

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

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declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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

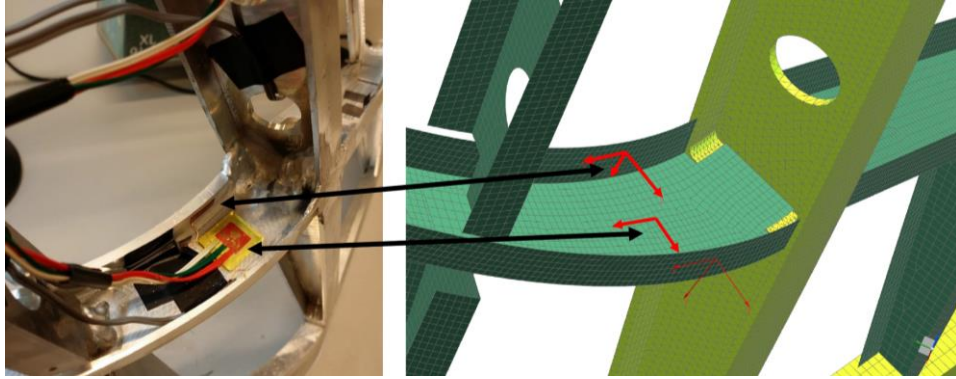
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	19.2
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	18.9
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)		63.5 %
	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			

University of Wales Trinity Saint David

School of Engineering

Can FEA replace physical testing?

Advanced Stress Analysis and FEA

M6X00420

Cornelius May

1701329

- Motorsport Engineering BEng –

22/04/2020

Contents

Table of Figures	2
Case Studies	2
Introduction	3
Why companies typically carry out FE analysis alongside physical testing?	4
Why companies carry out FEA:	4
Why companies carry out physical testing:	5
How a physical test may be correlated to an FE model?	6
Can/should FE analysis replace physical testing?	8
Conclusion.....	9
Bibliography	10

Table of Figures

Figure 1: Node and Element Diagram (Introduction to Finite Element Analysis (FEA) or Finite Element Method (FEM), 2020).....	3
Figure 2: FEA to real world Comparison (Hickey and Xiao, 2017)	7
Figure 3: Drop testing crash structure(Kumar et al., 2012)	8

Case Studies

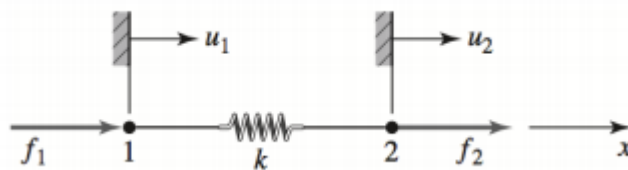
- **FEA and Optimization of Tie Rod of motor vehicle** (Kankarej and Nema, 2016)
- **Design and Finite Element Analysis of a Composite Monocoque Chassis** (Grimes *et al.*, 2012)
- **Finite Element Modelling and Simulation of Car Crash** (Hickey and Xiao, 2017)
- **Drop Test Analysis of Impact Attenuator for Formula SAE Car** (Kumar *et al.*, 2012)

Introduction

The design and engineering of a component can often be a long and complex process with multiple requirements being expected of the final product and a range of constraints placed on the engineers designing them (Churazova, 2018). Throughout this paper, the uses of Finite Element Analysis (FEA) by a variety of engineering teams will be investigated, with the aim of determining its viability as a tool to fully replace physical testing.

FEA is currently used as a tool to estimate how a part will perform throughout its lifetime through simulations such as stress analysis, and to understand how it will affect the environment around it such as in CFD analysis (CaliberDesign, 2020). It allows a components designer to see what geometry or material is likely to limit the performance of the part throughout its lifetime. Being able to predict which design iterations will cause issues, allows companies to save money. "Over Design" will result in the part being more expensive, either as a result of the effort required to manufacture the part, or because of the cost of excessive material being used (Thornton, 2011). "Under Design" on the other hand will result in the part not being able to perform the task it is required for.

In order to simulate the part, FEA operates under the process of separating the geometry and its surroundings into individual one, two or three dimensional elements (Mottram and Shaw, 1996). This allows for estimations to be made of what is happening throughout the material. This is necessary when the equations, call for infinitesimally small elements to be used. Increasing the element size allows for the same equations to be used however, results in less accurate results (Bosch, 2018).



NEEDED?

Figure 1: Node and Element Diagram (Introduction to Finite Element Analysis (FEA) or Finite Element Method (FEM), 2020)

Figure 1 shows how elements and nodes are perceived by an FEA package. Each node is a connection point between multiple elements whilst each element itself is treated like a spring, having a length and a stiffness. Each element has two forces acting on it, at point 1 and point 2 as well as an initial length, and a length as a result of these forces. The resultant length is calculated using the equation below. At each node, the resultant forces of all the connected elements is calculated and applied to each load. Only the component of the resultant force along the axis of the element is transferred.

$$f = k \times u$$

Equation 1: Hooke's Law

Each node represents an area of the geometry linking multiple elements to one another. Using this method allows the stress along the individual elements to be calculated showing how the stress propagates through the part (Bosch, 2018). The accuracy of results gained is limited by the complexity of the model and the engineer's understanding of the problem (N/A, 2020). Over simplifying a parts geometry can change the way the part behaves in the given scenario. On the other hand, not simplifying the component enough will result in high calculation times. It is often down to the designers own experience to determine which parts of the geometry can be simplified and where the mesh density should be increased for more detail (Mottram and Shaw, 1996).

Before the use of computers became a possibility, engineers were forced to perform calculations by hand in order to ensure requirements for the part were met. Since this gave limited insight into how the design performed, geometries were often greatly simplified since the complexities were not yet understood (Costen, 2019). The calculations on these sections gave an estimation of the parts capabilities. Being able to complete these calculations by computer allowed the element size to be decreased as computers are easily capable of coping with large numbers of equations that need solving. The smaller element sizes gave the confidence to introduce complexities into the geometries of components as the designer was able to understand which changes would cause failure. This method allows material to be taken away for the purposes of weight reduction and for material to be introduced in the areas where it is required for structural integrity.

Why companies typically carry out FE analysis alongside physical testing?

Why companies carry out FEA:

Simulation methods universally have the advantage that physical models are not required. These are both expensive and time consuming to produce, so keeping prototyping to a minimum reduces the amount of time required for each development cycle. When an FEA model is created there is usually a baseline real-world parallel against which the model can be compared. Completing similar tests in both environments or applying similar loads to both the simulated and real-world component, gives results that can be compared. Once the results are as close to each other as possible, taking into consideration any known errors, work can continue in the FE environment, allowing for rapid and cheap iterative design. Once a final design has been achieved, a final comparison between the FEA and real world should show that results still align. Although legislation does not allow for FEA to fully replace physical testing, once testing has been used to create a correlated model, iterative design can continue via simulation, until a point is reached where regulations require a physical test to be carried out. Since the FEA model was previously correlated, there is high confidence that subsequent physical results will match.

When designing a part, it is important for the design engineer to be confident that the part is going to be able to perform the task it is being designed for, whilst keeping the manufacture as cheap as possible. The failure of the part can include its inability to perform the task it has been designed for, even if this does not mean that it has broken (Iremonger, 1984). Excessive bending or fatiguing over time can also be considered a failure in a stress analysis, whilst in CFD the fluid not flowing in a predefined fashion can also constitute a failure. FEA is not limited to the performance of the part itself but can also be used to look at how the part interacts with its environment. Failure could be as a result of the part not interacting with its environment in a desirable manner (Szabo and Babuska, 1991).

Before designing a part, the engineer responsible will collect a list of requirements. This list will include tasks the part will need to be able to perform, potentially including external dimensions, material limitations and surface appearance. All requirements will be written in a manner that allows them to be measured so that they can be compared to the final design (Hooks, 1993). Companies use FEA to test new designs against their requirements. Tests can be repeated using a number of design iterations in quick succession, often being able to run in quicker than real time (Lee, 1999).

Another reason FEA is favoured within industry, is the amount of data that can be collected from each run. Every aspect of the analysis can be measured with as much or little accuracy as necessary (N/A, 2020). In real world testing, the data that can be recorded is limited by the sensors available. The number of sensors or their accuracy is often limited by the available budget. When using a

computational analysis, precision is simply limited by the calculation time as any FEA package will be able to give the accuracy and precision needed. As many “sensors” as necessary can be applied, each measuring different things, such as stress or temperature. These sensors can even be simulated to be positioned within the structure to view internal behaviour of the geometry. Furthermore, these sensors will not interfere with the behaviour of results, whilst real world sensors, which require mounting and are often in contact with the surface of the material, can influence the parts performance. An example of this would be a strain gauge which is mounted to the surface of a geometry. Although the effect it has, is tried to be kept at a minimum by making the material as flexible as possible, the presence of the gauge on the surface will have an effect on the stresses seen (*What is a strain gauge?*, 2020). Strain gauges are a cheap method for getting result meaning that some of its downsides are issues engineers would happily deal with. An example of this is a strain gauge, which can only give an insight into the behaviour at the surface of the material. However, this can often be sufficient for the needs of the test. X-ray diffraction on the other hand is a method of non-destructive testing, used to measure stresses in a structure by measuring the distance between crystallographic planes (*X-ray diffraction (XRD)*, 2018). It can measure stresses throughout the material, not just on the surface. However, the specialised equipment is expensive and cannot be easily maneuverer or positioned, making it difficult to use in many scenarios.

Why companies carry out physical testing:

There are a number of limitations that can affect the accuracy of results gained through the use of FEA. Physical testing is often used to correlate the results gained on the computer to the real word (*Analysis Correlation | Correlation of FEA & CFD Analysis to Real-World Data*, 2020), allowing the design engineer to determine what factor of safety might be required in order to ensure that failure can be avoided.

Another reason physical testing is often required, is as a means of determining the loads being applied to the component under investigation. An example of this is the case study **FEA and Optimization of Tie Rod of motor vehicle** (Kankarej and Nema, 2016). In this study a tie rod was being analysed for the purposed of weight reduction. An initial investigation was carried out, allowing a better understanding of how the current part was performing. This involved the creation of a CAD model and an initial FEA study in ANSYS. In order to understand what forces the part was being exposed to, a rig set-up was used. These results could then be used in the FEA study. Once a model had been correlated to the results from the test rig, the parts geometry could be altered, allowing weight reduction, whilst still making the part capable of performing its tasks. In this investigation, the physical testing was essential. Due to the complex nature of a steering and suspension assembly, without the physical testing it would be very difficult and time consuming to calculate the forces the part would need to withstand in order to meet its requirements. Without this accurate data to input into the FEA, the results could be completely useless.

As previously outlined, in order to achieve a reasonable calculation time for an analysis, the geometry of the part is often required to be simplified. This requires a great deal of understanding to be applied on the behalf of the Designer. Since the main downside to an overcomplicated analysis is increased calculation time (VanDyke, 2015), they must understand, which areas of the geometry will affect the precision of the results and which are just slowing down calculations. In real world physical testing, the time to results in not effected by the components complexity. As a result, the part can be tested with all the intricacies of the final design, gaining the most accurate results. This reduces the opportunity for errors to be introduced by the engineer.

The accuracy of the data gained from an FE analysis is limited, in part, by the mesh density (VanDyke, 2015). Even the smallest mesh density is not the same as the “infinite mesh density” when using physical testing. Furthermore, there are different calculation methods, such as Von Mises, used when the computer is calculating results. Although these different approaches have been proven to gain accurate results under their individual, pre-defined, scenarios, even if the user has not picked the wrong set of equations, the results will be less accurate than physical testing can be.

As a result, the complexity of the scenario will be a large factor when considering physical testing. Even if the component itself is not particularly complicated, a complex scenario could make it difficult to simulate. In that case, physical testing might be required to ensure the engineer does not oversimplify the result. An example of this from the investigation by (Abbey, 2014) shows how physical testing is required when investigating crash scenarios. Due to the way in which components are designed to progressively crumple, it is considered to complex a scenario for FEA alone to be reliable. Multiple loose and fixed components of varying densities and stiffnesses can all be taken into account to calculate a final result, however, in order to be sure that nothing has been missed, a physical test is still essential.

Some scenarios call for geometries or materials for which the material properties do not follow a known trend. When these physical properties are unknown physical testing is necessary either to replace FEA entirely, or to validate the results gained. When FEA has been used on these types of materials, an approximation of the expected behaviour is often used. An example of this can be seen in the case study by (Grimes *et al.*, 2012), **Design and Finite Element Analysis of a Composite Monocoque Chassis**. Here a carbon fibre monocoque was being created. Each year the team creates a new monocoque, allowing them to physically test their design, and compare results to the FEA they have created.

Logical reasoning is required to interpret results of an FEA analysis (Skotny, 2019). In order to ensure that the correct assumptions have been made and the correct conclusions drawn, physical testing can visually demonstrate what the numbers might be suggesting.

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

In order to correlate any type of simulation to the real world, the scenario being used must be a similar as possible. Materials being used, geometry dimensions, applied forces and environmental factors must all be considered.

The first area to consider is the part that is under investigation. It is important that its material properties are known as accurately as possible since, inputting incorrect information into the FE model will result in incorrect results. Any FE solver will need to know, material constants, such as the UTS, and stiffness of the material (2020 *SOLIDWORKS Help*, 2020). This information is required, as it allows the solver to have enough known variables to solve the simultaneous equations for strain or displacement. Although this could be assumed to be constant for a given grade of a known material, it is usually advisable to perform tests to determine these values (*Yield Strength - Strength (Mechanics) of Materials - Engineers Edge*, no date). Furthermore, the materials dimensions must be input accurately. FEA packages will tend to use a CAD model input in order to define the geometry. The user must ensure that these are dimensioned correctly. Although this might not affect the fatigue performance of the part, it could affect the amount of displacement the part sees, causing it to fail its requirements. When performing FEA, the user will often simplify the geometry, finding features that are deemed to not affect the results and removing them, in order to reduce calculation time. Whilst these changes might not have a significant effect on the parts behaviour, it will reduce the accuracy

of the analysis, making correlation more difficult. As a result, it is advised to only do this where necessary and when the user can be confident that the results will not be adversely affected.

Even if there is absolute confidence that the inputs into the FEA environment are accurate, there is always a level of uncertainty as to the accuracy of the results. It is often unknown, which set of equations the solver has decided to use in the given scenario, or the user has used their best judgement in order to simplify the geometry but needs to confirm that this has not had adverse effect on the precision of results. This is where it becomes imperative to correlate simulation results to the real world.

In industry, physical testing is often used as a benchmark stopgap to ensure that FEA results show the correct trends. Sometimes, to gain improvements, a trial and error approach has to be taken in an attempt to improve the geometry. Instead of wasting time, money and manpower in order to test a new design on a physical prototype, an FEA simulation can be conducted. In order to gain confidence that the improvements will be representative in real life, once certain benchmarks have been achieved in the simulation, they will be tested in the real world.

Real world testing can come in a variety of formats. The simplest and most popular approach is to recreate the exact scenario that is being designed for. An example of this might be when crash structures are being designed for a vehicle such as in the case study **Finite Element Modelling and Simulation of Car Crash** (Hickey and Xiao, 2017) . In order to confirm that the components will behave as intended, vehicles are crashed, and the components analysed afterwards and compared to the simulated component.

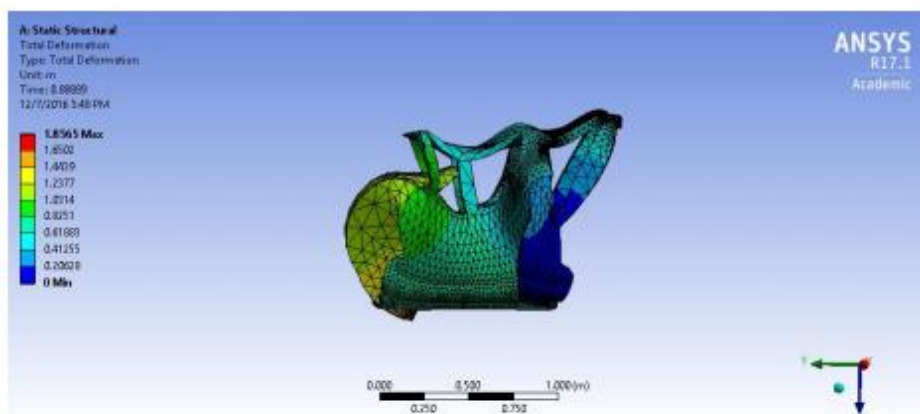


Figure7. Total deformation of car at 100mph



Figure 2: FEA to real world Comparison (Hickey and Xiao, 2017)

This, however, can be a very expensive approach and although simple to conceive, often complicated to carry out. In the given example, this would mean an entire vehicle being destroyed where it might only be a single component under investigation. If this is the case, physical testing might consist of specialized equipment, where only the component under investigation is exerted to the forces the engineer would expect it to see in the given scenario. An example of this given by (Kumar *et al.*, 2012) in their investigation **Drop Test Analysis of Impact Attenuator for Formula SAE Car**. In this study, a drop test was used to test the behaviour of the nose cone and compare the results to the calculated results. Although this relies upon some knowledge and understanding on the behalf of the engineer, it is a cost-effective method for correlating to an FEA simulation.



Figure 3: Drop testing crash structure(Kumar *et al.*, 2012)

Can/should FE analysis replace physical testing?

As discussed previously, whenever an FE analysis is conducted, there is a question over the accuracy of the results. Physical testing allows the engineer to gain confidence that the direction in which the design is moving is going to gain real world improvements.

With computer processors becoming faster, the accuracy that can be gained in each timeframe is always improving. Ever since FEA first became a possibility companies have used it in order to reduce the amount of prototyping and physical testing they are required to do. As the accuracy of results have improved, the role FEA plays in the development process has increased, allowing more and more physical testing to be replaced by simulation, however, there is still a need for physical testing. There are legal requirements, that make physical testing essential. They require manufacturers to demonstrate their products compliance with health and safety regulations (*Directive 2006/42/EC of the European Parliament and of the Council*, 2006). This can be difficult to prove solely through FEA.

Even the most accurate FE analysis requires the engineer to make several assumptions and approximations. Although these often gain accurate results, many would hesitate to rely on these as the physical tests are the only proof that the assumptions were correct.

Conclusion

As a result of the pros and cons outline previously, it is unlikely that any amount of FEA is ever going to be able to entirely replace the need for physical testing. In some form it will always be necessary to back up the results of simulation with physical evidence or “in situation” testing. Nevertheless, industries have already begun to reduce the amount of physical testing they conduct, favouring the cost-effective computational alternatives. This trend is likely to continue as companies continue to find ways of grouping multiple tests together, allowing them to reduce the number of prototypes necessary.



Bibliography

- 2020 SOLIDWORKS Help (2020). Available at: https://help.solidworks.com/2020/english/solidworks/cworks/c_basic_concepts_of_analysis.htm (Accessed: 26 March 2020).
- Abbey, T. (2014) *Structural FEA in the Automotive Industry, Digital Engineering*. Available at: <https://www.digitalengineering247.com/article/structural-fea-in-the-automotive-industry/> (Accessed: 2 March 2020).
- Analysis Correlation | Correlation of FEA & CFD Analysis to Real-World Data* (2020). Available at: <http://www.egsindia.com/analysis-correlation.html> (Accessed: 21 April 2020).
- Bosch (2018) *Bosch Automotive Handbook, Bosch Automotive Handbook, 10th Edition*. doi: 10.4271/0768081521.
- CaliberDesign (2020) *Why Use FEA?* Available at: www.caliberdesign.co.nz (Accessed: 2 March 2020).
- Churazova, A. (2018) *Designing More Durable Consumer Products with FEA*. Available at: <https://www.simscale.com/blog/2017/06/durable-consumer-products/> (Accessed: 2 March 2020).
- Costen, E. (2019) *FEA vs Hand Calculations, asrengineering*. Available at: <https://asrengineering.com/2019/04/02/fea-vs-hand-calculations/> (Accessed: 25 March 2020).
- Directive 2006/42/EC of the European Parliament and of the Council* (2006).
- Grimes, O., Bastien, C. and Christensen, J. (2012) 'Design and Finite Element Analysis of a Composite Monocoque Chassis for the Shell ECO Marathon Car Project 2012'.
- Hickey, A. and Xiao, S. (2017) 'Finite Element Modeling and Simulation of Car Crash', *International Journal of Modern Studies in Mechanical Engineering (IJMSME)*. Online, 3. doi: 10.20431/2454-9711.0301001.
- Hooks, I. (1993) *Writing Good Requirements*. Available at: https://reqexperts.com/wp-content/uploads/2015/07/writing_good_requirements.htm (Accessed: 25 March 2020).
- Introduction to Finite Element Analysis (FEA) or Finite Element Method (FEM)* (2020) University of Victoria. Available at: https://www.engr.uvic.ca/~mech410/lectures/FEA_Theory.pdf (Accessed: 25 March 2020).
- Iremonger, M. (1984) *BASIC Stress Analysis*. Page Bros Ltd.
- Kankarej, P. S. and Nema, A. A. (2016) *FEA and Optimization of Tie Rod of motor vehicle, International Research Journal of Engineering and Technology*. Available at: www.irjet.net (Accessed: 26 March 2020).
- Kumar, D. et al. (2012) 'Drop Test Analysis of Impact Attenuator for Formula SAE Car', *International Journal of Scientific and Research Publications*, 2(10). Available at: www.ijsrp.org (Accessed: 26 March 2020).
- Lee, K. (1999) *Principles of CAD/CAM/CAE Systems*.
- Mottram, J. T. and Shaw, C. T. (1996) *using Finite Elements in Mechanical Design*.
- N/A (2020a) *Advantages of FEA, Product Research and Engineering*. Available at: <http://www.pretechnologies.com/services/finite-element-analysis/advantages> (Accessed: 2 March 2020).

N/A (2020b) *What is FEA ?*, *SimScale*. Available at: <https://www.simscale.com/docs/content/simwiki/fea/whatisfea.html> (Accessed: 25 March 2020).

Kotny, L. (2019) *How to Interpret FEA Results?*, *Enterfea*. Available at: <https://enterfea.com/how-to-interpret-fea-results/> (Accessed: 26 March 2020).

Szabo, B. and Babuska, I. (1991) *Finite Element Analysis*. Available at: <https://books.google.co.uk/books?hl=en&lr=&id=JsCg-QWUT28C&oi=fnd&pg=PA1&dq=Finite+element+analysis&ots=jSAtrNnBgM&sig=2ugkKRVp7KOSHkbJK-DtidW0lz4#v=onepage&q=Finite+element+analysis&f=false> (Accessed: 11 March 2020).

Thornton, J. (2011) *FEA and the Question of Credibility*, *ASME*. Available at: <https://www.asme.org/topics-resources/content/fea-and-the-question-of-credibility> (Accessed: 2 March 2020).

VanDyke, D. (2015) *Dangers of Modern FEA* | *VGO Inc*. Available at: <http://vgoinc.com/general/dangers-of-modern-fea> (Accessed: 26 March 2020).

What is a strain gauge? (2020). Available at: <https://www.omega.co.uk/prodinfo/straingauges.html> (Accessed: 26 March 2020).

X-ray diffraction (XRD) (2018) *StressMap*. Available at: <https://www.stressmap.co.uk/x-ray-diffraction-for-measuring-residual-stress/> (Accessed: 16 March 2020).

Yield Strength - Strength (Mechanics) of Materials - Engineers Edge (no date). Available at: https://www.engineersedge.com/material_science/yield_strength.htm (Accessed: 21 April 2020).