

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	JONES	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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:	<i>Assignments will not be accepted without a signature here</i>	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	19.5
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	18
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	17.4
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	5.5

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)		60.4 %
	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			

University of Wales Trinity Saint David

School of Engineering

Can FEA replace physical testing?

Advanced Stress Analysis & FEA

M6X00420

Timothy Matthew Jones

1701384

26/04/2020

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1 Introduction

Across various disciplines of engineering, the finite element analysis (FEA) is a fundamental tool in the design and development of all products and structures. This assignment determines how FEA is used in industry, focusing solely on one industrial application as a case study. It will also determine why FEA is carried out alongside physical testing, discovering how they intertwine in the product development process. Another aim of this assignment is to understand how a physical test may be correlated to a finite element model. This will look at how FEA models portray simulations to that of which relate to a real-life scenario. It will also look at the how the results of physical and FEA testing can be correlated. With the development of Finite element analysis and the advancement in computational methods, does this pose an end to physical testing? will the sole use of FEA be used in the development stages of products and carried forward to production? This assignment will address the future of FEA in industry and whether it is cable of completely replacing physical testing. Furthermore, a discussion will be made, discussing if FEA could replace physical testing, should it be able to. Within this section what health and safety and ethical issues would restrict this from becoming the future, over that of the benefits FEA presents.

An FEA analysis can be performed in many ways, each respective to an individual product or structure. Therefore, to aid in the completion of these objectives a case study is selected focusing on a single application, addressing each question and its relation, relative to that scenario. The case study selected is the manufacturing and development of wind turbine blades. Their broad range in power output, blade dimensions and structural integrity to withstand the stresses by fluid structure interaction (FSI) requires intensive product testing, both physical and computational, due to the severe risks such a product displays.

2 Why companies typically carryout FEA alongside physical testing

FEA is a method primarily used by engineers in which computerized simulations are used to calculate and predict how products will behave in a real-life scenario. These may include properties such as stresses, strain, vibration, heat transfer and fluid dynamics. The underlying foundations of FEA use the finite element method (FEM). FEM uses governing equations of engineering principles found in nature, and is the numerical tool that enables the solving of complex integral or differential equations with large quantities of unknowns (Onate, 2009). The finite element method is an approximation as it needs to use discretization. Discretization divides a structure into smaller elements to allocate known values into the computational model, making an infinite variable solvable (Szabo & Babuska, 1991) (TUT, et al., 2010). Within a computational model, the process of producing these elements is known as meshing. The more elements covering a structure, the denser the mesh. Calculations are performed at smaller intervals and therefore theoretically increasing the accuracy at representing real-life physical properties.

Physical testing and FEA both aim to optimize the performance and integrity of the product. However, the finite element analysis was designed with the purpose of reducing the number of prototypes used in the testing and development of products (SIMSCALE, 2013). Reducing the number of prototypes has several benefits over that of the conventional method of physical testing. For many industries there needs to be a fine balance between FEA and physical testing. Thus, utilizing FEA methods without making additional complications to the infrastructure or a reduction in accuracy (Ratchev, et al., 2007).

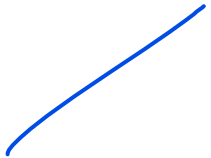
By reducing the number of prototypes, it massively reduces the expenditure of materials. A standard 4.2 MW onshore wind turbine blade assembly can weigh in around 70 tonnes, producing blades around 23 tonnes each (Vestas, 2020). The cost in supplying 23 tonnes worth of materials and manufacturing would be expensive especially since several prototypes need to be manufactured to be able to conduct multiple tests and of different variations. The process of designing, manufacturing, testing and then repeating this cycle to optimize any product is very time consuming. FEA of wind turbines eliminates the need

for excessive manufacturing and allows the completion of projects in a much shorter duration. Due to the rapid increase in renewable energy and sustainability projects, wind turbines are needed to be developed and manufactured quickly to keep up with the demand by consumers and energy directives. FEA enables a projects duration to be shortened as its ease of use and fewer prototypes allows a more time efficient optimization process. Once an FE model has been built, multiple tests can be carried out using the constructed model as a base model where singular variables can be changed, dependent on the test under analysis

According to the office of energy efficiency & renewable energy, physical testing of wind turbine systems needs validation and certification before they should go into production and deployment stages. Wind turbines present many health and safety risk factors and need proof of testing. Therefore, physical testing is still highly regarded and required in the wind turbine industry. However, such accredited facilities capable of testing turbines these standards are scarce. These sites are far too expensive for any single company to construct and own themselves. These testing sites are run externally, located centrally to allow the facilities to be used several companies (Office of Energy Efficiency & Renewable Energy, 2013). Here is an example of how FEA and physical testing work alongside each other. Limited access of such testing sites pushes the need for computational alternatives to develop and optimize designs, but still requires physical testing at various points for validation and ensuring all standards are met physically and not just theoretically.

FEA has become a universally used product testing tool, especially in the wind turbine industry. The ever-growing demand and need for the development of renewable power generation has rapidly increased in the scale in which the technologies are being built. Larger blades increase the cross-sectional swept area of the turbine, increasing the total energy that can be extracted by the turbine and their efficiency compared to that of turbines with a smaller radii (Veers, et al., 2003). Vestas, one of the leading companies developing wind turbines produce single blades upwards of 70 meters (Vestas, 2020). As previously mentioned, testing facilitates are scarce due to their costs but also their size is far to large for a single company to own. Not only would each company each have to have their own wind tunnel and testing facilities but with the rate of which these blades are increasing, so would their facilities. FEA presents a practical solution with very little

limitations to the size of blades and the complete turbine, apart from additional computational time.



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

Firstly, to construct an FE model the geometry of the component it must be developed and exported using a 3-dimensional design package. Once the blade has been exported the FEA model needs a set of parameters in order describe the properties at each point of the model. A mesh is constructed discretizing the body into layered shell elements. Layered shells are efficient at representing laminate composite materials containing hundreds of individual layers (Laird & Montoya, 2012). Typically, a wind turbine is investigated to determine the global stresses, strains, vibrations and torsional load.

Wind turbines commonly use a computational fluid dynamics (CFD) and FEA pair. CFD is a computerised numerical simulation that calculates and displays the characteristics of fluid flow, such as velocity, pressure and density (SimScale, 2017). As the blades undergo fluid structure interaction (FSI), the stresses and strain applied by this FSI can be altered by the relative deformation. Therefore, the pair are solved simultaneously as a couple as each one directly impacts that of the other.

The correlation between FEA and physical testing can be determined by comparing their result against each other to determine their accuracy. The department of mechanical engineering at the university of Newcastle, Australia conducted tests analysing the structural performance of two 2.5-meter radii wind turbine blades against their respective FEA simulation counterparts. These used FEA to predict the blades performance and then conducted the same tests physically. Static and dynamic loads were used to test the blades deflection and frequency of vibrations. In this example both blades were seen to have a 7% increase than the predicted vibration. The deflection in the blades also were shown to have an increased value 6% above the measured deflection. The FE model were shown throughout the study to portray the non-linear relationship through several of the tests, although the accuracy was off by a small margin of area. The department concluded that the result were appropriate and using these finite element method predictions to modify than manufacturing of their blades. Alongside FEA being used to further aid the design

they also planned to incorporate accelerometers to further understand of the mechanics of wind turbines (Bechly & Clausen, 1997). This suggests that FEA has its limitations due to the need to further study the mechanical structure of the turbine and its interaction with air flow which would first need to be discovered to apply to the computational model.

The relationship between physical testing and FEA overlap tremendously. The advancements made into computational methods have increased the complexity of FE models to a point to which the simulations parameters than need to be imputed to describe the characteristics of a material and integrity of structure cannot be predicted accurately (Thornton, 2010). Therefore, physical testing is required to be able to set the parameters for the simulation. Simulations are only as good as the information that has been given to them so by entering an inaccurate value would in return display inaccurate results. FEA requires physical testing but then in return it can conduct simulations to a similar degree of accuracy in a shorter time frame and for a fraction of the cost. Physical testing is also used to validate the results. This relationship intertwines the benefits if both methods. The accuracy of physical testing combined with the speed and cost-effective nature of FEA. FEA can also optimize the aerodynamic nature of a turbines blades without compromising its integrity. This is accomplished through simulations which would otherwise be considered impossible simply utilizing manual optimization. Computational power enables countless more iterations over that of the lesser possible manual iterations, enabling new and alternative optimizations (Muskulus & Schafhirt, 2014). FEA and physical testing complement each other to the extent that one it would be impractical to design and optimise a product using one method alone.

4 The future of physical testing and FEA

FEA has existed for a millennia in the form of simple hand calculations. It made progress over the years but the foundations of current FEA recognised in the late 1800's (J.Wood, n.d.) (O'Donnell Consulting Engineers, 2020). It wasn't until the introduction of computation methods that it enabled it to reach the tool in which it has become today. Even over the past decades the advancements in computational power have increased

exponentially. With such progress being made it is difficult to picture to what FEA will be capable of in the coming decades.

The development in FEA itself has advanced and is continuously advancing rapidly providing new ways to more accurate pathways to optimize products (Veers, et al., 2003). However, although advancements in computational methods have been made, since wind turbines are such a niche sector and are very complex engineering systems there are limited by the availability of the software that can analyse them, especially to analyse a fully assembled turbine (Muskulus & Schafhirt, 2014). These include the structural instability phenomenon as the blades design increases in scale (Camanho & Lund, 2006).

The finite element analysis was designed with the purpose of reducing the quantity of prototypes (SIMSCALE, 2013). This implies that physical tests are intended to be carried out, allowing various alternative testing methods such as simulations to be used to benefit the process without erasing physical testing from product development completely.

As the fundamental equations are by nature differential equations, discretization will always present the issue that not all positions are known. An accurate approximation can be determined but not 100% accurate. However, it can be argued that to what level of accuracy is enough to validate the integrity of a structure (Prantil, et al., 2013). Physical tests will always be more accurate than

Without physical testing the foundations of FEA would prove difficult to conduct a finite element analysis with the absence of any form of physical testing. The simulations that are conducted are especially complex and impossible to gage the parameters of a product without first testing the physical properties of (Thornton, 2010). The vary foundations of FEA are built on physical testing, disregarding the possibility of FEA replacing since the results produced would be based off assumptions.

Negligible of whether FEA could or could not be able to replace physical testing, wind turbines currently need to undergo certification before approval. There are many requirements turbines must adhere to but IEC 61400 part 23 refers specifically to the structural testing of the blades prior to larger scale production. The International Electrotechnical Commission (IEC) stipulate that to ensure the integrity of the blade, the physical tests to be undertaken include static load tests, fatigue tests and applying a static load after fatigue has been reached. These were said to be chosen to best indicate the integrity of the blade as a whole and could then be certified (International Electrotechnical Commission Webstore, 2014). FEA is being used more in industries but

final physical testing ensures the customers and distributors that the product is functional. Even if FEA could simulate the same values of physical testing to the same accuracy, the display of physically testing increasing value from the viewpoint of the customer into the quality and reliability of the product.

Moreover, these tests are not only conducted to validate the results of FEA simulations but are incorporated to ensure product safety. As the financial costs and the hazardous nature of wind turbines, their health and safety should not be compromised to save time and money on testing. Their certification given by physical testing also acts as an external, uniform benchmark across all wind turbines to ensure quality is to a recognised standard.

In conclusion FEA has become an essential tool when incomes to testing wind turbines. Advancements have in these software's have driven forward the development and optimization of blades over the past decade which would have been impossible without FEA's involvement. However, FEA would be highly unlikely to succeed on its own and even if it could as its based off physical tests. Measures have been implemented through certification to ensure products are physically tested to meet structural standards. FEA and Physical testing complement each other

INTERESTING REPORT, HOWEVER CONSIDER USING
DIAGRAMS TO CLARIFY YOUR POINTS, THIS WOULD
HAVE MADE YOUR REPORT MUCH CLEARER IN
PLACES.

5 References

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