

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	MIGLIORATI	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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
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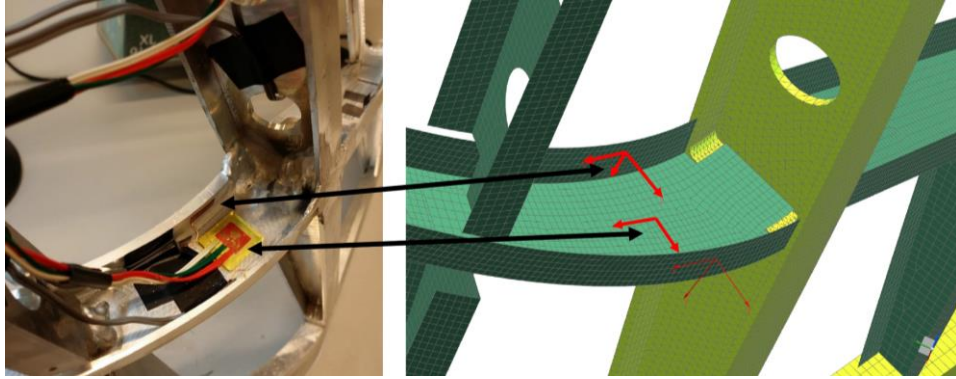
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	18
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
(Assessed in point 2)	30	21
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
(N/A)	0	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
(Assessed in point 3)	30	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	6.3

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)		65.1	%
	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			

ADVANCED STRESS ANALYSIS & FEA -M6X00420
CAN FEA REPLACE PHYSICAL TESTING?



University of Wales
Trinity Saint David

DAVID MIGLIORATI N'DOUA

1 April 2020

ABSTRACT

The aim of this assignment is to investigate what's the approach of motorcycle companies when it comes to design motorcycle chassis and swing arms explain why FEA plays an important role during the design process of a chassis. A short first introduction regarding how different types of frame are manufactured was done, highlighting pros and cons of the two configurations.

The torsional stiffness test and natural frequency test were analysed and explained, showing math and physic principles behind them, both physical experiments were compered to their relative FEA models showing discrepancies in the results obtained reasoning any possible reasons causing them.

In the last part of the report, the personal opinion of the author regarding the possibility of FEA to replace physical test was explained supporting the point of view also with and a real motorcycle scenario example.

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1 WHY COMPANIES TYPICALLY CARRYOUT FEA ANALYSIS ON MOTORCYCLE FRAMES ALONGSIDE PHYSICAL TESTING?

1.1 MOTORCYCLE FRAME INTRODUCTION

The motorcycle frame is the main structural component of the vehicle, its shape, material, wall thickness are the main three factors that determine the frame stiffness. Frame stiffness plays a fundamental role for the motorcycle handling characteristics which lead to a comfortable or uncomfortable rider feeling.

The main two material used to produce chassis and swingarms in the motorcycle industry are steel and aluminium.



Figure 1 Yamaha WR 250F 2020 (aluminium casted)



Figure 2 Yamaha WR 250F 2006 (steel welded)

The two above pictures show the aluminium and steel version of the same bike model of two different years. Figure 1 represents the Yamaha WR 250-F 2020 model year (aluminium, Figure 2 Yamaha WR 250F 2006 (steel). (Yamaha, 2015)

As visible from the two pictures, choosing aluminium or steel determine the type of manufacturing process that has to be used to produce the part.

Steel frames are made by bended tubes which are welded together with usually a smaller wall thickness than aluminium ones.

Aluminium frames are made by aluminium die casting process and then machined or totally CNC machined from a block of material. (TVS MOTOR, 2018)

Just looking at the picture is noticeable that being the steel stronger and stiffer than the aluminium, less material is needed to perform the “same” task. Stiffness depends on the Young’s Modulus of material, higher the Young’s Modulus stiffer is the material.

Here the formula:

$$E = \frac{\sigma}{\varepsilon}$$

Here a list of the Young's modulus values of the following materials used for frame and swingarm production (González, 2004):

STEEL: 218 GPa

CARBON FIBER: 228 [Gpa]

TITANIUM :110 [Gpa]

ALLUMINIUM 69 [Gpa]

$$\sigma = \frac{F}{A} \text{ and } \varepsilon = \frac{\Delta l}{l_i} \text{ (Caligaris, 2012)}$$

Where:

σ : is the stress applied to the material [N/mm²]

ε : is the strain of the material tested

F: load applied [N]

WHAT MOTORCYCLE FRAME DESIGNERS AND MANUFACTURES LOOK FOR?

Motorcycle manufactures when it comes to design a produce a new frame looks for the right balance between stiffness and flexibility according to the type of motorcycle they are dealing with. For example, a road racing bike require a completely different characteristics than an off-road bike. The road racing motorcycle have to deal with very high acceleration, deceleration, plus the swingarm is highly stressed during cornering in wide lean angles. Off-road bikes frames need be strong because they deal with instant and strong impacts due to presence of obstacles and flexible the same time to transmit the rider the best possible riding

When it comes to design a new frame, engineers have pre-set goals that could be reducing overall weight or moving the centre of gravity in a specific position, changing then dynamics behaviour of the new bike, this can be done by changing diameters of the tubes (trellis steel frame) or changing tubes orientation; by using an FEA mode, multiple configurations can be tested and evaluated very quick. (Saurabh, 2010)



Figure 3 KTM 250 SXF 2015 (orange), 2016 (grey)

The above picture shows the main frame of two 2015 and 2016 KTM 250 SX, the frame has been shortened by a very small amount and according to the designers these changes have increased torsional ~~stiffen~~ by 20% and decreased the longitudinal stiffness by 30% keeping the material unchanged (Lewis, 2015).

STIFFNESS

In the next sections some chassis and swingarm design simulation and testing will be explained showing discrepancies between FEA and physical model.

Executing FEA analysis allows to produce a model close to reality, however validity of the model built and reliability of the results obtained are the main issues of the FEA analysis, the issue could be due to the high level of complexity of the chassis so it's very difficult to model.

Doing physical testing along FEA helps validate the designs produced, validating frame models, updating it and making it as close as possible to the real scenario in order to have the most reliable results to make the right decision. Without FEA the risk of carry on a wrong decision would rise, wasting time and money for the designers and manufactures (Yasar, 2019).

2 HOW A PHYSICAL TEST MAY BE CORRELETED TO AN FEA MODEL?

2.1 TORSIONAL STIFFNESS TEST

2.1.1 TESTING RIG

One of the most common motorcycle frame tests is the torsional stiffness of the steering head stock.

The motorcycle frame is placed in an opportune test rig, fixing the headstock by a pivot tube going through the headstock hole, the clamp is connected to a rotary wheel by a rotating shaft.

The rotary wheel is used to apply a certain amount of torque to the system, the angular displacement of the steering head can be measured by dial gauges positioned as follows in Figure 4.

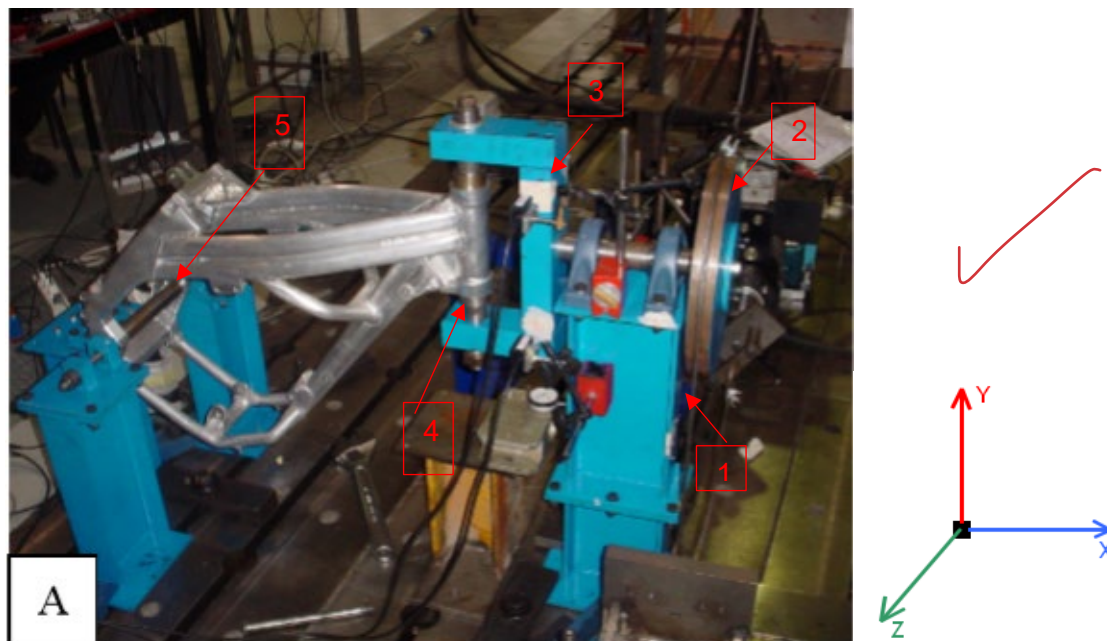


Figure 4 Main frame on the test rig, ready for torsional stiffness test

RIG COMPONENTS NAME LIST:

- 1) STRING
- 2) PULLEY
- 3) CLAMP
- 4) HEAD PIVOT
- 5) SWING ARM AXLE

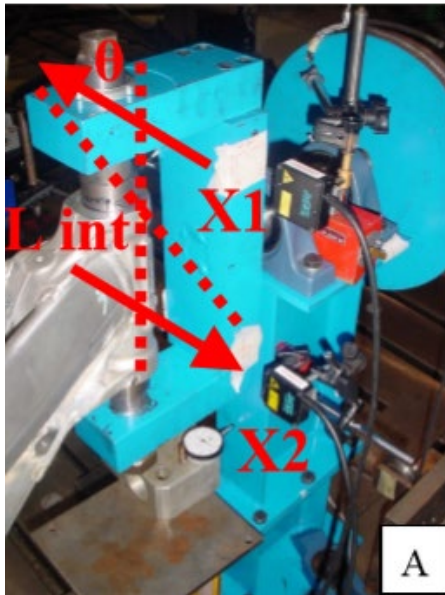


Figure 5 Steering head and electronic gauges measuring displacement (Boccione, 2005)

2.1.2 CORRELATIONS BETWEEN FEA AND PHYSICAL TEST AND MATHEMATICAL PRINCIPLES

In the physical torsional stiffness test the load is applied by loading the string on the front pulley, being the string positioned on the edge of the pulley at a certain distance from its centre a “Moment is applied”.

Where:

$$Mt = F * x$$

M: moment applied to the steering head [N*m]

F: load applied [N]

X: pulley's radius [m].

The steering head rotation is given by the following

$$\varnothing = \arctg \frac{(X1 - X2)}{L}$$

Where:

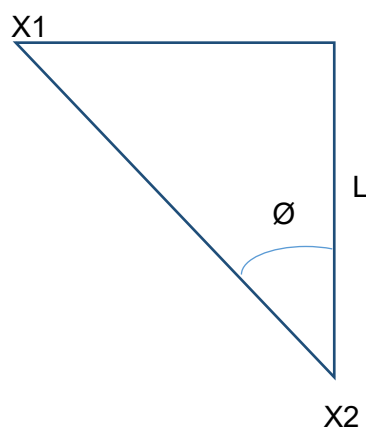
L: vertical distance from the two measure points X1 and X2 [m]

X1: horizontal position of top of steering head (measured by top gauge) [m]

X2: horizontal position of bottom of steering head (measured by bottom gauge) [m]

Ø: steering head rotation [deg]

Graphical representation:



TORSIONAL STIFFNESS:

$$Kt = \frac{Mt}{\varnothing} [\text{N}\cdot\text{m}/\text{deg}]$$

The steering headstock test can be done applying multiple loads and then understand what's the relation between load applied and stiffness. It's also advisable to carry out the test with engine mounted on the frame to see how the engine affects frame's behaviours.

2.1.3 FEA MODEL AND SIMULATION

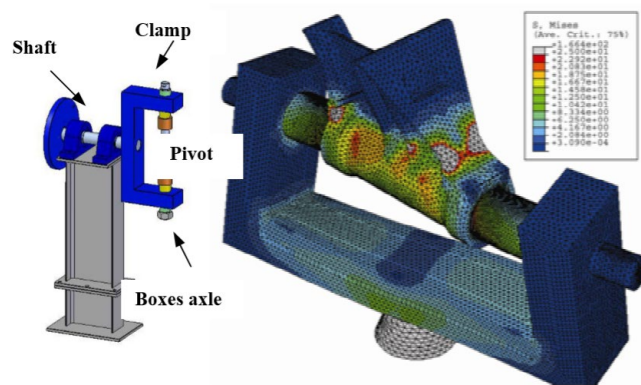


Figure 6 FEA model

The FEA model always starts by representing the rig (structure) and the frame using a CAD software. The aim is always to design the CAD model as close as possible to the physical components, this will enable to avoid most of the errors. Once the CAD model is checked measuring all the relevant data, moving to an FEA package the boundary conditions can be set. For the frame the best way is to split the component into smaller parts analysing one part at time.

The whole system has to be meshed, it's advisable to create a finer mesh in the headstock zone in order to acquire the most accurate results as possible.

A SMALL ERROR AT THESE
BOUNDARY CONDITIONS WOULD LEAD
TO LARGE ERRORS IN THE
RESULTS.

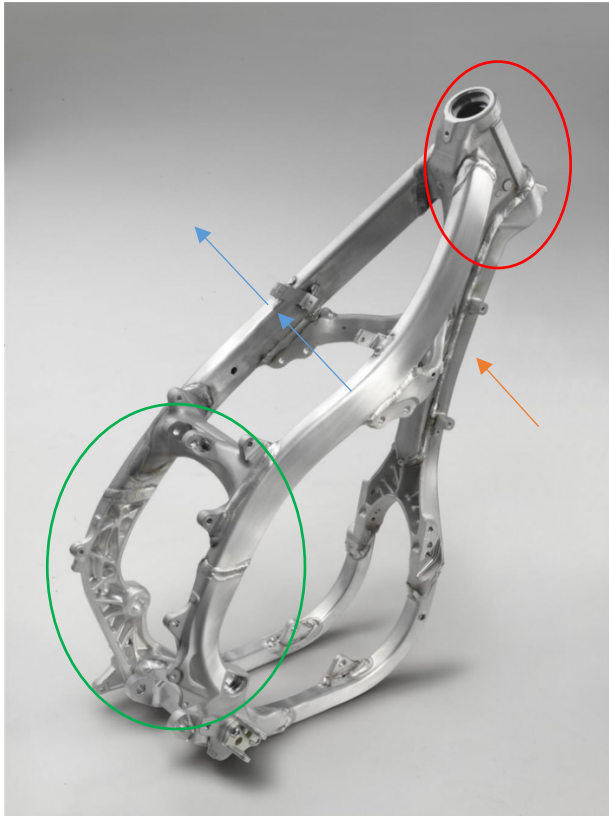


Figure 7 Example of splitting frame in sections

Steering head (red)

Anterior box (orange)

Sub frame lateral plates (green)

Perimetric tubes (blue)

LOADS AND CONSTRAINTS

In order to replicate the physical test conditions, the frame is constrained at the swing ~~arm~~ pivot, locking its movement along X and Y direction (see Figure 3) it could only rotate around the Z axis but this movement is blocked by the steering head pivot, allowing the headstock to rotate just around the X axis. The structure is loaded applying a torque at the shaft, the value has to be equal to the one applied in the physical test.

Once the simulation has run the results of torsional stiffness can be visualized and analysed.

Here a comparison of both physical and FEA of the torsional test executed by the University of Milan (Politecnico di Milano)

2.1.4 TEST RESULTS COMPARISON

STEERING HEADSTOCK TORSIONAL STIFFNESS				
FRAME CONDITIONS		PHYSICAL TEST	FEA TEST	$\Delta\%$
		N*m/°	N*m/°	
NO ENGINE		1050	1170	11.42857
WITH ENGINE		1320	1380	4.545455

Figure 8 Physical test vs FEA test

Analysing the results, it's visible that there are discrepancies between the physical test and the computed ones as expected. The FEA results data are bigger than the physical test, overpredicting in both cases the torsional stiffness. This is due to the fact that the FEA test was built using tetrahedral nodes, the use of these nodes make the frame tight so more effected by the loads applied (Boccione, 2005). In this case the type of nodes could have been changed, run the simulation again and see if the changes made reduces the gap with physical test data. Once the gap between reality and FEA model is found, changes can be made to the model in order to make the model as close as possible to the reality.

2.2 NATURAL FREQUENCY TEST- HAMMER TEST

The natural frequency test is a physical analysis done on the mechanical part that are at high risk of resonance due the presence external loads vibrating at the same frequency of the natural frequency of the chassis. The value of natural frequency can be found by using different techniques such as hammer test, impact test, coast down peak hold test. In this section the hammer test will be explained (Pellegrino, 2020).

For a motorbike the external loads that could put the structure in resonance are jumps, bumps, motion of the rider on the seat too.

NATURAL FREQUENCY FORMULA AND PRINCIPLES

The natural frequency of any objects is defined by the following formula (Johnson, 2018).

$$f = \sqrt{\frac{K}{m}}$$

Where

f: is the frequency [Hz] or [1/s]

K: is the stiffness of the component chassis in this case [N/m]

m: mass of the chassis [Kg]

The formula is fundamental to know as it's possible to understand the relation between frequency and stiffness and frequency with mass. Stiffness is directly proportional frequency which means that an increase of "K" determines an increase of natural frequency (keeping mass unchanged) while an increase of mass determines a decrease of the natural frequency.

This means that if we want to lower the natural frequency of the chassis, we need to add some weight on it or make the chassis with a less stiff material.

*T
USE THIRD
PERSON
NARRATIVE*

2.2.1 TESTING RIG

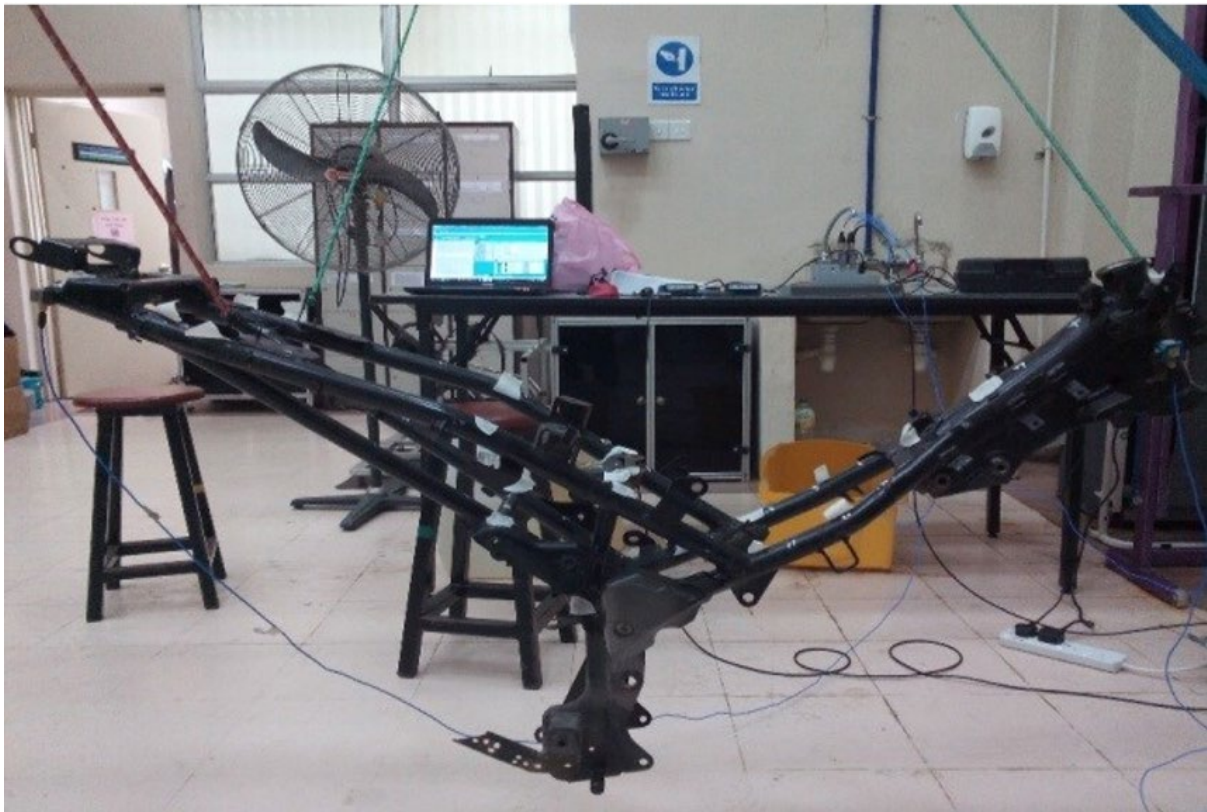


Figure 9 Chassis hanged

If the investigation is done for just the natural frequency of the chassis, it has to be stripped completely, then a series of fixed points has to be decided drawing dots or sticking reference points on the chassis Figure 9. The test can be conducted even with the engine mounted.

The test rig consists in the frame hanged with strings , making it free to move, in order to put it in a stress-free boundary condition, by using the electronic hammer connected to an accelerometer the frequency is measured (Siemens, 2019)

In order to accurately visualize the chassis behaviours and to acquire the most accurate data, a wireframe model of the chassis is often used for the test Figure 8.

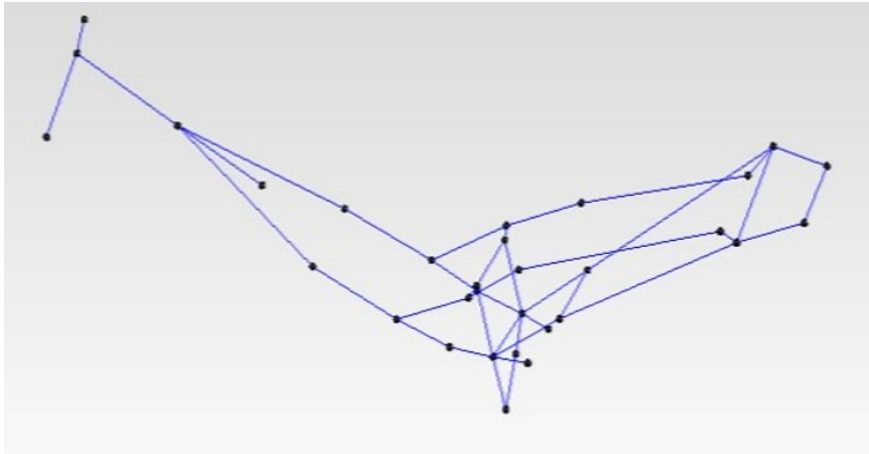


Figure 10 Chassis wire frame model used for gathering data.



Figure 11 Hammer test of motorcycle chassis with engine (Siemens, 2019)

2.2.2 FEA MODEL AND SIMULATION

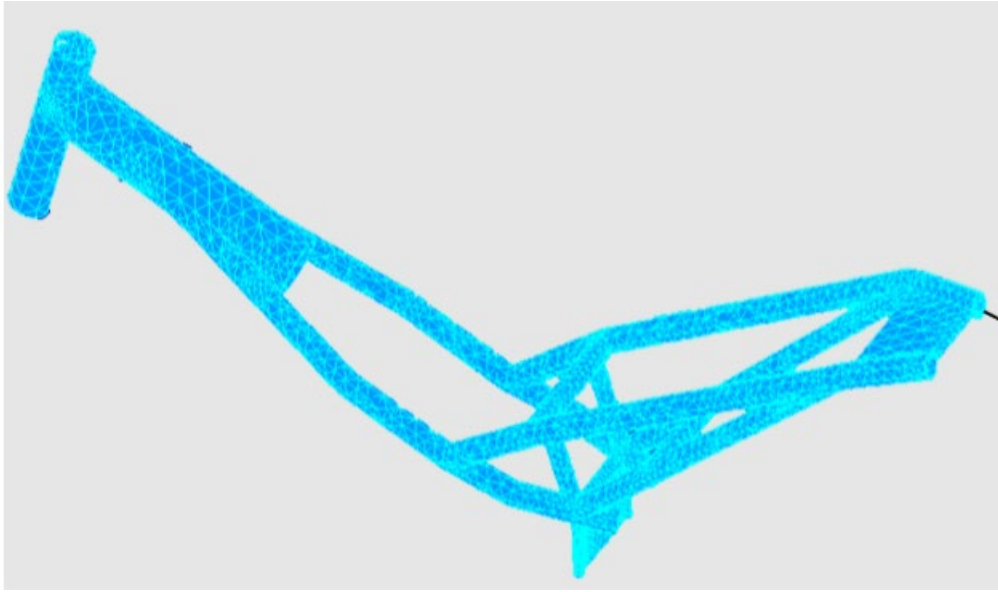


Figure 12 Chassis meshed

As every FEA simulations, material information such as, Young's Modulus, density and thickness have to be inputted in the software used.

LOADS AND COSTRAINTS OF A MODAL ANALYSIS

For the natural frequency analysis, the boundary conditions have to be set as "free in order to be able to move freely.

This type of analysis does not require any external loads as the software will "load" the structure at different frequencies called "modes" where the chassis will assume different shapes called "mode shapes", at each mode shape is then possible to see how much and where the chassis deforms. (Kurowski, 2015)

2.2.3 CORRELATIONS BETWEEN FEA AND PHYSICAL TEST

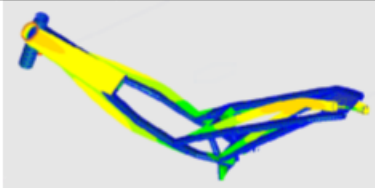
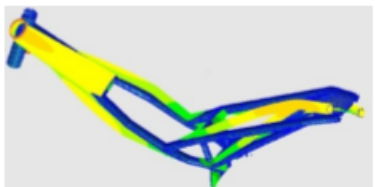
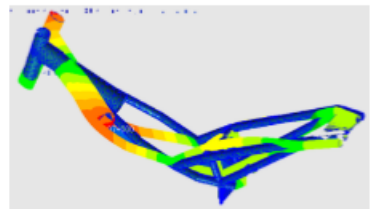
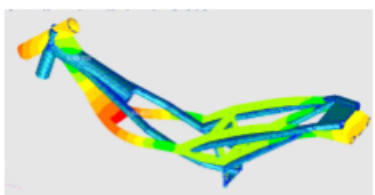
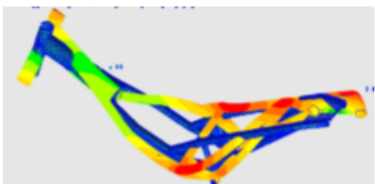
Mode	Natural Frequency (Hz)	Mode Shape
1	241.15	
2	264.76	
3	380.40	
4	397.66	
5	517.43	

Figure 13 FEA natural frequency results

Mode	Natural Frequency, Hz	Mode Shape
1	246	
2	288	
3	383	
4	390	
5	516	

Figure 14 Physical test natural frequency results

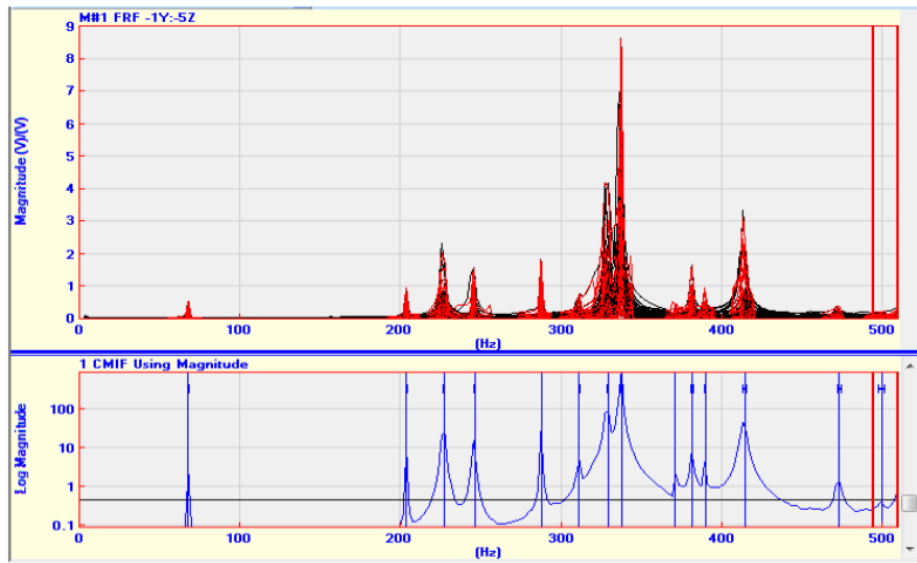


Figure 15 Physical test results graph

2.2.4 TEST RESULTS COMPARATION

NATURAL FREQUENCY TEST				
MODE	PHYSICAL TEST	FEA TEST	$\Delta\%$	
	Hz	Hz		
1	246	241.15	1.971545	
2	288	364.76	26.65278	
3	383	380.4	0.678851	
4	390	397.66	1.964103	
5	516	517.43	0.277132	

Figure 16 Results comparison table

Figure 10 and Figure 11 show the results of natural frequency of the two approaches, FEA and physical respectively. The results have been laid in Figure 13 table, the percentage of error difference between the two approach was then calculated.

Looking at Figure 12 graph, which represents the relation between frequency and magnitude of the deformation of the chassis, is visible that the biggest magnitude occurs around 350 Hz a very big deformation of the chassis can be seen at “Mode 4” of the FEA test at the natural frequency of 397 Hz. Analysing the results, the biggest discrepancies occurs at “Mode 2”, while in all the other four cases the percentage of error stays below 2%, which probably suggests a mistake done by the person carry on the test.

3 FEA ANALYSIS AND PHYSICAL TEST VALIDATION APPROACH

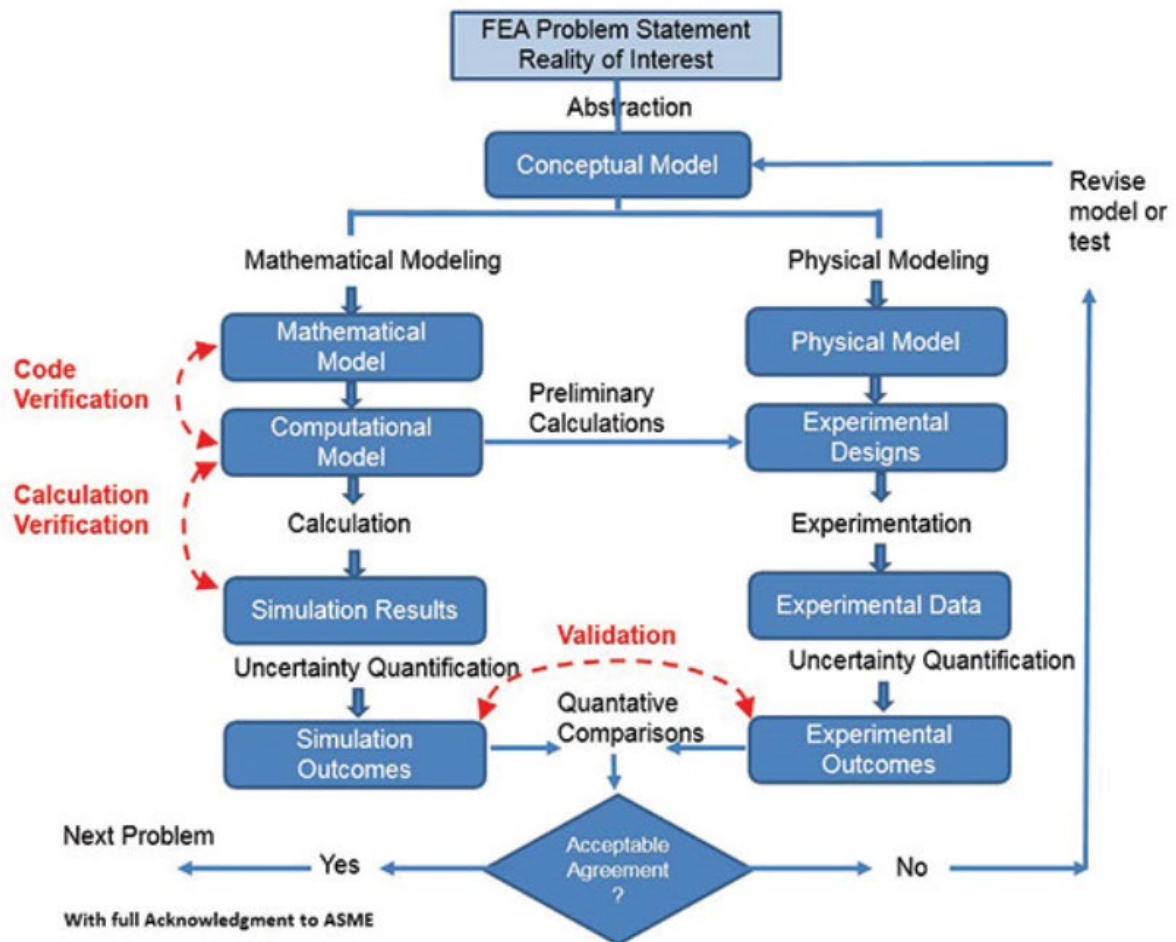


Figure 17 FEA model validation (Abbey, 2015)

The graph above shows the correct approach that has to be followed when it come to verify and validate any FEA model with a physical test. It's important to remember that neither the physical test of the FEA are always right, both can have some errors due to approximative inputted data or due to human measuring mistakes, for this reason it's fundamental to evaluated both the data executing a quantitative comparison, trying to spot any minor or big problems (Abbey, 2015).

As it has been shown in the previous section a probable human measurement error occurred in the physical test, in this case it would be necessary to carry on multiple physical tests until the data gathered remain quite consistent.

INTERESTING
EXAMPLE.

4 CAN/SHOULD FEA ANALYSIS REPLACE PHYSICAL TESTING?

FEA analysis is a very useful way for motorcycle factories for accelerates the decision-making process when it comes to try something new, saving time also means saving money by the company so the analysis use has an economical benefit.

However, in the motorcycle world physical testing in laboratory and at the track is essential to understand how the structure behaves and it's fundamental for the validation of the FEA models produced by the company. (Thornton, 2011)

Validation is clearly the biggest factor and reasons for a physical test, practical tests are fundamental useful when it comes to design a new swingarm for a new motorcycle where designers have no preceding experience.

4.1 SUBJECTIVE BIKE FEEL

ALSO, REGS
MAY REQUIRE
THIS

In the highest motorcycle championships such as MOTO GP, Superbike and Supercross the chassis and swingarms are designed for the Rider most of the time. Firstly, each rider has his own physical characteristics such as weight and height, these two factors plays a very important role for bodyweight location and rider position affecting then bike's dynamic and handling (Dal Pozzo, 2015).

Secondly, each rider has his own perception of how the chassis reacts to his movements during acceleration, breaking and cornering. Chassis are designed and developed during physical test on the track usually during the off season, this process is very long and delicate and it cannot be replaced by FEA ANALYSIS.

IT CAN BE HARD
TO SCIENTIFICALLY
QUANTIFY SUCH THINGS.

It's impressive how sensible professional riders are when it comes to test new parts, in the last few years a solid amount of work has been done by Supercross teams to design differ engine mounts. As it has been explained previously the presence of the engine in the chassis makes a relevant difference, increasing the torsional stiffness. The engine mounts which connects engine to the chassis deliver the whole vehicle stiffness and solidity, and they also have to deal with managing the vibrations (Motocross Action, 2020).

FCP is an American company specialized in designing and development of engine mounts, and they spend a considerable amount of time testing their mounts at motocross track asking feedback to the riders, without testing the best mount couldn't be developed. (Motocross Action, 2020)

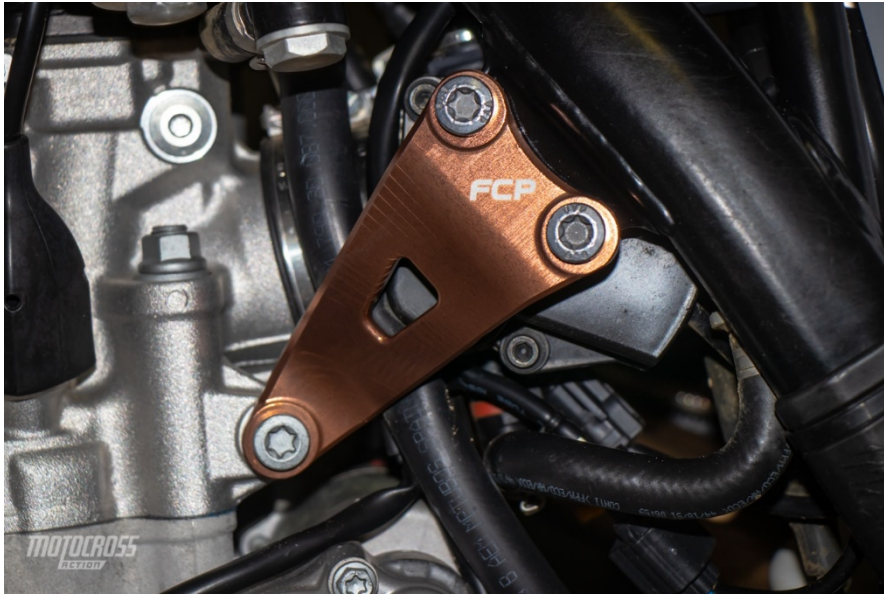


Figure 18 FCP engine mounts

The most common material used for engine mounts are aluminium, steel and titanium, for a company as FCP is definitely useful doing some FEA analysis as they can simulated how each material or geometry would behave on the chassis in a very quick time, without FEA the engine mount would be need to be machined and manufactured before performing the test, which is economically expensive and time consuming.

As it has been shown previously the engine the vibrations transmitted to the rider depends on the engine mount mass and material stiffness so the company can test them with their FEA packages but then the physical test is needed.

THE IMPACT ON THE
DESIGN PROCESS COULD HAVE
BEEN EXPLAINED IN MORE
DETAIL.

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