

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	GHIRMAY	Student P number:	
Programme:	BEng Automotive and Manufacturing streams		
Module:	Advanced Stress Analysis & FEA	Module Level (4, 5, 6):	6
Module code:	M6X00420	Contribution to Overall Module Assessment (%):	50 %
Lecturer:	Kelvin Lake	Internal Verifier:	Rob Goodson
Assignment Title:	Can FEA replace physical testing?	Assignment No (x of x):	1 OF 1
Hand Out Date:	25/02/2020	Submission deadline:	29/03/2020

Referencing:	In the main body of your submission you must give credit to authors on whose research your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have read or quoted in order to complete this assignment (e.g. for books: surname of author and initials, year of publication, <u>title of book</u> , edition, publisher: place of publication).		
Disclosure:	I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people. All references have been duly cited.		
Student's Signature:	Assignments will not be accepted without a signature here	Date:	
Turnitin: Lecturer to tick to indicate if an electronic version of the assignment must be submitted to Turnitin. Note: the Turnitin version is the primary submission and acts as a receipt for the student. Penalties for late submission: Up to four weeks late, maximum mark of 40%. Over four weeks late, Refer. Only Year Tutors and the Programme Director may grant an extension.			YES
			✓
			NO

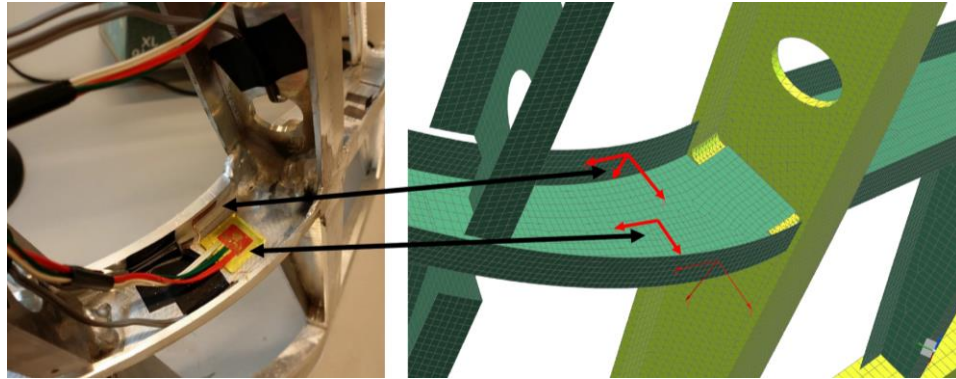
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- DO NOT put this form into Turnitin or it will match many similarities with other students' submissions.

TASK DESCRIPTION

This assignment explores FEA and the role that it plays in product development. It is expected that the student will research this topic (referencing any sources used, using Harvard or Vancouver).

GUIDANCE FOR STUDENTS IN THE COMPLETION OF TASKS



The above image shows a component undergoing physical testing and the corresponding FE model. Your task for this assignment is to discuss the following;

1. Why companies typically carryout FE analysis alongside physical testing.
2. How a physical test may be correlated to an FE model.
3. If you think that FE analysis can (or should) ever replace physical testing.

In order to do this, you should consider a case study and use this to discuss the above tasks.

This report should be 3000 words long and should be submitted via moodle

STRUCTURAL SECTION MARKING CRITERIA AND STUDENT FEEDBACK

This section details the assessment criteria. The *extent* to which these are demonstrated by you determines your mark. The marks available for each criterion are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Common Assessment Criteria Applied	Marks available	Marks awarded
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions.		
(Assessed in point 1)	30	20.7
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
(Assessed in point 2)	30	19.8
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
(N/A)	0	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
(Assessed in point 3)	30	20.4
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		
(Assessed in report presentation and structure)	10	6.3

Assignment Mark Overall (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		67.2 %
	Up to one-week late		
	Over one week late		

COMMON ASSESSMENT AND MARKING CRITERIA

	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
Assessment Criteria	0-29%	30-39%*	40-49%	50-59%	60-69%	70-79%	80-100%
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions	Little or no evidence of reading. Views and findings unsupported and non-authoritative. Referencing conventions largely ignored.	Poor evidence of reading and/or of reliance on inappropriate sources, and/or indiscriminate use of sources. Referencing conventions used inconsistently.	References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.	Inclusion of a range of research-informed literature, including sources retrieved independently. Referencing conventions mostly consistently applied.	Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.	A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied.	Outstanding knowledge of research-informed literature embedded in the work. Outstanding selection of relevant and credible sources. High-level referencing skills consistently and professionally applied.
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.	Major gaps in knowledge and understanding of material at this level. Substantial inaccuracies.	Gaps in knowledge, with only superficial understanding. Some significant inaccuracies.	Evidence of basic knowledge and understanding of the relevant concepts and underlying principles.	Knowledge is accurate with a good understanding of the field of study.	Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.	Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.	Highly detailed knowledge and understanding of the main theories/concepts, and a critical awareness of the ambiguities and limitations of knowledge.
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence	Unsubstantiated generalisations, made without use of any credible evidence. Lack of logic, leading to unsupportable/missing conclusions. Lack of any attempt to analyse, synthesise or evaluate.	Some evidence of analytical intellectual skills, but for the most part descriptive. Ideas/findings sometimes illogical and contradictory. Generalised statements made with scant evidence. Conclusions lack relevance.	Evidence of some logical, analytical thinking and some attempts to synthesise, albeit with some weaknesses. Some evidence to support findings/ views, but evidence not consistently interpreted. Some relevant conclusions and recommendations, where relevant	Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument. Valid conclusions and recommendations, where relevant	Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity & significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions / recommendations.	Thoroughly logical work, supported by evaluated evidence. High quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.	Exceptional work; judiciously selected and evaluated evidence. Very high quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Highly persuasive conclusions
4. Practical Application and Deployment Effective deployment of appropriate methods, materials, tools and techniques; extent of skill demonstrated in the application of concepts to a variety of processes and/or contexts; formulation of innovative and creative solutions to solve problems.	Limited or no use of methods, materials, tools and/or techniques. Little or no appreciation of the context of the application.	Rudimentary application of methods, materials, tools and/or techniques but without consideration and competence. Flawed appreciation of the context of the application.	An adequate awareness and mostly appropriate application of well established methods, materials, tools and/or techniques. Basic appreciation of the context of the application.	A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with some use of examples, where relevant.	A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.	An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, with extensive use of relevant examples. Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.	Outstanding levels of application and deployment skills. Assimilation and development of cutting edge processes and techniques.
5. Skills for Professional Practice Demonstrates attributes expected in professional practice including: individual initiative and collaborative working; deployment of appropriate media to communicate (including written and oral); clarity and effectiveness in presentation and organisation.	Communication media is inappropriate or misapplied. Little or no evidence of autonomy in the completion of tasks. Work is poorly structured and/or largely incoherent.	Media is poorly designed and/or not suitable for the audience. Poor independent or collaborative initiative. Work lacks structure, organisation, and/or coherence	Can communicate in a suitable format but with some room for improvement. Can work as part of a team, but with limited involvement in group activities. Work lacks coherence in places and could be better structured.	Can communicate effectively in a suitable format, but may have minor errors. Can work effectively as part of a team, with clear contribution to group activities. Mostly coherent work and is in a suitable structure.	Can communicate well, confidently and consistently in a suitable format. Can work very well as part of a team, with very good contribution to group activities. Work is coherent and fluent and is well structured and organised.	Can communicate professionally and, confidently in a suitable format. Can work professionally within a team, showing leadership skills as appropriate, managing conflict and meeting obligations. Work is coherent, very fluent and is presented professionally.	Can communicate with an exceptionally high level of professionalism. Can work exceptionally well and professionally within a team, showing advanced leadership skills. Work is exceptionally coherent, very fluent and is presented professionally.

Student Self Evaluation Form

Student name:		Student P number:	
Programme:		Year of programme	
Assignment Title:			

This section repeats in brief the common assessment criteria detailed on previous pages. The *extent* to which these are demonstrated by you determines your mark. Using these criteria, tick the box that best indicates the level of achievement you feel you have achieved with regard to each of them.

Common Assessment Criteria Applied	Level of Achievement						
	REFER		3 rd	2:2	2:1	1 st	1 st
	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
1. Research-informed Literature	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
2. Knowledge and Understanding of Subject	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
3. Analysis	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
4. Practical Application and Deployment	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
5. Skills for Professional Practice	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐

PLEASE COMMENT ON AREAS IN WHICH YOU FEEL THAT YOU HAVE PERFORMED WELL	PLEASE COMMENT ON AREAS YOU FEEL THAT YOU NEED TO DEVELOP

Student's Name		Date	
Student's Signature			



Prifysgol Cymru Y Drindod Dewi Sant University of Wales Trinity Saint David

University of Wales Trinity Saint David

SCHOOL OF ENGINEERING

CAN FEA REPLACE PHYSICAL TESTING?

HABTOM GHIRMAY

STUDENT NUMBER- 1810854

L6 MECHANICAL ENGINEERING

25/04/2020

ADVANCED STRESS ANALYSIS AND FEA (M6X00420)

Contents

1. Introduction.....	1
2. Why companies typically carryout FE analysis alongside Physical testing?.....	1
2.1 To Limit Physical Test use.....	1
2.2 Gives high Prediction and Increases the flexibility of blade testing.....	1
2.3 Improve standard Approximate blade test	2
3. How a physical test may be correlated to an FE model.	2
3.1 Computational Accuracy:	2
3.2 FE model correlation with actual testing	3
4. Can FE Analysis ever replace Physical testing?	3
4.1 The factors barrier for FE Analysis.....	3
References.....	5

1. Introduction

In this research wind turbine blade taken as a case study, with the advantage of the wind energy increased to reduce the cost of energy. The demand of wind turbine increased worldwide, through the decades. The size of the wind turbine blade was increased to supply high energy, but with increase of the size of blades are becoming more influence on aeroelastic issues caused by the aerodynamic load, gravity load and centrifugal load.

The wind turbine blades are critically needed a test to demonstrate the certainty level of the blade, specify life cycle, predict the ultimate load, and fatigue loads (Dr Časlav Mitrović, 2014). In this work a test would be using Finite element analysis and physical test.

2. Why companies typically carryout FE analysis alongside Physical testing?

1. To Limit physical test use
2. Gives high Prediction and flexibility of blade test
3. Improve standard approximate blade test
4. To develop parameters blade test

2.1 To Limit Physical Test use

Structural physical testing for wind turbine is helped by applying equivalent mechanical load to compare with the aerodynamic loading of the blade during working condition. Static test took by applying loads using weights, cranes, hydraulic actuators and electronic actuators connected to the blade in multiple areas of the blade parts to get the testing data (E.M. Fagan, 2017). FEA model can reduce the steps of the testing by set up blades are made up with 3D lofted shell sections which sets the data from the experimental data of a blades design criteria, number of models required for the optimisation study (E.M. Fagan, 2017).

The price for only a physical test is expensive, but in many companies, they were used FE analysis test with physical test.

THIS DEPENDS. IF THE SOFTWARE USES CLASSICAL LAMINATE THEORY, THE THROUGH-THICKNESS STIFFNESS IS NOT MODELLED.

2.2 Gives high Prediction and increases the flexibility of blade testing

Structural component FEA modelling is selected with many companies constructed with 3D composite shell elements. FEA is a very capable to describe the characteristics of the composite shell layers through the entire thickness of the shell (Lin Wang, 2016). FEA model has a massive advantage to examining the details of the stress distributions in each layer of the composite blade structure specially for the structural component of the blade (Lin Wang, 2016).

FEA is a great advantage to test failure alongside of the physical test reading, to assess the risk of failure in the material of the blade for fibre failure and inter-fibre matrix failure based on the failure criterion (E.M. Fagan, 2017). The criterion is model by using five multi-axial stress interaction equations which defines all the failure surface for different failure modes (E.M. Fagan, 2017). Some of the failure modes analysis by FEA are matrix cracking, combinations of transverse and shear stress. With FEA there are many options depending on the area of the blade such as stable and reliable analytical procedure, geometrical and material non-linear analysis.

Finite element analysis of wind turbine blade can be used different complexity of modelling test method for the blade geometry (Owaisur Rahman Shah, 2016, p. 1). Blade can be model as a simple beam to simplify the simulation time and can be used three-dimensional shell.

After couple of working cycle, a wind turbine blade for assessing the strength, stiffness, load bearing capacity and loading strain on the root blade can be suitable to analysis them using FE method. Based

on the FE analysis can be determined a prediction of a non-linear stress among the multilayer structure of the blade, failure prediction of the layer under static or cyclic loads and model test by degradation the blade strength due to fatigue and sudden load varying and FEA can predict the remaining life, strength and stiffness (L. Mishnaevsky Jr, 2012).

2.3 Improve standard Approximate blade test

In a testing of wind turbine blade material and structure, tests on several scales of the blade can be taken in order to measure material properties and estimate the load capacity relative to the structure of the blade, according to the computation design model. A safety of factor considers representing the unknow effect on the blade such as loading, degradation, cracking and failure of the blade. To determine the safety of factors accurately, the information of the effects of the loading conditions can be considered in varieties of weather influences and microstructure parameters of wind blade composites materials on its strength and lifetime prediction (Leon Mishnaevsky Jr. ID, 2017). The solutions for the material deformation and microstructure parameters of the blades which are the integral and differential equations are solved using FEM (finite element method) (Leon Mishnaevsky Jr. ID, 2017). Sub-component method is used for the finite element analysis to simplify the domain size of the geometry.

Finite element model can be assessing the residual fatigue and residual strength by using the structural detail of the blade and material, it also predicted future load history (M.McGugan, 2015). FEA for wind turbine blade can be used during the operation to decide in an inspection period.

3. How a physical test may be correlated to an FE model.

Finite element analysis is a tool which is not exactly gave the same result as physical test, but the result is depend on the correlation to the experimental result or data (University, 2019, p. 470). The accuracy of the result depends on the percentage of closeness among the two principles. Accuracy of Finite element model measures by computational accuracy and correlation with physical test (University, 2019, p. 470).

3.1 Computational Accuracy:

1. Geometry: the geometry of the wind turbine manufacturing of the blade is made from a multiple part which are assemble to each layer. A blade constructed from a composite material, and the turbine hub connected with a steel root. A box spar is in the wind turbine blade which gives a flexural and torsional stiffness to the aerodynamic shell of the blade, but this spar is along the length of the blade structure and web to provide shear strength to the structure.
2. Material Properties: the characteristic of a composite material which was interlaminar, bonded properties, and single lap joint is tested the model, but full scale test also took on the complete blade structure in static bending to calculate the stiffness of the structure and strain of the skin of the blade (Owaisur Rahman Shah, 2016). Mechanical properties of the composite materials are longitudinal Young's modulus, lateral Young's modulus, shear modulus, Poisson's ratio, and thickness of the ply, and they are to be selected from the manufacturing data.
3. Design of a blade cross section: Structural of the blade modelling considers aerodynamic shell, caps or flanges, adhesive bond between the cap and shell made from multiple layers, and shear web. In the aerodynamic shell a shear deformation can be take place along the sandwich structures. The outer layer is a smooth, and at both leading and trailing edges the

layer is split among and there is a material added in between to increase buckling strength of the blade (Lin Wang, 2016).

4. Mesh: the mesh quality size of the geometry depends on the joints of the layer of the composite material. The mesh classified along the geometry, spar cap and the blade shell edges in one mesh size and shape, sandwich structure of the blade shells in the another mesh categories and sandwich structure of the blade shells and shear webs also in the another mesh categories (Jinshui Yang, 2012). Mesh study gives the appropriate strategy to the quality of mesh.
5. Boundary conditions: the boundary conditions depends on the loads over the blade which are aerodynamic (the air flow through blade), gravity (due to the weight of the blade) and centrifugal loads (rotation of the blade), but the main focus depends on the study. The root is the fixed boundary condition of the FE model.

3.2 FE model correlation with actual testing

Stress: the stresses result from the actual test relates to the Finite element model like longitudinal stress which happens under the extreme flap-wise loading for the blade structure, compressive stress along the suction side and tensile stress to the pressure side (Jinshui Yang, 2012). The highest stress strain of the geometry location of blade region compare the finite element with experimental, in which gives damage region in the blade.

Strain: the experimental measured strain using strain gauge compare with numerical modelling prediction can be relate based on a position of the geometry. The shear strain of shear webs can be measure with experimental and relates the result to finite element model, the shear strain among shells and shear webs. The shear strain can be different value for shear webs relative to the location, in both experimental and FE model can be reach maximum shear strain (Jinshui Yang, 2012). Due to the fluctuation value of the shear strain a shear-deformation happen on the shear webs, and location of the shear webs failure and blade collapse can be located.

Deflection: the blade deflection can be tested by simulation and experiment test; the deflection depends on the maximum loading to the blade. The deflection explains the stiffness of the wind turbine blade (Jinshui Yang, 2012).

Mass: the mass of the blade for the physical test and FE model can be compared to validate the model result.

Buckling (F. Lahuerta, 2017): FE modelling study the test by sub-component simulation of the Buckling failure over the blade. The trailing edge opening angle caused by edgewise moment which formed compression loads along the trailing edge. A large opening angle of a trailing edge can be the delamination that is a fracture failure on the trailing edge adhesive joint. The relation with experimental test and FE model observed characteristic change of the stiffness (Buckling).

4. Can FE Analysis ever replace Physical testing?

Finite Element Analysis is a simulation tool using numerical equations (numerical technique used to determine the approximated solution for an integral and partial differential equations), FEA testing is used alongside of Physical testing (the test is accomplished from experimental test) that means the FE alone would not complete a test in a wind turbine blade (Wong, 2010). FE Analysis cannot replace physical completely but can reduce physical test procedures on testing (Thornton, 2011). In a testing wind turbine blades the FEA testing gives prediction of test.

4.1 The factors barrier for FE Analysis

1. Certification of test: there is uncertainty on the composite material and structural behaviour of the blade due to the load carrying and impact of the environments, but in order to reduce

those uncertainty wind turbines carried out a standard wind turbine blade test “IEC 61400-1 and IEC 61400-22” for both the composite material and full-scale blade test (Bin Yang, 2013). Full scale test is tested the strength of the blade in both ultimate and fatigue test. In IEC 61400-23 full-scale test carried out such as blade properties (weight, natural frequency, and elastic behaviour), static strength (flap wise and edgewise), fatigue strength (flap wise and edgewise) and repeated static test after fatigue test (flap wise and edgewise). In 2012, National Renewable Energy Laboratory was tested and, they provided measurement equipment and facilities for testing wind turbine blade (Bin Yang, 2013).

For full-scale measurement, a video-metric technique testing equipment is used for deformation of large wind turbine blade, the advantage of this instrument is it can quickly capture three dimensional and environment.

2. FE model assumptions and Implications: In a modelling of Finite element there are so many assumption in the process to simplify the complication of the model, but those assumptions can reduced standard wind turbine blade testing (Mathijs Peeters, 2018, p. 16). The load setting for the FEA testing was considered from the load distribution of full-scale certification test.

Characteristic of interlaminar strength geometry of the material is simplified the solid geometry of a composite material determined by selecting a double cantilever beam and end notched flexural for delamination mode tests (Owaisur Rahman Shah, 2016). Composite material bonded with different adhesive thickness measured it strain along the bond in the delamination. The cohesive of the composite material test start with single lap and up to complete test. The test for blade counts by two static bending tests, the first load test was the design load of the wind turbine blade which would test the required wind turbine blade bodies full-scale test measurement (Xiao Chen, 2014). The second test was examined based on the design load test, and the test load would be overloaded to examine the wind turbine blade failure. All the test took from history of the turbine blade and loading direction followed the geometrical cross-section of the blade in a direction flap wise, edge wise and trailing edge (Xiao Chen, 2014). The blade position test on the axis rotated to a counter clockwise by fixed the blade as a cantilever beam and pulling upward to test the case. The test can be recorded the loads, deflection, and strain along the blade of the turbine (Xiao Chen, 2014).

3. FEA is monitored by user input to set the data and required calculation. The results of the input data depend on the user, so the results are not certain as physical test. However, the FEA can limit the cost of physical test and gives a highly close prediction for wind turbine blade test. Especially in a manufacturing the model analysis can be a good picture and it would be a step forward to physical test.

GOOD SECONDARY RESEARCH. YOU HAVE CHOSEN A VERY DIFFICULT CASE STUDY AS MODELLING COMPOSITES IS NOT EASY.

GOOD DETAILS OF 'SIGN OFF' TESTING BEING A BARRIER TO JUST USING FEA.

References

- Bin Yang, D. S., 2013. Testing, Inspection and Monitoring Technologies for Wind Turbine Blades: A survey. *Renewable & Sustainable Energy Reviews*, Issue 22, pp. 515-526.
- Dr Časlav Mitrović, D. G. V. D. N. P. D. S. S. S., 2014. ADVANCED STRUCTURAL TESTING METHODS FOR SMALL WIND TURBINES BLADE UP TO FAILURE. *Applied Engineering Science*, Issue 12, pp. 129-136.
- E.M. Fagan, M. F. S. L. T. F. A. D. J. G., 2017. Physical experimental test and structural design optimisation for a composite wind turbine blade. *Composite Structures*, Issue 164, pp. 90-103.
- F. Lahuerta, M. J. d. R. L. E. N. K. D. S., 2017. *Assessment Of Wind Turbine Blade Trailing Edge Failure with Sub-component Test*. Wieringerwerf, Knowledge Centre WMC.
- Jinshui Yang, C. P. J. X. J. Z. S. X. J. J. a. H. D., 2012. Structural investigation of composite wind turbine blade considering structural collapse in full-scale static tests. *Composite Structures*, Issue 97, pp. 15-29.
- L. Mishnaevsky Jr, P. B. R. N. D. J. L. a. T. P. P., 2012. Materials of large wind turbine blades: recent results in testing and modeling. *Wind Energy*, Issue 15, pp. 83-97.
- Leon Mishnaevsky Jr. ID, K. B. H. N. P. J. B. M. M. a. B. F. S., 2017. Materials For Wind Turbine Blades: An Overview. *Materials (MDPI)*, 10(1285), pp. 1-24.
- Lin Wang, A. K. T. N. P.-L. D. a. T. B., 2016. Structural optimisation of vertical-axis wind turbine composite blades based on finite element analysis and genetic algorithm. *Composite Structures*, Issue 153, pp. 123-138.
- Lin Wang, R. Q. A. K., 2016. Fluid Structure interaction modelling of horizontal-axis wind turbine blades based on CFD and FEA. *Journal of Wind Engineering and Industrial Aerodynamics*, pp. 11-25.
- M.McGugan, G. B. H. a. K., 2015. *Damage tolerance and structural monitoring for wind turbine blades*, Denmark: The Royal Society.
- Mathijs Peeters, G. S. J. D. a. W. V. P., 2018. Comparison of Shell and Solid Finite Element Models for the Static Certification Tests of a 43 m Wind Turbine Blade. *Energies, MDPI*, 11(1364), pp. 1-18.
- Owaisur Rahman Shah, M. T., 2016. The identification of structurally sensitive zones subject to Failure in a wind Turbine Blade Using Nodal displacement based Finite Element Sub-modelling. *Renewable Energy*, Issue 87, pp. 168-181.
- Thornton, J., 2011. *American Society Of Mechanical Engineers*. [Online]
Available at: <https://www.asme.org/topics-resources/content/fea-and-the-question-of-credibility>
[Accessed 15 04 2020].
- University, A., 2019. *Practical Aspects Of Finite Element Simulation, Study Guide*. 5th ed. Michigan: Altair university.
- Wong, K., 2010. *Digital Engineering 247*. [Online]
Available at: <https://www.digitalengineering247.com>
[Accessed 15 04 2020].
- Xiao Chen, W. Z. X. L. Z. a. J. Z. X., 2014. Failure Test and Finite Element Simulation of a Large Wind Turbine Composite Blade under Static Loading. *Energies, MDPI*, Issue 7, pp. 2274-2297.

WHILST I CAN UNDERSTAND YOUR POINTS, SOMETHING THEY COULD BE CLEARER