

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	WILKS	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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	16.8
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	17.4
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	17.1
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	5.8

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)		57.1 %
	Up to one-week late		
	Over one week late		

COMMON ASSESSMENT AND MARKING CRITERIA

	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
Assessment Criteria	0-29%	30-39%*	40-49%	50-59%	60-69%	70-79%	80-100%
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions	Little or no evidence of reading. Views and findings unsupported and non-authoritative. Referencing conventions largely ignored.	Poor evidence of reading and/or of reliance on inappropriate sources, and/or indiscriminate use of sources. Referencing conventions used inconsistently.	References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.	Inclusion of a range of research-informed literature, including sources retrieved independently. Referencing conventions mostly consistently applied.	Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.	A comprehensive range of research informed literature embedded in the work. Excellent selection of relevant and credible sources. High-level referencing skills, consistently applied.	Outstanding knowledge of research-informed literature embedded in the work. Outstanding selection of relevant and credible sources. High-level referencing skills consistently and professionally applied.
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.	Major gaps in knowledge and understanding of material at this level. Substantial inaccuracies.	Gaps in knowledge, with only superficial understanding. Some significant inaccuracies.	Evidence of basic knowledge and understanding of the relevant concepts and underlying principles.	Knowledge is accurate with a good understanding of the field of study.	Knowledge is extensive. Exhibits understanding of the breadth and depth of established views.	Excellent knowledge and understanding of the main concepts and key theories. Clear awareness of challenges to established views and the limitations of the knowledge base.	Highly detailed knowledge and understanding of the main theories/concepts, and a critical awareness of the ambiguities and limitations of knowledge.
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence	Unsubstantiated generalisations, made without use of any credible evidence. Lack of logic, leading to unsupportable/missing conclusions. Lack of any attempt to analyse, synthesise or evaluate.	Some evidence of analytical intellectual skills, but for the most part descriptive. Ideas/findings sometimes illogical and contradictory. Generalised statements made with scant evidence. Conclusions lack relevance.	Evidence of some logical, analytical thinking and some attempts to synthesise, albeit with some weaknesses. Some evidence to support findings/ views, but evidence not consistently interpreted. Some relevant conclusions and recommendations, where relevant	Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument. Valid conclusions and recommendations, where relevant	Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise and sustain persuasive arguments, and to review the reliability, validity & significance of evidence. Ability to communicate ideas and evidence accurately and convincingly. Sound, convincing conclusions / recommendations.	Thoroughly logical work, supported by evaluated evidence. High quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Strong, persuasive, conclusions, justifiable recommendations.	Exceptional work; judiciously selected and evaluated evidence. Very high quality analysis, developed independently or through effective collaboration. Ability to investigate contradictory information and identify reasons for contradictions. Highly persuasive conclusions
4. Practical Application and Deployment Effective deployment of appropriate methods, materials, tools and techniques; extent of skill demonstrated in the application of concepts to a variety of processes and/or contexts; formulation of innovative and creative solutions to solve problems.	Limited or no use of methods, materials, tools and/or techniques. Little or no appreciation of the context of the application.	Rudimentary application of methods, materials, tools and/or techniques but without consideration and competence. Flawed appreciation of the context of the application.	An adequate awareness and mostly appropriate application of well established methods, materials, tools and/or techniques. Basic appreciation of the context of the application.	A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with some use of examples, where relevant.	A very good application of a range of methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.	An advanced application of a range of methods, materials, tools and/or techniques. The context of the application is well considered, with extensive use of relevant examples. Application and deployment extend beyond established conventions. Innovation and creativity evident throughout.	Outstanding levels of application and deployment skills. Assimilation and development of cutting edge processes and techniques.
5. Skills for Professional Practice Demonstrates attributes expected in professional practice including: individual initiative and collaborative working; deployment of appropriate media to communicate (including written and oral); clarity and effectiveness in presentation and organisation.	Communication media is inappropriate or misapplied. Little or no evidence of autonomy in the completion of tasks. Work is poorly structured and/or largely incoherent.	Media is poorly designed and/or not suitable for the audience. Poor independent or collaborative initiative. Work lacks structure, organisation, and/or coherence	Can communicate in a suitable format but with some room for improvement. Can work as part of a team, but with limited involvement in group activities. Work lacks coherence in places and could be better structured.	Can communicate effectively in a suitable format, but may have minor errors. Can work effectively as part of a team, with clear contribution to group activities. Mostly coherent work and is in a suitable structure.	Can communicate well, confidently and consistently in a suitable format. Can work very well as part of a team, with very good contribution to group activities. Work is coherent and fluent and is well structured and organised.	Can communicate professionally and, confidently in a suitable format. Can work professionally within a team, showing leadership skills as appropriate, managing conflict and meeting obligations. Work is coherent, very fluent and is presented professionally.	Can communicate with an exceptionally high level of professionalism. Can work exceptionally well and professionally within a team, showing advanced leadership skills. Work is exceptionally coherent, very fluent and is presented professionally.

Student Self Evaluation Form

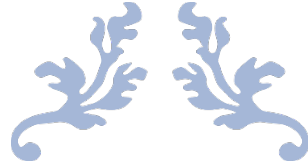
Student name:		Student P number:	
Programme:		Year of programme	
Assignment Title:			

This section repeats in brief the common assessment criteria detailed on previous pages. The *extent* to which these are demonstrated by you determines your mark. Using these criteria, tick the box that best indicates the level of achievement you feel you have achieved with regard to each of them.

Common Assessment Criteria Applied	Level of Achievement						
	REFER		3 rd	2:2	2:1	1 st	1 st
	OUTRIGHT FAIL	UNSATISFACTORY	SATISFACTORY	GOOD	VERY GOOD	EXCELLENT	EXCEPTIONAL
1. Research-informed Literature	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
2. Knowledge and Understanding of Subject	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
3. Analysis	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
4. Practical Application and Deployment	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐
5. Skills for Professional Practice	0-29% ☐	30-39% ☐	40-49% ☐	50-59% ☐	60-69% ☐	70-79% ☐	80-100% ☐

PLEASE COMMENT ON AREAS IN WHICH YOU FEEL THAT YOU HAVE PERFORMED WELL	PLEASE COMMENT ON AREAS YOU FEEL THAT YOU NEED TO DEVELOP

Student's Name		Date	
Student's Signature			



CAN FEA REPLACE PHYSICAL TESTING ?

M6X00420



MARCH 1, 2020

UNIVERSITY OF WALES TRINITY SAINT DAVID
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Abstract

The main emphasis of this study is to investigate the feasibility of finite element analysis (FEA) becoming the engineering main stay when looking at product design and development. Firstly, by looking at the current ways companies in the engineering sector use FEA in addition to physical testing and the reasons for this. Then to examine how physically testing can be correlated to a finite element model (FEM), paying attention to the validity of said results. Before finally compiling the finding in this study to answer the question should FEA ever replace physical testing.

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Finite Element Method

Computer Aided Engineering (CAE) takes traditional engineering techniques and deploys them into a virtual environment. One way this is used is by designing or recreating a component in a software package such as Solidworks. From this, various analytical methods can be implemented on components, one of these been FEM. FEM takes an intricate problem and splits it into smaller pieces that can be approximated and solved to get a solution that reflects how the component would behave depending on set boundary conditions. Sometimes referred to as boundary value problems or field problems these are mathematical problems, where at least one of the dependant variables must satisfy a differential equation throughout the domain of the independent variables and satisfy the condition set by the boundary conditions (Hutton, 2017). Due to any continuous object having infinite degrees of freedom, the FEM reduces this to finite using meshing “splits into smaller pieces” in the form of a known amount of points called nodes. These nodes form shapes commonly tetrahedral whereby mathematical calculation take place to find the desired results such as Von Mises Stress or displacement (University, 2015).

FEM can be said to follow the methodology of S.I.M.P.L.E (Lake, 2020);

Splitting a complex problem into smaller elements.

Interpret the geometry.

Material information.

Physical properties.

Loading.

Evaluation of the results.

Types of Analysis

- Linear static analysis
- Nonlinear analysis
- Dynamic analysis
- Buckling analysis
- Thermal analysis
- Fatigue analysis
- Optimization
- CFD analysis



Figure 1- Showing Finite Element Analysis Carried out on a Con-Rod Assembly

Why Companies Typically Carryout FEA Alongside Physical Testing

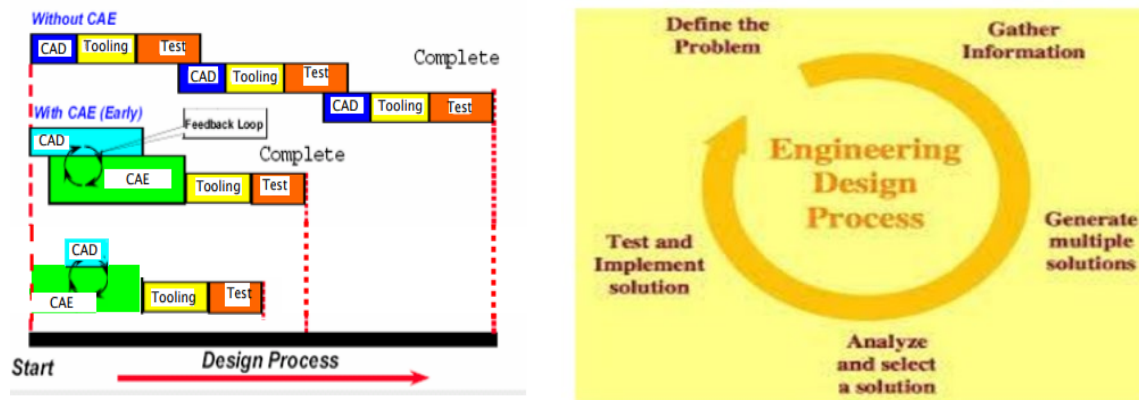


Figure 2-Showing a Diagram of the Design Process

When considering the design process, the main drives for any company such as Honda is profit. In times gone by this process was a long and ambiguous. One of the main reasons for this is problems within the design only been highlighted at the testing stage which until the rise of CAE was always a physical test and if a problem was found with the component, the design, machine/tooling and then test stage would have to be repeated, until the prototype met the design definition.

As can be seen in the figure above the introduction of CAE earlier in the design process reduces the overall process tenfold (Lake, 2020). FEA being one of the main stages within CAE. In agreement with (Performance, 2020) and (Pretechnologies, 2020) the reasons behind and advantages the implementation of FEA are as follows:-

The overall initial product design is vastly improved by multiple variations of the design been able to be tested within the design software, while being subjected to the loads and other boundary conditions that have initially been defined by the conditions the part is expected to endure. From this a fatigue safety factor can be known, as a value of above one is always needed as this indicates the allowable range of stress is equal to the range of stress and below one the part will most definitely fail.

This then leads to the point in which fewer physical prototypes need to be created. Once the initial design has been optimised a prototype can be subjected to physical test, with the results being used to change the design further and therefore the design improves at a faster rate and the time and number of prototypes being vastly reduced every time this part in the process is repeated. Meaning greater efficiency and less expensive design cycles.

The use of topology optimisation can also be used within the software, reducing the amount of material used within the design without effecting the parts structural integrity. This goes hand in hand with the material choice since the design engineer can find the balance between material selection while optimizing the material layout (design).

One major point to consider when conducting FEA is the analogy "if you put rubbish in you get rubbish out" but as long as the boundary conditions are set correctly the findings from physical testing should not differ far from the FEA results though this will only ever be an approximation (University, 2015). As with all knowledge, as companies use FEA more they gain more knowledge of what to expect and therefore reduce the number of design cycles further. The main point being overall time and cost is dramatically reduced whereas design optimisation is dramatically increased.

How a physical test maybe correlated to an FE model



Figure 4--Showing a Motorcycles Yokes



Figure 3- Showing a Motorcycles Yokes and Head-stock Assembly

When it comes to designing a product such as motorcycle steering yokes many things need to be considered. The reasons for this are that the yokes are not only a major part of the chassis connecting the steering system to main chassis/frame, it also acts as a spring damper system when the motorcycle is at extreme angles of lean. This is due to the motorcycle's suspension only having one hundred percent effectiveness when the vehicle is completely upright or perpendicular to the ground, so when the motorcycle is mid corner at high velocities angles of around sixty degrees of lean can be witnessed, meaning the three major parts of the chassis (swing-arm, frame, yokes) need to be able to flex in order to absorb any bumps in the road, in such away these vibrations do not align with the natural frequency of the chassis, this is known as chatter within the industry and is extremely dangerous for motorcycle and rider. Especially if said motorcycle was to be used in a racing environment where depending on the circuit, changing the yokes would be advantageous to deal with different scenarios, that may be found from circuit to circuit. It is for these reasons a FE model would need to be modelled as accurate as possible, so when designing new yokes the design engineer can be sure they are creating the desired flex or stiffness of the part. The following techniques need to be adhered to, for reason of validity (Hutton, 2017).

The first stage when correlating your FE model to the real-world part is to first conduct tests on how the material behaves and that you have selected the same material and constrained your design correctly within your FE model. To do this, a simpler shape is required such as a piece of square or cylindrical bar. This limits the amount of calculations undertaken within the FE model, thus a greater degree of accuracy. The test is a simple one, by use of a hydraulic press a load should be applied to the bar and by use of a dial test indicator gauge (DTI gauge) the displacement recorded. The test should be carried out several times with the same load to gain a sound average, then experiment with different loads. The same loads should be applied to your FE model with results within ten percent being thought as good (University, 2015), but for this simple test results of less than five percent should be seen. If there is a large discrepancy within the results one major thing normally overlooked is if the part in the FE model has been fixed. This tells the software the part is attached to something with unlimited stiffness, which is unachievable in the real-world, to overcome this the part should be attached to a spring that mimics the stiffness of the test bed in the physical test. If there is still a large deviation in results, hand calculations to check your results would be an appropriate step, which shouldn't be a problem due to the simplicity of the test. The mesh refinement should also be considered as a smaller mesh will give you more accurate results but having a detrimental effect on solve time, decreasing the mesh size will gain more accuracy to a point where the accuracy no longer increase just that of the solve time.

The next stage is to recreate the part within the software, scanning the physical part being the most efficient, whilst drawing the part is the other option, keen observations and measurements should be undertaken so that the virtual model is identical and defined correctly. Before loads and other tests can be undertaken the weight and centre of gravity should be checked against the physical part, with these being one hundred percent accurate.

Dynamic analysis of the parts can now commence. Load and strain data must be collected from the motorcycle. This involves attaching strain and axial gauges to the yokes of the vehicle. A test should be carried out in the motorcycle's desired environment i.e. a race circuit with sensors and gauges attached so that the forces, moments and strains can be collected. This data should then be acquisitioned, and the loads uploaded to the design software for use on the virtual part. Strain gauges can then be applied within the software. These come in many different forms such as single and rosette, with their orientation been controlled by xyz vectors, 2 nodes or an angle of offset (Pretechnologies, 2020). These should be attached in the same places as the physical test, in places where the highest stress can be seen. A test should be then run using the acquired loads and various graphs plotted such as strain over time as a use of a comparison. The results can be also overlaid with attention to the magnitudes, polarities and the peaks/troughs.

Model analysis can then be used to explore the phenomenon known as chatter. Again, like the experiment above sensors in form of accelerometers can be attached to the steering assembly and the system subjected to different vibrations or shocks to find the parts natural frequency. The uses of these sensors out on circuit would allow the engineer to determine the different mode-shapes and damping co-efficient. Then correlate these against the FE model when the same loads are applied. It would then be possible to make changes to the design while been able to make sure the part does not enter its natural frequency (Guillaunme, 2015).

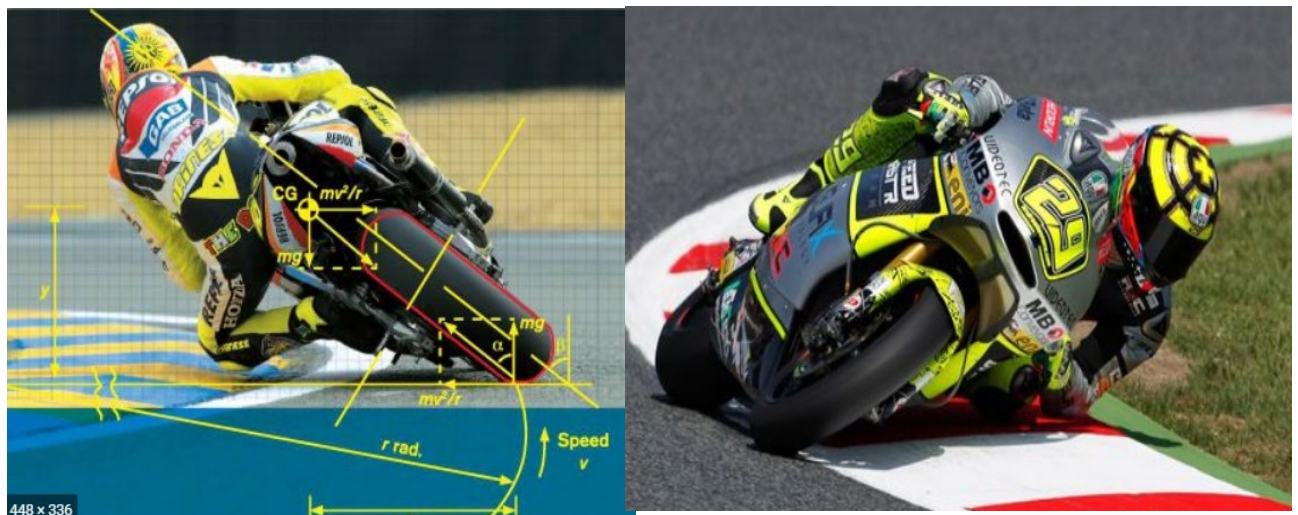


Figure 5- Showing the Extreme Lean Angles and Forces a Motorcycle is Subjected to.

Can FE analysis replace physical testing?

This question requires an open mind to answer, not so long ago the earth was the centre of the universe and the stars were people gone but not forgotten. There is no mistaking that since the rise of the computer the leaps and bounds, we as a race have come. From cracking codes to being able to simulate water falling into a glass. The more appropriate question is will we ever want it to?

FEA has become the main stay in most engineering companies from the motorcycle industry to aerospace and much more. This is due to reason discussed previously such as how it improves dramatically the time needed to design something, limiting the number of physical tests needed and optimising the part so less material or machining time is needed. Examples of companies using FEA to its full protentional are as follows; Vins Motorcycle use Ansys to design all their motorcycle swing-arms and only conduct a physical test when the motorcycle is being test ridden to check its handling capabilities (Motorcycles, 2018). So one could argue that in this case no physical test occurred because the part was not tested on a machine and the values correlated, more so only the test riders experience and this form of testing will never be removed from the design process because not only is it a test of all the components, the company must conduct a test into the driveability and tactility of the motorcycle. Jaguar also created the body shape of their XE range without a single physical test or prototype being created with a quoted drag coefficient of 0.26 with hope of the their full range been designed in this way by the end of 2020 (IMechE, 2016). These two examples leading to massive cost benefits made with proof of reliable results.

QUANTIFY!
Although it can be seen the many benefits of using FEA alongside physical tests, the three biggest issues with using just FEA are as follows; having a ten to fifteen percent margin of discrepancy is far to large and while ever that is acceptable, physically testing must be used to verify any part. Number two, the analogies " rubbish in rubbish out" while ever there is a human in 100 percent of control there will be a margin for error. Whilst nearly all design engineers will be full trained and know how to use the software correctly, it only takes one person to make a mistake and disaster could unfold, as the saying goes "to err is human". One possibility is the software having most of the control and as data storage and computing power dramatically increases one hundred percent accurate FEA models can be produced and then the human interaction is only deciding that what is produced fits the design specification. We now live in an age of 3-D printing so maybe in the future instead of parts been machined they get printed to duplicated how the FEA model says the component will act. But the main point why the author believes physical tests will never be abolished is due to us as humans not trusting the machines completely, due to empathy/emotion or artificial inelegancies lack of it (Grey, 2018) .

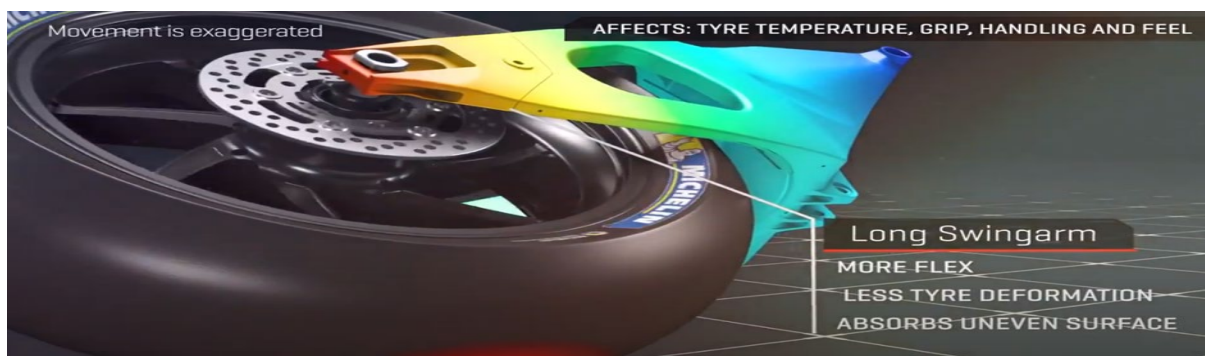


Figure 6- Showing Finite Element Analysis of a Motorcycles Swing-Arm

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WHILST YOU HAVE CLEARLY ABSORBED WHAT WE HAVE DISCUSSED IN CLASS, FURTHER RESEARCH WOULD HAVE ADDED TO YOUR REPORT. YOU HAVE MADE SEVERAL MISTAKES IN YOUR WORK - PROOF READ IT!
YOUR REPORT JUST FINISHES, YOU NEED A CONCLUSION TO FINISH OFF YOUR REPORT.