

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

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declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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

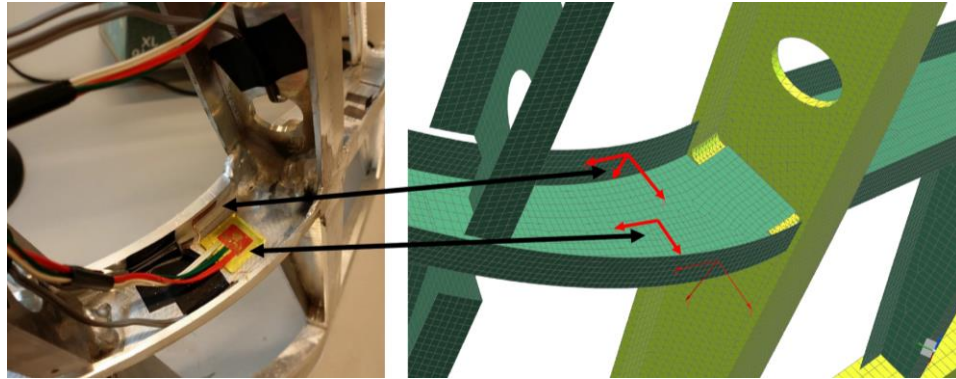
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	21.9
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	22.5
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	21.3
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	7.4

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)		73.1 %
	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

Can FEA Replace Physical Testing?

Advanced Stress Analysis & FEA

M6X00420

Callum-James Hill

BEng Motorsport Engineering

P148699

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Contents

1	Acronyms.....	3
2	List of Figures	3
3	List of Graphs.....	3
4	Introduction	4
5	Finite Element Modelling	5
6	Why Use FEA Alongside Physical Testing?.....	7
7	Correlation of a Physical Test to a Finite Element Model	10
8	Is FEA capable of replacing physical Testing?	12
9	Conclusion	14
10	References	15
11	Appendices	17
11.1	Appendix One FEA Model & Test Setup of Automotive Seat Structure	17

1 Acronyms

FEA – Finite Element Analysis

FEM – Finite Element Method

CFD – Computational Fluid Dynamics

NVH – Noise, Vibration & Harshness

OEM – Original Equipment Manufacturer

CAE – Computer-Aided Engineering

CAD – Computer-Aided Design

PDE – Partial Differential Equations

BC – Boundary Condition

2 List of Figures

Figure 1 Global Mesh Refinements - From Coarsest to Finest (Comsol, 2016).....	5
Figure 2 Local Mesh Refinement (Comsol, 2016).....	6
Figure 3 The Design Process	8
Figure 4 Topology Optimization (Broekaart, 2019).....	9
Figure 5 Constraint and Load of Spanner (Comsol, 2016).....	10
Figure 6 Effect of Geometric Discontinuity on Stress Distribution (UV), 2015)	12
Figure 8 Automotive Seat Structure FEA Model (Radesh Vangipuram, 2008).....	17
Figure 9 Automotive Seat Structure Test Setup (Radesh Vangipuram, 2008).....	17

3 List of Graphs

Graph 1 Elastic & Plastic Region (Welch, 2017).....	6
Graph 2 Automotive Seat Structures Correlation (Radesh Vangipuram, 2008)	13

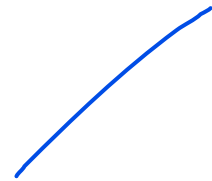
4 Introduction

This paper examines FEA and its crucial role within the engineering product design process and attempts to answer the question, will FEA ever be able to ultimately replace physical testing? The Finite Element Method is a numerical approach used to carry out Finite Element analysis of any physical phenomenon (Harish, 2019). FEA is the most frequently used method to solve complications within engineering and mathematical problems and works by breaking down a component into a multitude of smaller “*Finite Elements*” and with the use of mathematical equations aids predicting the behaviour of each element, “*adding up all the individual behaviours predicts the behaviour of the actual object*”. (Autodesk, 2018).

The three main topics of discussion within this study are as follows;

- Analysis of why companies customarily carry out FEA apace with physical testing.
- How a physical test may be correlated to a Finite Element Model.
- Whether there is a possibility that FEA is viable to completely replace physical testing.

In order to sufficiently cover each topic of discussion a case study from 2008 titled “*Parameter Design Based FEA Correlation Studies on Automotive Seat Structures*” (Radesh Vangipuram, 2008), was taken into consideration and used to aid in discussing the above topics based around FEA within the automotive industry. Finally, visual aid of the physical testing set up and FEA model of the case study can be found in Appendix 11.1.



5 Finite Element Modelling

FEA aids engineers of all disciplines to optimize components during the design phase, reducing the number of physical prototypes and testing required. *“The description of the laws of physics for space and time dependant problems are usually expressed in terms of partial differential equations (PDE’s)”* (Comsol, 2016). PDE’s are complicated equations that need to be solved in order to calculate relevant quantities of a structure, to be able determine certain behaviours of a component under a certain load (SimScale, 2016). In regards to most geometries the PDE’s are unable to be solved using analytical methods, FEA only gives an approximation solution of the problem and is a numerical approach to get the actual results of these PDE’S, simplified *““FEA is a numerical method used for prediction of how a part or assembly behaves under given conditions”* (SimScale, 2016).

A common compromise within FEA is the balance between a reasonable solve time and the accuracy of results. The more complex a model becomes the more computational power and time is required. *“Each point, or node, adds degrees of freedom (DOF) to the system”* (Xceed, 2017), DOF’s are unknowns for which a system of equations is solved, DOF’s of a node tells the amount of ways in which it is free to move and also highlights the type of loads that are able to be transmitted through the node. As the number DOF’s increases so does the complexity of the model and in turn so will the solve-time, therefore in order to develop an accurate but also computationally efficient FEA model the convergence of the mesh is assessed. *“FEA configures a model for analysis using a complex system of points or nodes which are connected into a grid called a mesh”* (Engineers Edge, 2010). The mesh convergence determines the number of elements that are required within an FE model to ensure that the results are not affected by altering the size of the mesh. Following convergence, additional mesh refinement will not have any consequence on the results (Xceed, 2017). The refinement of the mesh is one of the most crucial factors for the accuracy and validity within an FE model. If a mesh is too coarse it may yield inaccurate results as the component is subdivided into larger elements, whereas a finer mesh subdivides the components into smaller finite elements *“FE models with fine mesh yield to highly accurate results* (Liu, 2020). Global refinement of the entire mesh is usually needless, in most circumstances, the mesh only needs to be refined in regions where the highest levels of stress are experienced. Thus, local mesh

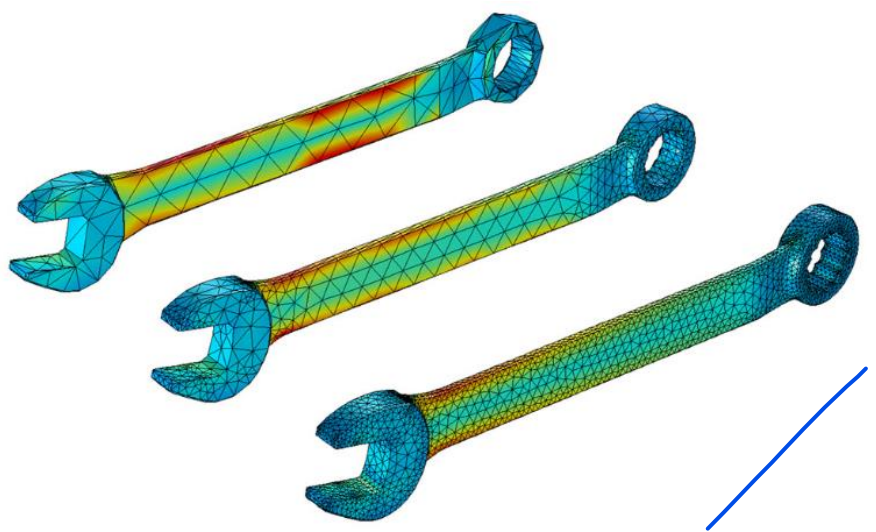


Figure 1 Global Mesh Refinements - From Coarsest to Finest (Comsol, 2016)

refinement is usually “*more economical and as effective as global mesh refinement*” (Thompson, 2017).

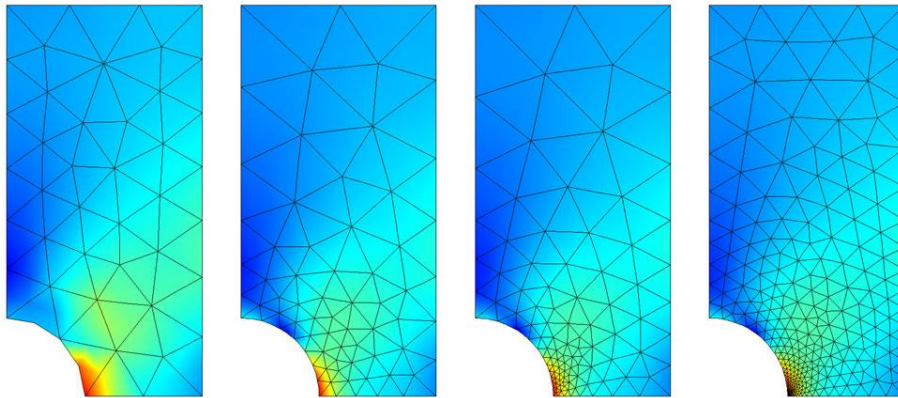
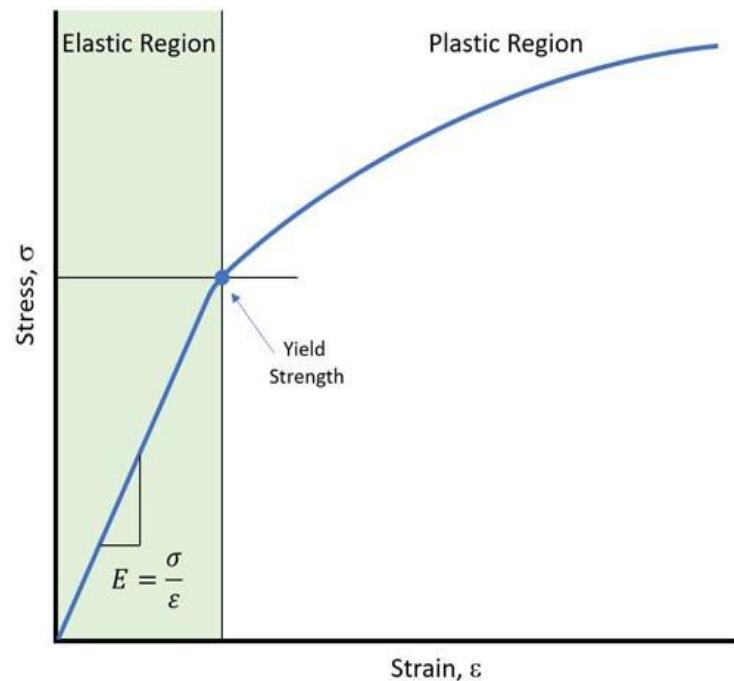


Figure 2 Local Mesh Refinement (Comsol, 2016)

There are numerous variations of FEA including but not limited to; Linear and Non-Linear static, Dynamic, buckling, thermal & CFD (Kelvin Lake, 2020). The case study considered within this paper is based on the physical testing and FE model of an automotive seat structure subjected to quasi-static load inputs. The majority of mechanical systems are subjected to loads that fluctuate over time, each system has a characteristic time which in turn determines whether the load is regarded as static, quasi-static, or dynamic (UIOWA, 2019). Quasi-Static loading can be analysed using static analysis and is associated with loading where inertial effects are negligible. In other words, time and inertial forces are inconsequential.

“*With static analysis, you can analyse linear static and nonlinear quasi-static structures*” (SimScale, 2016). A Linear structural analysis assumes the relationship of stress to strain remains within the elastic region and does not surpass the point of yield, meaning the deformation the component withstands is elastic and will return to its original state. Whereas, a nonlinear analysis is where the stress-strain relationship is given by a curve instead of a single value of the elasticity modulus. Furthermore, it defines what happens when the load exceeds the point of yield and plastic deformation begins to occur. This model is well suited to ductile materials such as mild steels (Welch, 2017).



Graph 1 Elastic & Plastic Region (Welch, 2017)

6 Why Use FEA Alongside Physical Testing?

Within the Automotive Industry there is an ever-increasing complexity to mechanical components. Therefore, an over reliance in CAE tools are required to determine the feasibility of potential prototypes. Finite Element Analysis has been widely implemented in not just the automotive industry but all areas of engineering as a productivity tool for engineers in order to reduce development time and costing. Furthermore, it can be used to analyse how the design of a component reacts under real-world boundaries and conditions and allowing the appropriate modifications to be made before physical prototyping *“used by design engineers as a design tool during the product development process because it allows them to analyse their own designs while they are still in the form of easily modifiable CAD models”*. (Kurowski, 2016). Without the use of FEA, design engineers would be required to make the leap straight from an initial CAD model to early physical prototyping, where if a major material or structural flaw were to arise, it would cause a largely negative impact to the cost in time delays and iterations in design cycles.

FEA is a versatile tool which provides comprehensive results, calculating the physical response of a system at any location, including some which may have been neglected in an analytical approach. In addition to this, FEA software provides a safe option to simulate a potentially destructive, dangerous or impractical load condition. It also then allows design engineers to assess the safety of a component when very close to failure, allowing for minimum factors of safety. Ultimately it allows the design engineer to *“Discover and eliminate possible sources of component failure before production and manufacture”* (Cambridge Design Technology , 2016). Moreover, FEA also allows the user to test for failure in ways that may not be a possibility with physical testing alone. In the long-term FEA is a relatively small investment and with computational power coming on leaps and bounds in recent years it offers a rapid calculation time for most applications (Pre Technologies , 2020).

Subsequently, the use of FEA can greatly limit in the investment of expensive prototypes and physical testing, providing there is a sufficient correlation between FEA modelling and physical testing. In regard to the case study considered in this paper it states that *“The seat system is one of the most expensive assemblies in a vehicle”* (Radesh Vangipuram, 2008), by utilising FEA software in turn reduces the manufacturing costs of making numerous prototypes, reducing the amount of physical testing needed and essentially saving companies money.

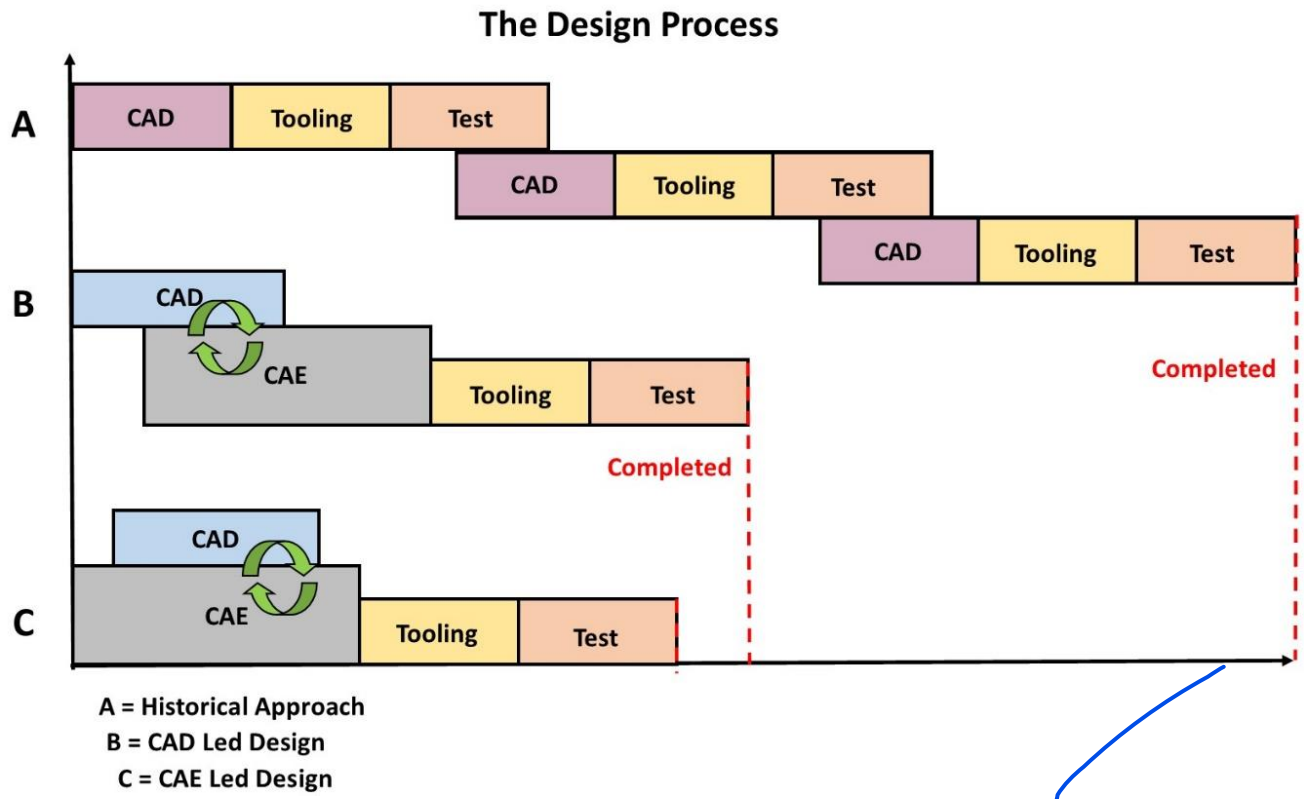


Figure 3 The Design Process

The use of FEA not only saves companies on expenses but also drastically benefits in reducing the time taken to complete the design stage of a new component. Figure 3 displays three different variations of the design process from over the years as the capability of computer-aided engineering software became more complex. Furthermore, it is worth mentioning that the diagram was created by the author based on a diagram from Level 5 lecture notes by Kelvin Lake retrieved from the UWTSD Moodle archives.

Before the use of FEA the design process of a new structure would follow a method of; CAD design, tooling of physical prototype, physical testing and the re-design of the CAD model. This method is continuously repeated until the design engineers are satisfied with the final model, making it a vigorously time consuming and expensive process. During the earlier stages of CAE software, a new component would undergo a CAD led design process consisting of; an initial CAD model which then with the use of FEA is assessed and redesigned accordingly, the process is repeated until the design is feasible, finally a physical prototype is then manufactured and tested. Subsequently, modern CAE software allows a “CAE led” design process where; the design is made in CAE and assessed with FEA before a CAD model is produced and reassessed, then a physical prototype is made followed by physical testing.

An example of CAE led design is Topology optimization. Optimization using topology was introduced several decades ago in 1988 and is a mathematical approach for optimizing components, it selects the elements in a FE mesh that best maximises the trade-offs in both minimizing material usage and the components weight whilst maximizing the strength for a given manufacturing process “*You’re basically starting with an ideal solution, from a mathematically efficient design*” (Auto Beat, 2015).

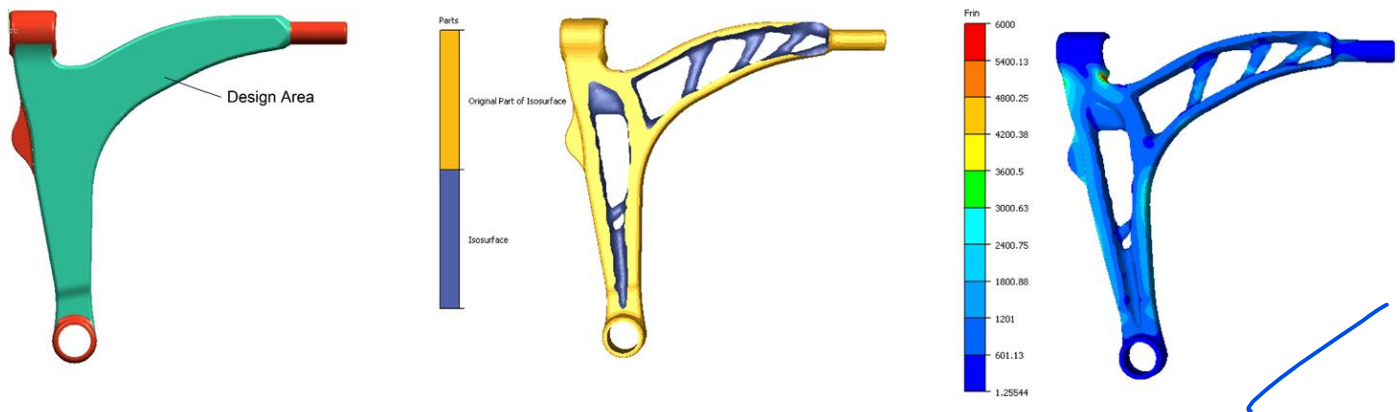


Figure 4 Topology Optimization (Broekaart, 2019)

In summary, all of these factors prove that companies from all branches of engineering simply must utilise FEA alongside physical testing in order to be innovative in reducing the costing and time consumption of the design process, allowing new structures and components to be produced and brought onto the market at a quicker rate.

7 Correlation of a Physical Test to a Finite Element Model

As previously discussed in section 6 the use of FEA is an important factor of the design process resulting in a reduced quantity of physical test samples that are costly. Subsequently, the results of the physical test and the FEA results need to be in agreement with each other, and any deviation able to be objectively explained. This correlation between the results of an FEA test and its subsequent physical test in regard to any component must be clearly understood and quantified in both magnitude and direction. The percentage deviation of the results between an FEA and physical test is referred to as the “*Error Percentage*”, the complement of this percentage is known as the degree of correlation. It is absolutely crucial that the degree of correlation is within tolerance as the misapplication of FEA “*may lead to erroneous design decisions, which are very expensive to correct later in the design process*” (Kurowski, 2016).

There are numerous methods to achieving accurate correlation between real-world testing and FEM predictions. In the case study concerning automotive seats it is stated that the analysis of the entire seating system becomes not only time consuming, but also the cumulative errors propagated through the system interfaces can result in non-optimal solutions. The study further states that “*The automotive seat system consists of three main sub-systems, and many other components*” (Radesh Vangipuram, 2008). The reliability and robustness of the FEA simulation are extremely important contributing factors, especially if FEA is to be used in place of physical tests. This requires that the FEA simulation optimizes the entire process by breaking down the analysis into sub-systems and component levels. Individually testing the sub-systems and components of the automotive seating system will have a better correlation with physical tests due to the reduced number of interfaces.

One of the more difficult aspects of setting up an FEA model to simulate accurate results in turn correlating with real world testing, is the application of the correct boundary conditions; understanding how the structure is loaded by external forces and how it is constrained from moving globally in space (Abbey, 2015). One article states that boundary conditions have a major impact on the result of analysis and “*a simple mistake in boundary conditions*” could make the difference between a FEA model with a 30% error and a 3% error (Cyprien, 2016). The main types of loading available within an FEA model include but are not limited to; Force, Pressure and temperature, these are applied to nodes, edges, surfaces, points and elements or remotely offset from a feature. Additionally, the design engineer defines the environments with constraints as well as the loads, these constraints are a major contributing factor to the accuracy of the

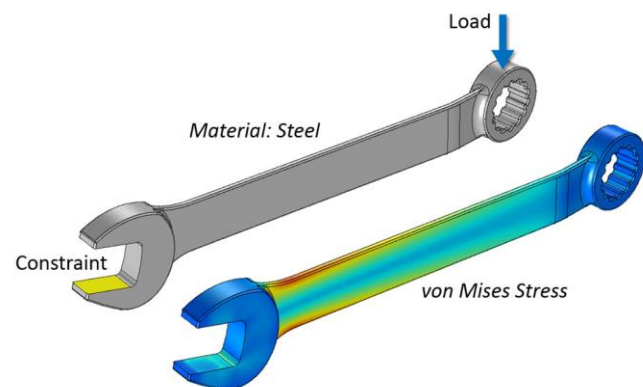
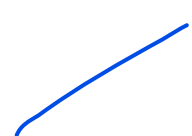


Figure 5 Constraint and Load of Spanner (Comsol, 2016)

model *“The way that the model is constrained can significantly affect the results and requires special consideration”* (Value Design Consulting, n.d.).

Another section within the case study *“Parameter Design Based FEA Correlation Studies on Automotive Seat Structures”* states that one of the other most significant aspects of using FEA simulation as an effective tool is the confidence in the analysis results. It further states that simulation of a components design using FEA modelling needs its validity verified with a *“small sample size”*, these types of tests are more commonly referred to as *“correlation tests”*. Furthermore, correlation tests are highly encouraged before the initial mass-produced prototypes are built for verification testing. It is vitally important that the FEA simulation displays a very profound degree of correlation with the physical test in order to predict the validity of future alterations to a components design *“unless this is proven with good reliability and accepted by the product developers, the full benefits of using CAE as an effective tool would always be questioned”* (Radesh Vangipuram, 2008).

Finally, another method of correlating FEA simulation data with that of physical testing is with the use of a *“Virtual Strain Gauge”*. This allows design engineers to position virtual strain gauges on a component within a FEA model in user defined reference directions and correlate the virtual strain histories with physical test data, to gain confidence in the FE models predictions. Furthermore, virtual strain gauges can be utilised to study the effect of geometric variations on the strain results during the design and development stage, *“this can be helpful for a sensitivity study rather than individually testing each component to study their responses”* (Prenscia, 2016).



8 Is FEA capable of replacing physical Testing?

FEM is the most widely used method for solving problems in engineering and mathematical models. Furthermore the use of FEA within the development process of any new component has become an absolute necessity among design engineers in all sectors of industry. On the other hand, is the use of FEA simulations accurate enough to ultimately replace all physical prototypes and testing? In short, no it cannot, there is an abundance contributing factors and differentiating variables in real-world conditions, therefore FEA will never be able to perfectly represent physical testing.

Like most things, FEA is not without its limitations. For example. the results generated from a FEA simulation are only as accurate as the data inputted “*Garbage in, Garbage out*”, if an incorrect mesh size is selected or the wrong boundary conditions and/or constraints are applied to a model it will inadvertently falsify the results. Errors in FEA can be classified under the following three categories;

- “*Improper understanding of the physical phenomena or inappropriate choice of analysis*”
- “*Modelling strategies not in alignment with objectives of FEA*”
- “*Lack of understanding of the limitations and strengths of FEA*”

(India, 2015)

An article on the “*Sparta Engineering*” website stated that they focussed specifically in Linear FEA. They further stated, that one of the most common cases of a FEA simulation generating inaccurate results was due to stress concentrations. At the location of a stress concentration, there is a large amount of stress in a minute area. For example, Figure 6 shows a rectangle with a hole cut out in the middle where a higher concentration of stress is acting around the hole. Stresses acting within these areas can be beyond the yield point of a material. Therefore, due to the sudden increase of stress in such small areas “*linear FEA is not accurate at predicting effects in these stress concentrations*” (Penner, 2016).

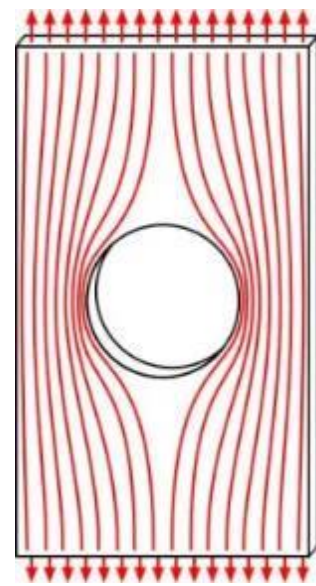


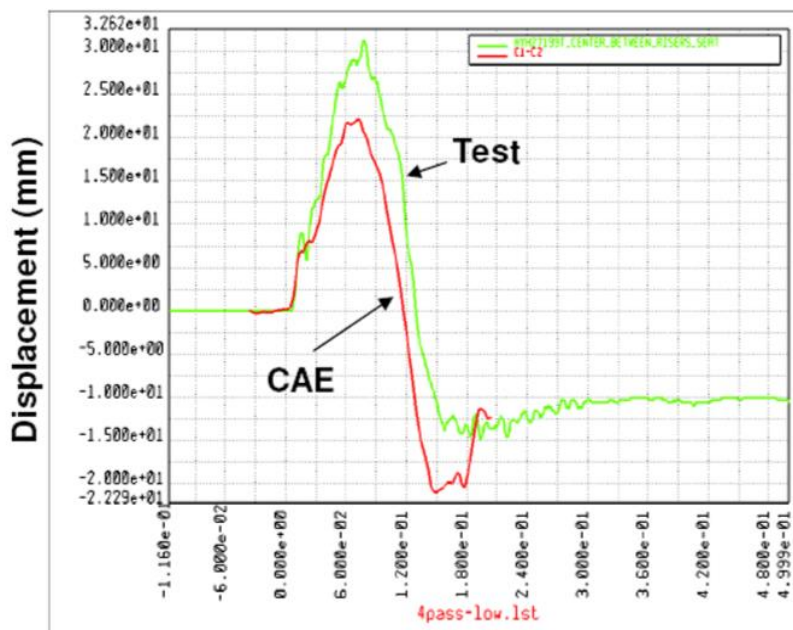
Figure 6 Effect of Geometric Discontinuity on Stress Distribution (UV, 2015)

The case study considered used the quasi-static and dynamic analysis on automotive seat structures to illustrate the steps of using FEA modelling and testing as a method to reduce cost and time consumption. A consistently high degree of correlation was said to have been achieved throughout the study, although there were certain contributing factors which caused inconsistencies between the FEA model and physical test. Firstly, on the physical seats there is welding between the structural components, which are assumed to be perfect within the model. The FEA models do not reflect additional material, or the effect of heat affected zone of welding. Additionally, within the FEA simulations the bolted connections had transfer energy at 100% efficiency. This is unrealistic in comparison to a physical test, because the bolted joints dissipate energy due to inherent friction and “*various other micromechanics of bolted joints*” (Radesh Vangipuram, 2008).

The properties of any given material within a FEA model are at their minimum values. Whereas, in a physical component, the materials properties may be different as a result of “*raw materials manufacturers’ variations*”.

“*The constraints used in the FEA models may not match the D.O.F of the actual test sample.*” (Radesh Vangipuram, 2008), this is another concern stated within the case study, as even though the FEA model itself essentially takes care of this, what happens in real-world situations can be understood, only upon completion of the first physical test. Further proving that whilst FEA is vital, the idea of a company advancing straight from CAD and FEA modelling to a final product is just not realistic, there is a wide array of underlying problems that could cause a FEA simulation to generate results that do not accurately represent that of physical prototype testing.

Within the case study it is clear that the CAE models made all available effort to simulate the actual real-world physical test conditions, but as previously stated it’s not without its limitations. For example, it’s extremely difficult to accurately model the variations of material gage thickness and stress and at the same time ensuring that the test samples are within an acceptable range with the FEA models. Subsequently, the case study states that the variations of not just the welds, but also the joints were the most difficult aspect to accurately model within a FEA simulation, questioning the validity of the FEA results if they were incorrectly modelled (Radesh Vangipuram, 2008).



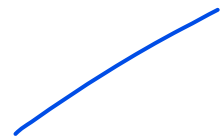
Graph 2 Automotive Seat Structures Correlation (Radesh Vangipuram, 2008)

Graph 2 shows the FEA correlation results of the Automotive Seat structure within the case study which has been subjected to dynamic load inputs to the entire seat system during a forward frontal impact. It shows a clear correlation of the trend of results throughout the test. However, the results do not completely represent one another. More displacement took place during the actual physical testing. Thus, physical testing cannot be completely replaced as FEA is just an approximation and even though it is capable of producing an extremely high degree of correlation, there will always be some degree of error.

9 Conclusion

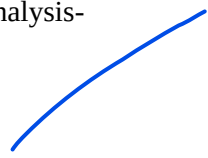
This paper has emphasized the influence and importance computer-aided engineering has in the early stages of the design process, especially FEA modelling and simulation. FEA helps limit potential problems and reduces the time consumption of a new component during the design stage by reducing the amount of physical prototypes that need to be manufactured. Potentially, saving companies thousands and thousands in expenses during the development process.

To conclude, whilst FEA is widely used tool and has become a necessity in the life of a design engineer, it can not and should not replace prototypes and physical testing entirely. Even though the complexity and capability of CAE software packages are advancing at a swift rate, FEA has numerous limiting factors that will always question the validity of the results. Finally, the conditions of real-world testing contains so many variables, computational FEA or even hand calculations need to be accompanied with physical testing for credible analysis.



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11 Appendices

11.1 Appendix One FEA Model & Test Setup of Automotive Seat Structure

Figure 7 & Figure 8 below display the FEA model and actual test set up of the automotive seat structure that was subjected to quasi-static load inputs from the case study that was considered within this paper to aid in comprehensively covering each topic of discussion.

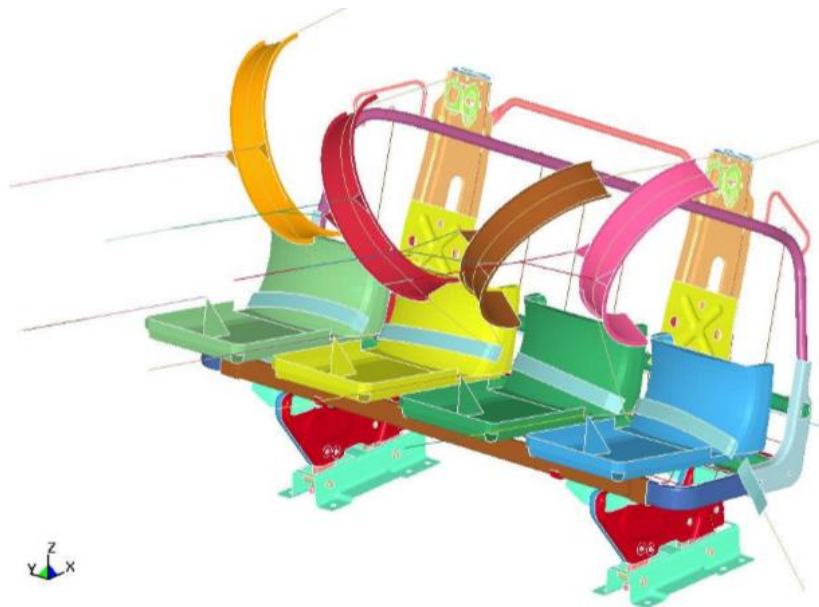


Figure 7 Automotive Seat Structure FEA Model (Radesh Vangipuram, 2008)



Figure 8 Automotive Seat Structure Test Setup (Radesh Vangipuram, 2008)