

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

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declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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

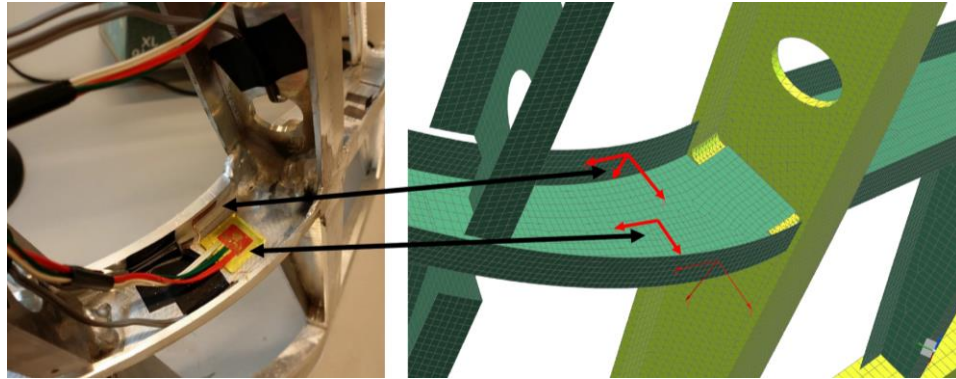
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	18.4
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
(Assessed in point 2)	30	20.1
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	6.8

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)		65.3 %
	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

Advanced Stress Analysis & FEA

Module Code: M6X00420

Can FEA replace physical testing?

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April 5th 2020

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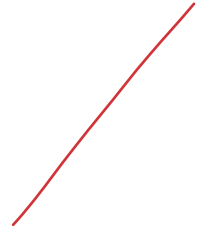
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1 Introduction

The aim for this project is to discuss the differences between finite element analysis (FEA) and physical testing, and how they correspond with each other. In addition, this project will discuss whether FEA should ever replace physical testing.

The objective is to consider a case study of the authors choice and use this to discuss the following above.



2 What is the difference between FEA and Physical testing?

2.1 What is FEA?

Finite element procedures are an important aspect in engineering analysis and design, in order to solve physical problems. Referring to Figure 1, represents a summarised process of FEA, where it shows the physical problem, whether it is an actual structure or structural component, which loads are applied too. This physical problem requires certain assumptions being made to govern the differential equations represented in the mathematical model to assess the accuracy gathered from the results in FEA. However, if the criteria have not met the requirements, this procedure will need to be repeated with finer meshes until the solution accuracy has been met. The finite element solution will only solve one selected mathematical model combined with assumptions, in response to the predicted response, where the choice of the mathematical model needs to be appropriate as it is critical to determine the actual physical problem, where analysis can be obtained (Bathe, 2014).

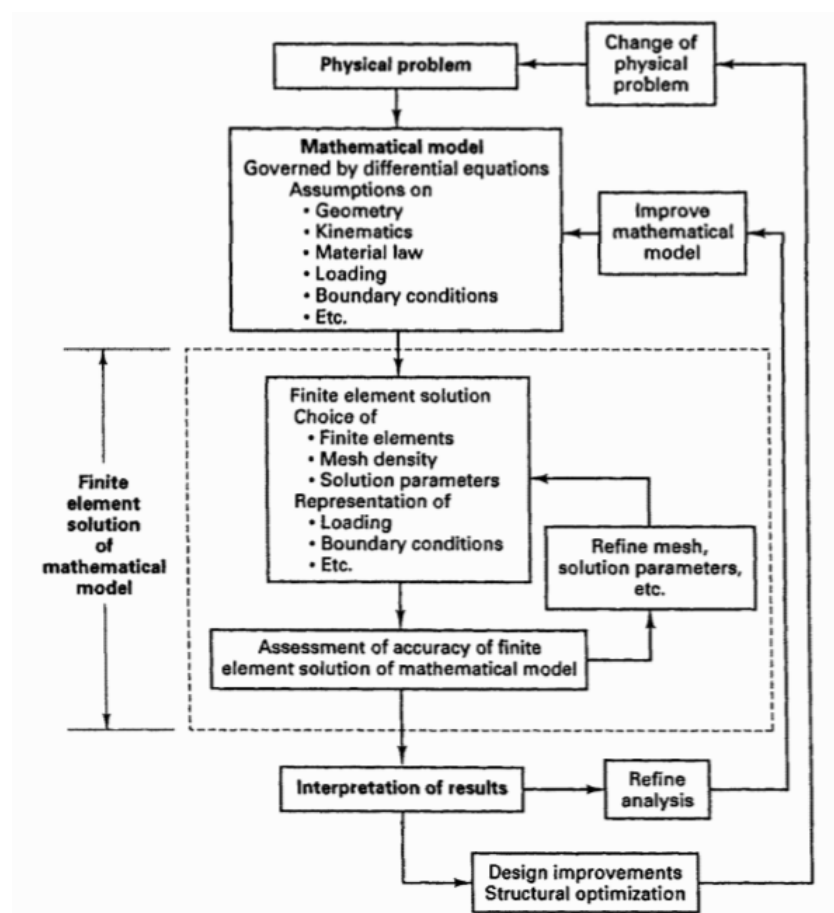


Figure 1: The process of finite element analysis (Bathe, 2014)

The finite element methods consist of five main steps: Pre-processing, which divides the problem domain into finite elements. Element Formulation, which develops equations to solve these finite elements. Assembly, finding the equations of the whole system within the equations used for each individual element. Furthermore, these equations will be solved, leading to Postprocessing, determining the stresses and strain acting on the model, whilst analysing the response (Fish & Belytschko, 2007).

In addition, preprocessing allows the user to develop a part of a model to be analysed in depth, in which the geometry is divided into several sub-regions, such as elements which are connected into points in the elements called nodes. These points within the body can either have fixed displacements or prescribed loads. Meshes can be applied to the body, so the FEA can be done conveniently depending on the mesh size (Roylance, 2001).

Furthermore, the analysis can be performed by the pre-processor data output, where this solves a system of linear and non-linear algebraic equations such as Equation 1, where K represents the matrix depending on the type of problem being challenged, 'u' are the displacements and 'f' is the external applied forces acting on the nodes (Roylance, 2001).

$$K_{ij} * u_j = f_i$$

Equation 1: Matrix equations abbreviated (Roylance, 2001)

Referring to the postprocessing, the stress is a measurement of the force acting on a plane through a designated point of interest on the body. This strain will multiply according to the material properties defining a new physical quantity. This act is known as Hooke's law, Figure 2, where the stress is directly proportional to the strains and represented in Equation 2 (Akin, 2009).

$$\text{Hooke's law } (\sigma) = \text{Youngs Modulus of elasticity } (E) * \text{Strain } (\epsilon)$$

Equation 2: Hooke's law (Akin, 2009)

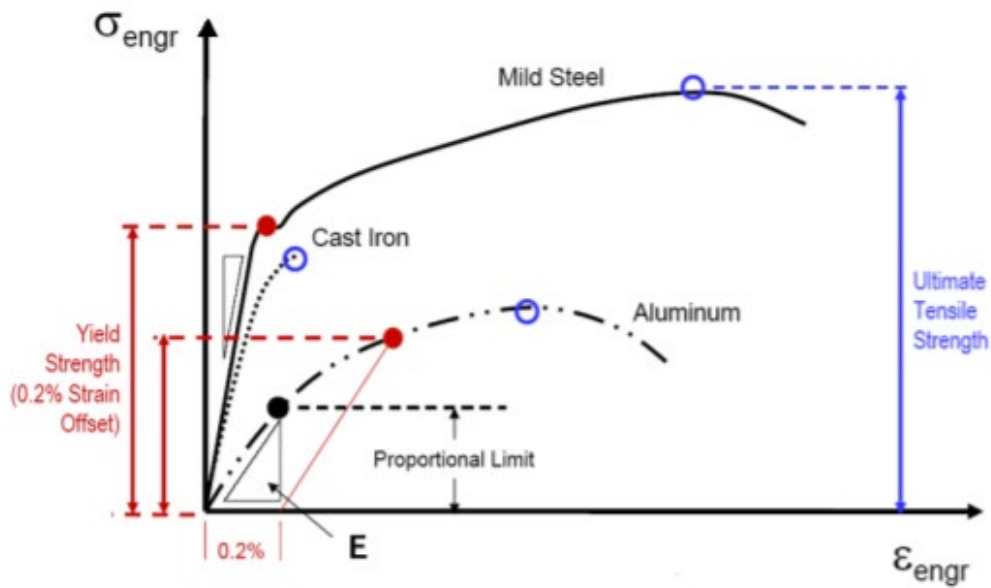


Figure 2: Hooke's law for initial linear stress-strain (Akin, 2009)

Furthermore, referring to Equation 1, the matrix analysis of members is structured and connected in axial forces by considering the stiffness of each element at a time, determining the forces by the displacement of the nodes in FEA. This matrix will consist of the sum of the forces combined according to each element, where the node must equal to the sum of the force externally applied, where this applies to a linear algebraic equation where the node displacements are unknown, and the node forces are known. Where this can be formed in Equation 3 (Roylance, 2001).

$$\begin{bmatrix} k_{11} & k_{12} & k_{1n} \\ k_{21} & k_{22} & k_{2n} \\ k_{n1} & k_{n2} & k_{nn} \end{bmatrix} \begin{Bmatrix} u_1 \\ u_2 \\ u_n \end{Bmatrix} = \begin{Bmatrix} f_1 \\ f_2 \\ f_n \end{Bmatrix}$$

Equation 3: Matrix form (Roylance, 2001)

NOT NEEDED

2.2 What is Physical testing?

Before FEA, engineers were limited, as hand calculations and physical testing were constructed. These methods produced adequate results assuring the outcome of the designs complied accordingly with the performance requirements. However, many assumptions were made, and tests were presumed for the performance insights and revised the approach to the design. Using hand calculations limited engineer's ability to optimise the design, especially where over complex designs were too problematic to analyse by hand. Therefore, FEA allows greater access to detailed information within the design's performance (emmetcosten, 2019).

Physical testing of complex designs can be an expensive and time-consuming process. With the advent of 3D printing, prototypes of parts can be made and in doing so the prototype timeline can be decreased, however accessible 3D printing sources decreases the prototype timeline, limiting the use for structural purposes. The use of 3D printing materials is not representative to the production grades, meaning they are more likely to break and more fragile. In addition, the test equipment and fixtures required are expensive, and the physical testing takes a long period of time to complete. Furthermore, once the physical testing is complete, it can be problematic to analyse the outcome from the physical testing (Hugo, 2019).

With the use of hand calculations, there is no need for expensive software, it provides a good starting point for the initial design. The use of hand calculations, is by far quicker to setup compared to a complex FEA model, and allows good analysis for simple problems within the design. During the initial calculations, the moment and shear loads as well as reactions are considered during statics (Hugo, 2019).

Initial equations, such as, deflection and stress can be carried out using the following equations below;

$$Y_{\max} = \frac{-w * L^3}{3EI}$$

Equation 4: Deflection (mm)

$$\sigma = \frac{M * y}{I}$$

Equation 5: Stress (MPa)

NOT NEEDED

2.3 Benefits and Limitations

2.3.1 Benefits of Finite Element Analysis

FEA can provide many benefits for the engineering industries, such as, engineer designers, project managers and product development managers. FEA modelling is a useful source of software, allowing the ability to highlight possible design and material flaws in components during the computer aided design stage. This allows for the parts to be redesigned with a few changes rather than redesigning the whole component. It is also useful for modelling the behaviour of components, where stresses act in everyday use, referring to where physical testing may have been required (Cambridge Design Technology, 2020).

Some designers move swiftly from their CAD models into early concept prototyping followed by functional testing. This is because if the prototype has any structural or material flaws, the re-prototype stage can result in costly time delays and iterations in the design cycles, causing a negative time to market, impact effecting the company (Cambridge Design Technology, 2020).

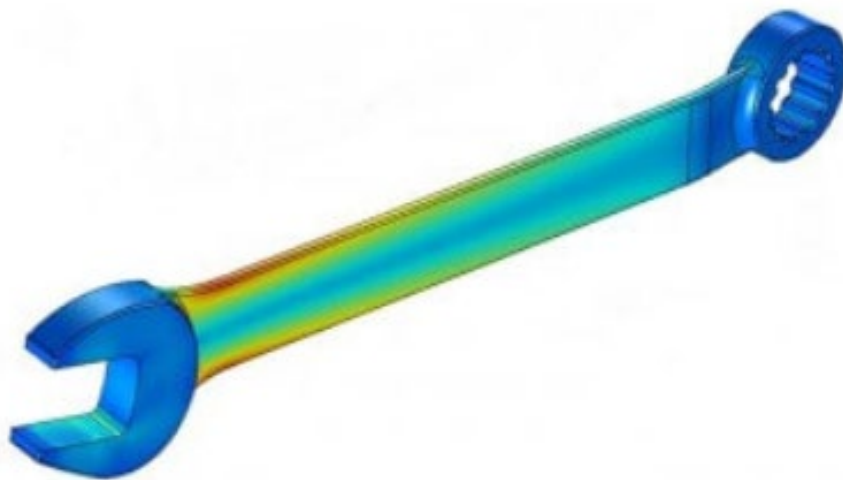


Figure 3: FEA analysis on a CAD model (Cambridge Design Technology, 2020)

FEA testing can help design managers to reduce design project times and, therefore, the entire 'design to manufacture' process. Furthermore, they can optimise the product design, allowing prototyping and production costs to be minimised. Finally, FEA can analyse and eliminate any possible sources of failure acting on the component before the production and manufacturing process.

According to (Cambridge Design Technology, 2020), the main five key benefits from FEA are:

- Testing for failures which are not possible during prototyping.
- Assessment of safety of the component referring to the minimum factors of safety when close to failure.
- Increased confidence ensuring the design will work as intended.
- Savings of cost and time alongside re-prototyping.
- Quantifiable improvements within the component, such as, weight reduction, strength and durability.

2.3.2 Limitations of Finite Element Analysis

According to (Dascotte, 2004), it is important that the integration and analysis software application does not develop into a problem itself. There are two main procedures which combine in the uncertainty of numerical simulation results; physical and numerical uncertainty. Physical uncertainty contains four main levels:

- Boundary and initial conditions - containing the impact of the velocity and angle and the weight of the vehicle.
- Material Properties - containing the uncertainty of yield stress, strain-rate parameters, density and local inadequacies.
- Geometry - profile, thickness, manufacturing and assembly tolerances.
- Loads - impacts occurring on the model.

In addition, the numerical uncertainties can be known as:

- Conceptual modelling uncertainty insufficient data from physical processes, lack of knowledge within the system.
- Mathematical modelling; is the model accurate enough to validate.
- Discrete errors; element types, mesh density, geometrical detail.
- Numerical solution; rounding to the nearest number, overlap of tolerances, integration process.
- Human errors; programming and coding errors, wrong utilisation of the software, error occurred in data or units.

These forms of scatter may or may not occur, with or without physics being involved (Dascotte, 2004).

3 Why companies' carryout FE analysis with physical testing

3.1 The Verification and Validation Plan

Companies take verification and validation seriously, where designers, analysts and test engineers embed this ethos into their management approach. Verification and validation assigns applicability to both the FEA model simulation methods and test programmes to the real-world assembly. This process is integrated between analysis and test disciplines in order to understand the physics applicable to the modelling techniques and reasons for test failures, where active redesign and preventative innovative designs abilities improve significantly (Abbey, 2015).

Referring to the ASME process chart, represented in Figure 4, an understanding of relation between verification and validation within FEA and physical testing can be seen.

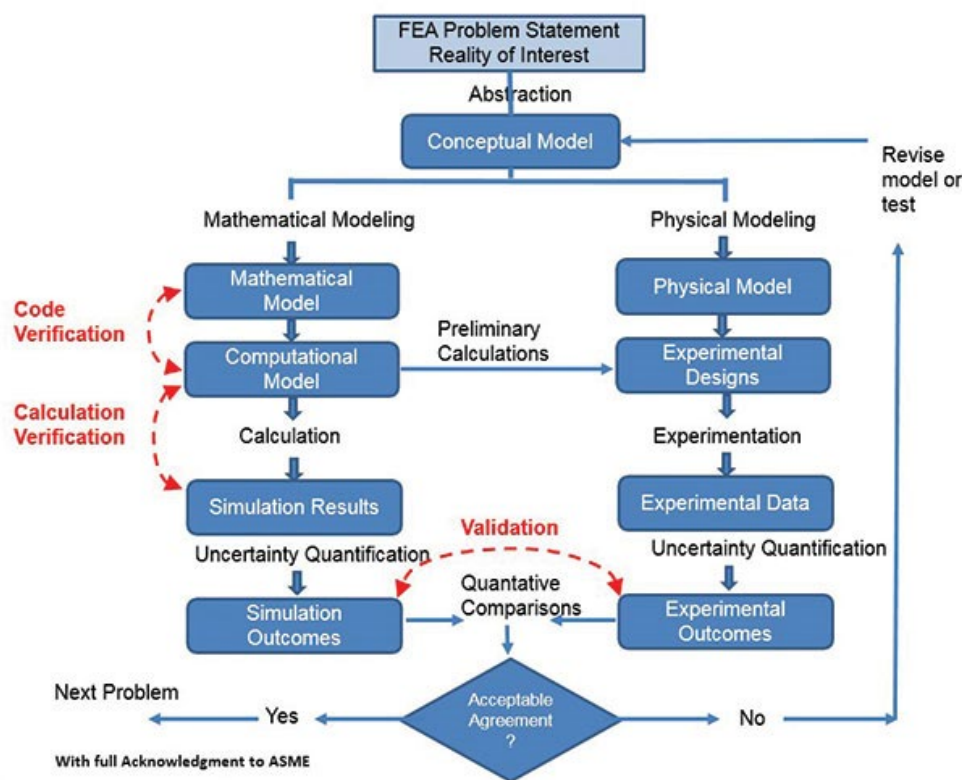


Figure 4: ASME V&V flowchart (Abbey, 2015)

In comparison, FEA analysis and physical testing consist on a set of metrics. This implies that the traditional single comparison, such as: ultimate failure level, maximum deflection or peak acceleration is enhanced by increasing the amount of metrics.

Moreover, giving a larger validation between the FEA model and the physical testing. Physical testing and FEA analysis can assist plan and assume outcomes. Companies use FEA to predict the outcome of physical testing towards the fixture strength and stiffness of the component. Example, in some cases the interaction between the fixture and physical test is inevitable and or can be quantified, such as, dynamic interaction or fixture flexibility (Abbey, 2015).

Both physical testing and FEA analysis have a step called uncertainty quantification, where methods access mesh convergence to allow confidence in FEA local stresses. FEA is the assessment of uncertainty in boundary and loading conditions, where accurate modelling aspects can be problematic, sensitive studies can be carried out on load levels in boundary stiffness and others. Companies which act on verification and validation, need FEA tools to facilitate these actions.

3.2 The importance of physical testing alongside FEA analysis

According to (Crowley & Cantillion, 2018), directs the reader to the importance of mechanical testing, its benefits and how Rockatek as a company have become an important part to customers' development strategies. Physical testing can often be considered as pointless, overpriced, and time consuming; in this day and age it is hard to argue against that statement. Companies may decide to cut costs, condense time and budgets being spent on testing. However, there are greater risks to companies who choose this route, as unexpected failures may occur in services products and this will have a greater failure that occur in service products will have a greater cost and time implications. Physical test verification contain many key benefits such as:

The characterisation of material properties, validation of the product function/FEA simulations, provision of empirical data to refine and improve simulations, proof of iterative product improvement and clear, visible evidence of product integrity to clients (Crowley & Cantillion, 2018).

Companies should invest in physical testing. Although, this entails specialist equipment, in which trained engineers design the physical test, setup the equipment and accurately analyse results using a dedicated physical test is cost-effective for companies executing reliable accurate test programs.

4 How physical testing correlates to an FE model?

A comparison of hand calculations and FEA to physical testing was conducted according to (Rawson, 1994); this article provides a case study of a thermoplastic bumper to replace steel bumper systems. This study was conducted by GE Plastics in order to predict the outcome of the performance of thermoplastic bumper designs using hand calculations and a detailed FEA from the results according to physical testing. This study represented the process in design for the thermoplastic bumper according to the hand calculations and FEA, which compares the results obtained from the original physical test.

Comparing the methods used firstly, to estimate the bumper performance with the use of hand calculations then representing the design of the detailed finite element analysis, the user can develop multiple useful designs with engineering thermoplastics (Rawson, 1994). These hand calculations prove that the approximations made to estimate the feasible results within the three to four point bend. These results show the performance approximation across the entire bumper system resolving in fluctuation between the supports, which acts as a method for energy consumption shown in Figure 5.

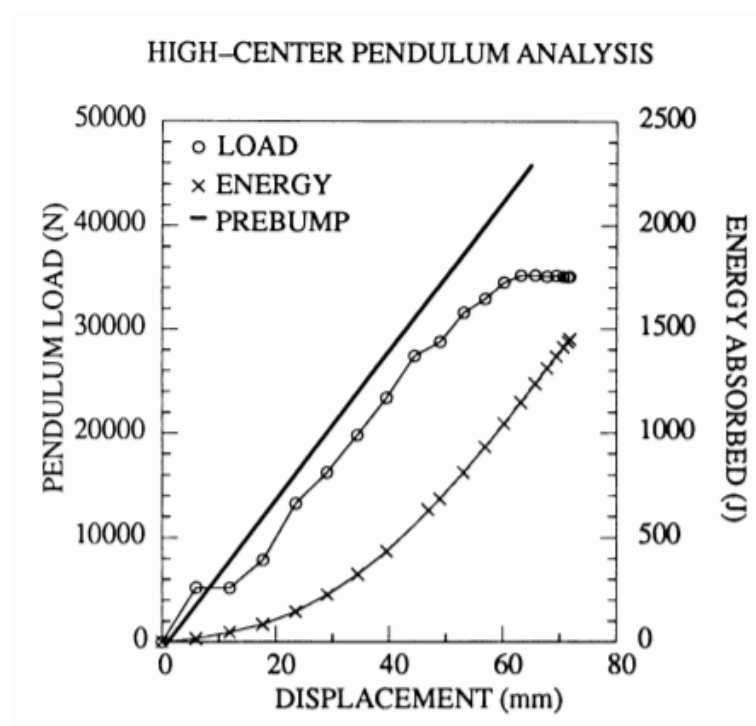


Figure 5: Comparison of PREBUMP to detailed Finite Element Analysis of a High Centre Pendulum Impact
(Rawson, 1994)

Furthermore, referring to the Appendices, these graphs represent the results matching between FEA and physical testing. Figure 7 compares the difference on a rigid barrier for the thermoplastic bumper which weighs an approximation of 6kg acting on the impact. During this study, the boundary condition was assumed as there is a difference on the two curves for the FEA results. This graph, Figure 7, represents a correlation to a point as it is over-constraint. This case study states that the boundary condition provides an accurate representation between results as buckling occurs (Rawson, 1994).

In addition, Figure 8 represented the correlation of linear hand calculations (PREBUMP), the FEA and physical testing for a centre to centre pendulum impact acting on the same thermoplastic bumper for the previous test, shown in Figure 7. As a result because the event was linear the correlation between the three methods were good for this case (Rawson, 1994).

Finally, the final correlation of the FEA to physical testing on the test vehicle for the thermoplastic bumper is represented below, in Figure 6. This correlation of the data performed is excellent according to (Rawson, 1994), where both methods predicting trends and matching peak rail loads within a 10% margin.

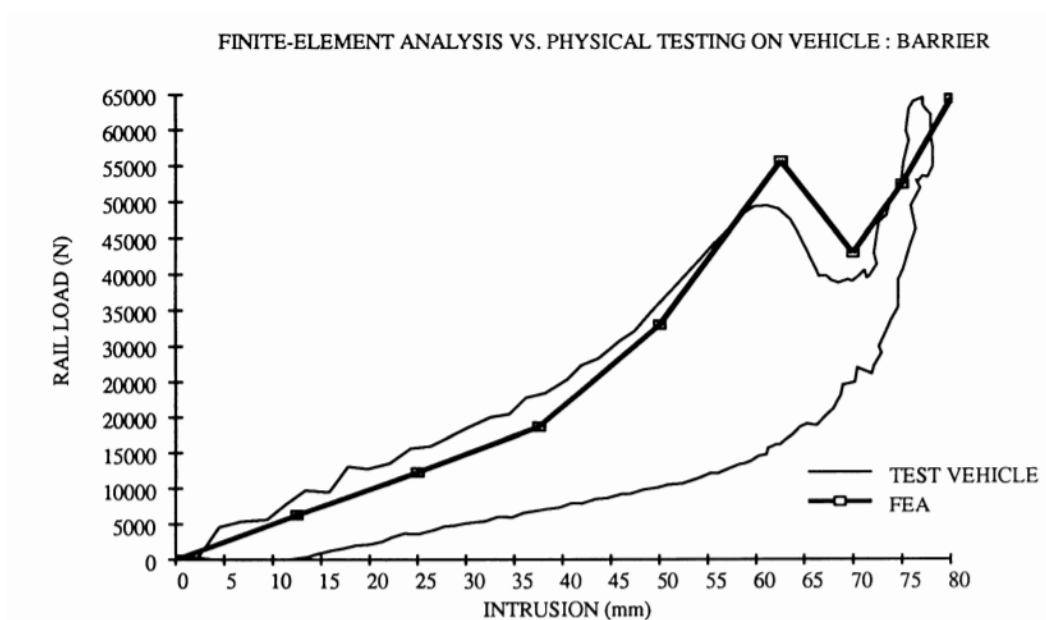


Figure 6: Comparison of Finite-Element Analysis to Physical Testing on a Test Vehicle for a Barrier Impact
(Rawson, 1994)

5 Should FE analysis replace physical testing?

Referring to (Tahera, et al., 2012), physical test results help improve and validates the FEA test models and validate that the iteration is important. The start of the CAE analysis should explain the specification for procurement, and the FEA testing should assist the physical testing. This case study uses a virtual test designed specifically for this physical test. Virtual testing is represented on a piston over a scenario across the entire range of parameters which are not encountered on the test bed. This virtual test for a piston would not be appropriate for any other component such as a connecting rod.

In addition, the case study (Tahera, et al., 2012), states it is necessary to create a finite element analysis test model before the physical test begins. One of their engineer states;

The baseline product definition is physically tested, and that information is fairly adequate for simulation to run for multiple variables for longer time to find the optimum setup. Then a physical test is required to validate the simulated result (Tahera, et al., 2012).

This allows the virtual test model to be further validated, adjusting values gathered from the physical tests. Limitations within the variation within variables can be adjusted in finite element analysis testing in serval iterations until it represents the physical test model so the engineers can proceed enough with confidence in their finite element analysis test model. As the finite element analysis test matures, this will produce faster testing results than the physical testing (Tahera, et al., 2012).

6 Conclusion

To conclude, both methods of finite element analysis and physical testing should be considered together, in order to validate results. This process allows an approximation of what the results will consider during physical testing and, depending on the mesh size and solution time, the results of the finite element analysis should match within a certain percentage as shown in the case study (Rawson, 1994), where both methods correlate together.

7 References

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8 Appendices

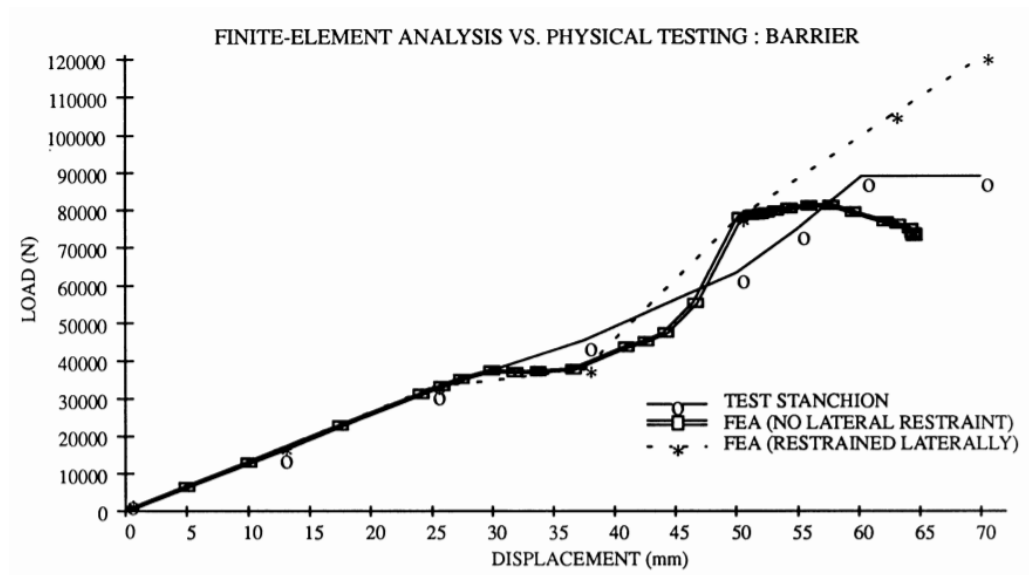


Figure 7: Comparison of Finite Element Analysis to Physical Testing on a Rigid Fixture for a Barrier Impact (Rawson, 1994)

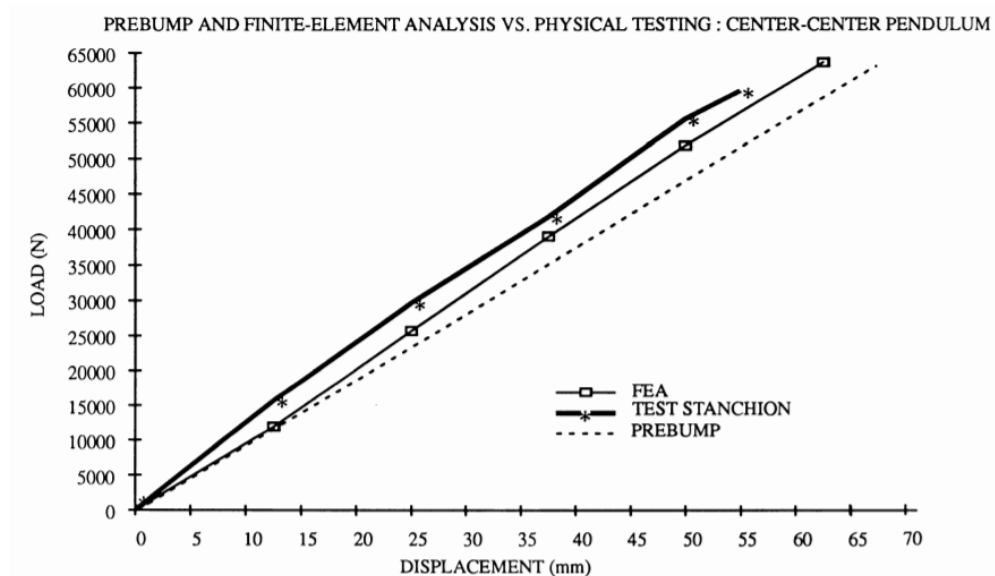


Figure 8: Comparison of Finite-Element Analysis and Linear Hand Calculations to Physical Testing on a Rigid Fixture (Rawson, 1994)