

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	DYER	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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	15.6
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	14.4
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	16.5
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

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)		52.5 %
	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			

FEA and practical testing

M6X00420

Iwan dyer

P149128

Introduction

The aim of this report is to look at why even today both physical testing and Finite Element Analysis are so heavily used industry. This will be included typical forms or FEA that are carried out alongside their physical counterparts in physical testing even though it would be possible to do just one and get similar results. The report will then go on to discuss the similarities between the physical test and their simulated results. Finally, the report will conclude on whether or not FEA is a feasible substitute for all forms of physical testing.

Overview of FEA and Physical testing

Both physical testing and simulated test can be considered a form of quality control as these tests show whether or not a design is fit for production or indeed has any large safety concerns that may need to be worked out before the product goes in to mass production (if that is the intent of the part). As is said in Balbir S. Dhillon's book Quality Control, Reliability, and Engineering Design "The origin of quality control can be traced as far back as the history of the industry itself" (Dhillon, 2016) this shows just how long testing of parts has been going on for. For obvious reasons FEA has not existed for as long as physical testing has. When physical testing started, computers and software did not exist. When physical testing started it could be as simple as a short visual inspection of the part before it is let out of the factory or checking if an assembly of parts work the way they were designed before being sent out.

Physical testing

NDT

INTERESTING, BUT NOT IN THE BRIEF
Nowadays physical testing is just as scientific as the simulation that is run on a component. Currently physical testing is split in to two main fields NDT or non-destructive testing and DT or destructive testing. Starting with NDT there are many different forms of test and they vary on the purpose of the component, for example, there is ultra-sonic testing which uses ultra-sonic wave propagation through a material to sense if there are any hairline cracks or any sub-surface cracks that the a visual inspection would not detect (testing, 1999) there are also magnetic flux leakage which is a process

where a magnetic field is induced inside of a part the field lines run parallel to the part, any cracks that are perpendicular to that of the magnetic field (as long as they are close to the surface) will form magnetic flux leakage this then will attract any magnetic particles to the area closest to the crack. (mix, 2005) There are still some simple NDT methods that are carried out such as leak testing to see if seals can hold up , or something as simple as checking a part for rust are all considered NDT as the part is not damaged in the process of testing. Most companies carry out some form of NDT on every part or a selection of parts before a batch is allowed out of the factory these days. For example, Allevard springs a company that supply's Ford with coils, they test every part before they are placed in to bins ready to be shipped, the test is a simple completion test.

DT

Up till the invention of FEA, destructive testing was the only way to estimate the damage that the part would take by impact or exceeding its maximum force load. Today destructive testing is still used very regularly, however its use has seen a decline since FEA has become far more prevalent in engineering as computers are far more capable of running more complex simulations. However, it would be impossible for FEA to be as accurate as it is without destructive testing this is because destructive testing give us the tensile strength of the material and its yield strength and if the properties of the material is not known then the easiest way to get them is destructive testing. This is not the only benefit destructive testing, most simulation have simplified modules to help with the use of computational power so small holes may be discounted or some small complexity's in the part may be discounted these could lead to failure in the part if not accounted for in the model.

FEA

FEA or Finite Element Analysis is a computer-generated simulation that is used frequently throughout the engineering-based production. FEA is based on the Finite Element method, a tool that allows the solver to approximate the solution to a set of partial differential equation that the vast majority cannot be solved. to approximate these partial differentials, they are equated with a numerical model which are then solved and then making the solution an approximation of the real solution. ((Anon., 2016))

There are 3 stages to Finite Element Analysis ; Modelling, Solution, and Visualization of solution. With modelling or pre-processing is where the part itself is designed in CAD (computer aided design) so in terms of the case study the wind turbine it is then goes through a process of defeaturing to simplify the geometry. Meshing is the second step there are 3 kinds of meshing beam mesh (1D) shell mesh(2D) and the a solid mesh (3D) . then the selected material is placed in the model (in this typically fiberglass) giving the model the properties of the selected material/ materials. Then the

loads and constraints are added to the model so the simulation knows what it forces that the model will undergo, this is possibly the most important step, as if these forces are incorrect then the model will be totally inaccurate. The next step is the analysis of the model this is where the “magic” as such happens where the computer takes the data that has been given and applies it to every node along the mesh and calculates the result of what that force would do to the part. Once this is complete then the post processing this shows the plots and deformation and the effect of the stress, deflection and if it will fail.

Question to answer

Why companies typically carryout FE analysis alongside physical testing.

Nowadays companies very rarely use only one form of testing as there are significant benefits to both physical testing of a part and a finite element analysis along with the accompanied limitations. The benefits and limitations to the product determine the form of testing done to the product and how extensively they are run. As a case studies look at 10Mw wind turbine aerofoils they, like more modern products, are designed using a form of cad (computer aided design) this means that the model or prototype already exists or can be tested in its current state without needing to be built which in the case of a full size aerofoil is significant. This also bleeds over to rapid prototyping which in engineering has become an increasingly used process in the design phase of production. FE can be used to quickly see high and low stress areas on a part which could either have mass removed or has supports added to them or if the shape of the part needs to be changed to spread the stress more evenly. (Iliescu, 2014) in the case of aerofoils it would be irresponsible to build full scale models for testing parameters such as stress, factor of safety and max & min deflection. This is why FE models are used to reduce cost and allow the designs to be quickly changed and adaptive till they fit the desired parameters (Cox, 2012)

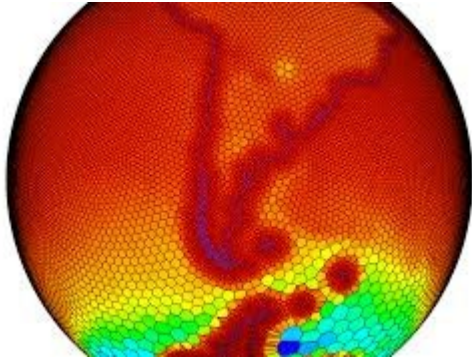
However, this being said, even in the production of aerofoils physical testing is still undertaken to ensure that the parts that are produced will work as expected in reality. The methods they may use include producing a 3d printed model of the part and running that in a wind tunnel. The companies may get test samples of prospective materials to run test on to see how they hold up in comparison to their simulated counter parts and see if one performs better in reality than in a simulation. As stated in the book Practical Stress Analysis with Finite Elements by Brayan Mac Donald “many FE software companies market FE as a method to end all experimental testing” and the book then goes on to state “it definitely does not eliminate the need for testing” (Donald, 2007) It then goes on to

suggest that without practical data most FE do not have the validation on its how to convince a company that it alone can be accurate enough to show that the product will function as predicted without outside data confirming so.

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

Physical testing and simulated testing could be correlated by running test that have the same condition, in reality as the simulated tests. This would allow the simulation to be validated and if it is in accurate because of boundary conditions or other variables they could be adjusted to allow the simulation to be more accurate the next time it is run. However, there is physical testing that can be done even if a part has already been made and is being reverse engineered for example using laser scanning to create an accurate cad model which can then either be used to create 3d printed models to be physically tested or create a detailed Finite Element model to then run the simulations on (sander, 2018) In the case of reverse engineering NDT could be used to determine the material property's and possibly the material itself making any Finite element model highly accurate.

The big problem with Finite Element Analysis trying to be correlated to a physical test can be broken down in to a few components. Firstly, there is how fine of a mesh is required this is because if there is a course mesh the accuracy of the part will be very low and the model will be partially useless for any high-level analysis. If the mesh is too fine the processing time will be increased and depending on the size of the part could take days to complete and if you have a deadline this will be no help. As stated in Yucheng Liu in the paper effects of mesh density on finite element analysis. (liu, 2013) "In finite element analysis, mesh density is a critical issue which closely relates to the accuracy of the finite element models while directly determines their complexity level." Backs this statement up, and this point is exactly why most companies that run extensive Finite Element Analysis run multi-textured meshes. Using multitextured meshes means that on critical point in the design the mesh is significantly finer than it is on the rest of the part. This then leads to a significant decrease in run time and keeps the Finite Element Analysis as accurate as possible. For a visual example of this see the image below.



(Anon., 2018)

The second problem that Finite Element Analysis relating to physical testing is its constraints. If the constraints are not an accurate reflection of what the part would undergo in a real physical test the simulation will be off. A good example would be air density around a turbine blade ,a difference in area density or air pressure for that matter would affect the air flow around the blade's ether increasing or decreasing the level of turbulence that the blade will experience. Any variation of the constraints of the simulation will lead to a greater and greater variation from the true value.

The third problem that may occur depending the model that is used oversimplification of geometries this would be the least common problem with the correlation between Finite Element Analysis and physical testing. This only occurs if, in order to save computational power a designer leaves holes or other small geometry out in order to simplify the model.

If all of these points are correct the model should have a high level of correlation with physical testing and should lead to the ability to prototype and reverse engineer objects with increased speed and a high level of accuracy and in some case give greater insight in to what is happening in a part that physical testing can (nagy, 2014) .This is due to the ability of computers to see inside of the models and can give companies improved inspection capabilities.

[If you think that FE analysis can \(or should\) ever replace physical testing.](#)

It is the belief of this report after the research that has been carried out that the may one day be powerful of enough of a tool to be used as the sole check for defects, in perfect conditions and with enough computer power a Finite Element Analysis would be accurate enough to prove a highly accurate respiration of what would happen in reality.

This would be in a perfect world and unfortunately, we do not live in such a place even though a Finite Element Analysis companies market it as the end of physical testing this is far from the truth ((sander, 2018)). At the moment it is a relatively reliable approximation of what will happen in reality and in engineering when there is normally lives or business at risk this is not reliable enough on its own (ponginan, 2000)). Therefore, today we almost always back up any result that we have from Finite Element Analysis with that of physical testing. Considering this one fact it is impossible to say if physical testing will ever be completely removed from the design cycle. In the case of aerofoils in wind turbines Finite Element Analysis could not be removed from the design process as it has become completely ingrained the stress design process especially in offshore wind turbines. as to

determine the accumulate damage to a full-scale wind turbine from small scale model is far less accurate than the result that a Finite Element Analysis would output and to do it by hand using the Palmgren-Miner's rule shown bellow

$$D_t = \sum_{L_i} \frac{n(L_i)}{N(L_i)}$$

this equation is used to show the damage to a part for every load cycle and in this case, this is the stress that is applied as the blade rotates (salam, 2016) this is the single most critical consideration to be made in the design process for wind turbines and hence is critical that it is done correctly. Being that it would take significant levels of manpower to be able to run the necessary calculations. In the last few years even, the tower has become increasing the focus for the use of FEA and traditionally the only testing that would be done on this part was physical testing but now that economic competitiveness of this key component as increased so has the need to optimise its design. (teixeira, 2019)

Conclusion

In conclusion Finite Element Analysis is an incredibly valuable tool in the production and design because of its value profit saving possibility's more of these stems from the ability to produce and optimise designs to insure they are the most effective they can be. However, replacing physical testing at the moment may be short sighted as it is the belief of this report that there simply is not enough data supporting the removal of physical testing with just FEA. This is because FEA a tool that estimates how a product will function under set condition. However, this report does not believe that just physical testing is good enough anymore for the state engineering is in, this is due to the fact that FEA allows a designer to see the internal structure of the component.

QUITE SUPERFICIAL
WITH VERY FEW
DETAILS.

CASE
STUDY ?

References

- Anon., 2016. *An Introduction to the Finite Element Method*. [Online]
Available at: <https://uk.comsol.com/multiphysics/finite-element-method>
[Accessed 2016].
- Anon., 2018. *the world*. [Art].
- cox, k., 2012. Structural Design and Analysis of a 10MW Wind Turbine Blade. In: *energy procedia*. s.l.:s.n., pp. 194-201.
- Dhillon, b. s., 2016. *Qaulity control, reliability and engineering design*. s.l.:s.n.
- donald, B. j. m., 2007. *Practical Stress Analysis with Finite Elements*. s.l.:s.n.
- iliescu, M., 2014. *fineite element method simulation and rapid protoyping*. s.l.:s.n.
- liu, y., 2013. Effects of Mesh Density on Finite Element Analysis. SAE.
- mix, b. P. e., 2005. *non-destructive testing*. 2nd ed. s.l.:s.n.
- nagy, e., 2014. *Rethink! prototyping*, s.l.: s.n.
- ponginan, r., 2000. *Finite Element Analysis With Inspire*, s.l.: s.n.
- salam, a., 2016. *Handbook of Materials Failure Analysis with Case Studies from the Aerospace and Automotive Industries*, s.l.: s.n.
- sander, m., 2018. *Enhancing Finite Element Analysis with Digital Image Correlation Point Cloud Test Data*, s.l.: s.n.
- teixeira, r., 2019. Stress-cycle fatigue design with Kriging applied to offshore wind turbines. *internatioal journal of fatigue*.
- testing, A. s. f. n.-d., 1999. *non-destructive testing handbook*, s.l.: s.n.