

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

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declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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

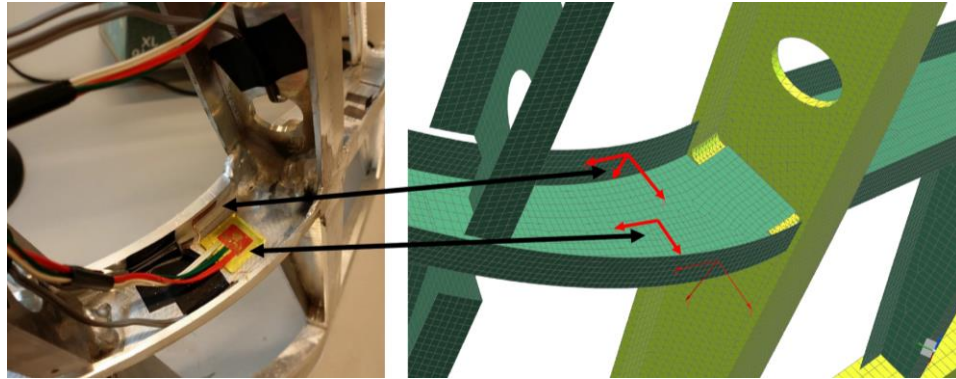
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	19.5
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
(Assessed in point 2)	30	19.2
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
(N/A)	0	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
(Assessed in point 3)	30	19.5
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		
(Assessed in report presentation and structure)	10	6.5

Assignment Mark Overall (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		64.7 %
	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?
(for Crash Helmet)*

*Advance Stress Analysis and FEA
(M6X00420)*

Joshua Grant Brimecombe

1701440

10/03/2020

Table of Content

1	Introduction	1
1.1	Aims	1
1.2	Objectives	1
2	Research.....	2
2.1	FEA	2
2.1.1	Literature Review	3
2.2	Physical Testing	4
2.2.1	Standards	5
3	Conclusion.....	5
4	References	6

1 Introduction

The report evaluates the use of Finite Element Analysis (FEA) against the use of physical testing in crash helmets. Extreme sports are inherently dangerous, and the protection used whilst participating is massively important in the prevention of injury and preservation of life. Arguably the helmet is the most important and cross stream applicable piece of protective equipment. Helmets are used across many sports including snow sports, water sport, cycling and motor racing. This varieties makes for a massive market and opportunity for FEA influenced design for increased safety whilst also optimised of other characteristics such as durability, weight or strength.

1.1 Aims

The aim of this report is to evaluate the use of FEA in the design and testing of crash helmets, whilst correlating the use of FEA and physical testing within the design and product development process.

1.2 Objectives

To meet the aims set out above, an investigation of the method currently used by manufacturers and designers. To analyse the correlation between FEA and physical testing, both must be explored and the purpose and benefits of them laid out. Then a conclusion can be drawn on which method should be used and how.

2 Research

The design process of a product (sports crash helmet) traditionally is an iterative process that works on the bases of basic calculations, an elimination process that is based off of trial and error. This inherently has issues, one of those issues is the time taken for the design as the development goes through repetitive stages of design, development and testing.

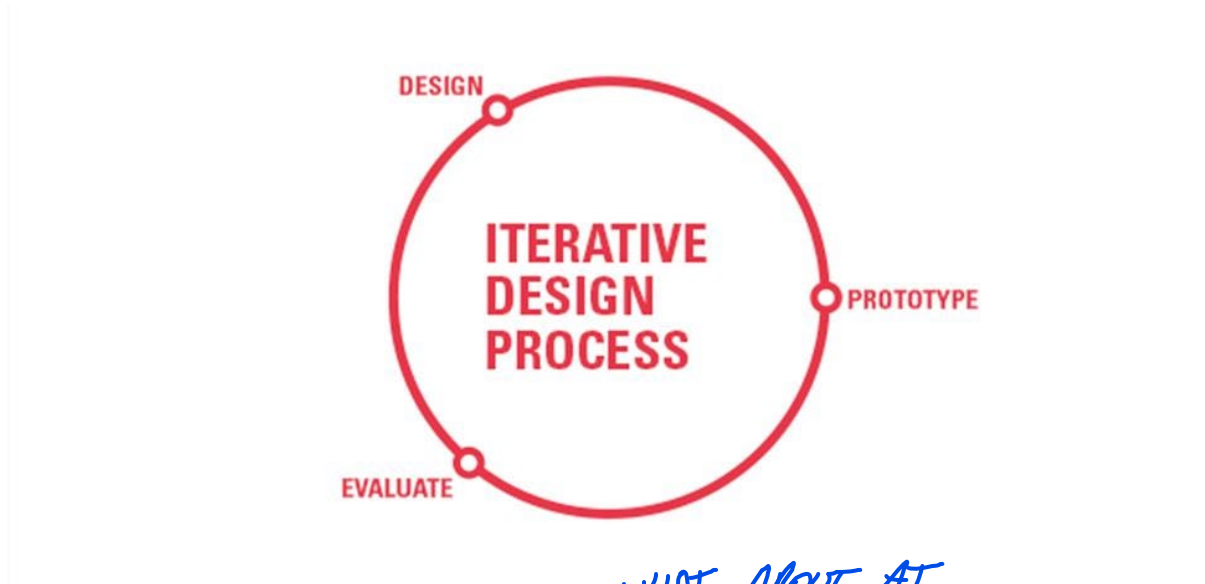


Figure 1 Iterative Design Process (MEEE, n.d.)

FEA and computational methods have a role in the model above (Figure 1), predominately in the evaluative stage (MEEE, n.d.). The use of computational testing allows to conduct many different tests without destroying any products this reduces cost in materials but takes computational time to run and solve the calculations.

2.1 FEA

Finite Element Analysis models a geometry in either one, two or three dimensions. The model is then turned in to a mesh structure or surface (volume or shape) the mesh consists of elements and nodes, which the software then uses a combination of matrixes, simultaneous equation and other stress calculation such as Navier-Stokes equations and von Mises, to calculate the stress, pressures and forces in the model or system. The benefit of computational method is that they are extremely efficient at running repetitive tasks which is ideal as each node and for every axis of freedom multiple calculation need to be calculated making the matrix grow exponentially. This is why the mesh quality is important as the smaller the mesh the more nodes and calculations this increases the computational time required but also increases the accuracy.

2.1.1 Literature Review

The report 'Understanding how a sport-helmet protects the head from closed injury by virtual impact tests' written by Yunhua Luo and Zhaoyang Liang (2017) was peer reviewed and appeared in the journal of Bio-Medical Materials and Engineering. The aim of the report was to understand how the helmet protects the head and the impact it has on the soft tissue of the brain, the performance of the helmet design was analysed by the results of the stress, strains and pressures found in the Finite Element Head Model (FEHM), which are indicators of traumatic brain injury. The methodology studies helmeted FEHM vs non-helmeted FEHM as well as shell stiffness, foam density and foam thickness of the helmet, each parameter was changed individually. The results of the non-helmeted model were validated against experimental data, which correlated with only a 4% total difference (Luo & Liang, 2017).

A case study published in the journal of 'Materials: Design and Application' by Teng et al. investigates "helmet design with respect to helmet performance in shock absorption tests" (Teng, et al., 2012). This study also validates the results of the method (FEA) against experimental results, this give these reports correlation and real-world application, allowing the results to inform design decisions. This use of FEA is evaluative of a model which allows pre-design decisions to be made. Teng et al. measures "linear accelerations, rotation accelerations, and impact forces" (2012), which is a more macroscopic approach than Luo and Liang's microscopic approach of the "intracranial pressure and stresses/strains in the brain tissues" (2017). Teng et al. conclude that while "helmet safety in drop tests is useful" (Teng, et al., 2012), the validation of the helmeted head model "reduces the duration of research and design cycles, and cuts experimental costs." (Teng, et al., 2012), meaning the "model serves as a valuable tool to assist the future development of safety helmet technologies." (Teng, et al., 2012).

Helmet design is not only about safety. It is important to be safe whilst participation in dangerous sports but a helmet can only protect you if you are wearing it, 97% of cyclist who die in traffic accidents are not wearing a helmet (Teng, et al., 2012). To combat this, it is important that helmets are not a performance inhibitor, which is why the aerodynamics of a bicycle helmet are analysed in the report published in the 'Movement, Health and Exercise' journal. The report looks at FEA and CFD (Computational Fluid Dynamics) to evaluate the maximum stress values and the flow of air over the two different designs comparing them to each other. The second more streamline design was found to be both more aerodynamic and have a greater impact resistance (Abdullah, et al., 2015).

The previous reports look at bicycle helmets, motorcycle helmets can be looked at in the same way. Motorcycle helmets require different geometry and materials due to high speed nature of the sport. Two older reports both in the International Journal of Impact Engineering (Mills, et al., 2009) (Sadaq, et al., 2014). The report written by Sadaq et al. compiles test results for both ABS and PVC Plastic to compare the “von-mises stress, strain and deformation” (Sadaq, et al., 2014) at 50, 60 and 70 km/h in the front, right and back direction. There are many variables which were all tested against each other.

The other report that analyses motorcycle helmet impacts exclusively looks at oblique impacts as “In accidents, motorcycle riders full-face helmets often make oblique impacts with road surfaces.” (Mills, et al., 2009) the report analysis uses FEA to “predict the rotational and linear accelerations” (Mills, et al., 2009) the key factor in these forces is the friction in the system this was calculated using the validation of British Standard BS6658 and COST 327 experimental data. As a result of the FEA the report concludes that it saw a 15 Krad s^{-2} of rotational force which “would probably cause rotational head injury” (Mills, et al., 2009).

2.2 Physical Testing

Physical tests are still conducted on crash helmets this is to prove the protectiveness of the helmets for marketing purposes and evaluation in the design stage, but most commonly physical testing is due to meet safety standards set out by governing bodies. Computer simulations can be incorrect for a large number of reasons including but not limited to errors in the calculations, smudge-factor error, but, the largest error is the human input of variables, units, boundary conditions including mesh strategy decisions. This makes computer simulations untrustworthy unless validated which is where the physical testing comes in, as there is fewer errors or factors for failure. If a helmet passes a physical test it is a lot more trustworthy than its simulation counterpart as it is a tangible real-world test. Validation is the key to using FEA properly, which requires either physical testing, practical testing or experimental data.

There are many physical tests that can be performed, these include different angles, speeds, weights, shapes of object and head forms. The factors that decide what tests are conducted is the sport or environment that the helmet is intended for as each sport has different incidents due to the forces, angles and environment where the sport takes place.

2.2.1 Standards

Standards are an agreed upon way of doing something, in the case of helmet safety standards it is a certified way of testing a helmets protectiveness, they also set out minimal limits. (BSI, n.d.)

There are different standards for different sports, products and scenario's, several of which are covered in a report on 'Current standards for sports and automotive helmets: A Review' (Connor, et al., 2016). The report investigates numerous tests including impact tests, penetration tests, retention tests, roll off tests, crush tests and friction tests; whilst discussing the testing methods and errors and helmet design and usage.

3 Conclusion

In conclusion FEA should be used heavily to influence the design process. The use of computational methods to aid in the design process decreases time of design development which then decreases costs, which is less than the cost associated to manufacturing prototypes and physical sample to test. Computational software can also be used to optimise design for unique and specific requirements (weight, stiffness, rigidity, aerodynamics).

But FEA cannot replace the physical testing for certification and standard's testing, as the theoretical computational models is not the same as physical testing as no one wears the computer model. Simulations can have inaccuracies, errors and problems.

I think there is an important role for both FEA / computational methods as well as physical testing to validate models, prove concepts and meet standards and other test-based requirements. If both used correctly and too an optimum it can create an efficient, optimised and high-quality design solution for a perfect product.

THIS REPORT WOULD BE CLEARER WITH SOME IMAGES. WHAT DOES THE PRODUCT LOOK LIKE? HOW IS IT TESTED? ETC

YOU HAVE OBVIOUSLY RESEARCHED THIS AREA BUT HAVE NOT REALLY GIVEN ANY DETAILS OF THE TESTING CARRIED OUT.

4 References

- Abdullah, M. N. et al., 2015. SIMULATING BIO-COMPOSITE CYCLING HELMET PERFORMANCE THROUGH FEA AND CFD APPROACHES. *Movement, Health & Exercise*, 4(1), pp. 77-91.
- BSI, n.d. *What is a Standard*. [Online]
Available at: <https://www.bsigroup.com/en-GB/standards/Information-about-standards/what-is-a-standard/>
[Accessed 01 03 2020].
- Connor, T. A., Meng, S. & Zouzias, D., 2016. *Current Standards for Sports and Automotive Helmets: A Review*, s.l.: s.n.
- Luo, Y. & Liang, Z., 2017. Understanding how a sport-helmet protects the head from closed injury by virtual impact tests. *Bio-Medical Materials and Engineering*, 22 March, Volume 28, pp. 279-291.
- MEEE, n.d. *Iterative Design Process*. [Online]
Available at: <https://www.meee-services.com/why-prototype-iteration-in-a-product-development-is-needed/iterative-design-process/>
[Accessed 01 03 2020].
- Mills, N. J., Wilkes, S., Derler, S. & Flisch, A., 2009. FEA of oblique impact tests on a motorcycle helmet. *International Journal of Impact Engineering*, Volume 36, pp. 913-925.
- Sadaq, S. I. et al., 2014. Impact Test on Motor Cycle Helmet for Different Impact angles using FEA. *International Journal of Engineering Trends and Technology*, Volume 12, pp. 278-281.
- Teng, T.-L., Liang, C.-L. & Nguyen, V.-H., 2012. Development and validation of finite element model of helmet impact test. *Materials: Design and Applications*, 11 May, 227(1), pp. 82-88.