

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	KACZMARCZYK	Student P number:	
Programme:	BEng Automotive and Manufacturing streams		
Module:	Advanced Stress Analysis & FEA	Module Level (4, 5, 6):	6
Module code:	M6X00420	Contribution to Overall Module Assessment (%):	50 %
Lecturer:	Kelvin Lake	Internal Verifier:	Rob Goodson
Assignment Title:	Can FEA replace physical testing?	Assignment No (x of x):	1 OF 1
Hand Out Date:	25/02/2020	Submission deadline:	29/03/2020

Referencing:	In the main body of your submission you must give credit to authors on whose research your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have read or quoted in order to complete this assignment (e.g. for books: surname of author and initials, year of publication, <u>title of book</u> , edition, publisher: place of publication).		
Disclosure:	I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people. All references have been duly cited.		
Student's Signature:	Assignments will not be accepted without a signature here	Date:	
Turnitin: Lecturer to tick to indicate if an electronic version of the assignment must be submitted to Turnitin. Note: the Turnitin version is the primary submission and acts as a receipt for the student. Penalties for late submission: Up to four weeks late, maximum mark of 40%. Over four weeks late, Refer. Only Year Tutors and the Programme Director may grant an extension.			YES
			✓
			NO

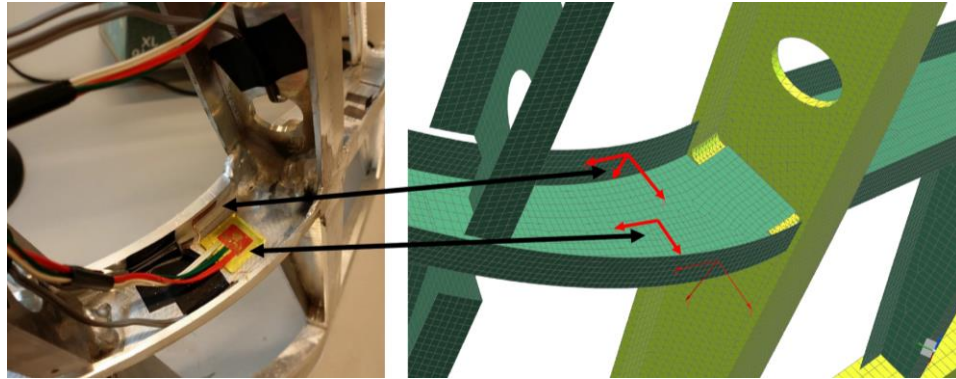
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- DO NOT put this form into Turnitin or it will match many similarities with other students' submissions.

TASK DESCRIPTION

This assignment explores FEA and the role that it plays in product development. It is expected that the student will research this topic (referencing any sources used, using Harvard or Vancouver).

GUIDANCE FOR STUDENTS IN THE COMPLETION OF TASKS



The above image shows a component undergoing physical testing and the corresponding FE model. Your task for this assignment is to discuss the following;

1. Why companies typically carryout FE analysis alongside physical testing.
2. How a physical test may be correlated to an FE model.
3. If you think that FE analysis can (or should) ever replace physical testing.

In order to do this, you should consider a case study and use this to discuss the above tasks.

This report should be 3000 words long and should be submitted via moodle

STRUCTURAL SECTION MARKING CRITERIA AND STUDENT FEEDBACK

This section details the assessment criteria. The *extent* to which these are demonstrated by you determines your mark. The marks available for each criterion are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Common Assessment Criteria Applied	Marks available	Marks awarded
1. Research-informed Literature Extent of research and/or own reading, selection of credible sources, application of appropriate referencing conventions.		
(Assessed in point 1)	30	19.5
2. Knowledge and Understanding of Subject Extent of knowledge and understanding of concepts and underlying principles associated with the discipline.		
(Assessed in point 2)	30	20.4
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	22.5
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		
(Assessed in report presentation and structure)	10	6.8

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)		69.2	%
	Up to one-week late			
	Over one week late			

COMMON ASSESSMENT AND MARKING CRITERIA

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

Student Self Evaluation Form

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

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

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

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

Student's Name		Date	
Student's Signature			

University of Wales Trinity Saint David
School of Engineering

Can FEA Replace Physical Testing?

Kacper Oskar Kaczmarczyk

1701199

BEng Motorcycle Engineering

15/03/2020

Advanced Stress Analysis & FEA

M6X00420

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1 Introduction

This report talks in detail about what can be achieved with today's FEMs, in the context of design optimisation of ICE connecting rod and components surrounding it.

Author also talks about few methods which can be applied to the physical test correlation, which helps with FEA model validation.

Lastly, author makes a case against the replacement of physical testing with FEA, describes why physical testing is so important and what undesirable consequences the lack of physical testing may have on a company.

2 The Importance of FEA

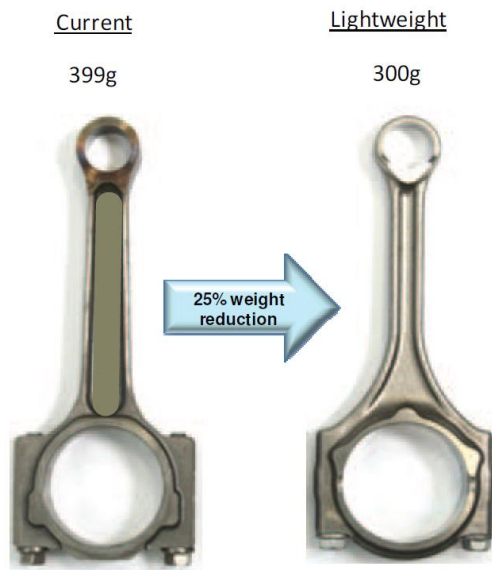


Figure 2-1: Connecting Rod, Results of FEA Optimization (MATHEUS DOS SANTOS FERREIRA, 2013)

Finite Element Analysis (FEA) is frequently carried out alongside physical testing in the design process. Physical testing is usually carried out for two purposes: 1) FEA model validation, 2) final design testing & evaluation. The use of physical testing is always minimized as much as possible due to the inherent costs, not only materialistic but also time related, associated with the production of the required physical prototype, as well as the testing equipment, required personnel etc. This was very apparent in author's research as many sources have shown the physical testing chapters to always be the shortest, showing what author could only describe as 'neglect'. Author's research has shown a clear dependability and trust of engineers in their FEA software packages.

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FEA, of which there are 10 types (Lake, 2020), is used to optimize physical designs. This is due to the relatively low costs associated with the design creation and testing. More recently, the increase of affordability of computational power, allowed engineers to improve design processes, one of which is to generate topology based on the design case, as oppose to the previous 'traditional' create, test, improve cycle. These strategies allow for the creation of even more advanced designs while keeping the costs affordable.

Naturally, the same design processes are applied when designing Internal Combustion Engine (ICE) components, such as connecting rods. Connecting rod, as shown in Figure 2-1, is a pin jointed beam which connects the engine's crankshaft to the reciprocating assembly, which consist of gudgeon pin, piston and piston rings.

Due to the extremely complicated loads, which not only consist of stresses associated with the cylinder gas forces and assembly inertias, but also thermal and shear forces, all of which are very dynamic due to the nature of the crankshaft system, as well as all of the processes occurring around the connecting rod (combustion, coolant flow, oil to structure interaction etc.), the 'classical' 0-Dimensional beam theory which is often based on empiricism, is very much not suitable for this design case. As such, the only alternative to FEA are the physical trails which aim to build empiricist solutions, which naturally are incredibly inefficient and as a result, not applicable in 21st century.

As Figure 2-1 has shown, FEA is used to optimise the connecting rod's mass, while retaining acceptable FSF (Fatigue Safety Factor)/ reliability. This is because lighter connecting rod will decrease inertias, reducing bearing and crankshaft loads as well as the wasted engine torque which is required to accelerate 'bottom end' assembly. This results in better fuel consumption.

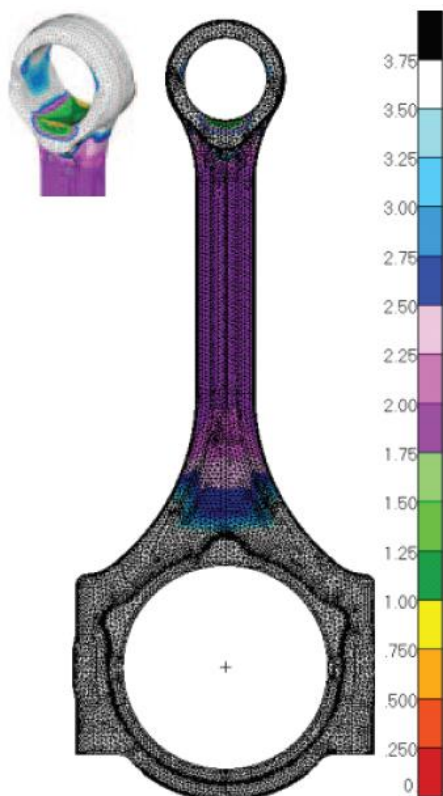


Figure 2-2: FEA Results of Maximum Engine Torque (MATHEUS DOS SANTOS FERREIRA, 2013)

All of these factors are extremely important to today's vehicle manufacturers, since their product sales are directly affected.

Furthermore, FEA allows for computation of parameters which would be impractical to measure in real life, for example: the maximum engine torque distribution, as shown in Figure 2-2. This ability allows engineers to carry out more detailed analysis, which aids to further understand the problem and as a result, help the engineer to make a much better decision regarding the design.

Also, modern FEA software packages allow for the consideration of multiple interactive systems, such as: connecting rod and crankshaft shown in Figure 2-5 or connecting rod big end bearings shown in Figure 2-3.

SCALE ?
WHY IS FIGURE 2-5 BEFORE FIGURES 2-3 & 2-4 ?

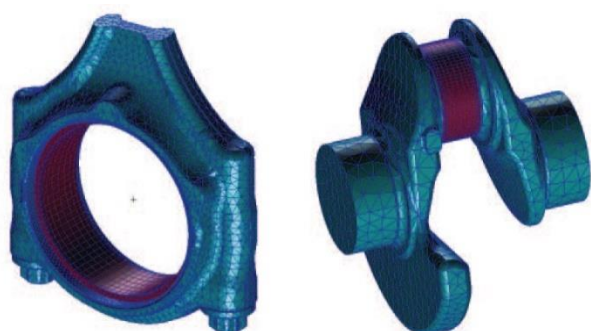


Figure 2-5: Connecting Rod Big End & Crankshaft Models (MATHEUS DOS SANTOS FERREIRA, 2013)

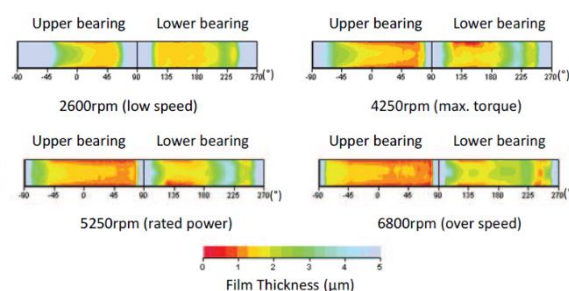


Figure 2-3: Oil Thickness History Maps (MATHEUS DOS SANTOS FERREIRA, 2013)

The fusion of these interactive systems allows for consideration of the dynamic effects which other components in the assembly have on the component being designed. Naturally, this improves the design capability as more factors are considered, many of which were previously an afterthought, due to the design and testing costs as well as the design importance of the connecting rod itself.

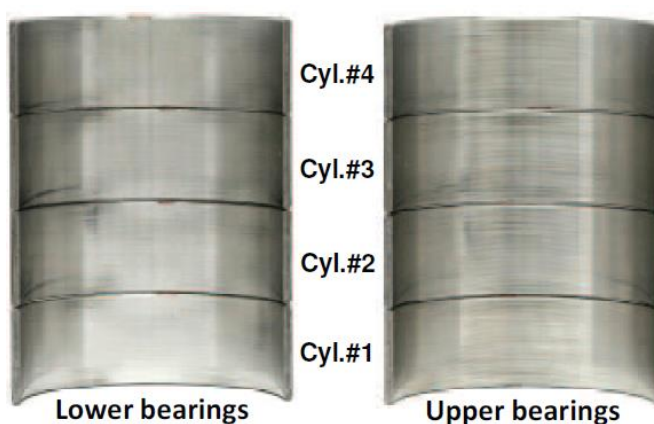


Figure 2-4: Connecting Rod Bearings After 300 Hour Endurance Test (MATHEUS DOS SANTOS FERREIRA, 2013)

Figure 2-4 shows that due to the bearing model incorporation, the big end bearings installed on the new connecting rod design had very good wear, after 300-hour endurance test. This means that not only the new connecting rod design allowed for better performance of a

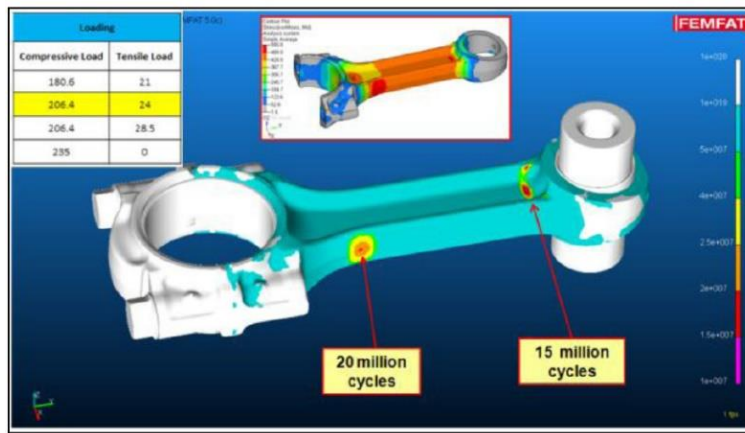


Figure 2-6: Fatigue Life Evaluation (Suresh Kumar Kandreegula, 2016)

separate component but also due to initial success, further design iterations and testing weren't required, saving enormous amount of time and finances which could be spent on other design aspects, allowing for even more improved and as a result, efficient design: performance value divided by cost of the design.

Lastly, as the connecting rods operate inside production ICEs, the reliability is crucial. As Figure 2-6 shows, FEA also allows for the simulation of fatigue. This is important as fatigue failure of such component cannot occur before the end of life cycle of the product, otherwise the manufacturer is going to lose money, either directly via warranty or indirectly via loss of reputation. Fatigue testing is carried out physically on a special rig over very long period of time, due to the enormously high expected life cycle of the connecting rod, about 10^9 cycles (McDonald, 2019). Naturally, such physical testing is too time consuming to allow iterative design cycle. Therefore, FEA is used to determine the fatigue concentrations and the expected local fatigue failure cycle. This allows engineers to improve the identified fatigue regions and ensure the likelihood of success of the expensive life cycle test.

3 Physical Test Correlation

The objective of correlating the FEA results to a physical test is to validate the FEA model, so that the engineer can be confident in two aspects: 1) the time spent on design optimisation won't be wasted as the FEA model is predicting the real life results to good enough accuracy, so that the results of the simulation can be analysed and improved upon. 2) The final design will deliver the performance as designed, meaning that the further investment of the prototype and physical testing is worth-while.

There are many ways to correlate the results of physical testing, the methods are always tailored to the design case that is being considered. However, the most common physical test consists of the use of strain gauges, which will measure the local strain magnitude typically over time. Though it is most common for physical tests to be static due to the inherently lower complications compared to dynamic tests, making the accuracy and analysis of static tests much better, which means that the time aspect is usually not considered.

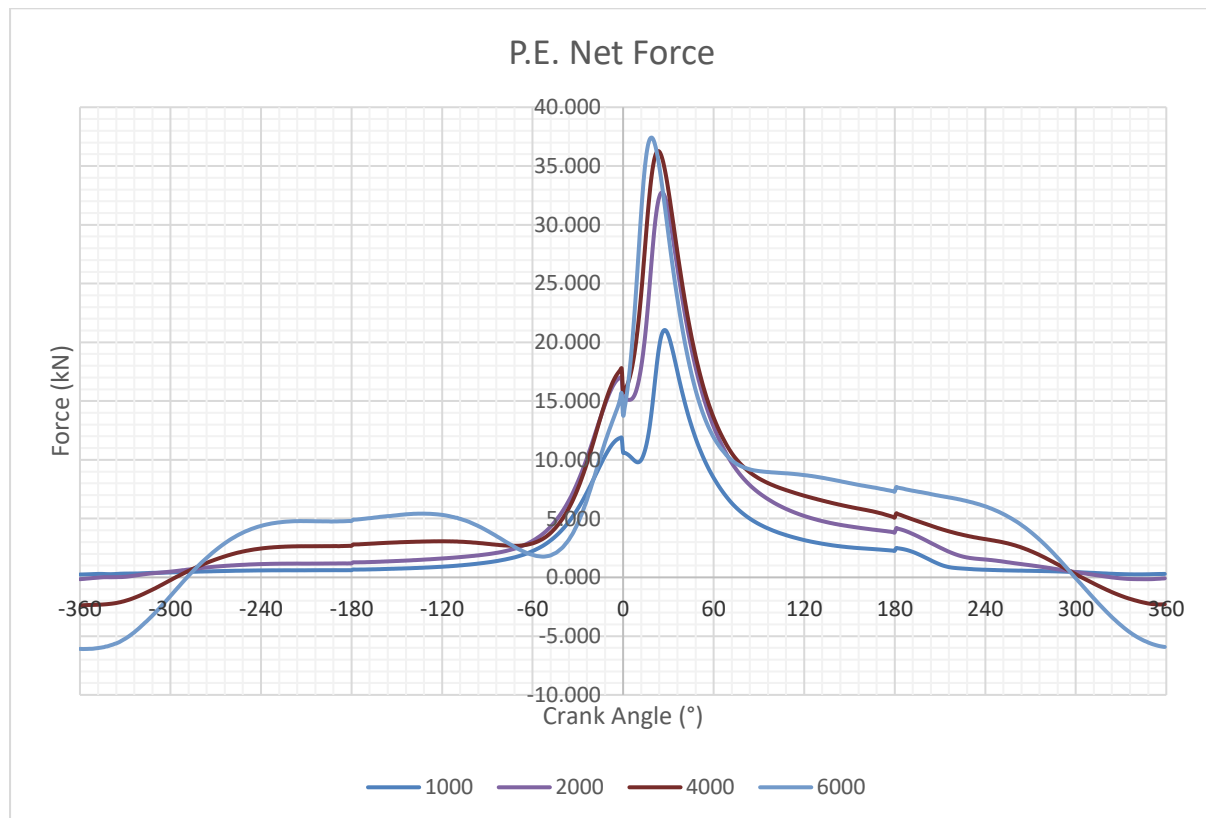


Figure 3-1: Production Engine Net Connecting Rod Shank Force as Function of Crank Angle

Due to the complicated environment that the connecting rod is in a typical 4 stroke engine, normally only two design scenarios are considered: 1) around TDC (Top Dead Centre) on expansion stroke, due to the highest compressive force caused by combustion. 2) around TDC exhaust stroke due to the highest tensile force due to lack of inertia opposing forces. This is shown in Figure 3-1, which shows instantaneous connecting rod forces as function of crank angle at various engine rpm, which author created for report: "Con-Rod Accelerations, Forces & Displacements".

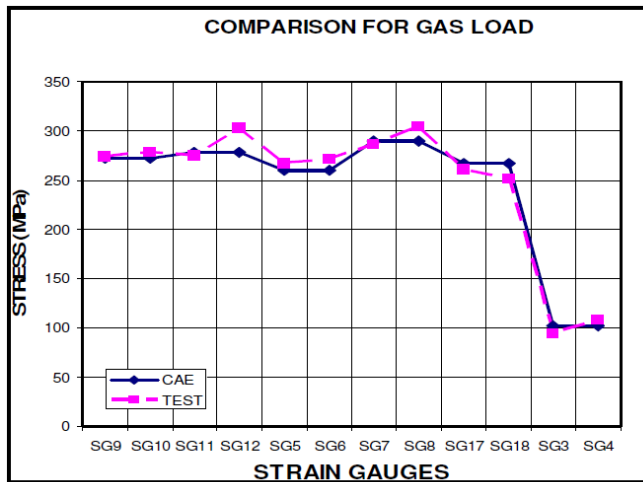


Figure 12.a: Comparison of CAE and TEST results.

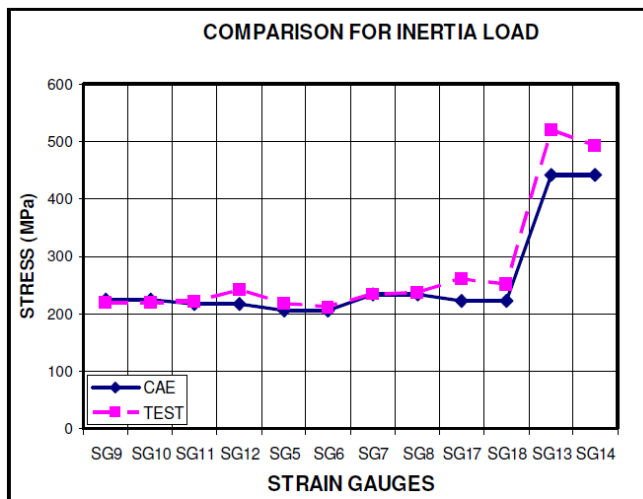


Figure 12.b: Comparison of CAE and TEST results.

Figure 3-2: Connecting Rod Physical Test - Gas Load & Inertia Load Strain Gauge to Simulation Comparison (Abhijit Londhe, 2009)

Figure 3-2 shows the comparison of the static stress magnitudes between the values which were recorded via several strain gauges and the simulation, in maximum compressive and tensile cases, caused by combustion and inertia respectively.

The first correlation which can be done is the assessment of the overall profile, e.g. does the simulation show the same behaviour as the physical test? In Figure 3-2, it is clear that strain gauges 9 through 18 show very similar magnitudes, however, the strain gauge pair of 3,4 and 13,14, show magnitudes which are about 2 times bigger and smaller as the other magnitudes, in tensile and compressive loading respectfully. Since the behaviour of the simulation agrees with the test, it is likely that the boundary conditions of the simulation as well as other 'setup' conditions such as mesh, have been most likely correctly created.

Second correlation which can be done is the assessment of the polarity, e.g. when real life data shows a positive absolute increase of magnitude, does the simulation predict positive or negative?

This usually is also used to determine the validity of the boundary conditions, since polarity inaccuracy are usually caused by incorrect direction of loading, e.g. compressive where it should be tensile and vice-versa. A good graphical representation of polarity is a graph which

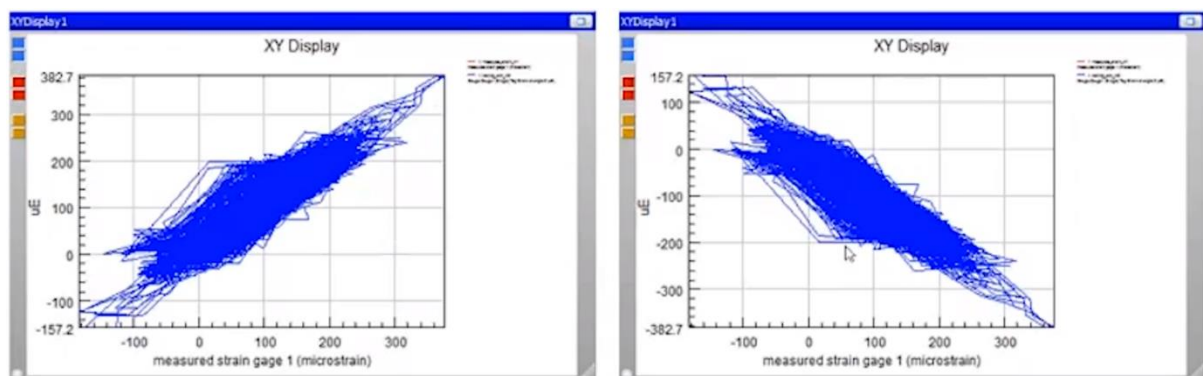


Figure 3-3: Data Polarity Plots (Presencia, 2018)

plots two data sets against each other, as shown in Figure 3-3, as then the positive directly proportional line will indicate a good polarity correlation. Additionally, such graph can also be used to show skewness/ model bias towards either over or under prediction.

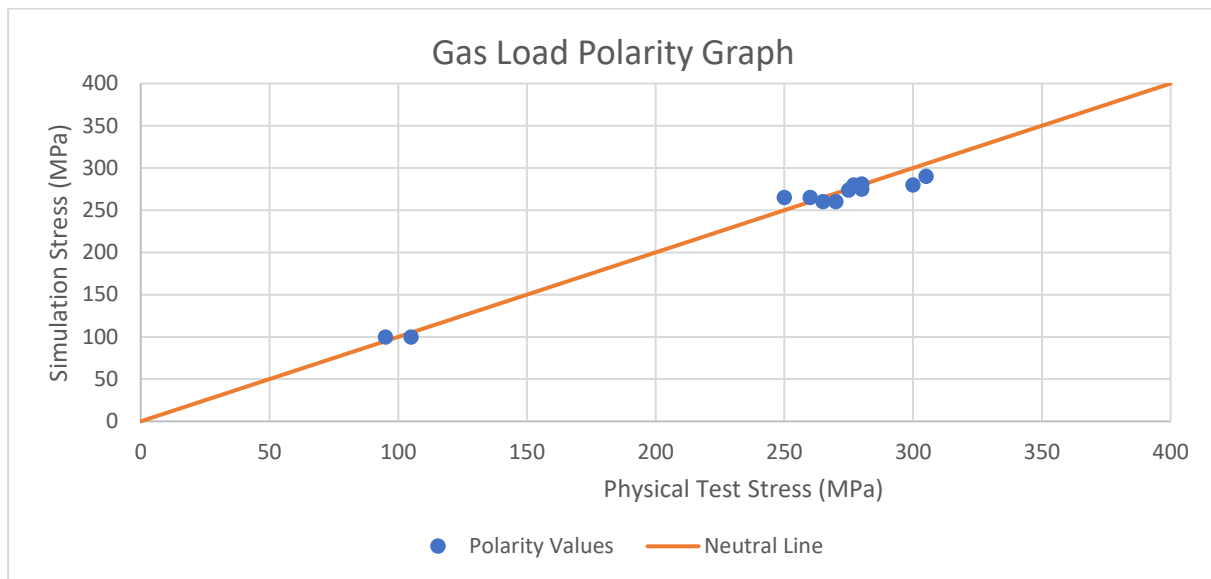


Figure 3-4: Gas Load Polarity

Figure 3-4 shows the polarity graph author created based on the values read from Figure 3-2. It shows the polarity to be very good since all data points occur very closely to the neutral line, it also shows the simulation to be biased towards underpredicting since most data points fall under the neutral line.

Another correlation which can be done is the assessment of the absolute values, e.g. how accurate each data point is compared to physical testing. To show this, author has created Figure 3-5 which shows the inaccuracy of the simulation at each strain gauge location.

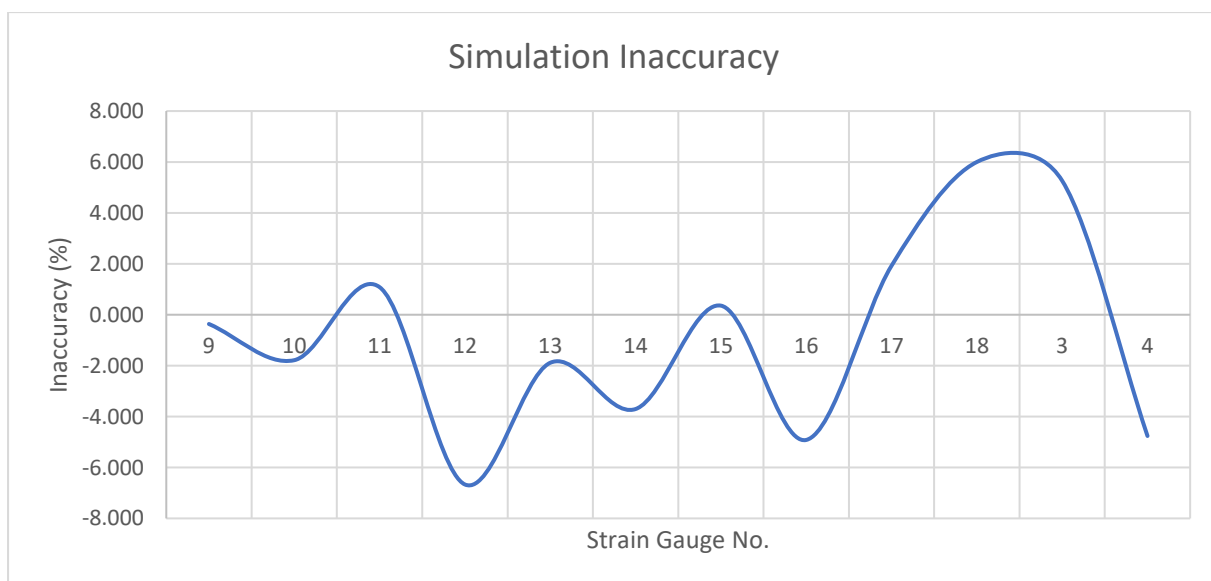


Figure 3-5: Simulation Inaccuracy

Based on the results shown in Figure 3-5, it is clear that the overall accuracy of the model is $\pm 6\%$, which is respectable. It is also showing that the majority of data points are in fact under predicting, just as in Figure 3-4, however, it also shows that nearly all over predicted values have inaccuracy very close to the $\pm 6\%$ tolerance. Therefore, this correlation is not only useful to determine model accuracy but also to create a deeper understanding of why the accuracy is at certain level and how it can be improved, since the most severe local inaccuracies can be individually studied to determine either, local problems such as coarse mesh, or global issues such as model restraining etc.

4 Should Finite Element Analysis Replace Physical Testing?

As it has already been mentioned in The Importance of FEA chapter, FEA especially when incorporated into CAE (Computer Aided Engineering), is a tool which when correctly applied, can enable engineer to develop better optimised design, which is the objective of every engineer.

However, FEA cannot and should not ever be used on its own as it is impossible to perfectly simulate anything, to do so engineers would have to develop models which operate on quantum and planet size at the same time, as it is right now, we are struggling to get molecular sized models right on their own. *DO NOT USE COLLOQUIAL LANGUAGE USE THIRD PERSON*

The reason why such a complicated model is required to truly 'replace' physical testing is because real life is equally complicated. An FEA model which doesn't replicate real life perfectly is not able to replace physical testing as such model doesn't account for every factor which the component might encounter in real life. Furthermore, even if such model existed and was readily available, it doesn't mean that the case study has been correctly setup by the user. Therefore, even a 'perfect' model can very easily calculate very unrealistic results.

As previously shown in Figure 2-3 and Figure 2-4, when correctly applied, FEA can improve the performance of components in real life. However, for FEA to do so, the model used must be valid, e.g. the model accurately represents and agrees with real life, as without validation work carried out before design optimisation, it is impossible to be confident that what software shows will also happen in real life, where it actually matters.

Author believes it is crucial to remember that any FEA method is just an estimation tool which is and most likely never will be perfect due to the complexity of real life. This is why 'safety factors' are employed; they allow engineers to account for lack of confidence in their FEA method. ✓

Test sequence	Load amplitude (kN)	No of cycles completed	F.O.S
1	57.73	Run out	1.25
2	58.26	Run out	1.24
3	60.11	Run out	1.20
4	61.96	Run out	1.17
5	63.82	Run out	1.13
6	66.98	Run out	1.08
8	69.75	Run out	1.04
7	72.51	Failed at shoulder	0.96
9	72.51	Failed at shoulder	0.96
10	71.13	Failed at shoulder	1.00

Figure 4-1: Fatigue Safety Test Results (Abhijit Londhe, 2009)

Physical Test Correlation chapter has shown that FEA accuracy of about +/-6% can be achieved, once validation has been carried out. This means that in real life 6% bigger or smaller stress can occur anywhere in the tested local regions, this could potentially be even bigger in other untested localized regions, which is another reason to test the component physically. This is why physical testing is carried out at the very end of the design process. Figure 4-1 shows the results of load testing of the same connecting rod as in Figure 3-2. It shows that the connecting rod has failed when the designed load (Factor of Safety 1.00) was applied. However, it didn't fail when 4% lower load was applied

instead, which is within the +/-6% model accuracy. If that connecting rod hasn't been physically tested and went into mass production, then the manufacturer which assembled engines with those connecting rods would loose astonishing amounts of money, both directly and probably even more indirectly, as the connecting rods would be failing and they would have to be replaced with a stronger component, which would also cost money to develop and produce.

Locations	Test data		CAE	% of Correlation
	Strain	Stress (Mpa)	Stress (Mpa)	
1	1.57E-03	329	350	94.00
2	1.83E-03	384	400	96.00
3	1.36E-03	286	300	95.33

Figure 4-3: Connecting Rod Physical Test Data Correlation

Sample No.	Cover Factor	Test Loading (KN)		Target no. of Cycles	Completed test cycles (million)	CAE (million)
		Stress (Mpa)	Stress (Mpa)			
1	1.4	180.6	21	5 million/Specimen	10	-
2	1.6	206.4	24		10	15
3	1.6/1.9	206.4	28.5		10	-
4	1.82/0	235	0		10	12
5	1.82/0	235	0		10	-

Note : VECV testing machine capacity 10 million cycles.

Figure 4-2: Optimised Connecting Rod Fatigue Testing

Figure 2-6, which is +6%. Figure 4-2 shows the results of the fatigue physical testing, which all of connecting rod specimens have completed successfully, although the test did not carry-on to the CAE designed limits. This shows that even though the same FEM accuracies in Figure 4-1 and Figure 4-3 were achieved, the desired outcome wasn't achieved in Figure 4-1, which shows how crucial physical testing is.

Sometimes it could be tempting to not carry out physical testing to reduce the time and financial expenses. This most commonly happens when an engineer has become very confident in their FEM (Finite Element Method) due to very good results from the previous project, for example: Figure 4-3 shows the FEA model accuracy of the connecting rod shown in

5 Conclusion

It is very apparent to the author that FEA, especially when applied to CAE, is a very powerful tool which can yield extremely well optimised and diverse designs at relatively low costs.

However, all of the FEA models/ cases must be validated before and after the design optimisation, as this ensures the FEA results to be realistic, making the analysis of further designs worthwhile. The final physical test is also crucial, since it allows the analysis of the component's behaviour in real life, which is where the component will be used in.

✓
THE IMPACT OF FEA ON
THE DESIGN PROCESS COULD
HAVE BEEN DISCUSSED FURTHER.
FOR EXAMPLE, HOW LONG
WOULD IT TAKE TO DEVELOP
SUCH A COMPONENT WITH &
WITHOUT FEA?

6 References

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