

## BACHELORS DEGREE ASSIGNMENT SPECIFICATION

|                   |                                           |                                                |             |
|-------------------|-------------------------------------------|------------------------------------------------|-------------|
| Student name:     | JANUARIO                                  | 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  |

|                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                         |              |            |   |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|------------|---|
| <b>Referencing:</b>                                                                                                                                                                                                                                                                                                                                                                             | 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). |              |            |   |
| <b>Disclosure:</b>                                                                                                                                                                                                                                                                                                                                                                              | 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.                                                                                                                                                                                                         |              |            |   |
| <b>Student's Signature:</b>                                                                                                                                                                                                                                                                                                                                                                     | <i>Assignments will not be accepted without a signature here</i>                                                                                                                                                                                                                                                                                                                                        | <b>Date:</b> |            |   |
| <b>Turnitin:</b> 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. |                                                                                                                                                                                                                                                                                                                                                                                                         |              | <b>YES</b> | ✓ |
|                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                                                                                                                                                                                                                                                                         |              | <b>NO</b>  |   |

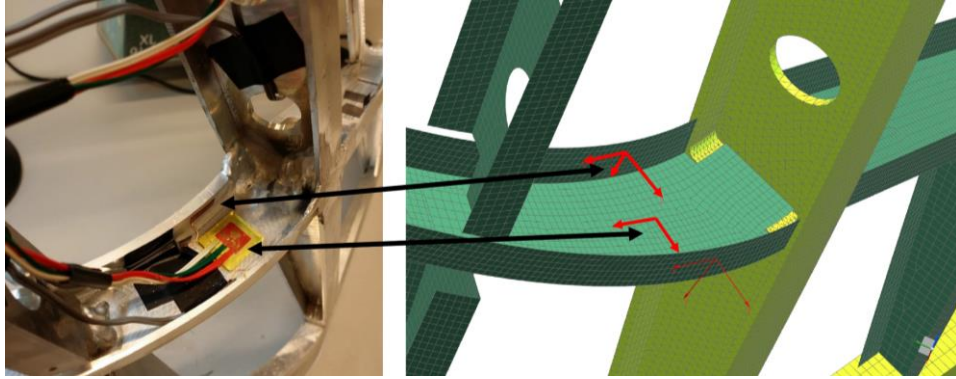
| Learning Outcomes tested (from module syllabus)                                                              | Assessment Criteria To achieve each outcome a student must demonstrate the ability to: |
|--------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------------|
| 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 |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|---------------|
| <b>1. Research-informed Literature</b><br>Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions.                                    |                 |               |
| (Assessed in point 1)                                                                                                                                                                                  | 30              | 20.7          |
| <b>2. Knowledge and Understanding of Subject</b><br>Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.                                        |                 |               |
| (Assessed in point 2)                                                                                                                                                                                  | 30              | 22.5          |
| <b>3. Analysis</b><br>Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence                                                     |                 |               |
| (N/A)                                                                                                                                                                                                  | 0               |               |
| <b>4. Practical Application and Deployment</b><br>Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems. |                 |               |
| (Assessed in point 3)                                                                                                                                                                                  | 30              | 22.2          |
| <b>5. Skills for Professional Practice</b><br>Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.               |                 |               |
| (Assessed in report presentation and structure)                                                                                                                                                        | 10              | 7.3           |

|                                                                                                                                                                                                                   |                                                        |  |       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|--|-------|
| <b>Assignment Mark Overall</b> (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.) | <b>Late Submission Penalties (tick if appropriate)</b> |  | 77.7% |
|                                                                                                                                                                                                                   | 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%                                                                                                                                                                                                                                                                        |
| <b>1. Research-informed Literature</b><br>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.                                                                     |
| <b>2. Knowledge and Understanding of Subject</b><br>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.                                                                                                                           |
| <b>3. Analysis</b><br>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 |
| <b>4. Practical Application and Deployment</b><br>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.                                                                                                                                                |
| <b>5. Skills for Professional Practice</b><br>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 <sup>rd</sup>                    | 2:2                                | 2:1                                | 1 <sup>st</sup>                    | 1 <sup>st</sup>                     |
|                                           | OUTRIGHT FAIL                     | UNSATISFACTORY                     | SATISFACTORY                       | GOOD                               | VERY GOOD                          | EXCELLENT                          | EXCEPTIONAL                         |
| 1. Research-informed Literature           | 0-29%<br><input type="checkbox"/> | 30-39%<br><input type="checkbox"/> | 40-49%<br><input type="checkbox"/> | 50-59%<br><input type="checkbox"/> | 60-69%<br><input type="checkbox"/> | 70-79%<br><input type="checkbox"/> | 80-100%<br><input type="checkbox"/> |
| 2. Knowledge and Understanding of Subject | 0-29%<br><input type="checkbox"/> | 30-39%<br><input type="checkbox"/> | 40-49%<br><input type="checkbox"/> | 50-59%<br><input type="checkbox"/> | 60-69%<br><input type="checkbox"/> | 70-79%<br><input type="checkbox"/> | 80-100%<br><input type="checkbox"/> |
| 3. Analysis                               | 0-29%<br><input type="checkbox"/> | 30-39%<br><input type="checkbox"/> | 40-49%<br><input type="checkbox"/> | 50-59%<br><input type="checkbox"/> | 60-69%<br><input type="checkbox"/> | 70-79%<br><input type="checkbox"/> | 80-100%<br><input type="checkbox"/> |
| 4. Practical Application and Deployment   | 0-29%<br><input type="checkbox"/> | 30-39%<br><input type="checkbox"/> | 40-49%<br><input type="checkbox"/> | 50-59%<br><input type="checkbox"/> | 60-69%<br><input type="checkbox"/> | 70-79%<br><input type="checkbox"/> | 80-100%<br><input type="checkbox"/> |
| 5. Skills for Professional Practice       | 0-29%<br><input type="checkbox"/> | 30-39%<br><input type="checkbox"/> | 40-49%<br><input type="checkbox"/> | 50-59%<br><input type="checkbox"/> | 60-69%<br><input type="checkbox"/> | 70-79%<br><input type="checkbox"/> | 80-100%<br><input type="checkbox"/> |

| PLEASE COMMENT ON AREAS IN WHICH YOU FEEL THAT YOU HAVE PERFORMED WELL | PLEASE COMMENT ON AREAS YOU FEEL THAT YOU NEED TO DEVELOP |
|------------------------------------------------------------------------|-----------------------------------------------------------|
| <br><br><br><br><br><br><br><br><br><br>                               | <br><br><br><br><br><br><br><br><br><br>                  |

|                     |  |      |  |
|---------------------|--|------|--|
| Student's Name      |  | Date |  |
| Student's Signature |  |      |  |



**Prifysgol Cymru**  
Y Drindod Dewi Sant  
**University of Wales**  
Trinity Saint David

# CAN FEA REPLACE PHYSICAL TESTING?

## ADVANCED STRESS ANALYSIS & FEA

### SUPERVISION

Professor Kelvin Lake

MEng Motorcycle Engineering

Level 6

Semester 2

**ANTONIO JANUARIO**

**SWANSEA**

April 2020



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## 1. INTRODUCTION

The following assessment was developed for the module of Advanced Stress Analysis & FEA – level 6 of the Motorcycle Engineering Degree.

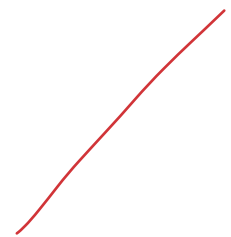
The aim of the proposed assignment is to explore the FEA role in the product development of a company. To do so, a motorcycle swingarm will be chosen as a case study, as it represents one of the most relevant structural components in a motorcycle's chassis, being in charge of the rear suspension mechanism, dynamic performance and safety of the motorcycle while in motion.

The lateral and torsional stiffness of the motorcycle swingarm need to be tuned to improve the stability, response and performance of the swingarm during all the possible driving scenarios. Once there are different motorcycles with difference ranges of weight, power and purpose, this will imply different stiffness values for different types of motorcycles.

Those stiffness values were result of several iterations and tests by the manufacturers and are kept confidential, reason why there is not much information published about this matter by companies.

In relation to the assignment, firstly, a research will be carried out to better comprehend why companies perform FE analysis alongside with physical testing. Once this research is conducted, it will be explained how a physical test may be correlated to a FE model and some examples will be presented to back up the stated correlation.

Lastly, the author will comment whether during the design process of a motorcycle swingarm the FE analysis can or should ever replace physical testing.



## 2. WHY COMPANIES TYPICALLY CARRY OUT FE ANALYSIS ALONGSIDE PHYSICAL TESTING

Due to the scarcity of information related with this chapter about the current case study, a motorcycle swingarm, it was decided to conduct a research about FE analysis and physical testing carried out over different components on companies of the same engineering sector. The design process of MotoGP winglets, Formula 1 components and some structural components of hypercar companies will then be analysed instead.

One of the biggest motorcycle companies in the world, Ducati, believes that “Racing is synonymous with the technological avant-garde”. Based on this statement, Ducati uses the MotoGP program as a means for the development of new technology and components. Thus, as an example, when performing the aerodynamics studies, Ducati believes in a three-step process in order to achieve high-level development – Sketch, CFD analysis and Testing. (Ducati, 2019)

Once the initial sketches are finalised and are converted into CAD surfaces, CFD simulations can be started in order to test pressure and velocity trends over different motorcycles configurations. After analysing and selecting the solutions with best results in the FEA environment, the selected options will then be produced in real life and submitted to physical testing in a controlled environment.

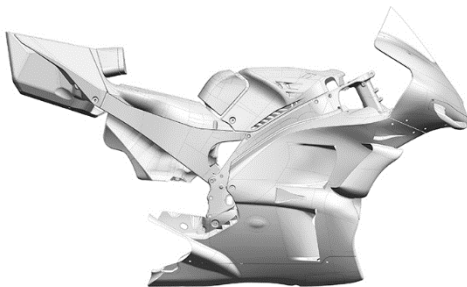


Figure 1. Ducati MotoGP CAD

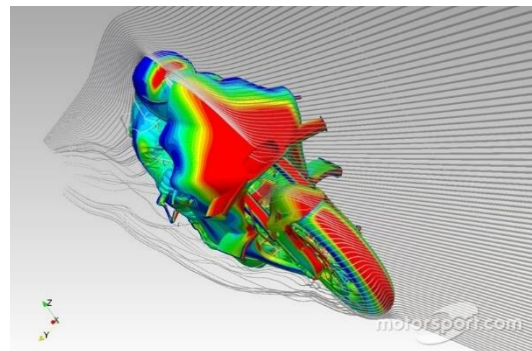


Figure 2. Ducati MotoGP CFD simulation

In this step, the 1:1 scale components produced will be tested in a wind tunnel with known and controlled conditions in order to validate the CFD results and to decide which solutions offer the best aerodynamic performance.



*Figure 3. Ducati at wind tunnel*

After the validation process with the wind tunnel experiment, the successful parts will then move forward to a second and final test phase of the aerodynamic development. In this final phase, the prototype components will be tested on the motorcycle in a real scenario, with the motorcycle in its driving environment, the racetrack. Conclusions about how the new components perform will be taken from sensors attached to the motorcycle and from the test rider's comments.



*Figure 4. Ducati MotoGP testing at racing circuit*

It is important to carry out FE analysis alongside with physical testing, as it can be concluded from what Ducati states. In this case, CFD analysis alongside with controlled physical testing (wind tunnel) will allow the validation of the work developed by the engineers, permitting quicker progress and to virtual test more components in a shorter time frame. This will allow to test fewer parts but with high probability of success in the racing circuit.

Within the Formula 1 industry, the design process does not differ that much from the MotoGP companies. There is still parallel FE analysis being developed alongside with physical testing, with a higher relevance given over to the physical testing, in order to reduce the risk of failure during racing situations.

Being Formula 1 a sport where components need to be engineered to perform at their limit, a good correlation and results from the FE analysis and physical testing needs to be achieved so as to not compromise in terms of safety.

Thus, as the Mercedes-AMG Petronas Formula One Team states (*How Do F1 Teams Test & Develop Components?*, 2019), after the newly designed components are approved over the FE analysis, they go over to Test & Development center. This is where all the mechanical testing is made, with a focus in reliability, making sure that all the parts will be strong enough to withstand the forces during a racing season.

The physical testing will not just be used for testing newly developed parts, but also to guarantee that the components that came after a maximum performance scenario in real life (racing) could be proof tested and fatigue tested once more to assure that they are reliable for the rest of the season and to validate all the previous work already done in the FE analysis and validation physical testing.

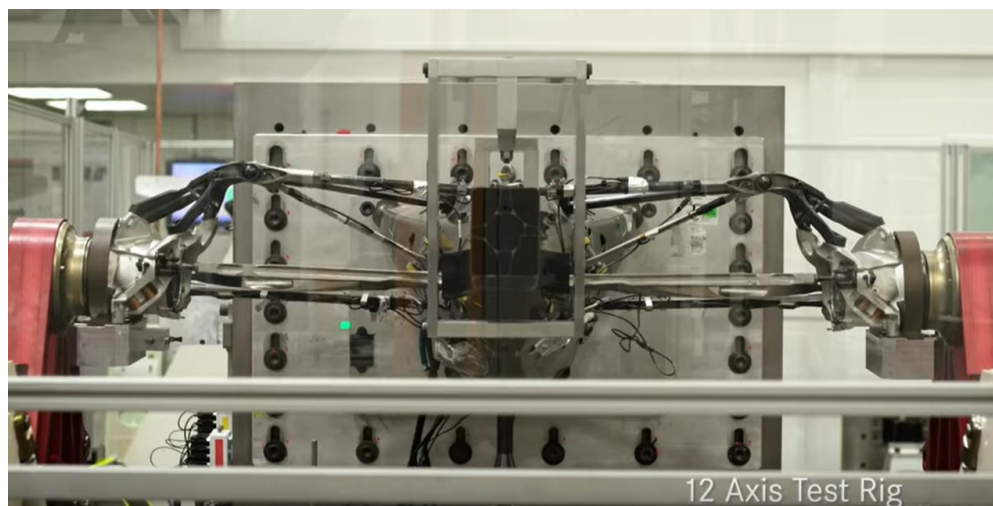


Figure 5. Mercedes F1 12 axis test rig

In a car manufacturing company, more specifically in a hypercar company, the FE analysis are extremely relevant in the design process of the car components. It could be expected that, the closer the FE analysis predicts the results from real life testing, the lesser the risk of failure during a real physical test, consequently avoiding the failure of a car component that could represent a cost of hundreds of thousands of pounds for such a company.

As an example, at RIMAC, the reference company for full electric hypercars, Daniele Giachi, the Director of Vehicle Engineering, states that one of the biggest challenges is the global homologation, that involves design, development and testing of crucial structural components of the car (*CRASHING THE RIMAC C\_TWO HYPERCAR 5X*, 2019). The FE analysis is used from an early stage to virtual test parts for safety and stiffness, with the set goal of having a good correlation between FEA and real physical testing, in order to reduce the risk of failure when crashing a prototype of 1 Million euros.



*Figure 6. RIMAC FEA vs Physical Testing of full vehicle*



*Figure 7. RIMAC FEA vs Physical Testing of system level*

As other companies from the same sector, the design process starts from a designed concept, followed by several simulations recurring to FE analysis until the component is fully optimised within a certain compromise between all the engineering areas involved. Only when the FEA results are satisfactory, is the real physical testing able to start. In an initial phase it starts with component level testing, then system level, ending with full vehicle testing.

### 3. HOW A PHYSICAL TEST MAY BE CORRELATED TO A FE MODEL

In this chapter it will be explored how a physical test could be correlated to a FE model. The case study introduced in Chapter 1 will now be used as an example to explain this correlation.

As mentioned before, the case study to be considered consists of the design process of a motorcycle swingarm that represents one of the most relevant structural components in a motorcycle's chassis. Fortunately, the design process of a motorcycle swingarm encompasses several engineering challenges, that require the correlation between a real physical test and a FE model to be successfully performed.

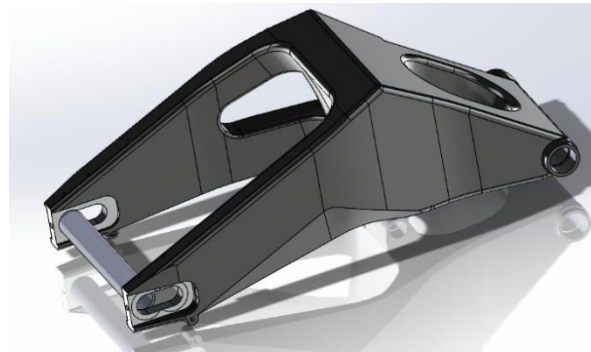
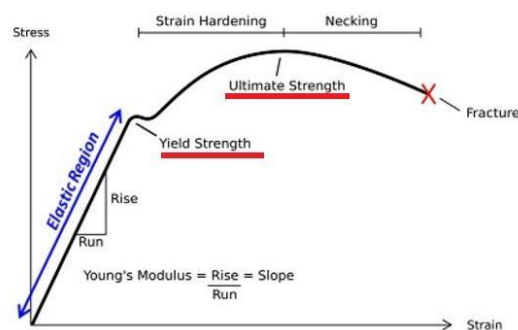


Figure 8. Motorcycle Swingarm

A motorcycle swingarm is commonly manufactured out of steel or aluminium, both elastic materials, with their stiffness values characterized by a certain modulus of elasticity,  $E$ , also known by Young's modulus. This modulus represents a linear relation between stress and strain in the materials' elastic region.



Stress - strain curve for a ductile material  
Figure 9. Stress - strain curve for ductile material

A motorcycle swingarm is normally an optimised component, designed to perform at limit situations during various driving scenarios while lasting a lifelong. This infinite life is achieved if the maximum stress value submitted to the swingarm is not superior to the Yield Strength value and if there are no cyclical stresses of value superior to the fatigue limit. Either way, the swingarm will always perform in its elastic region.

As an initial step, it is recommended to perform a real physical test to a simple part, with a numerical solution, and to compare the results against a FE model of the same test in order to validate the software used. Once the chosen software is validated or a percentage of error is determined, it will be possible to start the design of the new swingarm and use the values obtained on the real physical tests performed as

a reference for the swingarm FEA results. It can happen that the percentage of error on a simple part will be different from the error observed in a more complex component, such as a swingarm. However, to start the FE model of the complex part, the error observed on the simple part will have to be used as a starting reference point.

Once the purpose of the new motorcycle is decided, a market study could be performed in order to choose a swingarm to be used as a reference for the new one to be designed. Then, physical tests could be performed in the swingarm in order to identify stiffness values, natural frequencies, etc...

Having in consideration the fact that metals are an isotropic material, with same mechanical properties in all directions, only one mechanical physical test will be needed in order to validate the FE model. This means that by validating the FE model of a specific test to the respective physical test, all the remaining simulations to analyse the stiffness and strength of the swingarm could be performed using the same observed error as a reference.

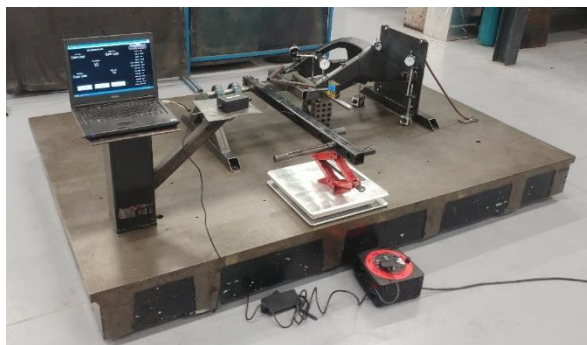


Figure 10. Physical test - Stiffness jig

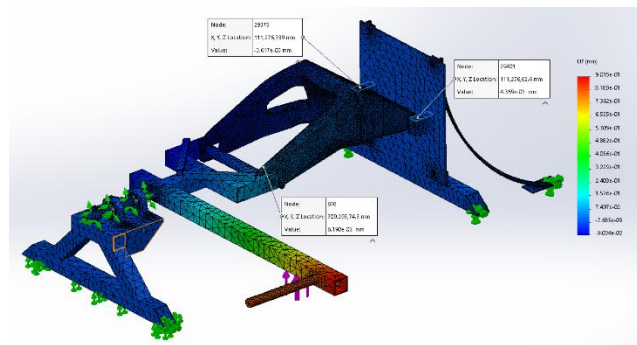


Figure 11. FE model - Stiffness jig

Performing simulations over assemblies usually brings added complexity to the FE model. This could represent longer time to run a simulation which subsequently results in a bigger cost. Also, the complexity of the physical test, with different materials, different connections such as bolts and welds and also the not so precise measuring devices, will result in poor measurements when compared against the FE model. Even if it consisted of an outstandingly performed physical test, due to the complexity of the assembly and all the constraints defined with different types of connections, it would not result in an accurate result.

Due to the above, it is ideal to start by developing an FE model at a component level, applying the fixtures and loads in the single component. In order to obtain a good correlation between the single component FE model and the physical test, which will involve more parts, it is needed to assume that all the parts from the test jig are infinitely rigid.

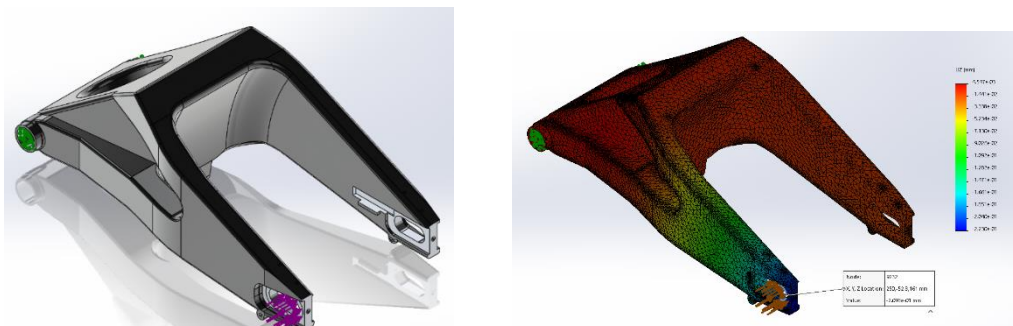


Figure 12. FEA simulations of the swingarm

Due to the impossibility of building an infinitely rigid jig in real life, a certain deviation between the results from the physical test and FE model is to be expected. Anyhow, so as to minimize this error, the jig from the physical test must be built as stiff as possible.



Figure13. LDV experiment - Swingarm



Figure 14. Results from LDV experiment

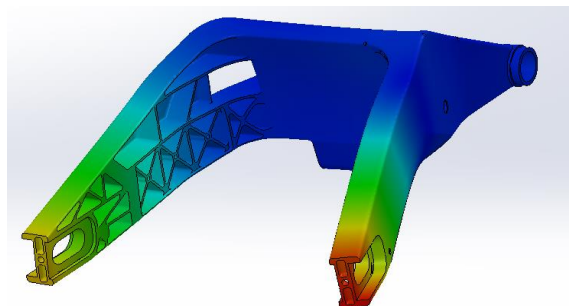


Figure 15. Frequency simulation - example of result

Lastly, when the newly designed swingarm is manufactured, it will be possible to test it in the already built jig and have the most accurate comparison of the FE model against the physical test until now.

This will be the only phase of the design process where the same component with the same geometry and material of the FE model could be physical tested in a jig built to replicate the conditions stipulated in the virtual model.

Once the validation, an error between the results could be determined and now be taken in consideration when operating changes to the designed swingarm in order to achieve the pretended / targeted results.

GOOD  
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PROTECT  
WELL.

## 4. IF YOU THINK THAT FE ANALYSIS CAN (OR SHOULD) EVER REPLACE PHYSICAL TESTING

In this chapter the author will give his opinion about whether FE analysis could or should ever replace physical testing.

For the case study being analysed, a motorcycle swingarm, the types of FE analysis performed, which normally have a real representation in a physical test, are: Linear static analysis, Fatigue analysis and NVH analysis (vibration). In such manner, when answering the question of the current chapter, these will be the type of analysis taken in consideration.

It is relevant to understand that developing a FE analysis represents an approximation of the real values obtained in a real-life scenario and never an exact representation of them. This approximation results from the method used to perform calculations, where the finite element method divides the component in smaller elements, called mesh, calculating each individual stiffness matrix in order to obtain results all over the component/swingarm (stress values, temperature, displacement values, etc.).

Defining the correct mesh will represent a challenge when looking for the most accurate results, mostly because of the numerous parameters that could be defined. The type of the element (1D, 2D, 3D, etc.) could be changed; areas with higher stress values will demand smaller element length; to resolve the simulation, a convergency study of the mesh will have to be performed; a subjective study will also need to be conducted; the geometry of the component has to be considered when choosing the mesh, etc. Adding to these challenges, when submitting the material specifications in the simulation there are some details that normally are not considered, such as welding considerations (thickness of the weld, heat-affected zone, different material of the filler...), as well as the material properties, which could change slightly even if from the same type and also changes in the material properties due to the manufacturing process.

All the challenges towards the performance of a successful FE analysis that are stated above, make the author believe that physical testing could not generally be replaced by a FE analysis. Not only because of the way the FE model is set up, but also due to physical testing being the only representation of a real performance scenario over the final component that could attest the safety of the developed part.

However, there are some exceptional situations where the opposite situation could be observed, where a physical test could replace a FE analysis. This is observed when there is a full understanding and control of all the constraints and objectives of the problem, when an engineer with experience over subjects such as FEA and manufacturing is involved and has expertise in building the specific component in consideration, when only a small change needs to be performed to the original component, when there is access to good quality jigs for physical test experiments and when quick progress is needed.

## 5. CONCLUSION

After the development of this study, it can be concluded that it is of great importance for companies to carry out FE analysis alongside with physical testing during the design process of a component. FE analysis will permit to test innumerous interactions of a component until it is fully optimised, reducing the number of physical testing that has to be performed, consequently reducing costs. Either way, physical testing is extremely relevant as it represents the only method to assure the safety of each component and to validate the performance results achieved with the FE analysis.

Depending on the industry, the weight given to FEA and physical testing will vary according to various factors, such as budget, time, human resources and workshop facilities available.

In the racing industry, where quick development is needed, it could sometimes be preferred to move straight to the testing phase, skipping the FE analysis. In cases when the engineering problems get even more complex, the FE simulations will consequently increase the time to obtain solutions, reason why an experienced engineer will provide the expertise and experience required for quicker progress, thus being able to push the design process directly to the testing phase.

In any case, in the event of a different technology needing to be implemented or the failure of a physical test representing a big cost for the company, FE analyses will be essential in the product development and economical success of a company.

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