

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	MARTIN	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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	18.9
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	19.5
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	6.5

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)	
	Up to one-week late	
	Over one week late	

64.7 %

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
Advanced Stress Analysis & FEA

M6X00420

Ainsley Martin

P149894

26/04/2020

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1. Introduction

This assignment will look into the real world use of Finite Element Analysis (FEA).

WHAT IS FEA? FEA is the use of a computer software to solve complex mathematical problems to show how a product will react to different real world situations such as forces, vibration and heat.(Zienkiewicz, Taylor and Zhu, 2013). FEA uses partial differential equations to solve these problems and different types such as elliptic, hyperbolic and parabolic can be used depending on the problem. FEA is used to give an estimated result to these problems.(SimScale, 2016)

It will explore its current role in the design process of a product and why it is being used. The use of FEA alongside real world physical testing will be looked at. The correlation between the real world tests and the FEA is important to ensure the results from the FEA can be trusted. Finally, the possibility of FEA replacing physical testing will be explored.

The case study being investigated for this report is 'Strength Prediction of Bumper by Correlating FEA with Test'(Wen and Neely, 2011). This study looked at the rear bumper design of a golf cart, the current design did not meet the current safety requirements therefore a new design had to be created. The use of both physical testing in the field and in the laboratory was used alongside FEA testing to find the issues with the current design and to create a new and improved design.

2. Why Companies use FEA Alongside Physical Testing

Currently most, if not all companies that do FEA testing will also do physical testing alongside it. FEA can be a very cost effective way of testing as it doesn't require a physical model to be produced which would then have to be destroyed or damaged in testing. (Jirathearanat, Hartl and Altan, 2004) It can also reduce the time to produce results as it cuts out the time to produce a new model and redo the physical tests. Since most modern engineering products are designed using a computer aided design (CAD) package the design would still have to be created even if FEA was going to be used on the design, this means the time to create and modify would have to be done anyway and thus doesn't add any extra time to the process. (Shih *et al.*, 1998)

However, there are some issues with just using FEA which is why physical testing is used alongside it. One of the main issues with FEA is that without any validation it's hard to trust any of the results that are produced.

By using FEA results certain areas of stress concentration can be observed therefore, when the physical test is conducted the tester will have a rough idea of areas to investigate first. If the FEA has produced accurate results these areas should also see stress concentrations in the physical test. This can make looking for small areas of deformation or small hairline cracks easier to spot as the general area where they are produced has already been predicted. (Aggarwal and Garg, 2011)

■ Historical Approach

Design in CAD > Build Tools > Test parts
> Redesign in CAD > ... etc etc ...

■ CAD led design

Design in CAD > Assess in CAE >
Redesign in CAD > Assess in CAE > ... etc
etc...
Build Tools > Test parts

■ CAE led design

Design in CAE > Assess in CAE >
... etc etc...
Produce CAD > Assess in CAE >
Build Tools > Test parts

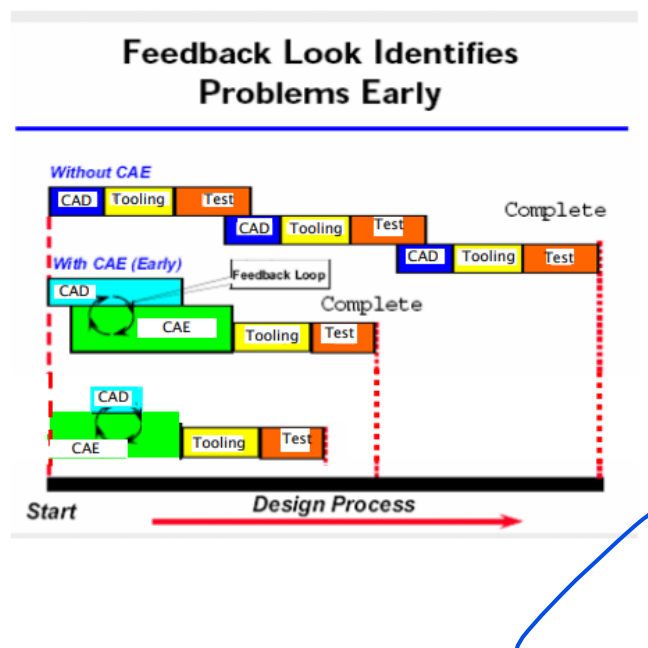


Figure 1 - Design Process (Lake, 2019)

Figure 1 shows an example of 3 types of the design process. The first is the historical approach where a design is first created in CAD, the model is then physically manufactured, and the physical model is tested. The test results are analysed and changes to the design can be produced in CAD. This process is repeated until the design meets the required criteria. This process can end up being expensive since a physical model needs to be produced for each iteration and the more iterations that are produced the more expensive the project becomes (Hawkes and Abinett, 1986). This can also increase the time required for the project. As can be seen from figure 1 when FEA (labelled as CAE) is introduced to the design process it can significantly reduce the time taken from the start to the end of the project. (Cross,

2008). This can also reduce the overall cost of the project since people are working on the project for less time and therefore if they are being paid by the hour they won't be working as many hours. Also, since less physical prototypes need to be produced this will save on manufacturing costs. (Sawant and Hujare, 2013)

The case study found that by using FEA along with physical testing the FEA could be first be validated, this was found to be difficult due to the material being used (glass fibre polymer). However, once it was correlated it allowed fewer physical tests to be conducted which both reduced costs and time. The FEA results allowed the strength of the crash on the rear bumper to be predicted, the physical testing of the final design was able to validate that the FEA had worked as intended to produce a new design. Without the physical testing certain parameters could not be correctly identified which could lead to uncertainties with the FEA results such as maximum allowed impact speed, stress and strain at the risk areas and the influence of the glass fibre. If these tests were not done it would be difficult to know where to start with the FEA. This would lead to using trial and error to find these parameters and even then they would still just be educated guesses with no data to back them up.

Using the validated data, a new design was able to be created using FEA, the stress, strain and fibre orientation were able to be optimised all through simulation. This process was deemed to be very time efficient and very reliable in this study. It states that the new bumper design met the specifications in different environments at a low cost with a short design cycle. (Wen and Neely, 2011). It also states that FEA and virtual prototyping can be a powerful tool but only when correlated with physical testing as there are certain data sets that need to be gathered prior and after FEA testing to ensure the results are accurate and have some data backing them up. The test conducted in this case study was able to be complete so quickly and successfully was partly due to the company having the original parts available for testing. This reduced both cost and time as no parts had to be manufactured to gather data to start allowing the redesign to begin. It states that this is especially important when complex materials are being investigated. (Wen and Neely, 2011)

3. Correlation Between FEA and Physical Testing

Correlation is essential in ensuring that the FEA results brought produced are accurate. Without any correlation the results can't be trusted and therefore are not useful by themselves. With correlation FEA can be a very powerful tool as it can significantly reduce the time taken from a products initial idea to the final product being created, this is because when there are correlated results a product no longer has to be created for each iteration.(Tan and Matzen, 2002) The main method of correlating FEA results to real tests is very simple. First the FEA is run using the CAD model used to create the physical product, the results seen on the FEA are compared to the physical product. If the cracks, deformation and/or breaking points are the same on the physical product are the same as the FEA, the results are able to be trusted more. To ensure the correlation between the FEA results and the physical test can be accurate, it is important that the forces that are applied in the FEA are replicated with the same conditions in the physical test. If they're not then it is unknown if the FEA has replicated the test accurately as they would be two different tests which would produce two different results in real life.(Zhang, Wang and Vlahopoulos, 2001)

Even once the results have had some proven correlation between the two it's still not guaranteed to be 100 percent accurate as there is always a chance for error when the geometry of the model is changed. However, it is trusted enough to be used as a replacement for some of the physical tests during the iterative design stage. Another way to validate the FEA results is to compare the FEA results to hand calculations.

With regards to the case study the real life correlation between FEA and physical tests can be seen. The study found that the current design was not able to cope with a corner impact and did not withstand a crash at 5mph which is required due to the current regulations. This required a new design to be produced where FEA would be used to prove the new design. This study states that 'Simplifying the model, applying boundary condition, setting non-linear material property, and obtaining the converged solution are the keys for accuracy'.(Wen and Neely, 2011).

By correlating FEA with physical tests allows the FEA tester to gain confidence with the boundary layer conditions and the properties of the materials to be used for a simplified model. Quasi-static testing can be slow but can be used to find failure with different fibre orientations which decides on the property of the polymer material. Quasi-static testing is when the load is applied at a slow rate, this type of testing is conducted to find out the structural performance of a material to find out how the material will crack and break.(Yao *et al.*, 2019)

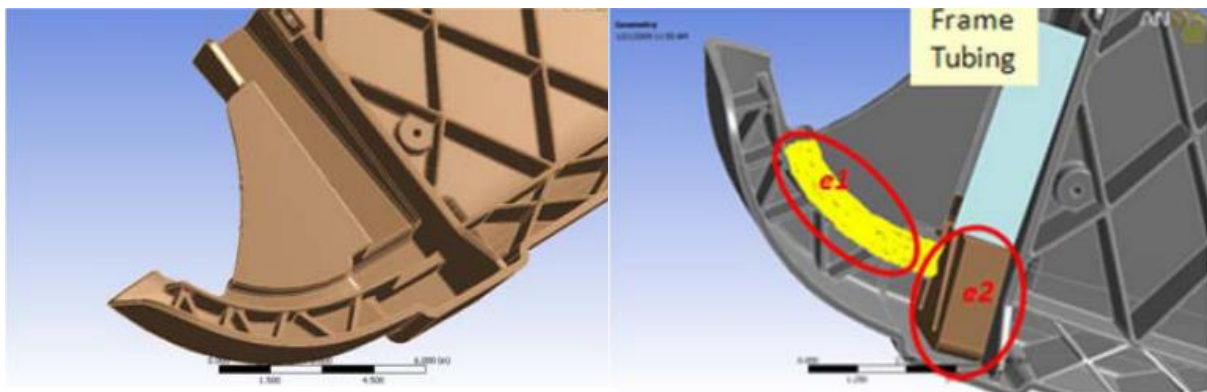


Figure 2 - Original vs Refined CAD Model (Wen and Neely, 2011)

Figure 2 shows the original model (left) and the reinforced design (right). As the original design failed when in a corner impact the next iteration was reinforced at the weak areas of the original design to try and improve the strength of it. To do this two blocks were added to the design, the first was added along the curve (as seen in yellow) and was used to prevent the bumper from bending. The second block (circled brown block) was added to transfer some of the load in the bumper to the block to provide some cushioning.

One advantage in this case study is that they had a large supply of the original bumper designs, this allowed the new design to be produced quickly. This new design could then be tested both in FEA and also a physical test using quasi-static testing. Once the simplified FEA results correlated to the real life quasi-static tests these settings could be used for future simulations and product development.

There were three main tests done for the new bumper design. The first test done was a field crash test. This was a physical test that replicated a real life crash scenario, to do this a cart was placed stationary with the new bumper placed on it. A second cart loaded with full capacity was driven at the first cart at a specified speed and was hit at a 30° angle. Multiple tests were done at different speeds using a new bumper of the same design each time until a failure of the bumper was seen. The test was repeated until damage was seen for each speed. The final maximum allowed crash speed was found to be 3.5 mph. All of the data gathered from these tests was then used for the second part of the testing which was the FEA prototyping of the design.

The FEA first needed to be correlated to the physical tests so the settings could then be used for further optimisation, therefore the force used was the cart at full capacity traveling at 3.5mph to replicate the real world test conditions. The test was replicated as close as possible however it was simplified, this was done to reduce the time taken for the tests and also to allow more refinement around the main areas. A simplified front bumper was created to act as the fully loaded cart. The only change from the real test was the reinforced bumper was the crashing body and the fully loaded cart was stationary. This was done so the tests could be replicated in the laboratory.

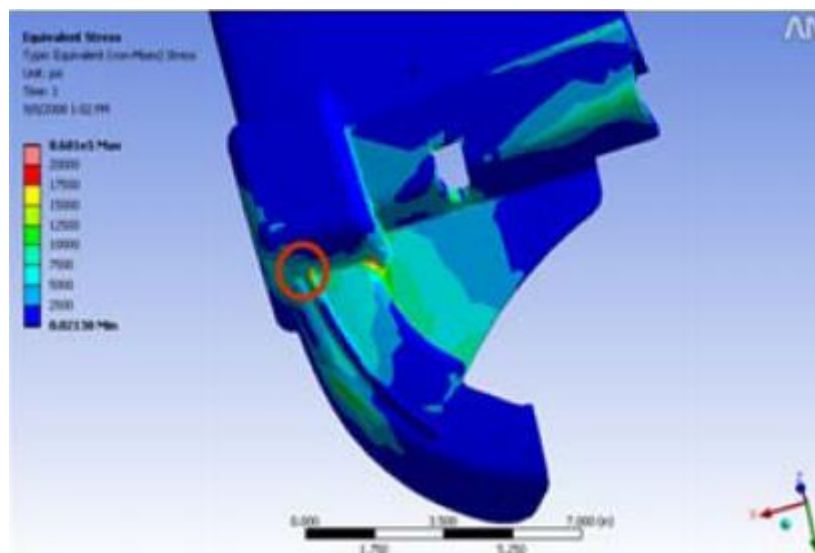


Figure 3 - FEA Results(Wen and Neely, 2011)

Figure 3 shows the FEA results. It was found in this study that the broken area was not found at the largest stress/strain area but was however located at the second largest. Both the FEA results and

the real world tests were used for the lab verification testing which would be done to determine what exactly caused the failure. The quasi-static test was conducted until the bumper failure and found a difference of 0.04 klbf from the FEA tests to the laboratory tests.

Utilising all the data gathered a new design could be created using CAD and tested using FEA since the areas of concern have been identified and the FEA has been correlated.(Wen and Neely, 2011)

Correlation is used in all forms of element analysis not just stress analysis. One common form of validation is the use of Windtunnel testing to validate computational fluid dynamics (CFD) results. This is especially common with the automotive industry where some large manufactures have full scale Windtunnels which can be used as a direct comparison to the CFD results.(Favier, 2010) By using a Windtunnel these companies are able to check that the CFD is producing the correct forces acting on the car, this would also be possible by using a scaled down Windtunnel as the CAD model could also be scaled down, so they are acting as the same size. However, by using a full scaled Windtunnel the exact flow structures being produced by the car can be compared against the CFD. This will ensure that the correct boundary settings and turbulence models are being used for the tests, once these have some conformation a model no longer has to be produced for each iteration as the settings being used have some conformation and can then be trusted for future tests.(Kasim, 2017)

4. Can FEA Ever Replace Physical Testing

As computing power is constantly progressing the question is asked if simulations such as FEA are able to completely replace physical testing. In an ideal world the answer would be yes. If FEA was able to replace physical testing it would be a large benefit to engineering companies. It would then allow no physical products to be manufactured until the final product manufacturing stage. Therefore, companies would be able to save a large amount of money as they would no longer have to spend money buying materials, using the machines and conducting destructive testing. They would also be able to save money on analysing the physical tests. This scenario would allow a company to perform all their tests using simulation which would rapidly decrease the time taken for a product to go from an initial idea to the final product as there would be no more manufacturing time or time taken to do and analyse physical tests.

However, in reality this is not the case. No matter how powerful computers are there are always chances for error. This could be user error or errors with the software. It is possible that the user could use an incorrect boundary conditions or an incorrect mesh strategy. By doing this the results could be skewed leading to incorrect results.(Deitz, 1997) It is also possible that the software could incorrectly predict stress concentration points which would again lead to incorrect results

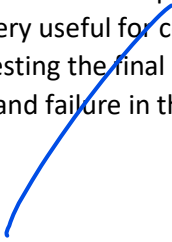
Completely replacing physical tests can have disastrous effects in certain fields. If a product has been incorrectly tested using FEA and hasn't undergone any physical tests there is a risk that an unexpected error can occur with the product.(Deitz, 1996) If the product's strength is essential in keeping someone alive and it fails due to an error that could have been seen by conducting a physical test the company could be sued. For smaller companies this could lead to the company closing or not being trusted with major projects again.

With regard to the case study one example of why FEA shouldn't fully replace physical testing was seen. When looking at figure 3 the broken area was not located at the largest stress/strain point but was located at the second largest stress/strain point. If only FEA was used it would be assumed that the largest concentration point would be where the break would occur. Therefore, work would be done to try and reduce the stress at this point. But as was seen in this test it was located in a different point. A few things could occur by trying to reduce the stress/strain at the incorrect point. The first is that time and money could be spent reducing the concentration at this point and with it not being the issue the product could still break as the main concentration point that caused the break has not been solved, this would mean the team would mean the design and test team would have to go back to the start and redesign the product again. The second is the redesign could make the breaking point worse and this could dramatically increase the time and resources needed as they would not know this was the original cause of the break.(Wen and Neely, 2011)

Since this test was conducted using golf carts at low speed impacts it's unlikely that the failure would result in a serious injury. However, it does show the possibility that the FEA results could be incorrectly analysed. If this test was done on more dangerous equipment such as heavy machinery the failure to identify the correct fault which could lead to failure could result in injury or loss of life.

5. Conclusion

From this report the use of both FEA and physical testing has been researched. It was found that in most forms of engineering product design where some form of stress or strain testing needs to be completed, both FEA and physical testing will be used alongside each other. The FEA testing is done to both speed up the design process and to save money. The physical testing is done prior and during the first FEA testing to try and validate the settings being used in the FEA tests since the results from the physical test such as forces applied can be implemented in the FEA testing. Once the FEA has been completed another physical test can be analysed to compare the simulation results against the real life results. This allows some correlation to be made between the physical and simulation tests. This report has also found that FEA testing can be very useful for companies but only when used alongside physical testing, if there was no physical testing the final results would all be produced from guesswork which could lead to inaccurate results and failure in the products.



6. References

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GENERALLY THIS IS A NICE REPORT,
CONTEXTUALISING THIS FURTHER & RELATING IT TO OTHER
APPLICATIONS WOULD HAVE ADDED TO THIS REPORT.