated, Visual Inspection is a low cost, straight forward method that can be completed relatively quickly. Many industries use Visual Inspection before investing in a more expensive method of NDT. However, it should not be underestimated as a method of inspection, Visual Inspection can be a critical method of inspection when other options are limited or not suitable for the purpose. Visual Inspection is used in applications that require remote internal inspection such as chambers, pipes, tubes and engines. By inserting a borescope, video imagery can be returned to a display screen to enable inspectors to sufficiently scan and inspect the material. Visual Inspection can be used in areas that are considered too dangerous for human access such as combustion chambers or places that are considered highly radioactive (Collacott, 1977). It also enables access when the component is still live. If the equipment can access the component and the equipment works in the operating conditions, the part can be visually inspected using advanced visual inspection methods while on line. It also can be used in critical inspection of parts that are inaccessible such as the aerospace and automotive industries for inspection in engines or inside a fuselage (Aviation Pros, 2014). Visual Inspection is an area that has a variety of scope and applications. Visual Inspection systems that are machine based can intelligently locate and identify weaknesses in applications (Rosandich, 1997). By creating intelligent Visual Inspection methods, the basic principles of good lighting, accurate sight and good material knowledge and information can be used to set up systems that are relatively low cost yet effective in highlighting potential component weakness, (Pham et al., 1995)

3 Ultrasonic Testing

Ultrasonic Testing was developed to allow testing of a variety of materials and components. It is the use of sound waves moving through a material and interpreting this to help define material properties and defects.

3.1 Scientific Principles of the Technique.

Ultrasonic Testing uses sound frequencies to detect any discontinuities. Sound waves are emitted from a probe, when they encounter a surface they bounce back and are picked up, to be displayed, by a receiver. If the speed of the emitting sound and the distance travelled to and from the receiver is known, the operator can determine where the deformity is in the part and even what the deformity is.

The sound frequencies used are above what is heard by humans, generally between 500kHz – 25MHz (Guidance Document, 2015) Different frequencies are used for different purposes and materials. It is important to use the appropriate frequency for the purpose as

this will affect the results of the inspection. There are two means that detect defects when using Ultrasonic Testing; sensitivity and resolution. Sensitivity helps to detect the discontinuities, whereas, resolution helps to define the deformities even when they are close together. Accuracy of measurement can depend on material type and refinement of both sensitivity and resolution depends on the ability to penetrate component material. There is a greater penetrative ability when the frequency is lower, but this can make it less sensitive to defects, alternatively high frequencies can't penetrate as deep but can pick up smaller discontinuities (Cartz,1995)

There are four main components used in Ultrasonic Testing; ultrasonic flaw detector, a connecting lead or cable, an ultrasonic probe and a couplant. As air is a poor conductor of sound waves a liquid or gel couplant is used to help the sound waves travel. The ultrasonic flaw detector has a screen and various controls to display information. A voltage pulse is fired, which vibrates crystals at a high frequency. The couplant is applied to the part to be inspected, followed by the ultrasonic probe. Defects are highlighted as the sound wave reflects on any surface in their path. The wave is then converted into an electrical signal and displayed on the screen. There are two common types of sound waves used for NDT. Compression waves, where the atoms vibrate parallel to the direction of sound, and Shear waves, which travel perpendicularly to the direction of sound and travel half the speed of compression waves. The type of wave produced will depend on the angle of the ultrasonic probe (Baldev et al., 2007)

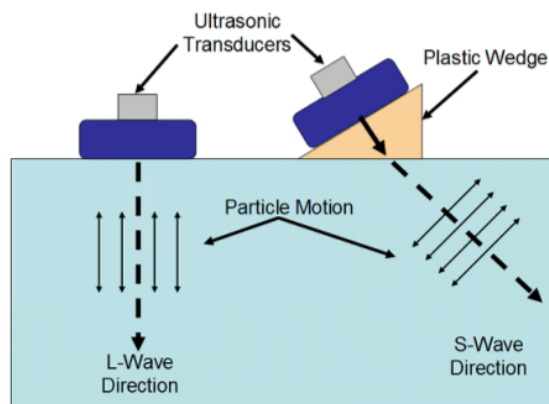


Image 1: Illustration of compression and shear wave direction (TATA, 2014)

The angle of the wave is important and must be understood by the inspector. The purpose of having the ability to create different waves can help identify the different faults and where they are positioned in the material. It is also possible for probes to have the ability to have

various waves in different directions which if interpreted correctly can help detect multiple defects. (Hughes, 2009)

3.2 Advantages and Disadvantages.

By using Ultrasonic Testing methods, an engineer can determine the mechanical properties and microstructure of a part as well as using it for imagery and microscopy purposes. Ultrasonic Testing as an NDT method is low cost and portable. The inspector can carry the relevant equipment to various locations in order to conduct a thorough inspection. Once the initial outlay of training and the cost of the equipment has been made, there is very little extra cost associated with Ultrasonic Testing. Ultrasonic Testing can be used on most material, excluding plasma and a vacuum (Mix, 2005)

There are situations and scenarios where the use of Ultrasonic Testing is not as effective as other available methods. The results of the inspection will only be as effective as the inspector undertaking it, this also includes the equipment and material preparation. The material should be accessible and clean for the inspection. The inspector should also be competent and familiar with the material that is to be tested, and as such should recognise the difference between inclusions in the material and defects. It is vitally important for the inspector to choose the right equipment and set up for the purpose to ensure that all defects are identified and detected. This is sometimes made possible by using a variety of probes and transducers. Resolution capabilities of the material and equipment will ultimately affect the ability to efficiently size the potential defect. There are also potential for human errors to occur with this method. It relies on the knowledge and experience of the inspector as well as the chosen set up and data interpretation. (Gardner, 1992)

3.3 Sources of Error and Assumptions

Similarly, to Visual Inspection, Ultrasonic Inspection can also be susceptible to human error as it relies on human interpretation of data. The inspector can make assumptions on the material used and the manufacture of it. The material can include many marks from manufacture which can be unnecessarily included if the inspector is not familiar with the material or the process. The inspector will have to be adequately trained and experienced with the material that is to be tested as well as familiar with the equipment that is being used. The data is to be interpreted and what, if any, the anomalies mean. If the inspector has comprehensive understanding of the capabilities of the method, Ultrasonic Testing is a very efficient way of detecting deformities and defects (HSE 1, 2000)

3.4 Typical Applications

Ultrasonic Testing is used to help engineers monitor and determine the condition of a material. It can identify the size, shape and type of defect both sub-surface and on the surface of metallic materials. Ultrasonic is a good method of portable inspection and because of this it is used widely for in-situ testing. This makes it ideal for inspection on components that are not easy to relocate for inspection purposes such as rail tracks and aircraft part inspection (Hull and John 1988). Ultrasonic Testing can detect any fatigue cracks in these components before visual identification can be made, and with this information failure of the parts can be prevented. Ultrasonic Testing can help engineers to understand thickness and properties of a material and how it is being affected by external factors or deteriorating over time.

Although, generally Ultrasonic Testing is undertaken by an NDT inspector there are examples of automated systems being used, specifically immersed or remote applications which can be programmed to conduct routine inspections throughout the manufacturing process and for final component inspections. Specific probes and transducers are made for certain applications and will vary depending on whether the inspector is looking for material thickness or fatigue cracks. It is vital the right equipment is used for the right application (Hull and John, 1988)

Good

4 Dye Penetrant Inspection

Dye Penetrant Inspection is the application of a liquid to a pre-prepared surface. It is used to highlight any surface defects of a part and is considered a quick and easy method to help inspectors recognise any surface issues on materials.

4.1 Scientific Principles of the Technique

There are several steps that are required for an effective Dye Penetration Inspection. Before inspection can start the surface of the material must be prepared. It is vital that this is conducted effectively as the results can be influenced, the surface needs to be clear of any contaminants that could affect penetration of the dye. Secondly, the dye is to be applied to the surface; the dye needs enough time to penetrate thoroughly (Penetrant Dwell Time) this is set by the manufacturer of the dye and will be dependent on the material type and the type of possible defects. Any excess Penetrant is to be removed and a developer applied. This will help draw the Penetrant to the surface of the material in order to be identified by the inspector. Once this has developed the inspection can then take place. The data is recorded and analysed. Once the inspection is complete, the surface is then to be cleaned and any residue left to be removed from the part. (HSE 2, 2000)

4.2 Advantages and Disadvantages

Dye Penetrant Inspection is very sensitive to small surface deformities and large parts can be inspected relatively quickly and at a low cost. Complex and intricate parts can be inspected with very few complications. The cost of equipment is low and can be made portable with the use of aerosol cans and brushes. The greatest benefit of this method is that it has very few material limitations and so can be undertaken on a component that is made up of composites or a variety of materials. (HSE 2, 2000)

As always there are disadvantages to this method. Access to the part is important and again the inspection is only as effective as the inspectors' knowledge and understanding of the process and material. It is critical for the part to be properly prepared as any defect or roughness can affect the results. The result can also be affected by any material processing that affects the surface of the material such as machining or surface blasting, as well as extreme temperatures. Chemicals are involved in the process and as such it is important for the inspectors to consider proper handling and disposal of the Penetrant after the inspection is complete. Although this method can be used on a wide variety of materials, it is not suitable for non-porous materials as the dye is absorbed by the material and cannot be picked up by the inspector (Welding Inspectors, 2019). Unfortunately with this method it is not possible for the inspector to identify how deep the defect is or if there are any deformities that lie under the surface of the material.

4.3 Sources of Error and Assumptions

This method is susceptible to errors and assumptions because of the simple approach of inspecting defects that are visible after dye application. By not fully comprehending what potential defects can occur, inspectors can equally miss defects or include marks that are not relevant. If the part is not prepared sufficiently the inspector can misinterpret some of the defects. As previously discussed, this method is only as effective as the personnel conducting the inspection (Mix, 2005)

4.4 Typical Applications

As Dye Penetrant Inspection can examine a variety of materials it is used to identify a variety of defects in many industries including aerospace, automotive and power generation. Engineers use this method to test a wide range of components in a variety of situations. Dye Penetrant is useful to detect, fatigue and grinding cracks, overload and impact fractures, pin holes and laps in welds and joints (British Standard BS EN571-1, 1997). This method is useful in examining cast components and welded materials after manufacture, as any cracks or defects are highlighted before they are sent to the end user. As it can be applied to both

small components or large it is used in many applications including framework and spark plugs (Hull and John, 1988). Dye Penetrant Inspection can also be applied to vessels and pipe work to determine if it is leaking fluid or gases. When the Penetrant is applied to one surface, any areas that are not sealed will show the dye from the other surface. (ASME, 2014) It can be used to help high volume inspection that need to be undertaken. Dye Penetrant Inspection can also be used on glass and plastic applications so engineers can employ this method to test composite materials and components that need to be inspected but are comprised of a variety of materials.

5 How NDT Results can be Used to Improve Stress Analysis

Results from NDT methods can help to improve stress analysis by furthering the knowledge already available for inspectors. Non-Destructive Testing methods have varying levels of ease and depth of inspection but all help to collect information and knowledge. This information can then be used by industries to gain further understanding of how material defects perform under certain circumstances, processes and external factors. This information helps industries to prevent total part failure and to maintain current applications. It helps engineers to plan maintenance schedules and budget requirements.

By developing advanced NDT methods residual stress analysis is more defined. Engineers can understand how cyclic stresses, loading and forces will affect properties of a material and component while in situ (Kudryavtsev, 2004). As the advancement of technology has increased so has the level of inspection that can be performed on components. Due to which asset owners are now expected to have a better understanding of their components and how well maintained they are. Engineers have an improved knowledge of how material degradation can and will occur, therefore they can create more detailed assessments of their assets and how they are being affected by the application stresses (Wintle et al., 2001).

NDT methods can help determine the residual stress on a component. These are stresses that are not caused by external factors and are explained by Dobmann (2001);

- Thermal residual stresses that arise due to cooling of different cross sections of homogeneous materials or of compounds of materials with different thermal expansion coefficients
- Residual stresses that arise due to forming operations under applied mechanical stresses,
- Residual stresses that arise due to inhomogeneous and/or time independent phase transformations in the microstructure.

By understanding the residual stresses and how they affect component longevity and stability can help determine how effective current material selection is and how critical that is going forward.

It is important to understand that NDT methods are more effective if multiple methods are used in conjunction with each other. The advanced technology available to engineers has enabled operational loading and stress intensity factor to be calculated and understood (Trampus and Krstelj, 2018) with which engineers and industry are now able to choose the most suitable material available for the application. It enables engineers to maintain the component while in service. The potential weaknesses have been highlighted and preventative maintenance can take place. This can also help prevent further weakening as through detailed analysis of the collected information, the next weak spot can be determined and prevented from failure by engineering methods such as support work or maintenance. There are limitations to all three of the processes discussed in this report with the main one being the reliance on human interpretation of the data collected. However, if a combination of NDT methods are used this eliminates the reliance on individuals for the information.

6 Conclusion

This report has discussed three methods of NDT, including advantages and applications. All of which have applications that are more suited, however, it is best to use a combination of NDT methods for a thorough stress analysis of a component. The results provided can help inform engineers and provide a more in depth understanding of the stresses on a component and how to manage these successfully.

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4. Contextualisation(+)

1.

Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

64/100

PAGE 1

PAGE 2



5. Structure (+)

Good explicit structure that clearly addresses the brief.



5. Presentation(+)

Generally your presentation is good

PAGE 3

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PAGE 5



Comment 1

Very specific to your reference.

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PAGE 10

**Good****Improving MoM**

Generally NDT can be used to find defects within a part. This helps stress analysis as these defects are assumed to be absent in most calculations. During Mechanics of Materials analysis, typically a certain cross section/stiffness/UTS is assumed - the presence of any defects will mean that these assumptions are incorrect and these nominal stresses need to be altered accordingly.

**4. Contextualisation(+)**

Good Contextualisation

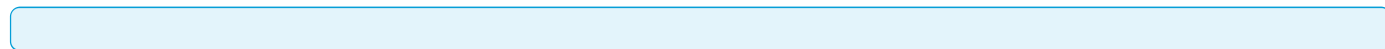
**1. Secondary(+)**

Good secondary research

GRADING FORM: ADVANCED STRESS 1920 PT NDT

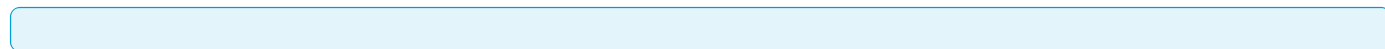
AIMEE DAVIES**64.25****RESEARCH-INFORMED LITERATURE****16.5**

KNOWLEDGE AND UNDERSTANDING



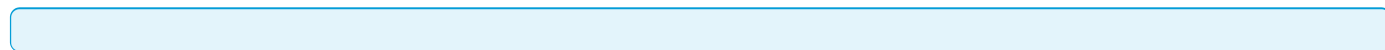
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PRACTICAL APP



25.6

PROF PRAC



6.4