

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

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declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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

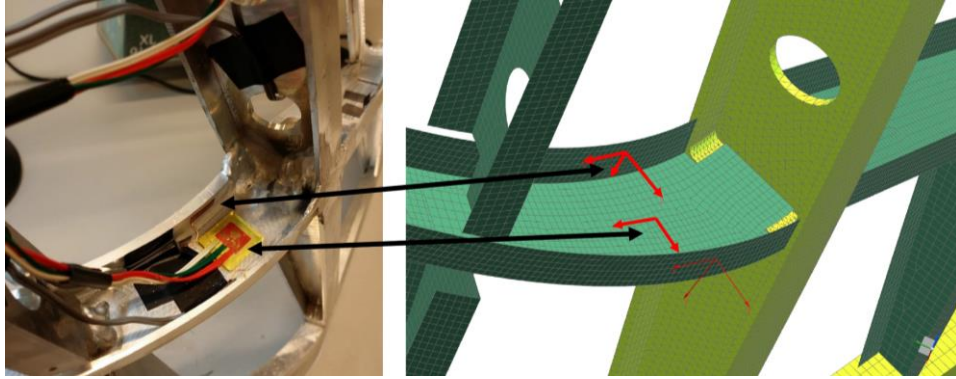
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	20.4
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	19.5
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
(N/A)	0	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
(Assessed in point 3)	30	19.8
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	6.4
		66.1

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)		%
	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

Will FEA ever replace
physical testing?

Simon Ellis-Williams
P150613

20/03/20

Kelvin Lake

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Figure 3.0.1 - comparison between FEA strain gauges and physical testing strain gauges.

The shape of the data on the left is similar to the FEA data underneath showing a good correlation, where as the data on the right shows a different shape all together, meaning the FEA model is invalid. (NCode,2018)

*VERY
LONG
TITLE!*

Figure 3.0.2 - a good similarity showing a 1 or 100% MAC (Seimens, 2019)

Figure 4.0.1 - Carabiner loading positions (Black Diamond, 2016).....

Figure 4.0.2 - Test one, loading the carabiner through its major axis. The crab took a load of 21.8KN before deformation was seen (Black Diamond, 2016)

Figure 4.0.3 - test two, loading the carabiner at an offset from its major axis at points B and C. This configuration deformed at 10.63KN (Black Diamond, 2016).....

Figure 4.4 – test 3, loading the crab from the nose of the locking gate, the furthest point from the major axis. Deformation was seen after just 5.21KN (Black Diamond, 2016)

1) Introduction

Finite element analysis (FEA) is a simulation tool used by engineers to test how parts or designs will perform over its lifetime and to ascertain how forces that are applied to it will have an effect on the material or design. This invaluable tool saves companies valuable hours in testing times, and a substantial amount of capital as it can determine any points of weaknesses in a material or design prior to it being sent for manufacturing. This paper will discuss why FEA is carried out and the benefits of doing so, how FEA models are correlated to real physical testing, and if FEA could, or should, ever replace physical testing.

USE PAST
TENSE

2) Why companies typically carry out FE analysis alongside physical testing.

As a tool, FEA presents invaluable opportunities to companies when it comes to testing new designs and products strength and durability. Physical testing of a product can be expensive, take valuable time, and in some cases may not produce the required results. To combat this and get new products to the market faster companies employ FEA to help design and test products. By carrying out this analysis, product weaknesses or shortfalls are identified before the product is sent for manufacture, saving on costs and labour.

GOOD
CONCISE
INTRO

2.1) Predict issues and create better products

Using FEA during the design process of a product can help predict design flaws with products that might have been overlooked in mathematical analysis or physical testing. For a small engineering company finding their way in the business world, the ability to physically test products may be limited to how much they can afford to spend on testing equipment, this limits their knowledge on how well their product will perform. Using FEA packages to replicate different test scenarios will give the company a better understanding of the product, pointing out any weak spots, or highlighting areas where material can be removed if weight is an issue, or added if it is not strong enough. (Caliber design, 2015)

By ascertaining any possible faults early on in the design process, time and money will be saved at the onset, which will also have a follow on effect later on when the product goes on sale. In any industry, if a product is deemed to be of inferior quality or standard there will be a large amount of customer complaints, warranty issues and recalls, which could cripple the company financially and ruin the reputability of the brand. For example, if mountaineering equipment was found to be inferior, customers would never trust their life to that brand again. FEA eliminates the possibility of any of these happening and the company keeps its reputation thereby encouraging future sales.

2.2) Save money

The biggest business factor considered by companies when using FEA software is the savings that can be attributed when compared to physical testing. Testing equipment can be extremely expensive compared to software licences for FEA software. Joseph Rhodes Ltd. ran a partnership with Sheffield University over a two-year period to see the implications of using FEA software in their business. When observing the results it was found that after two years they had made a substantial saving of a total of £114,000, and increased their turnover by 300%, from £7m in 2007 to £21m in 2010 (Ramakrishnan, 2012)

GOOD SECONDARY
RESEARCH SHOWING THE QUANTIFIED
BENEFITS OF INTEGRATING FEA.

In today's hyper competitive capitalist world, time is money, so the quicker products hit the market, the more profit is made. FEA software helps companies run multiple simulations in a short space of time compared to real world testing, this then leads to more products being readily available and of the required standard in less time. For example: Marianne Okal states that physically fatigue testing a carabiner to 8KN for 10,000 cycles will take 45 hours to complete (Okal, 2001). FEA is able to perform these tests in a matter of hours or even minutes saving valuable time and resources.

3) How a physical test may be correlated to an FE model.

Correlating FEA results to physical test data is an important part of any design process as it validates that the simulation is providing the user with valid results that can be trusted. In the past FEA was conducted via simple static analysis, testing that the part could take the worst-case scenario loadings, or around 90-95% of the loadings stated within a properties table for a given material. This older approach didn't account for weathering effects, fatigue, or other dynamic effects. (Prenscia, 2020)

Many tools have been created to correlate data with real tests. Including virtual strain gauges, and other sensors which can extract displacement data. Ncode is one such software that allows users to use these tools to compare FEA results to actual test data. To correlate the accuracy of the FEA of strain gauge data, some simple comparisons can be made as to the shape of the data sets, if the shapes between the FEA and physical test are similar then the data is correct. In figure 3.1 the red and blue data on the left show good correlation, while the graphs on the right show completely different shapes, showing that something is off. Checking the magnitudes on the X and Y axis of the data of both the FEA and physical test plots would also be useful in showing whether the FEA is representative of the real-world test. (NCode, 2018)

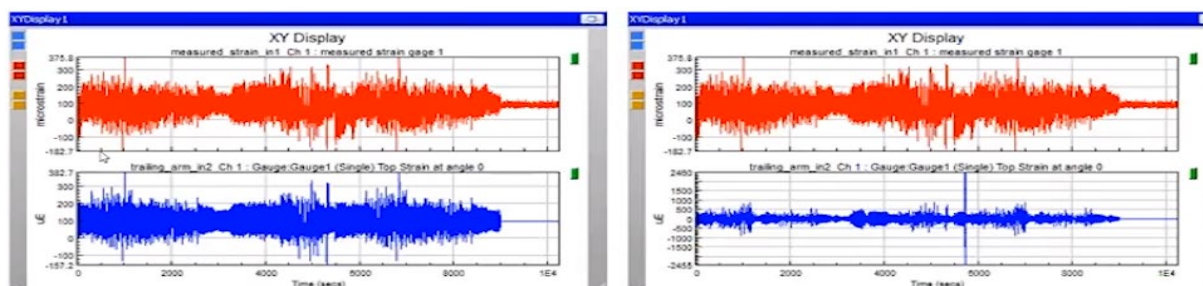


Figure 3.1 - comparison between FEA strain gauges and physical testing strain gauges. The shape of the data on the left is similar to the FEA data underneath showing a good correlation, where as the data on the right shows a different shape all together, meaning the FEA model is invalid. (NCode, 2018)

-THIS SEEMS QUITE
SUBJECTIVE.

-HOW COULD YOU
QUANTIFY THIS?

Modal assurance criterion analysis

Modal assurance criterion (MAC) analysis is used to characterise the dynamic behaviour of a part or structure in terms of its modes of vibration, and to check the similarity of mode shapes. If modes are good and move in the same direction a criterion value of 1 or 100% is shown. Whereas if bad similarity is seen then a value closer to 0 will be shown. (Seimens, 2019)

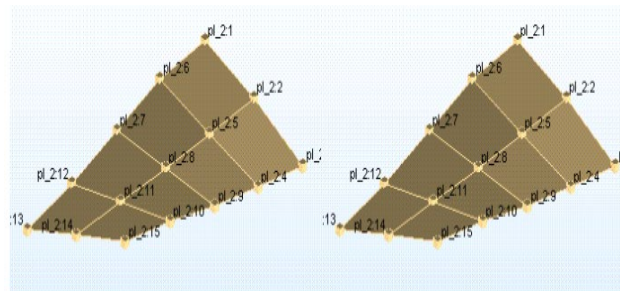


Figure 3.0.2 - a good similarity showing a 1 or 100% MAC (Seimens, 2019)

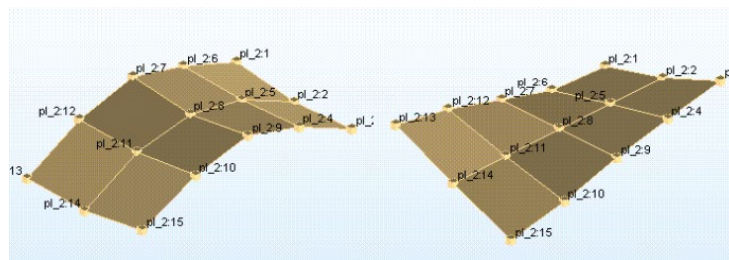


Figure 3.3 – bad similarity which would show a criterion value closer to 0, (Seimens, 2019)

MAC analysis can be used for several reasons such as limiting noise vibration and harshness, but the main reason it may be used is to compare experimental mode analysis to an FEA study, helping to show correlation between the FEA and physical test. MAC analysis is also used to check that assumptions made during the setup of boundary conditions and other parameters of an FEA case have not affected the accuracy of the resulting mode shapes. (Richardson, 2005)

4) Can FE analysis ever replace physical testing? Should it?

While FEA is a very capable tool and can provide faster answers to complex questions, there is still a lot of calculations and scenarios that it cannot account for. Due to this, certain idealizations need to be made. Imagine a bridge over a river, considerations would need to be made to understand if it was designed to perform to its full potential, such as

- Will it be able to take a full capacity load – what is a full capacity?
- Will the bridge deflect? – how will a lot of deflection make drivers feel when crossing the bridge?
- will it break unexpectedly?
- Is it designed to fail safely?
- Is the riverbank solid enough to support the bridge?
- What's the lifetime of the bridge?
- Will rust be a problem?

There are a lot of factors that need to be considered when designing something of this scale and trying to solve them all at once would be a major problem, so some estimations are made, and some problems such as the rusting issue or the river bank strength can be left out as this will not be a problem immediately. A simple model of the bridge is created to solve the main problem of if the bridge is strong enough to take the weight. This is known as idealisation, and lets big tasks be broken down into smaller, more manageable calculations which can help engineers give an estimation as to how structures and parts will perform.

Although simplified models of problems of problems can be made, the maths can still be extremely difficult to calculate manually, even for skilled engineers or mathematicians. Sometimes a problem may even turn out to be unsolvable due to the complexity, scope, and the assumptions made in the idealisation process. For most general cases, closed maths solutions can be used, and numbers can be plugged into known equations, but when tackling a completely new situation engineers would need to create the complex equation that models the problem mathematically. This would take a lot of effort and valuable time. FEA software does this for the engineer saving them time and having to do a lot of complex maths. So in this respect, FEA is an invaluable tool that allows engineers to do incredibly complex things with relative ease. (Skotny, Unknown)

Although FEA allows people to solve complex problems with many variables, still not anybody can just CAD up a part, do a quick FEA study and expect the part to work perfectly. Learning to use FEA software is a skill in itself and takes time to learn the nuances of the software. As with many analytical computer programs if a user's data inputs are rubbish, then the end result will be rubbish to an even greater extent. A lot of users have too much faith in the computer, see the colourful post processing, and accept the end results without validation. This can lead to serious catastrophic failures in some cases, so it is always important to validate the FEA results against real physical testing. (Toogood, 2012)

REGS MAY ALSO REQUIRE THIS

As well as validating FEA studies, physical tests will give customers more confidence in a product over a computer simulation study.

Carabiners (or crabs) have two main axis, a major and minor axis. The major axis would be loadings from A to C in fig 4.1. Black Diamond, a company that produce mountaineering equipment, were asked by a customer if loading a carabiner away from the major axis at points B and C would weaken its integrity. Black Diamond ran a test to see how this would affect the strength of the crab and found that under normal loading scenario from points A to C the crab which was load rated to 21KN too a loading of 21.8KN before deformation occurred.

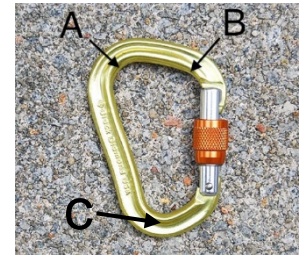


Figure 4.0.1 - Carabiner loading positions (Black Diamond, 2016)



Figure 4.0.2 - Test one, loading the carabiner through its major axis. The crab took a load of 21.8KN before deformation was seen (Black Diamond, 2016)

A second test was set up, loading the crab at points B and C to find out if the offset from the major axis did indeed affect the strength of the crab. It was found that doing so caused the crab to deform after only 10.63KN, reducing the load capacity by around half.



Figure 4.0.3 - test two, loading the carabiner at an offset from its major axis at points B and C. This configuration deformed at 10.63KN (Black Diamond, 2016)

Furthering this test to the worst-case scenario, Black Diamond also tested what would happen if the crab was loaded with the gate open, and the nose of the crab caught in the sling as figure

4.4 shows. In this scenario the crab only took 5.21KN before it deformed. (Black Diamond, 2016)



- WERE FEA
TESTS DONE?
- WHAT WERE
THE RESULTS?

Figure 4.4 – test 3, loading the crab from the nose of the locking gate, the furthest point from the major axis. Deformation was seen after just 5.21KN (Black Diamond, 2016)

This results and pictures of this test were given to the customer and would have provided them with the knowledge that they could load the crab in an offset position and still apply a reasonable amount of weight to it. This would also give a sense of security that a report full of FEA post processing and tables could never have. Its more than likely the customer has little to no knowledge of the FEA process, and even if they did, do they trust the person setting the experiment up? This is the advantage physical testing has over FEA. It is something tangible, something the user can see happening, its real solid data that can be instantly trusted.

So, can finite element analysis replace physical testing? Yes and no. whereas a few computer programs and licences are a cheaper alternative to buying expensive testing rigs, and can save valuable time in the design process of new parts, FEA is still a very complex program that requires a professional skill level to use. If a company can find such employees, then yes, FEA could replace physical testing. But skilled workers can be few and far between and may demand a high wage for their skillset that could end up costing more than machinery in the long run.

Should Finite element analysis replace physical testing? Not in the authors opinion. people make mistakes or get lazy, and the work produced can start to lack quality. Testing rigs will always give the correct answer. As stated previously, they provide tangible, hard data that cannot be argued with.

6) References

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