

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	JAMES	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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	21
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	21.6
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	7.5

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)		72 %
	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

Ryan James 0751093

09/03/2020

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1 Introduction

1.1 Aims

Through research compare Finite Element Analysis (FEA) with physical testing. Investigate the advantages and disadvantages of combining both methods for analysing a scenario. Explore whether FEA could ever replace physical testing.

1.2 Objectives

1.2.1 Choose a Field of application for the FEA and physical testing

Each question has been answered with a different case study to broaden the research into the chosen field of stress caused by physical loading and NVH.

1.2.1.1 FEA

FEA is a numerical method that can be performed to simulate many scenarios in engineering and science; basically any problem that can be discretised these include:

- Stress of materials and assemblies
- Fatigue of materials
- Heat transfer through a system.

The results are a mathematical representation derived from approximate assumptions made (Altair Hyperworks, 2011). For this assignment, forces on materials due to loadings, will be the application investigated. The validity of results and complexity of the process will be discussed within the report.

1.2.1.2 Physical testing

This can only be achieved if parts have been created. As stress loadings and forces on materials will be investigated, physical tests on materials under load will also be investigated these include:

- Strain gauge linear tests
- Photo elasticity (on isotropic and non-isotropic materials)
- Fatigue tests
- Acceleration force sensor tests.

The expense, difficulty, complexity, reliability, and correlation of these tests will be examined with comparison to FEA for this assignment.

2 Part 1 Advantages of FE Analysis Combined with Physical Testing

2.1 General pitfalls of any testing

When optimizing components (to reduce material and waste), therefore increasing performance of designed components, or in the general design of components, adequate forces, temperatures and contaminates for the working environment should be known. This presents a design problem for either method in knowing the boundary conditions and manufactured material properties of components and how to apply adequate safety factors viz. an ignorance tolerance (when increasing a designs strength due to the fact of not all factors known) (McNutt and Castillo-Rogez, 2014).

2.2 Physical test advantages

Accurately modelling the material properties within software presents problems as most are non-isotropic, due to composite layers, surface treating or manufacturing processes where different parts cool at different rates, creating softer cores etc (Swolfs, Verpoest and Gorbatikh, 2015). Although non-isotropic properties can be applied within software packages, custom layups of composites will have to be physically tested as they may not have the predicted properties (Swolfs, Verpoest and Gorbatikh, 2015). Any new component may have unknown voids or impurities due to the production process so testing the prototype either the final component or assembly or both can help reveal any unforeseen defect or show if it is over engineered.

2.3 FEA advantages

Creating an accurate virtual part and performing FEA has many advantages:

- No tooling machining costs
- Cheaper to adjust when errors made
- Can be optimised for material size and shape at little cost
- Simulations can identify problems in the design
- FEA tested Designs can be shared with customers at lower cost than prototyping
- FEA CAE led designs can reduce design steps.

EXPAND

2.4 Case study

2.4.1 Aluminium Fibres in epoxy resin

The bonding of two materials is complex to model as the modulus of the two materials cannot be simply added as the cohesion creates interfacial phenomena due to its surface tension which is difficult to predict. Johnson investigates this in “Influence of a matrix crack on stress transfer to an α -alumina fibre in epoxy resin using FEA and photo-elasticity”(Johnson *et al.*, 2006)

The study focussed on the effects of cracks in the resin matrix transverse to the fibres. Photo elasticity was used to measure the stress concentrations around matrix cracks within the epoxy resin. FEA calculations were examined in the photo elasticity results.

2.4.2 Physical Testing

A PTFE test mould was created to bond the aluminium fibre to the epoxy resin which was applied and the point of crack after curing was observed. A strain gauge was attached to the test piece to correlate the loadings applied with the stress on the PTFE mould.

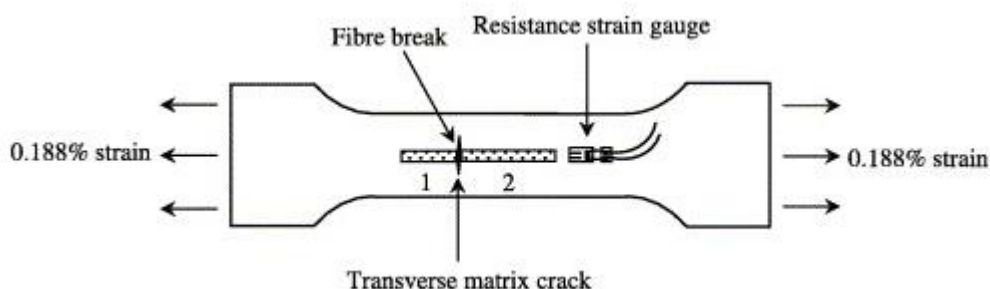


Figure 1 Test Sample Arrangement (Johnson *et al.*, 2006) (the fibre break was not pre introduced)

The resin matrix used was directly used as the photo elastic medium. This reduced the problems associated with having a photo elastic coating, such as the modulus and Poisson's ratio of the coating interfering with results (Fiedler and Schulte, 1997). When any physical test is carried out, interference from test equipment must be corrected for, such as the thickness of the strain gauge when checking a small component (Liu, Zhao and Jones, 2010).

2.4.2.1 Physical results

The following figure shows the increased stress concentrations due to the crack in the matrix.

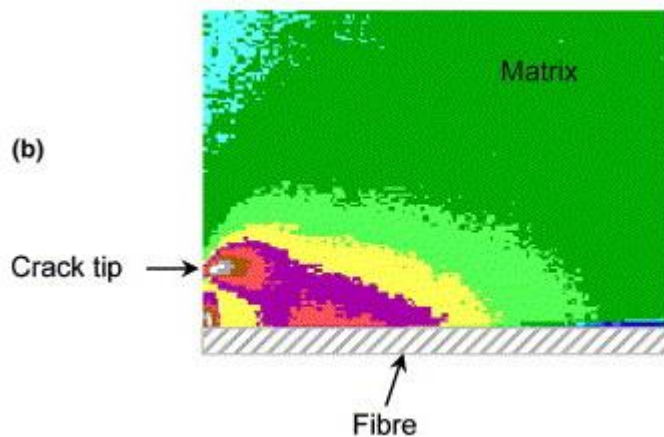


Figure 2 Photo elastic Image

Characterising the stress visually is useful as these types of cracks can form during the manufacturing and are not always accounted for.

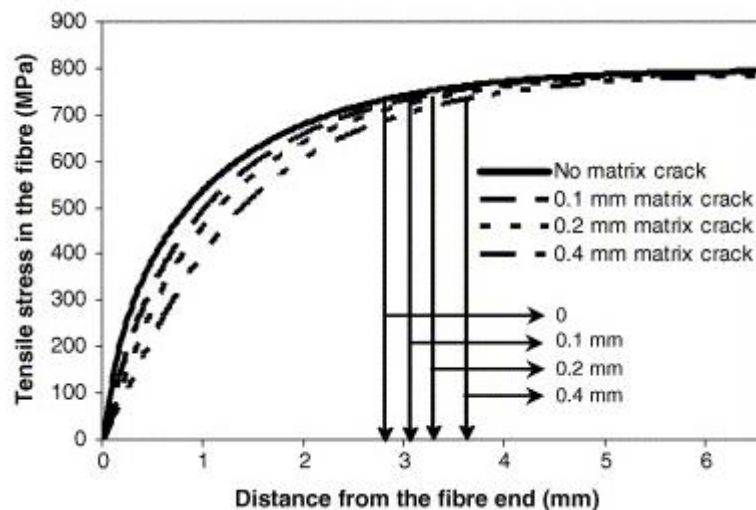


Figure 3 Strain Gauge Results

Figure 3 shows the larger the crack, the less tensile stress that is transmitted to the end of the aluminium fibre. Therefore, reducing the matrix and aluminium fibre combined composite strength.

2.4.3 FEA observations

An axisymmetric FEA model of a composite system was used, as there was only one fibre so one axis of symmetry. The assumption was made that the fibre is elastic and will return for small loads and the resin matrix is elasto-plastic which is flexible but will not stretch without changing geometry. It was also assumed that the fibre was perfectly bonded.

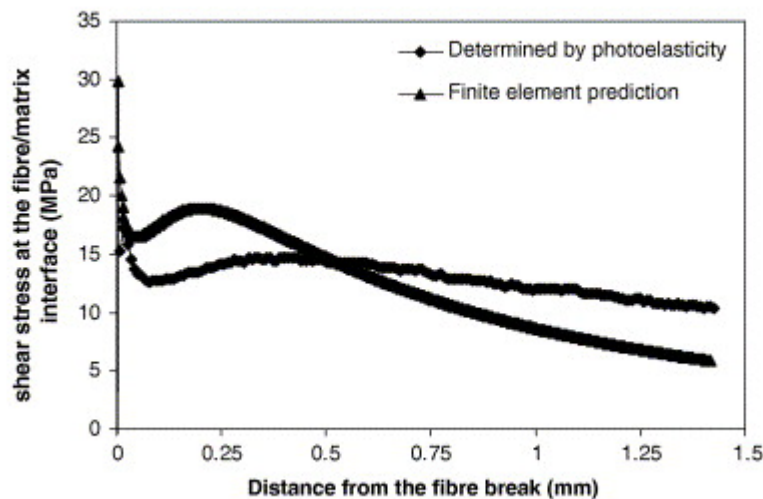


Figure 4 FEA results

The results show a cross over depending on where in the material the stress is being observed. The results show the FEA predicts higher composite strength at the break, but it rapidly diminishes after 0.25mm. The photo elastic showed the stress remains withing the material more constantly over a longer distance.

2.4.4 Study Conclusion

The focus of the test was to gain the advantage of both test methods to feed improved correction factors back into the results. As cracks and voids naturally occur withing curing of composite materials, having physical test results to play back into an FEA simulation is invaluable (Ricotta, Quaresimin and Talreja, 2008). They show that the FEA was over predicting the stress concentration at the fibre break and under predicting it further away.

3 Part 2 Correlation of FE Models with Physical Tests

Methods

This section will be answered with respect to accurate physical test results.

As FEA is an approximate technique it can be compared for correlation with experimental test results. Such results may provide data from strain gauges, harmonic frequencies, temperature and pressure distributions and deflection results.

FEA is a numerical test method whereas physical testing is an experimental test method. Either method can be corrected itself against other known similar works for example. Computational Fluid Dynamics (CFD) is another numerical test method. That is correlated with sets of known experiments such as the Mira study. For that approach, an identical test is performed in CFD to experimental wind tunnel results. From these comparisons the settings in the CFD simulation can be validated and used for similar studies as a point of correlation.

When correlating results all affecting conditions must be considered:

- Effects from welding
- Boundary conditions
- Fatigue effects
- Residual stresses
- Experimental conditions.
- Material attachments

Increasing computational power will not yield more accurate results if the correct conditions are not considered or the incorrect mathematical method appropriate to the scenario selected.

3.1 Case Study for Correlation

3.1.1 Solar Sails

NASA directed an investigation into FEA and test correlation of a solar sail “Finite element analysis and test correlation of a 10-meter inflation-deployed solar sail” (Sleight *et al.*, 2005). The solar sail is a gossamer space structure which means it is a large ultra-lightweight system. It must be ultra-low mass as every 1kg increase in the rocket payload mass results in at least 7kg of fuel for a multistage rocket (McNutt and Castillo-

Rogez, 2014). Furthermore, the solar sail captures photons from the sun in the solar wind utilising their momentum from the formula:

$$P = \frac{h}{\lambda}$$

Where:

P = momentum of a photon; h = Planck's Constant and λ = wavelength of the Light

This thrust propulsion system typically has 5 newtons of force for an 800 by 800 solar sail at the earth's distance from the sun but without the presence of air friction it is a viable propulsion method that must be optimised, with the added benefit of carrying no fuel (Mautner, 1995).

3.1.2 FEA and Physical Test

To optimise future designs, after initial designs and prototyping of a test version, two companies were utilised that specialised in FEA to carry out separate studies to correlate differing FEA models to utilise the best simulation for further work.

3.1.2.1 Physical Plan

Three phases were chosen to test the solar sail prototype as part of a ground test programme

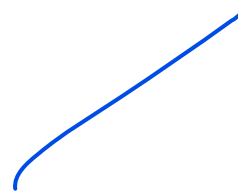
- Boom components
- Solar sail component
- Full subsystem.

The tests were carried out in the relevant conditions

- Environmental pressures and temperatures (these are pre validated conditions from previous missions and experiments)
- Solar flux loads
- Vibrational tests.

3.1.3 The Boom Test

The boom test will be looked at in more detail.



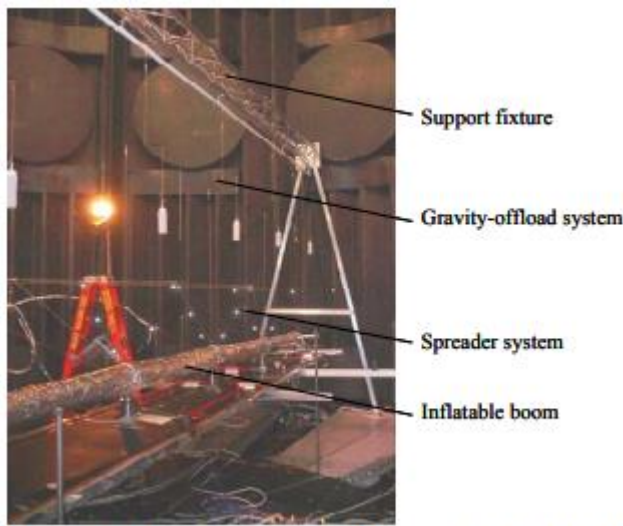


Figure 5 Boom Test Apparatus in thermal vacuum unit (Sleight *et al.*, 2005)

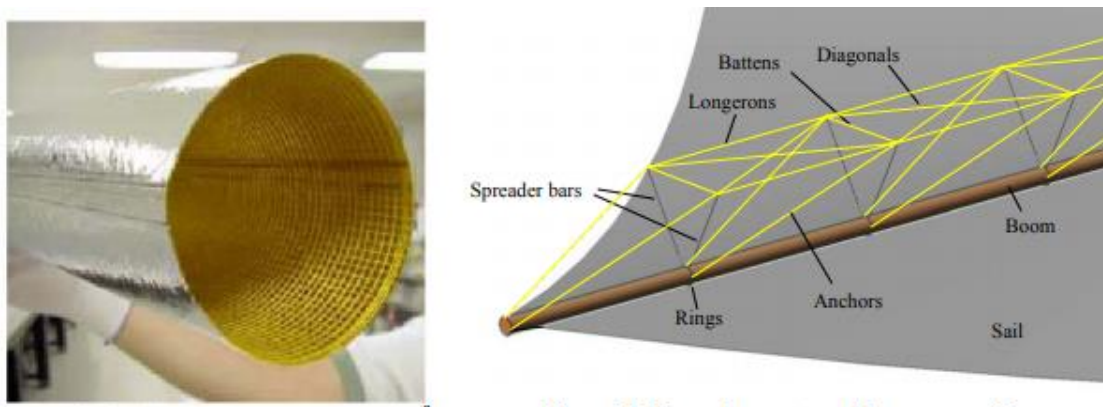


Figure 6 Boom Section and spreader system schematic (Sleight *et al.*, 2005)

The boom is semi monocoque inflated to increase rigidity it is constructed from composite materials. The boom must resist bending from the solar flux that is simulated in figure 5. The boom also has the sail spreader system as part of its construction. The sail spreader imparts the torsional bending from the solar flux. The physical test simulates the difference in gravity with the gravity offload system. The entire chamber can mimic the environmental pressures and temperatures seen whilst the apparatus applies loads and predicted extremes of vibration due to harmonic effects predicted from previous experience.

The physical test is performed on scaled down prototypes. The materials in question are non-isotropic and the NVH element has many varied boundary conditions and differing material joints making it a complex nonlinear solve.

The results were taken from the tests with photogrammetry and proximity sensors to measure the deflections and load cells were used to measure loads. An electromagnetic exciter was used to simulate vibrations with an accelerometer measuring the vibration data and high-speed cameras measuring frequencies.

3.1.4 The FEA

The FEA was carried out in two separate software packages by two independent companies to obtain the most accurate solution.

3.1.4.1 ABAQUS

The solution obtained through the ABAQUS software package had the following options selected to model within the software package

- No compression material behaviour of the composite
- The rings on the boom were concentrated masses
- Multi point constraints (to measure connections).

3.1.4.2 NEiNastran

- Rigid elements (to measure connections)
- Directional limited constraints.

3.1.4.3 Both teams' software application

- The gravity off load system was not explicitly modelled as that was not available until post physical testing.
- Point forces were used to represent weight of the test apparatus connection points.
- Material properties were provided by the manufacturer.
- Nonlinear analysis was performed.
- Similar loading cycles of pretension then the force raised until full load.

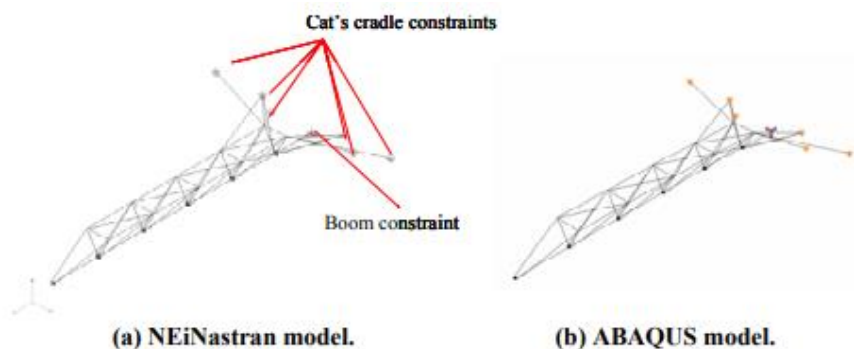


Figure 7 FEA Models (Sleight *et al.*, 2005)

Figure 7 shows the different constraint methods chosen by each team.

3.1.5 Correlation

Initial tests were concluded in FEA and comparisons were made with real data. Post comparison the FE models were adjusted and updated to improve correlation. Both FE packages predicted different results bellow shows the correlation for horizontal deflection.

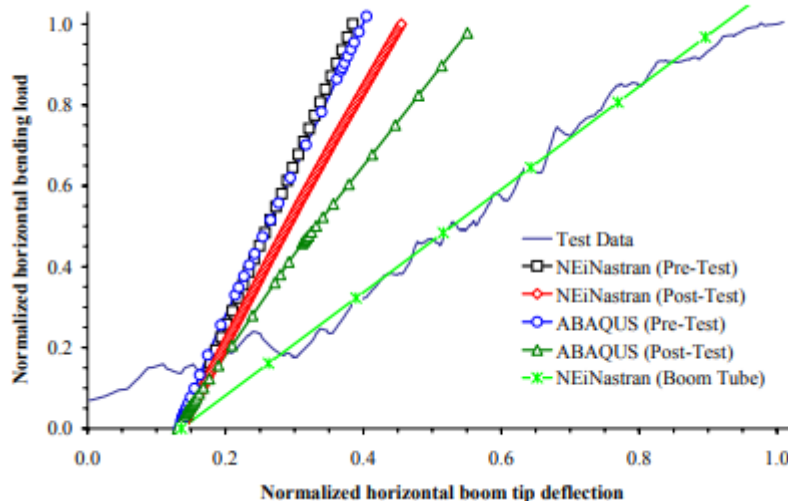


Figure 8 FEA and Physical correlation result horizontal deflection (Sleight *et al.*, 2005)

With the real test data available deflection caused by the apparatus for the ground test was updated in the models. The modulus between the boom ribs was also updated.

Figure 8 shows NEiNastran software was able to model the boom accurately for horizontal deflection.

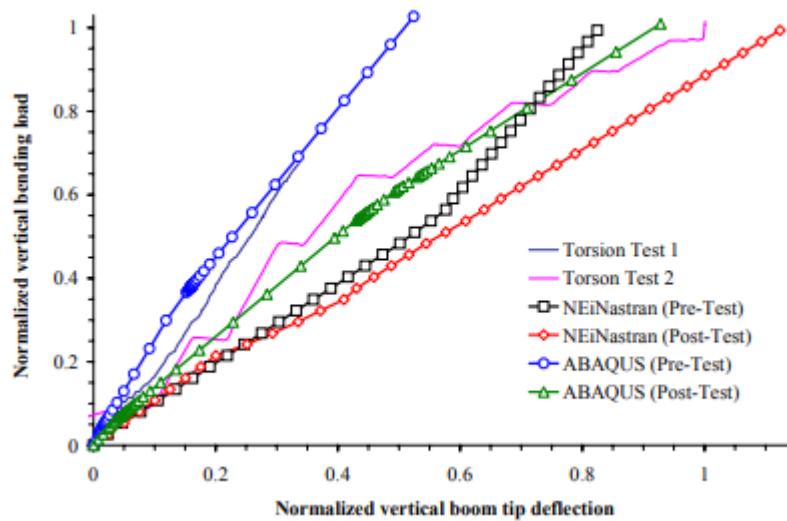


Figure 9 FEA and Physical result vertical deflection (Sleight *et al.*, 2005)

With the improved modelling the ABAQUS FE had the best correlation with vertical deflection.

3.1.6 NVH

Table 3. Comparison of test and FEA frequencies for 10-m beam structural assembly vibration test.

Mode	Test Frequency (Hz)	NEiNastran Frequency (Hz)	ABAQUS Frequency (Hz)
1	1.38	0.87 (-37.0%)	1.20 (-15.0%)
2	4.65	4.71 (+1.3%)	3.59 (-22.8%)
3	9.00	7.79 (-13.4%)	7.28 (-19.1%)

Table 3 shows the results for the corrected models. This shows the difficulties when correlating nonlinear models with NEiNastran achieving very accurate results in mode 2 but having the worst correlation in mode 1. The difference in frequencies could be due to the effect the gravity offload system in the test data, as that has not been accounted for, although the difference between the two FE models in mode 1 is 22%, which is not unexpected in a complex modelling process (Parambil and Gururaja, 2017).

3.1.7 Conclusion

Validation of FE models is required especially in bespoke expensive critical applications such as these (Vulpetti, Johnson and Matloff, 2015). Correlation of the test data should improve any future larger scale modelling, reducing the cost of repeated prototyping. Correlation is often achieved by changing conditions or material properties to match real world results until a reasonable trend is achieved (Elruby and Nakhla, 2019). These results show that although both models showed improvements in results with

correlation and each had its own advantage which can be attributed to user adjustment or software modelling.

4 Part 3 Will FE Analysis Replace Physical Tests

4.1 Advantages of FEA

FEA and CAE provide a faster more accurate pre prototype design process (Engelhardt *et al.*, 2019). When results have been correlated, the model can be adjusted with reasonable confidence of the final part having a similar trend to the changes made FEA model.

4.2 Advantages of Physical testing

Physical testing, when carried out in way that accurately represents real world conditions, gives the designer confidence in the accuracy of their FE model and their chosen design to a higher degree than just FE as the FE model may not be representative of complex non-isotropic and nonlinear conditions (Chen *et al.*, 2013). Physical testing also gives consumers and regulators confidence in the product (Ong and Huang, 2017).

4.3 Case Study

The European New Car Assessment Programme (NCAP) aims to create robust tests to emulate real world conditions and their affect on vehicle occupants. The tests they perform have been correlated against actual road traffic accidents and the risk to occupant injury have been compared by the Swedish national road administration in “How Do Euro NCAP Results Correlate with Real-Life Injury Risks? A Paired Comparison Study of Car-to-Car Crashes”(Lie and Tingvall, 2002). Higher NCAP scores are an incentive to vehicle manufactures. However, this creates a risk that designers will work to the test target rather than the underpinning values of the scoring system in creating an all-round car of improved safety.

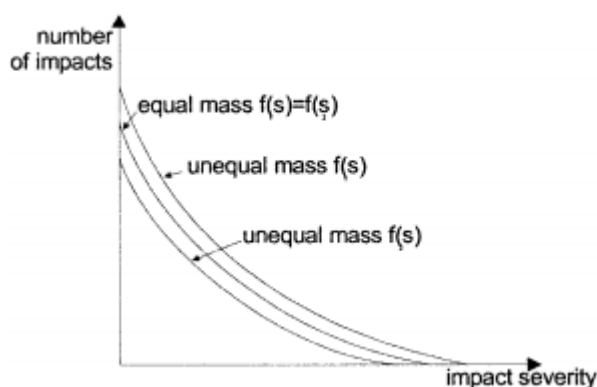


Figure 10 Effects of mass (Lie and Tingvall, 2002)

Figure 10 shows how the results were adjusted when two vehicles of differing mass collide compared to the collision of two of equal mass. The study looks at the result from a lower mass car receiving an impact from a higher mass car.

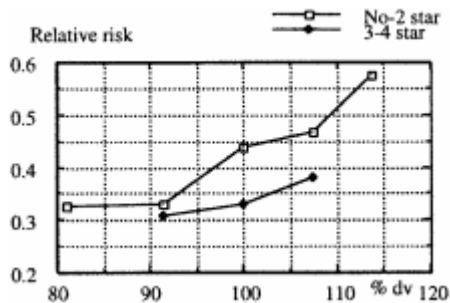


Figure 11 fatality risk against change in relative velocity (Lie and Tingvall, 2002)

Figure 11 shows greater than 100% velocity due to the lower mass car being knocked back in the impact. The study shows that the relative risk is lower in a higher NCAP scoring car. This shows that higher scores correlate with safer cars. The data sample was small so the results may not be a true reflection of NCAP safety standards as the number of accidents in Sweden with data available from traffic cameras and car diagnostics was unfortunately low.

4.4 Conclusion

In many applications FEA is unlikely to replace physical testing. Standards for products are defined by physical tests from car NCAP safety ratings to EU toy safety directives. Physical testing, such as NCAP, where ratings are awarded, aim to drive improvements in design allowing manufactures to achieve higher than base scores to improve occupant safety and also consumer confidence. Furthermore, when any bespoke item, such as the solar sail described, extensive testing will be needed to meet requirements as previous data to correlate against is not available. Advances in software, computing power and building up a library of correlated results may result in only needing to carry out final product testing in the future, but for many current applications that is not possible, especially with the impurities and problems caused by production techniques (Chen *et al.*, 2013). Further, other factors such as technological developments, changes to costs of materials used in components can lead to significant redesign potentially rendering previous results obsolete (as materials and techniques change new FEA to physical correlation is needed) (Jinlong *et al.*, 2020). Reliable and appropriate FEA models provide a lower cost method of adjusting designs as they require no tooling, materials, or manufacturing time.

5 Evaluation

The focus of this paper has been solely on the advantages of FEA and Physical testing.

Assumptions have been made:

- The correct sensors are selected and applied for physical testing.
- The physical test accurately represents real world conditions.
- The correct mesh size is selected balancing computational time with accuracy.
- The correct Element shape is selected for the geometry.
- The correct boundary conditions are selected
- The correct mathematical model is selected avoiding truncation error when the derivative constant (flux) is not corrected.
- The correct mesh is selected avoiding floating point error that can occur between two different shaped elements calculating in base 2 from a base 10 formula.
- The correct material properties have been selected.

The above list show that a good understanding of engineering and mathematical principles is required to carry out physical and simulated analysis. Furthermore, additional computational errors require an FEA engineer to have a basic understanding of the pitfalls of discretisation of a problem.

GOOD SECONDARY RESEARCH
GOOD DETAILS & CHOICE OF CASE STUDIES TO ADDRESS THE BRIEF.
YOU COULD HAVE DISCUSSED THE IMPACT ON THE DESIGN PROCESS FURTHER,

6 References

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