

Nathan Jones - Advanced Stress

by Nathan Jones

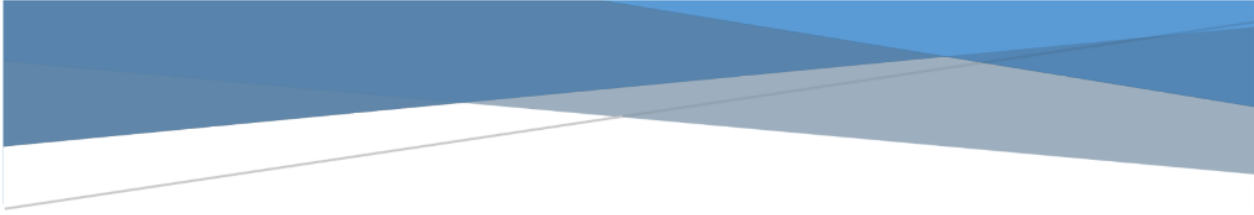
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ADVANCED STRESS ANALYSIS & FEA NDT Techniques

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1. EXECUTIVE SUMMARY

This report intends to look at how separate non-destructive testing methods can be used and the reasons why they can be used as oppose to traditional destructive methods of testing.

The non-destructive testing method of using ultrasonic as a mode of testing will be analysed to understand how through the use of ultrasonic waves defects in materials and components can be identified. The advantages, disadvantages and typical applications will also be reviewed to understand how and where this technique could be used.

A review of infrared testing will then be studied to understand how this process works and where this application could be used. Once this has been established a understanding of this process can help with regards to stress analysis will be drawn up.

Visual testing, the final method of NDT will then be examined to find out how this process works, the advantages and disadvantages and the potential errors and assumptions which need to be taken into account to achieve the best outcome will be reviewed allowing for all three processes to be understood.

Once all three methods are fully reviewed and understood a conclusion will be drawn up to explain why a specific method may be chosen as oppose to the others.

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5. Structure (-)

2. INTRODUCTION

This report is going to take a look into what non-destructive and destructive testing is as a whole within the engineering and manufacturing environment, it will then also evaluate what stress analysis is and how and why it is used within engineering.

Once a description of non-destructive testing has been drawn up, this report will then look to analyse three separate types of non-destructive testing (NDT), it will analyse ultrasonic testing, infrared testing and visual inspection.

For each of these three NDT methods an understanding of the process and the science behind it, the advantages, disadvantages, the potential errors and assumptions involved with using it, the typical applications and how these methods can improve stress analysis will be drawn up and then a conclusion of why a method may be chosen over the other will be described.

3. FINDINGS

3.1 NDT AND TRADITIONAL DESTRUCTIVE TESTING

What is Non-destructive Testing?

Non-destructive testing or NDT is a process which is used to analyse material and components to test for defects, and discontinuities within the material without causing any damage, meaning that once the evaluation has been complete the components would still be usable (Testing, 2019). (Deane, et al., 2019) and (Trampus, et al., 2019) also discuss NDT as a method in which the operator is guaranteed to remain safe whilst also gathering reliable data without damaging the integrity of the material being evaluated, but also is significant within the manufacturing and assembly process to help increase quality and reduce production imperfections (Dattoma, et al., 2018). When performing non-destructive testing there is a wide variety of different techniques available dependant on the environment, material and outcome required, all these variables need to be taken into account when identifying the method which is going to be used (TWI, 2019). "If the scope of work is straight forward, using a single test method is acceptable. However, there are times when a single test method does not provide enough information on the problem, and thereby combining different methods is essential. Knowing the advantages and limitation of each test method is key to applying the right combination of test methods to the evaluation (Lim & Cab, 2013) which agrees with (TWI, 2019) on selecting a method based of the required outcome.

What is traditional destructive testing?

Destructive testing is a method in which a material is destroyed in order to gain information with regards the materials mechanical properties. These properties can include the "strength, toughness and hardness" (Usama, 2015), (Testing, 2019) also states that when performing destructive testing the "physical properties of materials such as impact resistance, ductility, yield and ultimate tensile

strength, fracture toughness and fatigue strength” are what is found, although this testing can only be carried out on a sample of material due to its destructive nature. Similarly to non-destructive testing there is a wide variety of testing methods which can be completed, all of which have their own unique testing technique in order to gather and evaluate the test data (Woodhead Publishing, 2014).

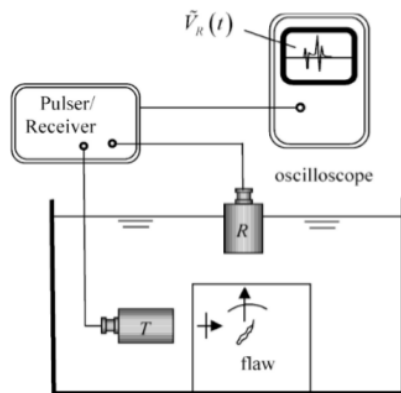
3.2 STRESS ANALYSIS

Stress analysis is a vital part of engineering due to the fact that the majority of engineering component failure is due to stress, and this affects all aspects of engineering whether its aerospace, marine, nuclear or architectural (Case, et al., 1999). Sometimes it can be very easy to identify when a material or structure is under stress but (NDT, 2019) describes the fact that stresses can remain inside of a material even “after the original cause of the stresses has been removed” which can be very difficult to identify without the use of NDT techniques, this agrees with (Sanderson, et al., 2019) who states internal stresses can cause structural failure unless non-destructive testing techniques “are routinely used to inspect structures for flaws.”

3.3 ULTRASONIC TESTING

- What is Ultrasonic Testing?

Ultrasonic testing is a non-destructive testing method which through the use of high frequency soundwaves can accurately identify the thickness or internal structure of the component being analysed (EWP, 2019), (Blitz & Simpson, 1984) also explain that ultrasonic testing can identify defects and thickness' of materials by measuring the time taken and change in frequency intensity. "The frequencies, or pitch, used for ultrasonic testing are many times higher than the limit of human hearing, most commonly in the range from 500 KHz to 20 MHz. (EWP, 2019)"



(Fig. 1) (Chen, 2007)

Looking at (Fig. 1) it can be seen that using ultrasonic testing has the ability to detect sub surface defects, this is due to the way ultrasonic testing works. Ultrasonic testing typically consists of several units, "a pulser/receiver, transducer and display device" the transmitter (pulser) is a unit which produces high voltage electrical pulses which in turn allows the transducer to generate high frequency soundwaves. The soundwaves then pass through the material and where discontinuities such as cracks will then be reflected back to the receiver, the new wave signal will then be displayed up on oscilloscope (NDT Resource Center, 2019).

- Advantages of Ultrasonic Testing?

When carrying out ultrasonic testing there is multiple advantages for using this technique as it can be used for most commonly used materials, as well as being highly accurate for locating and measuring defects (Blitz & Simpson, 1984), but also the fact that only one surface needs to be accessible due to the high penetration power achievable and that it can be made into an automated process to test manufactured components for quality assurance purposes (InstTools, 2019), as well as being automated it can also be mobile allowing for fast testing “in the field” (Gholizadeh, 2016). Additionally a major advantage to using ultrasonic testing for NDT is the overall effectiveness, capability, flexibility and cost implications which this method entails (Chen, 2007).

- Disadvantages of Ultrasonic Testing?

Although ultrasonic testing has its many advantages there is also drawbacks to this method, firstly it is “difficult to set up”, requires skill and knowledge to accurately scan a component and initial calibration can be tough due to the need of a near perfect test sample (Gholizadeh, 2016). (Blitz & Simpson, 1984) Also stated that “operators must be properly trained, experienced and possess a high degree of reliability and integrity” although having an automated process can make testing and inspection easier.

- Potential sources of error and assumptions that need to be made

When using ultrasonic testing as a form of NDT there is number of assumptions which need to be taken into account, (Yan, et al., 2018) states that there is a “series of assumptions, such as: objects have the characteristics of continuity and uniformity, objects are hyperelastic, microvariations of ultrasonic wave are superimposed on the finite deformation of the objects, and the deformation process is isentropic”, as long as these conditions are met then the component can be tested

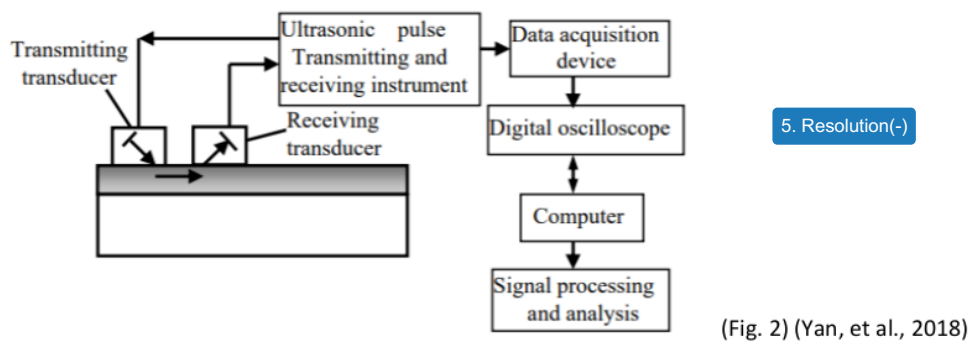
ultrasonically and can also then be analysed for the stress within the material, also when looking at ultrasonic testing there is also nonlinear tests for measuring stress based on nonlinear ultrasonic waves propagating through the material.

- Typical applications that use Ultrasonic Testing NDT

Ultrasonic testing has multiple applications due to its speed, accuracy, material choices and automation capabilities. Common applications for ultrasonic testing are for quality inspection of components on an assembly lines (Gholizadeh, 2016), testing for defects in welded structures, flaws in pipework and also for “forging and casting applications” (Buchler, 2002).

Additionally due to the advancement of additive manufacturing, ultrasonic testing has played a major part with verifying the integrity and quality of the component by being able to inspect the external and internal features of the 3D model (Lawley, 2015), to ensure that the component is suitable for its intended role.

- How the results of Ultrasonic Testing can be used to improve stress analysis

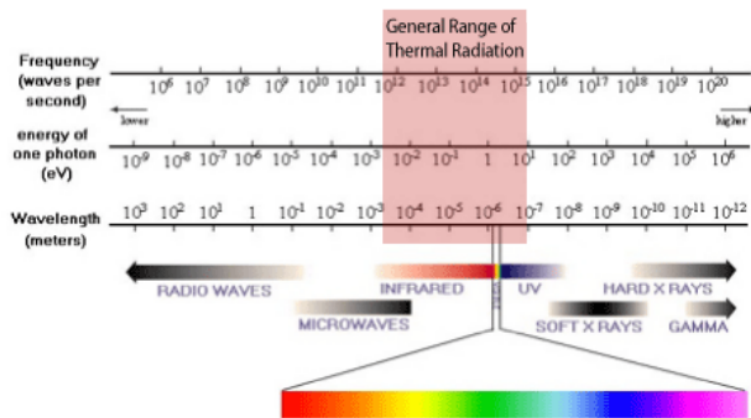


Looking at (Fig. 2) it can be seen that this is a classical stress measurement device, it works by using ultrasonic wave velocity/stress which then through the use of computer programming can then analyse the data obtained to understand the stress within the material. The main methods for testing stress through the use of ultra sonics is “the use of the relationship between ultrasonic velocity and stress; ultrasonic attenuation degree and stress; incident angle of Rayleigh wave and stress; echo power spectrum and stress; the interaction of acoustic beams and stress” (Yan, et al., 2018). (Deveci, 2003) also states that ultrasonic analysis can measure stress levels within a component, by measuring the time taken for the “ultrasonic wave’s time between sensor and transition zone is calculated. The stress calculation is based on velocity measurement of the ultrasonic wave” this directly agrees with (Yan, et al., 2018). Although in order to calibrate ultrasonic testing for stress measurement a stress free sample is required, but there has been specifically designed hardware for stress testing using ultrasonic measurements.

3.4 INFRARED TESTING

- What is Infrared Testing?

Infrared testing is a very common non-destructive testing method which offers a wide area of detection for surface and subsurface defects (Maldague, 2002). This is due to the ways in which infrared testing works, this method of non-destructive testing allows for temperature differences between “two objects or two areas within the same object” to be observed using a device which can see within the infrared frequency spectrum (NDT Resource Center, 2011), this correlates with what (Huff, et al., 2012) stated about all materials radiating infrared energy and how using an observation device “shows apparent surface temperature differences and thermal patterns across an object.”



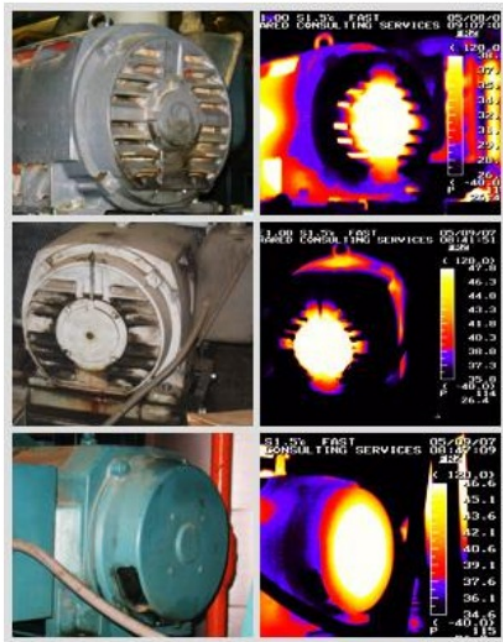
(Fig. 3) ((NDT

Resource Center, 2011)

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Looking at (Fig. 3) it can be seen that there is a wide range in which thermal radiation is present, but due to the long wavelengths not all radiation is visible to the human eye which is when a device such as an infrared camera is required, but once the material heats significantly the wavelengths shorten and can then be seen by the human eye in the form of colour change of the material, this means that using testing devices allows for damage to be identified before it is visible to the operator (NDT Resource Center, 2011).

Looking at (Fig. 4), it can be seen that although there is heat dissipating from the electrical motors it can't be seen by the human eye, but can be seen using thermal imaging cameras, which supports what (NDT Resource Center, 2011) states.



(Fig. 4) (ICS, 2019)

When looking at infrared testing, (Maldague, 2002) states that it can be split into two categories, these being passive testing and active testing, passive being for when “materials and structures which are naturally at different (often higher) temperature than ambient” whereas active testing requires an external stimulus to “induce relevant thermal contrasts”, this is also states by (Avdelidis, et al., 2011) who discuss active and passive infrared testing being used due to its wide material range.

- Advantages of Infrared Testing

Using thermography has a number of advantages within non-destructive testing, this can be down to its ease of use and speed (Meola & Carlomango, 2002), but also the fact it can identify near invisible defects such as separations, cavities and inclusions safely (Terumi, et al., 1999). (Huff, et al., 2012) also agrees that infrared testing is a fast process which can be completed in-situ and cover a large area.

- Disadvantages of Infrared Testing

Although infrared testing has its advantages, there is also disadvantages which occur when using this NDT method, when carrying out infrared testing the component must be different to the temperature of the surrounding area otherwise the image will be unresolvable, unless a thermal contrast has been created (Huff, et al., 2012) (Maldague, 2002).

- Potential sources of error and assumptions that need to be made

In order to get accurate, reliable results from infrared testing it is important to ensure that there is no reflections from surrounding objects, the infrared camera is correctly calibrated, the operator has knowledge and understanding of surface emissivity and that each individual pixel within the image has its own individual temperature value (Ford Motor Co, 2018). Although (Manuel, et al., 2016) states “temperature measurement errors may occur when the thermal radiation of the surroundings is reflected onto the measured object and is thus captured by the thermal camera”, this agrees with what was detailed about infrared testing by (Ford Motor Co, 2018).

- Typical applications that use this technique

Infrared testing has a wide range of applications from aerospace components (Deane, et al., 2019), to civil engineering and restoration of listed buildings (Clark, et al., 2003), when looking at civil engineering it can be used to discover how a building is performing such as “how heat energy is leaking from a building, and other anomalies such as water infiltration and moisture” (Usamentiaga, et al., 2014) . As well as these applications it is also used in mechanical systems such as pumps, bearings and pulleys to ensure these pieces of equipment are operating correctly (Henderson, 2008), (Matais & Armando, 2014) also agree that this technique is used widely to analyse mechanical systems but also for “civil structures”, another application is testing for material thinning due to corrosion, and electrical component inspection for ensuring heat isn’t causing accelerated wear to components (NDT Resource Center, 2011) and to help increase the longevity of these components.

- How the results of infrared testing can be used to improve stress analysis

When using infrared testing to help improve stress analysis it has been found that due to the improvement in “digital image processing methods” thermal stress, crack detection and stress concentration positioning has been widely improved as multiple images can be overlaid to directly locate the defect, and also using a method known as “SPATE (stress pattern analysis thermal emission)” (BINDT, 2013) it has also been proven to obtain accurate predictions for where failure will occur, allowing additional stress measurement devices such as stress gauges to be placed to allow for further analysis (Bremond, 2007). Once the digital image has been taken it can then also be stored and measured to compare, allowing for a comparison of the defect in the future to study how the defect is behaving (Ford Motor Co, 2007).

3.5 VISUAL TESTING

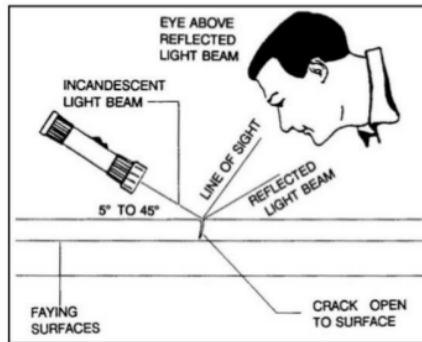
- What is visual testing?

Visual testing is a form of non-destructive testing which is known to be the most commonly used method of NDT used across all industries according to (NDT, 2019), this is also stated by (Applied NDT, 2019) who says that visual testing is the most extensively used NDT method to evaluate the condition of components. The typical defects which are normally found when carrying out visual testing are: cracks, corrosion, misalignment of parts and discolouration (TX NDT, 2019). When carrying out visual inspection there is a wide variety of additional optical aids which are available to the operator in order to help identify surface defects upon a component (BINDT, 2019), these aids can be such things as basic magnifying glasses to a borescope. It is said that through the use of the operators eyes and optical aid any surface defect should be able to be identified as long as the surface is cleared of all “rust, scale, dirt, paint, oil, metal spray and other impurities that prevent inspection” (Gavrish, 2013). Visual inspection is still widely in use today down to the fact it can be used in almost all industries and environments due to the visual aids which can be placed inside these restricted environments and operated remotely to ensure the safety of the operator (BINDT, 2019). Due to human vision “combined with instant, cognitive abilities of the human brain” visual testing can be highly accurate as the operator has the ability to “scan, measure, and detect depth, color, and flaws with great precision” (Baker Testing Services, 2019), this agrees with (Gavrish, 2013) stating the operators eyes can detect any surface defects.



(Fig. 5) (Klaus Gross, 2019)

It can be seen in (Fig. 5) a basic magnifying glass, and an endoscope both being used to inspect the internal bore of a tube for any defects.



(Fig. 6) (Baraan, 2009)

(Fig. 6) shows that using an additional aid such as a torch to shine light onto a surface being inspected can help bring up defects due to the reflected light beam, this in-turn allows the inspector to identify the defect.

- Advantages of Visual Testing

The major advantages to using visual testing as a form of NDT is that it is a highly useful method due to the speed, reliability and very little cost implications (Baker Testing Services, 2019), it is also said that visual inspection has very little limitations and has a wide range of applications. It is also said that due to it only being surface defect detection the part preparation is minimal and the process is very portable due to the equipment used (TX NDT, 2019), this allows for inspection to be carried out quickly and within the manufacturing environment, without having to put a stop to production (Ford Motor Co, 2007). (Inspectioneering, 2019) also state an advantage of visual testing to be “it is also one of the most reliable techniques. A well-trained inspector can detect most signs of damage.”

- Disadvantages of Visual Testing

Although there are advantages to using visual inspection there is also a variety of disadvantages such as poor lighting and surface preparation requiring time (BINDT, 2019), this contradicts (TX NDT,

2019) who states the process is quick due to minimal surface preparation being required. Additional disadvantage include that the process only allows for surface flaws to be detected and there is the possibility of the flaw being misinterpreted. “Although easy to learn, to become a visual inspector it requires qualification” which does then help improve knowledge and reduce the chance of misinterpretation of defect (TX NDT, 2019). (Baraan, 2009) states that working environment factors can also affect the accuracy of visual inspection dependant on temperature, noise and vibration.

- Potential sources of error and assumptions that need to be made

When carrying out visual testing as a form of NDT there are a few potential sources of error which can occur down to the fact that only surface defects can be identified meaning a flaw might be left unidentified if it is below surface level, and the eyesight of the inspector could potentially have deteriorated meaning a flaw could be missed (TX NDT, 2019). When using visual inspection as the only method of testing can cause error such as the results of an experiment carried out in Sandia National Laboratories which resulted with “Inspectors correctly rejected 85% of defective items and incorrectly rejected 35% of acceptable parts,” meaning human error can play affect (See, 2015). It is also stated that knowledge and experience is more important than certification because when completing the qualification to become an inspector it is assumed that “the character samples will be easier to inspect” meaning that real world experience should improve the operators work quality (Kavuri, 2015).

- Typical applications that use Visual Testing NDT

Due to the way visual inspection works there is a wide variety of industries which it is used, these can include: “bridge inspection, building, castings and forgings, pipe and pipelines and power plants” (Baker Testing Services, 2019), other industries include manufacturing of aerospace components, and assembly, to ensure that all parts are 100% checked prior to assembly (Rolls Royce , 2019). It is

said that visual testing is actually used in all industries in some way or other, this is due to the operator visually checking the parts, although they might not have official certification they have experience which would allow them to identify minor defects which they could then inform a certified inspector to come and identify the issue (Schoonahd, et al., 1973).

- How the results of Visual Testing can be used to improve stress analysis

It has been found that visual testing methods are the most commonly used methods for stress analysis within industry due to how widespread observational methods are (Genaidy, et al., 1994), this agrees with a statement by (Elbeheri & Zayed, 2016) who state “visual inspection is the most common technique for steel bridges inspection but it depends on the inspector experience and conditions” and that visual inspection can “note important structural components such as fracture critical members and fatigue prone details” allowing for additional stress analysis methods to be carried out, this was also stated by (Bader, 2008).



4. CONCLUSION AND RECOMMENDATIONS

After reviewing the three non-destructive testing methods in section 3, it can be seen that all the methods each have their own advantages and disadvantages, it can also be seen that certain methods are more commonly used than others.

Using the information gathered in section 3 it can be seen that visual testing is the most commonly used NDT method due to the wide range of industries which it is used in but also due to the speed and reliability of defects that can be detected (Baker Testing Services, 2019). As well as being very common there are also a few disadvantages to using this process as it only allows for surface defects to be detected and human error can result in missed flaws (See, 2015).

It was found that ultrasonic testing has a large number of advantages due to it being able to work with most commonly used materials, is highly accurate for locating and measuring defects and the fact only one surface needs to be accessible (Blitz & Simpson, 1984). Another benefit to using ultrasonic testing is that it is very common for use within stress analysis (Deveci, 2003).

The third method is infrared testing, this method is also very popular due to its wide range of applications due to surface and subsurface defects being detected (Maldague, 2002), this is also due to near invisible defects such as separations, cavities and inclusions being identifiable (Terumi, et al., 1999). This method is also used extensively for helping with stress analysis due to stress concentration and thermal stress being able to be located (BINDT, 2013).

After reviewing all three methods it has been found that although each method has its own advantages and disadvantages there are times when a single test method does not provide enough information on the problem, and thereby combining different methods is essential, this could mean that all three methods might be required to accurately diagnose a defect within a component, dependant on the environment, flaw and required result (Lim & Cab, 2013).

5. WORKS CITED

- Applied NDT, 2019. *Visual Testing*. [Online]
Available at: <http://www.appliedinspection.co.uk/ndt/visual-testing/>
[Accessed 7 November 2019].
- Avdelidis, N., Gan, T. & Castanedo, C., 2011. *Thermal Infrared Applications*, Florida : Society of Photo-Optical Instrumentation Engineers.
- Bader, J., 2008. *Nondestructive Testing and Evaluation of Steel Bridges*, Maryland : ENCE 710.
- Baker Testing Services, 2019. *Visual Inspection*. [Online]
Available at: <http://www.bakertesting.com/index.php/visual-inspection>
[Accessed 8 November 2019].
- Baraan, J., 2009. *Visual Inspection of Composite Structures*, EU: EASA.
- BINDT, 2013. *Stress measurement*. [Online]
Available at: <https://www.bindt.org/What-is-NDT/Stress-measurement/>
[Accessed 6 November 2019].
- BINDT, 2019. *Visual Inspection*. [Online]
Available at: <https://www.bindt.org/What-is-NDT/Visual-inspection/>
[Accessed 8 November 2019].
- Blitz, J. & Simpson, G., 1984. *Ultrasonic Methods of Non-destructive Testing*. 1 ed. London: Chapman & Hall .
- Bremond, P., 2007. New developments in Thermo Elastic Stress Analysis. *AAENDE*, 1(1), pp. 1-11.
- Buchler, J., 2002. *European Conference on Nondestructive Testing*. Barcelona, ECNDT.
- Case, J., Chilver, L. & Ross, C., 1999. *Strength of Materials and Structures*. 4 ed. London: Elsevier.
- Chen, C., 2007. *Ultrasonic and Advanced Methods for Non-destructive Testing and Material Characterization*. 1 ed. New Jersey: World Scientific .
- Clark, M., McCann, D. & Forde, M., 2003. Application of infrared thermography to the non-destructive testing of concrete and masonry bridges. *NDT & E International*, 36(4), pp. 265-275.
- Dattoma, V., Nobile, R. & Saponaro, A., 2018. NDT thermographic techniques on CFRP structural components for aeronautical application. *Procedi Structural Integrity*, 8(1), pp. 452-461.
- Deane, S. et al., 2019. Application of NDT thermographic imaging of aerospace structures. *Infrared Physics & Technology*, 97(1), pp. 456-466.
- Deveci, M., 2003. *MEASUREMENT METHODS OF RESIDUAL STRESSES*, VAAJAKOSKI: SAE International.
- Elbeheri, A. & Zayed, T., 2016. *Non-destructive Evaluation Techniques for Steel Bridges Inspection*, Toronto: Transportation Association of Canada.
- EWP, 2019. *Ultrasonic Testing*. [Online]
Available at: http://www.wermac.org/others/ndt_ut.html
[Accessed 3 November 2019].

Ford Motor Co, 2007. *Condition Based Monitoring*. Bridgend: Ford.

Ford Motor Co, 2007. *QPS - Visual Inspection 100% Check*. Bridgend: Ford Engineering .

Ford Motor Co, 2018. *Infrared Testing*. Bridgend: Ford, Emerging Technologies.

Gavrish, A., 2013. *Visual Testing (VT)*, Riga: TUV NORD.

Genaidy, A., Shedi, A. & Karwowski, W., 1994. Postural stress analysis in industry. *Applied Ergonomics*, 25(2), pp. 77-87.

Gholizadeh, S., 2016. A review of non-destructive testing methods of composite materials. *Procedi Structural Integrity* , Volume 1, pp. 50-57.

Henderson, B., 2008. *Analyzing Mechanical Systems Using Infrared Thermography*. [Online]
Available at: <http://www.maintenanceworld.com/analyzing-mechanical-systems-using-infrared-thermography/>
[Accessed 1 November 2019].

Huff, R., Spring, R. & Schwoegler, M., 2012. Infrared Thermography-A Versatile Nondestructive Testing Technique. *Quality Magazine* .

ICS, 2019. *Infrared Mechanical Systems Inspection*. [Online]
Available at: <https://irtest.com/sevices/infrared-mechanical-systems-inspection/>
[Accessed 30 October 2019].

Inspectioneering, 2019. *Overview of Visual Inspection*. [Online]
Available at: <https://inspectioneering.com/tag/visual+inspection>
[Accessed 8 November 2019].

InstTools, 2019. *Ultrasonic Testing (UT) : Principle, Advantages, Disadvantages*. [Online]
Available at: <https://instrumentationtools.com/ultrasonic-testing/>
[Accessed 4 November 2019].

Kavuri, S., 2015. *Size Effects in Human Visual Inspection for Micro/Meso Scale Parts* , Lincoln: University of Nebraska.

Klaus Gross, 2019. *Visual Testing*. [Online]
Available at: <https://www.klaus-gross.com/en/vt.html>
[Accessed 8 November 2019].

Lawley, P., 2015. Applications of Ultrasonic Non-Destructive Testing in 3D Printing. *The Journal of Undergraduate Research*, 13(4), pp. 27-42 .

Lim, M. & Cab, H., 2013. Combining multiple NDT methods to improve testing effectiveness. *Construction and Building Materials* , 38(1), pp. 1310-1315.

Maldague, X., 2002. *Introduction to NDT by Active Infrared Thermography*, Quebec City: Université Laval.

Manuel, M., Lin, S., Lu, W. & Lin, P., 2016. *Errors in Thermographic Camera*, Taoyuan: Department of Mechanical Engineering at Chung Yuan Christian University.

Matais, R. & Armando, A., 2014. *Robust Speckle Metrology Techniques for Stress Analysis and NDT*. 1 ed. Florianopolis: SPIE.

Meola, C. & Carlomango, G., 2002. Comparison between thermographic techniques for frescoes NDT. *NDT & E International*, 35(8), pp. 559-565.

NDT Resource Center, 2011. *Scientific Principles of Thermal Testing*. [Online]
[Accessed 29 October 2019].

NDT Resource Center, 2019. *Basic Principles of Ultrasonic Testing*. [Online]
Available at: <https://www.nde-ed.org/EducationResources/CommunityCollege/Ultrasonics/Introduction/description.htm>
[Accessed 3 November 2019].

NDT, 2019. *Introduction to Nondestructive Testing*. [Online]
Available at: <https://www.asnt.org/MinorSiteSections/AboutASNT/Intro-to-NDT>
[Accessed 7 November 2019].

NDT, 2019. *RESIDUAL STRESS ANALYSIS*. [Online]
Available at: <https://www.ndt.com.au/product-category/residual-stress-analysis/>
[Accessed 2 November 2019].

Rolls Royce, 2019. *Visual Inspection - Standard Operating Procedures*. Bristol: Rolls Royce.

Sanderson, R., Wee, F., Day, A. & Blackwell, S., 2019. *THE USE OF NON DESTRUCTIVE TESTING TECHNIQUES FOR RESIDUAL STRESS MEASUREMENT*, Cambridge: TWI Industrial.

Schoonahd, J., Gould, J. & Miller, L., 1973. Studies of Visual Inspection. *Ergonomics*, 16(4), pp. 365-379.

See, J., 2015. *Visual Inspection Reliability for Precision Manufactured Parts*, Albuquerque: Sandia National Laboratories.

Terumi, I., Toshimitsu, I. & Toshikatsu, I., 1999. On the NDT and E for the diagnosis of defects using infrared thermography. *NDT & E International*, 32(5), pp. 247-257.

Testing, T. A. S. F. N., 2019. *Introduction to Nondestructive Testing*. [Online]
Available at: <https://www.asnt.org/MinorSiteSections/AboutASNT/Intro-to-NDT>
[Accessed 15 October 2019].

Trampus, P., Krstelj, V. & Nardoni, G., 2019. NDT integrity engineering – A new discipline. *Procedia Structural Integrity*, 17 (1), pp. 262-267.

TWI, 2003. *Non-Destructive Testing*. [Online]
Available at: <http://www.twitraining.com/home/programmes-and-courses/non-destructive-testing/conventional-ndt-methods/ultrasonic-testing-welds>
[Accessed 3 November 2019].

TWI, 2019. *WHAT IS NON-DESTRUCTIVE TESTING (NDT)? - METHODS AND DEFINITION*. [Online]
Available at: <https://www.twi-global.com/technical-knowledge/faqs/what-is-non-destructive-testing>
[Accessed 15 October 2019].

TX NDT, 2019. *What is Visual Inspection?*. [Online]
Available at: <https://www.txndt.com/safety-section/visual-inspection>
[Accessed 8 November 2019].

Usama, M., 2015. *Destructive Tests*, Pakistan: Academia.

Nathan Jones – P151484

Usamentiaga, R. et al., 2014. Infrared Thermography for Temperature Measurement and Non-Destructive Testing. *MDPI*, 30(2), pp. 1-257.

Woodhead Publishing , 2014. *Coal Power Plant Materials and Life Assessment*. 1st ed. Amsterdam: Elsevier.

Yan, X., Dong, S., Xu, B. & Cao, Y., 2018. *Progresses and Challenges of Ultrasonic Testing for Stress in Remanufacturing*, Beijing: Chinese Mechanical Engineering Society.

FINAL GRADE

GENERAL COMMENTS

Instructor

65/100

PAGE 1

PAGE 2

PAGE 3

QM

5. Structure (-)

Your report structure should explicitly reflect the brief

PAGE 4

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QM

5. Resolution(-)

Make sure that any images that you take from other sources are of good enough resolution to be clear in your report

PAGE 10

QM

1. Secondary(+)

Good secondary research



5. Formatting



Comment 1

Whilst this is interesting - how is this related to stress analysis?



Comment 2

good



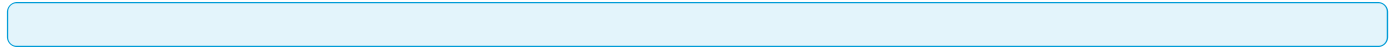
Improving MoM

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.

NATHAN
JONES

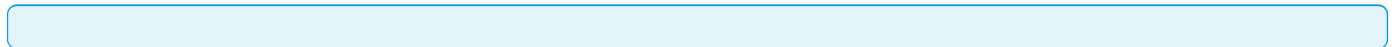
64.95

RESEARCH-INFORMED LITERATURE



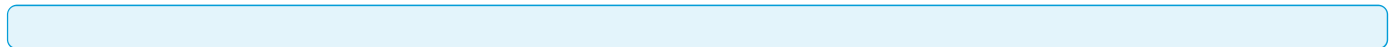
15.75

KNOWLEDGE AND UNDERSTANDING



16

PRACTICAL APP



26.4

PROF PRAC



6.8