



BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	MORRIS	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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	17.4
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	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)		59.1 %
	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

Advanced Stress Analysis & FEA

Ashley Morris

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Mechanical engineering

26/04/2020

Can FEA replace physical testing?

M6X00420



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

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1 Introduction

This report will look at a case study of a Finite Element analysis (FEA). Why companies look to use FEA alongside physical testing, this will be added with the correlation between FE model and physical testing. The final part of the report will conclude by evaluating whether FEA will replace physical testing or has a place alongside physical testing. The case study will look at the energy sector and how FEA can help solve a problem of a component within a part. A case study will be used to look at wind turbines and how FEA has helped develop and improve wind turbines. This will be achieved by either optimizing the component or using different materials to help the quality of the component and from this lower the likelihood of the component failing.

FEA is a numerical method for which provides solutions to problems that would otherwise be difficult to calculate. Whereas some solutions might give you the exact outcome, take a long time an FEA simulation will give you answer close to the outcome, but takes a lot less time to require with reasonable accuracy; this allows engineers to proceed with designs and fix problems much sooner than otherwise would have been possible (Brancheau, 2019). Since the creation of FEA, engineers have used FEA to help improve the designs of their products. FEA first started out in the aerospace industry in 1950 with Boeing in the United States and with Rolls Royce in the United Kingdom (Tipton, 2017). One of the first FE program was released in the 1960s by a professor of Berkeley University, this program was successful within universities and used for several years as it was continued to be developed (Tipton, 2017). HKS was founded in 1978 and went on to develop ABAQUS (Tipton, 2017).

2 Why companies typically carryout FE analysis alongside physical testing.

FEA software is used within the manufacturing industry to estimate the actual strength of a structure and behaviour, modelling, simulation, and design optimization of a part within the engineering industry. Once the part has been chosen and made within a CAD program options have to be made about the material in which the part will be made from (TUT, et al., 2010). This is an advantage to using FEA over physical testing, where with physical testing multiple prototypes would have to be made with different materials and tested, however, with FEA models you would just have to run the simulation of FEA take the results down and change the material and repeat the process again. This significantly reduces the time of the test and the receiving results by days, this also reduces costs as the cost of ordering or making materials is eliminated as, well as, the time it takes to make the prototypes. Companies will also apply increased number of nodes and elements to the FEA; this is in attempt to improve

the accuracy of the component being used in the FEA. This works in general, however, there will be an optimum point where the number of nodes increasing does not improve the accuracy of the FEA. From the results of the FEA you can look at several things, such as; the Von Mises stress variation throughout the part, displacement model and a tension graph (TUT, et al., 2010). These are good tools to look at to see if the part has any fault where it might be weak and fail, these would normally take three different physical tests: if a practical part was made and tested. This technology is only set to improve in the future with FEA packages: being able to predict more parameters, allowing for a greater deal of accuracy in the FEA models created (Vyas, 2015). This is followed by a greater computing power and would only help increase the speed of FEA on parts, thus, creating quicker solve times with more accurate results that would get the product out for production quicker. FEA allows for the designer to have their calculations worked out quicker by the program, FEA programs allow optimisation of a part that would save machine costs and reduce the mass of the component (Caliber Design, 2020). This can all lead to a better product being produced to be sold or used for such situations as wind turbine blade, that could be made lighter and more efficient due to FEA models helping in the design of the product.

In the case of a wind turbine for instance: it is very difficult and expensive to do physical testing on such parts would need to be made, tested separately and then put together, the FEA could look at all different aspects of a wind turbine, test each aspect, then combine the parts and do a complete task as long as the program is able to run this. For this report there will be a look at wind turbine blades where FEA has taken place, the FEA will look at analysing stress distribution and deformation of the wind turbine blades under the wind load (Yeh & Wang, 2017). This is done through the software ANSYS, through using FEA, three angular positions and pitch angles of wind blades can be analysed in the case study presented. This gathers results much quicker than physical testing would present in this situation. This allowed different areas of the blade to be tested, show distribution of stress and deformation of stress across these areas. These can show the small change in perhaps the angle, as shown in this particular case study. Where the material will reach its von Mises stress limit is reached when the blade is angled 120°C in the clockwise direction (Yeh & Wang, 2017). This would allow for companies such as these to look into design improvements to the model much sooner than previous use of physical testing would allow, with having the adverse of effect of reducing expenditure; through labour time, material cost and testing cost. This also leads to a smaller development time, which is ideal as it may mean a product may be put in a market quicker than previously possible, if the process is streamlined through FEA.

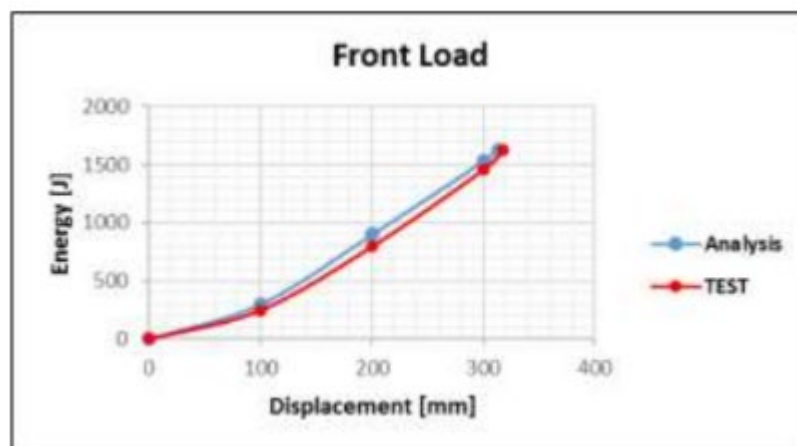
3 How a physical test may be correlated to an FE model?

Finite element models do try and accurately predict what behaviours the actual model would have. However, this does need to be proved by testing, which lays the question of how close can FE modelling get to actual testing. This is what the International Research Journal of Advanced Engineering and Science has done by creating a replica of rollover protective structure (ROPS), although not wind turbine wind turbine blade which is the main case being investigated in this report, it is however a look at how closely FE models can emulate physical testing and give an understanding of how FE models work. The tests were done on three parts of the ROPS, these were the rear, front loading and side loading (Karpat, et al., 2018). A replica of the ROPS used in the test was made and is shown below;



Figure 1 ROPS

FEA was done to try and model closely what bars would look like on a tractor for safety. The results are found in the subsequent images;



KES

Figure 2 front load- displacement and energy from ROPS

with regards to the front load results, the image show the smallest difference in results, where both the test and analysis move in the same gradient up with the analysis slightly underestimating the actual amount of displacement shown by the test. At the beginning and

the end of the curve is where the test and FE model are at the closest to the test, which is ideal as you want the FE model to be as close to physical testing as possible, but an overestimate is better than an underestimate in this situation. Therefore, the FE model has done its job in predicting displacement of the model, this is not the case here, even though displacement is very similar; it does underline an issue if just an FEA reading showed the part to not displace and risk someone, when in reality the movement could cause displacement over the recommended limit.

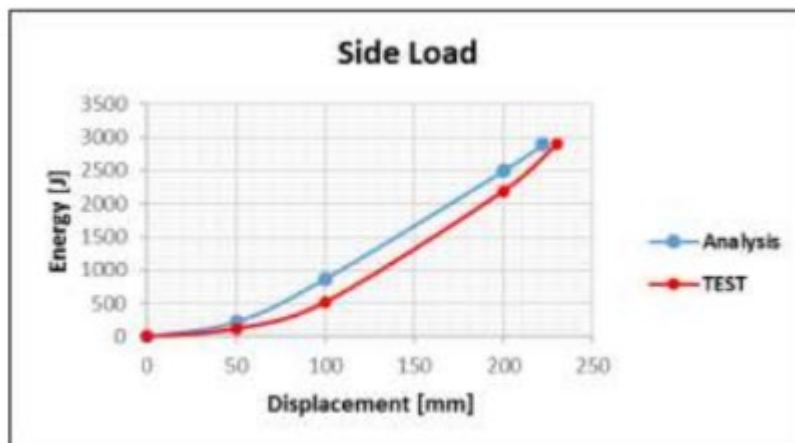


Figure 3 side load- displacement and energy from ROPS

With the load to the side of the bar, there was a larger gap between the FEA and physical test. The FEA is still underestimating the displacement that physical testing showed, the FEA closely matches physical tests at the beginning and the end of the testing, with the same as the front load, a gap between the displacement of the FEA and physical testing. This gap is larger than the ones shown on the front load, the displacement from FEA and testing go up in parallel the same as front load, the criticism for FEA in the front load are the same as the side node however, they are exacerbated by the larger gap of the FEA. Which would mean failure could be more likely.

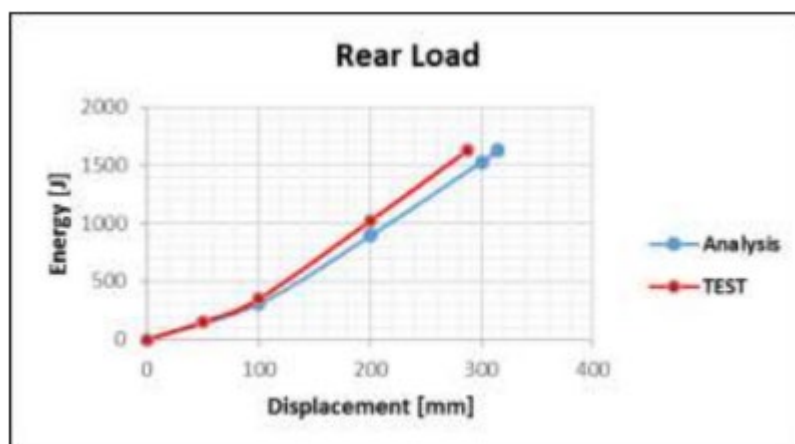


Figure 4 Rear load- displacement and energy from ROPS

The rear load is significantly different to the front and side load in regards to the FEA and physical testing, with the rear load the FEA is virtually identical to the physical testing at the start, however, as the test gets further away from the physical testing as the energy exerted on the part increases. In the rear load the FEA has overestimated the displacement that was found, which is preferable than underestimate; this was found in the other two test examples. Overall from this case, it can be seen that physical testing and FEA are very similar and in correlation with each other. The test goes further on with only one test suggesting a separation and widening in results of an FEA. The FEA displacement was only off by a couple of millimetres in each of the tests, so to analysis the case study chosen may need to consider in the deflection of the wind turbine to be a couple of millimetres out in either direction; as the FEA is not completely accurate.

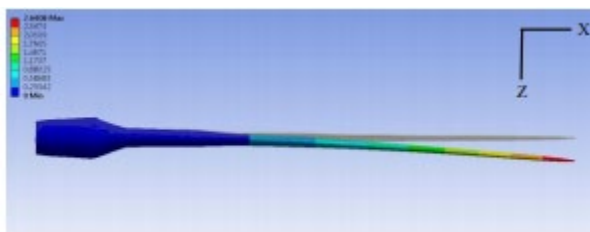


Figure 5 Deflection on wind turbine blade

It was shown in this model where the deflection would happen on a turbine blade and as expected, towards the end of the blade, of the three angular positions used for the wind turbine blade they recorded: 2.55m, 2.27m and 2.54m, respectively (Yeh & Wang, 2017). We can assume from the other example shown that the displacement on this part is very close to what would happen in physical test and would only be a couple of milometers out in either direction of the three results received from the FEA.

4 If FE analysis can (or should) ever replace physical testing.

If FEA can or should replace physical testing, this question can be split into two. Whether FEA can replace physical testing and if FEA should replace physical testing both questions have differing answers. FEA is being used more and more in designing products with near exact accuracy of how the product will react and this technology will only improve as computers and programs advance. This will only progress further until near perfect models can be made using FEA. These models could be complex enough to use a variety of different sceneries and be solved in a couple of ours; with improvements made and retested again, until the part passes its criteria with accuracy close to 100% of how the physical model would react to the situations. The question on whether physical testing could be replaced by FEA was looked at by Veryst Engineering LLC for golf balls being hit by a club, this was done to see if they could accurately simulate the action within FEA (Mraz, 2015). The company found that the results experimental

data was very similar to the actual data, however, it did not exactly mirror all of the results found. The conclusion of the investigation concluded that FEA could replace some forms of physical testing, but not all of the physical testing due to the complexity of parameters involved. This makes the case that FEA could replace physical testing, however it should not replace physical testing.

The reason for this is safety, is to make sure the product is safe to use and will not break under circumstances that the product will face in its lifetime. Though the product produced would be safe 99.9% there would be a slight chance that the FEA model had miscalculated and the data could be problematic, therefore, FEA should not replace physical testing all together. Especially, in a situation such as a wind turbine blade, where if failure were to occurred because no physical testing had commenced, which would could cost lives and be a greater expense to fix rather than testing a model before putting the model into production. The amount of physical testing will reduce further as FEA programs, improve maybe even down to only a single physical model being made for physical testing. This would give a guarantee a level of safety that could be looked at through industry standards. The areas in which FEA needs to improve upon are Systematic Maturity Model and transformation to exascale computing according to the HI-Tech CAE. They claim that existing models could be certified and would not need any physical testing (Vyas, 2015). Though they also acknowledge that physical testing will be required at some point in the design process of a component (Vyas, 2015). Systematic Maturity Model this is a model that would be develop to comprehensibly integrate material behave from process to their life span and would be able to reduce the number of physical tests needed (Vyas, 2015). Exascale computing is essentially more powerful computers that allow more parameters and variables to be calculated, would only help improve the viability of FEA to be used more and physical testing to be relied on less. The benefits of FEA will only increase as models can become more efficient from FEA design, these would only increase as FEA programs enhance.

In the case of wind turbine blade it is essential that the blade can resist stress, is lightweight, displacement and is durable over time. These factors could be looked at in depth by someone using a FEA program and could be optimised for the needs of the turbine blade, then after this could be put into prototype for physical testing before being put into production. This saves the company time for the design and manufacture, money both in terms of testing, manual labour while producing a product that is more reliable, efficient that can be in manufacture much quicker. FEA is only set to be increased in all industries including energy industry with physical testing being held off until a definite design and model is ready for production though standards, and physical testing must remain in place to guarantee safety and a product that can be reliable.

5 Conclusion

The beginning of this report was set out to look at companies and why they use physical testing alongside FEA as methods of testing components of a part or the hole part. While looking at a case study involving FEA within manufacture of a component. This was found to be because of the time taken for physical components to be made and tested takes much longer than creating the model in a CAD file, and placing the model in a FEA program to test to accuracy near to what would appear in physical testing. This means that improvements could be made to the model ahead of time, until the model would be ready for physical testing. This could be seen in the wind turbine blade chosen for the case study analysis. The second task in this report was to look at how closely correlated physical testing is with FEA; this was done by looking at a case study measuring the differences in the two forms of testing and then applying it to the case study being looked at in this investigation. It was found in the case study looking at ROPS and it was found that displacement on the ROPS was off by a couple of millimetres, when applied to wind turbine blades. The case study would indicate a very accurate model, though it cannot be compared to much until a physical wind turbine blade is made and tested to see if there is a close correlation, but in principle the accuracy of FEA is very near physical testing. The final questions were to look at whether FEA can replace physical testing or should it replace physical testing. It was looked at and FEA could conceivably replace physical testing now, however, it should not due to safety reasons and that all models of any component being put into production should be put into physical testing as by industry standards; though FEA will become more and more prominent within engineering in the future.

6 References

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