

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

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declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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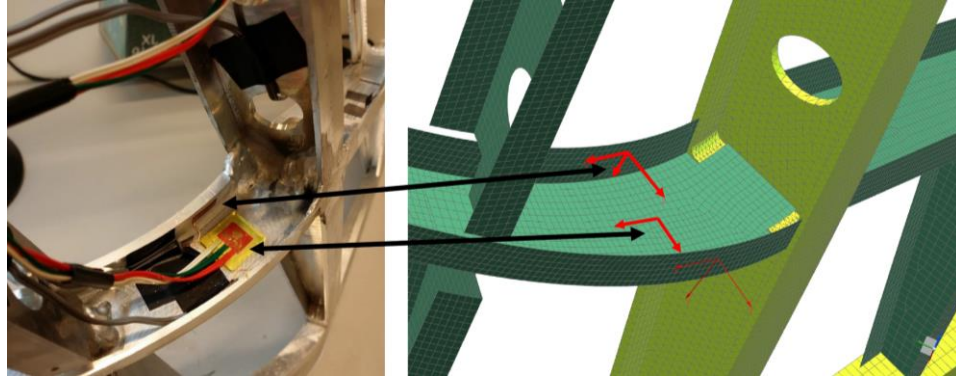
Learning Outcomes tested (from module syllabus)	Assessment Criteria To achieve each outcome a student must demonstrate the ability to:
Demonstrate an ability to analyse a range of engineering problems using advanced stress analysis principles.	

- 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	18.9
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	18.6
3. Analysis Analysis, evaluation and synthesis; logic, argument and judgement; analytical reflection; organisation of ideas and evidence		
(N/A)	0	
4. Practical Application and Deployment Deployment of methods, materials, tools and techniques; application of concepts; formulation of innovative and creative solutions to solve problems.		
(Assessed in point 3)	30	17.4
5. Skills for Professional Practice Attributes in professional practice: individual and collaborative working; deployment of appropriate media; presentation and organisation.		
(Assessed in report presentation and structure)	10	5.8

Assignment Mark Overall (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)	Late Submission Penalties (tick if appropriate)		60.7 %
	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%
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
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Can FEA replace physical testing?

Uzayr Ahmed

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Mechanical Engineering

22/04/2020

Advanced Stress Analysis & FEA –
M6X00420

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1 Introduction

As of 2017, in the UK and according to the NHS there were approximately 2.35 million patients that had undergone total knee arthroplasty (replacement) surgery, and greater numbers are occurring year on year, with an increase of 20,00 cases in 2017, compared to the previous financial year (Porter ,2017). Further, the same report notes the increasing number of younger patients (under 55) undergoing the surgery and suggests that surgeons need to take advantage of mature and rich datasets to get the initial surgery as right for the patient as possible. This suggestion is made based on the evidence the patients under 55 getting the surgery will likely need at least one revision surgery over their lifetime (Maradit Kremers, Hilal, MD, MSc, Larson et al. ,2015).

This report aimed to detail Finite Element Analysis (FEA) processes and the role it plays in developing parts and products within the industry in general, whilst also using a case study, to answer three research questions.

The study in question is a 2020 article, published in BMC Musculoskeletal Disorders (Springer Nature), that sought to use Finite Element Analysis processes to optimise implant procedures for total knee arthroplasty.

More specifically, this report aimed to answer three case statements:

1. The reasoning for FEA's use alongside physical testing
2. How physical testing correlates to Finite Element (FE) models
3. Whether (subjectively) FEA could or should ever replace physical testing

To achieve this a brief introduction to what FEA is and how it works is discussed, before considering and analysing a single case study to discuss the case statements above.

1.1 Core Principles

FEA is considered by many to be an effective tool to obtain mechanical factors and properties of a 3D geometry that has had its material defined, and then meshed. In this way, the use of FEA allows for a critical analysis on a product or part, before the initial physical prototyping phase (Yao, Erdemir et al. ,2018). This is especially helpful where mechanical factors under load would be otherwise challenging or impractical to obtain with a physical prototype (cost, size, etc).

FEA programs split a 3D model into many different elements by placing nodes onto the structure, which are then connected to superimpose a mesh grid. The elements that make up this mesh are smaller and "simpler" in geometric terms than the whole. This allows for material analysis on these lesser sections to be performed, before combining to give a

reasonably accurate approximation of the mechanical properties of the entire structure (Yue ,2015)

FEA modelling generally consists of three stages. Firstly, the pre-processing stage, where a finite element mesh is created, for which appropriate simulation parameters and boundary values are selected to creating the governing equation for the model. Second, the solution to the problem is found, i.e. the governing equation created by the model is solved. Finally, the post-processing stage, where the result(s) of the model is evaluated, outputting both tabulated and visual data, that can be analysed for interpretation (Rao ,2018).

Another key use of FEA that is not discussed in detail here, but should be noted, is topology optimisation. Using the same foundation as described above, the process of determining which sections of material do not contribute to the structural soundness of a model under load can be automated. I.e. topology optimisation looks at where best material is placed within a prescribed domain, to obtain the best structural performance (Sigmund, Maute ,2013).

1.2 Failure Analysis

FEA is being used more and more to analyse mechanical structures, becoming a valuable tool in predicting failure points for a myriad of mechanical features under stress/load, and more importantly can be used to reconstruct possible root causes (Karayan, Ahmad Ivan, Ferdian et al. ,2012).

This is principally achieved through the insight FEA modelling provides when compared with historically classical engineering analysis methods. A major factor contributing to this increased insight is FEA's ability to consider multiple factors that could possibly be related to a single failure event at once (Najafi, Rais-Rohani ,2012). Conventionally, factors that might fail require investigation on an individual basis i.e. one possible cause then the next and the next etc. This is a time-consuming process when done with physical testing and is a drawback FEA modelling can avoid by incorporating a combination of "physical environments" into the FEA model. To surmise, as Karavan, Freidan et al (2012) put it "For example, in the case of turbine blades involved in jet engine failure, engineers should [can] incorporate the thermal effect and load effect by the blade in the simulation, not to mention other possibilities from foreign particles that could initiate the failure."

FEA modelling also provides a less tangible but equally important advantage to classical engineering analysis methods, that is, its ability to produce images and animations of a failure event. This visualization can give a better understanding of why the failure event occurred especially when the root cause is somewhat abstracted from the event.

1.2.1 Medical Industry

The medical industry has found great use in new technologies into the product development process. FEA is primarily utilised to virtually verify the performance of a device over its intended lifespan (Driscoll ,2019).

Today FEA is considered one of the most reliable simulation techniques when evaluating, wear & tear, fatigue, and crack propagation over time (Ghosh, Roy et al. ,2018). This, coupled with a greater understanding of the mechanical properties of tissue within the human body, has seen FEA become a key utility in developing and designing orthopaedic implants.

Of note, FEA's use in the medical industry has been helped greatly by the newfound prevalence of 3D printers, and state of the art radiographic imaging techniques that use 3D scanners to allow for precise 3D models of real-world body parts (Wang, Fung et al. ,2014). These three techniques have been used to create pipelines, that scan in existing joints/bones, that are then analysed with the use case in mind using FEA, before being printed out for use for a specific patient. The combination of these technologies, in general, are referred to as "personalised orthopaedics" (O'Connor, Kransdorf ,2013).

2 Case Study

In this section, more context is provided for the case study, and then the methodology is described and explained. The results and conclusions drawn from the article are stated.

2.1 Context

The case study in question, titled "An optimization method for implantation parameters of individualized TKA tibial prosthesis based on finite element analysis and orthogonal experimental design", is a research article published by BMC Musculoskeletal Disorders, in 2020, by Yuefu Dong, Zhen Zhang, et al. TKA refers to "total knee arthroplasty" which is a surgical procedure whereby the entire knee joint is replaced by artificial material (Wainwright, Gill et al. ,2020). The study was the first of its kind, in the articles own words, this was due to "several TKA finite element models [being required]".

Dong et al. aimed to use FEA techniques to optimise the implantation parameters to reduce peak values of contact pressures of a tibial prosthetic on the polyethylene liner. This serves the ultimate purpose of increasing the long-term prosthetic survival rate. Prosthetic survival rate refers to the rate at which prosthetics deteriorate over time, i.e. after surgery is performed how many patients need prosthetics renewed or replaced over time (Dierens, De Bruyn et al. ,2016).

2.2 Experimental Methodology

The research takes a novel approach of applying an orthogonal experimental design to effectively reduce the number of finite element models required, which leads to a significant shortening in preoperative planning time.

2.2.1 Virtual Model Construction

Key measurements of the distal femur and proximal tibia were obtained using the imaging techniques discussed earlier and used to create an appropriately sized knee prosthetic system, which was then scanned via a laser scanner, directly creating two .stl files of the TKA prosthetic, a tibial and femoral implant. These files were then imported into a 3D medical modelling software, MIMICS 19, to create a solid virtual body, seen in figure 1.

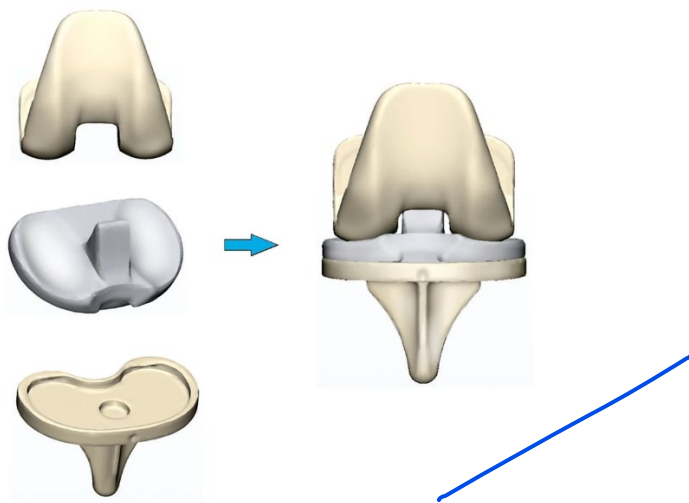


Figure 1 - TKA Prosthesis & Implants (Dong, Zhang, et al, 2020)

Implantation was performed using a previously verified knee joint model, authored by the same group. An osteotomy procedure was simulated on the knee joint model first, to maintain parity with real-world conditions, I.E. in reality cuts must be made to both the tibia and femur, to make space for and allow alignment with the implant.

The dependent variable(s) of the experiment constituted three parameters that affect peak contact pressure on the lining, that is the varus angle, the posterior slope and the external rotation angle.

The tibial prosthesis was implanted to the tibia first, then the femoral prosthesis was matched to the tibial prosthesis accurately, before being implanted to the femur. Finally, the polyethylene liner was implanted, creating the initial 3D model of the entire TKA knee joint. Implant parameters in this first instance were set to 0° varus, 1° posterior slope and 3° external rotation.

2.2.2 FEA Application

Both the knee joint and the TKA prosthetic were imported into a meshing software, and a mesh was generated to create a 3d finite element model. FEA was then carried out using Abaqus 6.14, with the behaviour of the knee joint being defined as an isotropic hyperelastic material. Using this assumption allows use of the strain energy density function to obtain contact pressure for an applied compressive load.

The total sum of elements when considering every meshed model in the first instance was 267,999, and with a total sum of nodes was 71,730, both large numbers indeed.

Appropriate boundary conditions were selected, and a compressive load of 1150 N was applied to the joint, the variable peak contact pressure on the upper surface of the polyethylene was then observed.

This pipeline process of simulating the surgery in MIMICS, meshing in Hypermesh and then carrying out FEA using Abaqus was repeated, to create the different finite element models with varied implantation parameters (dependent variables), meeting the requirements of factor combination required in orthogonal experimental design.

The distribution of peak contact pressure on the liner was analysed and compared between the 9 finite element models to verify if this experimental optimisation could reduce peak pressure and reduced wear on the liner. I.e. each dependent variable had three “states” that were varied sequentially, shown in table 1.

Model	Experimental level combination	Varus angle (°)	Posterior slope angle (°)	External rotation angle (°)	Peak value of the contact pressure (MPa)
1	A ₁ B ₁ C ₁	0	1	3	18.99
2	A ₁ B ₂ C ₂	0	2	4	17.10
3	A ₁ B ₃ C ₃	0	3	5	20.46
4	A ₂ B ₁ C ₂	3	1	4	22.18
5	A ₂ B ₂ C ₃	3	2	5	24.10
6	A ₂ B ₃ C ₁	3	3	3	21.26
7	A ₃ B ₁ C ₃	-3	1	5	22.68
8	A ₃ B ₂ C ₁	-3	2	3	29.73
9	A ₃ B ₃ C ₂	-3	3	4	24.25

Table 1 - Variable States (Dong, Zhang, et al, 2020)

2.2.3 Results

Ultimately the article found that even minor variation in implant parameters could lead to relatively large changes in contact pressure, based on a maximum change value of 12.63 MPa, even with small changes of dependent variables. It noted that of the three parameters, varying the varus angle had the greatest effect on peak contact pressure, followed by the posterior slope angle, with the external rotation angle having the smallest effect.

It goes on to determine the best combination of these variables through the application of range analysis, seen in figure 2. It found that for this patient, optimal implantation parameters are as follows, 0° varus, 1° posterior slope, and 4° external rotation.

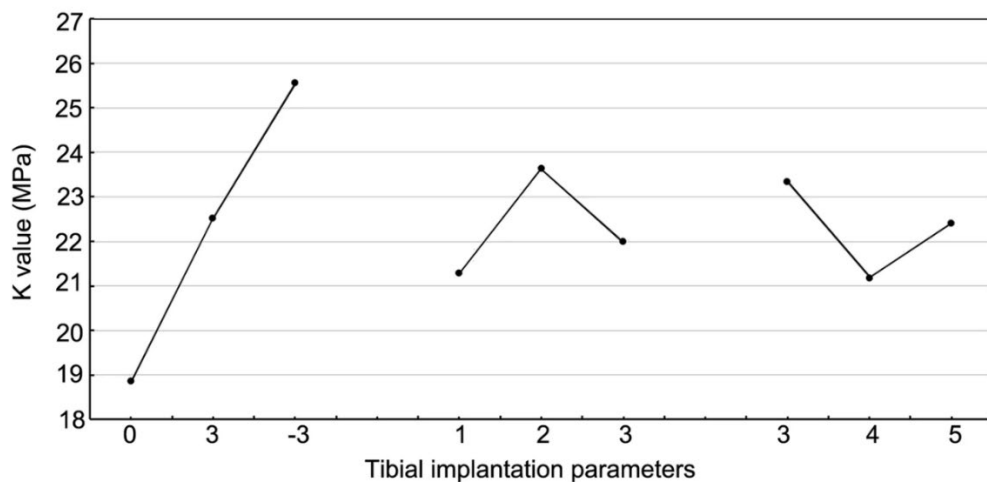


Figure 2 - Optimised Implant Variables (Dong, Zhang, et al, 2020)

The finite element model that was composed of these three specific values, found a 45.4% reduction in peak contact pressure when compared to the model that resulted in maximum value.

2.2.4 Conclusions Drawn

Dong et al. concluded that “[this study] showed that 0° varus, 1° posterior slope, and 4° external rotation were the optimal values” keeping a uniform load distribution and providing lowest peak values of pressure on the polyethylene liner.

The article ultimately concludes that the methodology used could be adapted for all patients receiving care for TKA and that it could form a new “basis for biomechanical decisions of accurate implantation of TKA prosthesis”.

3 Discussion

3.1 Usage

This allows us to, at least partially, answer the first case statement posited earlier, i.e. why companies’ carryout FEA. The optimal values for these parameters will vary on a patient by patient basis and require repeated tests whilst varying the values for the optimal to be obtained. It is impossible to apply this methodology practically (i.e. on an actual patient), as there is always a risk of infection and death, with a 0.5% mortality rate (NHS ,2019) for all knee replacement surgeries, making the moral and ethical implications obvious.

Extrapolating from this, it is sound to conclude that companies typically use FEA analysis where physical testing is either impossible or where running multiple testing scenarios is practically unviable. In cases where physical testing is performed alongside FEA modelling, this can generally be understood to act as a validation to the FEA model. It should also allow for a reduction in the number of prototypes that need to be manufactured before the product is finalised, which might aid in cutting costs in the long term.

However, the study also shows some of the inherent limitations to FEA modelling, demonstrating why companies might (and do) perform physical testing in tandem with FEA modelling. That is, within the context of the FEA model, only known potential optimisation or failure points are considered and subsequently coded into the model (Zienkiewicz, Taylor et al. ,2013). In practice, this means that the scope of an individual FEA model and test is limited when compared to real-world testing. Indeed, within the report, Dong et al themselves state that the study is limited by the lack of dynamic conditions applied. It is safe to assume then, that in cases where physical testing is possible, it is also done to assess the response of the system in a more dynamic way, potentially demonstrating problems/optimisation points that the analyst had not otherwise even considered a possibility in the FEA model.

3.2 Correlation

In terms of the second case statement, i.e. how physical testing correlates to FEA modelling, the case study at hand can not be used directly to answer this question, however, the means by which this could be achieved can be extrapolated and commented on.

Initially, the means by which FEA correlates to physical testing is clear, work previous to Dong et al.'s report had already established that the three variables being investigated affected peak contact pressure, via "physical testing", which in this case were real-world operation for which data had been recorded. In this sense, the FEA model correlates to real-world testing in terms of providing the "why" and "how" these variables affect peak contact pressure. This is also usually the case when a failure event occurs first and is then subsequently investigated with laboratory tests. The physical test generally identifies the failure point(s) and then FEA is applied to determine why the failure event occurred, such as in the study Karayan et al'. (2011) performed in investigating the failure of the seawater inlet pipe.

The analytical method for correlating FEA models to physical testing is generally reserved for validation purposes, i.e. demonstrating that the model is accurate compared to real-world events. Again, this is impossible for this case, but suppose that it was possible, it would simply be a case of recreating the variables and methodology found within the FEA model, in a practical scenario. Data would be parsed in the same manner, resulting in a real-world

equivalent of figure 2. The tests could then be directly correlated to one another, critically comparing the variance between the data. A low variance within some determined acceptable standard would constitute a valid FEA model and demonstrate the correlation between the two.

3.3 Replacement

With regards to the third case statement, it is the authors' opinion that FEA modelling should not ever replace physical testing outright, wherever possible. There are several reasons for this, the foremost reason being that without physical testing alongside, there can be no validation of the data acquired. Most real-world functions require significant simplification to be modelled using FEA, and great care must be taken in the coding of these functions to keep accuracy. Without a single instance of a real-world counterpart pre-production, there is no absolute function by which the FEA model can be called accurate, which could cause a myriad of problems regardless of what is being modelled. Model validation is essential, no matter how extensive or impressive new FEA technology may come to be, without validation it is impossible to do with any degree of confidence (Thornton ,2010).

Secondly, as detailed earlier, FEA on its own can only account for failure events that the analyst has some conceived notion of, setting the parameters of the model accordingly. This restricts FEA's use in failure analysis to events already deemed possible to occur. Essentially, FEA can and should be used as a sought of “pre” prototyping stage, shortening, and improving the development process, whilst never replacing it outright.

4 Conclusions

FEA is quickly becoming a vital step in the design process in a myriad of fields. This report has aimed to answer three research questions :

1. The reasoning for FEA's use alongside physical testing
2. How physical testing correlates to Finite Element (FE) models
3. Whether (subjectively) FEA could or should ever replace physical testing

This was achieved by providing introductory information on the workings of FEA and its applications in both product development and failure analysis. The research questions at hand were then answered using the context of a 2020 research article that utilised FEA to optimise implantation parameters of a TKA tibial prosthesis.

The case study at hand varied the implantation parameters within an FEA model that had been devised to simulate the procedure, finding that parameters of 0° varus, 1° posterior slope, and 4° external rotation were ideal to reduce peak stress levels.

It was then posited that FEA is used alongside physical testing for several reasons. That is, to reduce the number of prototypes required, reducing overall development time, and potentially developing costs. It found that physical testing also acts to validate FEA models.

This report then discussed the limitations that arise from FEA modelling, i.e. the “rigidness” of FEA models, only accounting for what the analysts have defined explicitly, in contrast to the real world.

It surmises how FEA models correlate to physical testing and discussed the way FEA models can be used to determine the root cause of failure event.

It finds that FEA modelling should never be used to replace physical testing outright, because the physical test itself provides validation to the FEA model, stating that analysts using models without validation should find no confidence in the results.



5 Bibliography

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