

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	SONG	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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	13.5
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	15
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	14.4
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	5.5

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)		48.4%
	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?

XILONG SONG

1904076

Bachelor of Engineering

08/04/2020

Advanced Stress Analysis & FEA

M6X00420

Introduction

REF: Finite elements are those discrete elements that can be combined to represent the actual continuous domain. The concept of finite element has been produced and applied as early as several centuries ago. For example, a polygon (a finite number of straight-line elements) is used to approximate a circle to find the circumference of the circle, but it has been proposed as a method. thing. The finite element method was originally called the matrix approximation method, which was applied to the calculation of the structural strength of aircraft, and because of its convenience, practicability and effectiveness, it caused a strong interest of scientists engaged in mechanical research. After decades of hard work, with the rapid development and popularization of computer technology, the finite element method has rapidly expanded from structural engineering strength analysis and calculation to almost all fields of science and technology, becoming widely used, practical and efficient Numerical analysis methods.

For a long time, FEA technology has become mainstream and has become an important product testing tool for most companies and research institutions. Because of its many advantages, FEA technology has now become an integral part of the engineer's product design process. FEA technology helps manufacturers greatly reduce product development time and related costs.

Nowadays, if all boundary conditions are applied carefully, FEA software is enough to predict product performance with high accuracy. As the software have become more and more advanced in the past few years, there is still a crucial issue for the use of physical tests that are currently regarded as standards and methods for verifying simulation results. Will FEA tools completely replace physical testing in the future? Are these tools mature enough to accurately understand and respond to any reality?

(Vyas, 2015) In this paper, author demonstrate the ability to analyse project and use advanced stress analysis principles to solve problems.

Contents

Introduction	2
1 TASK 1.....	4
2 TASK 2.....	4
2.2 Problem Description.....	4
2.3 Finite element analysis	5
2.31 Modelling	5
2.32 Restraint and load handling	5
2.33 Finite element analysis results.....	6
2.4 Establishment of mathematical model for optimal design	6
2.41 design variable.....	6
2.42 Objective function	6
2.43 State variables.....	7
2.44 Restrictions.....	7
2.5 Optimization process and result analysis.....	7
2.51 Optimization of the thickness of each section arm.....	7
2.52 Optimization of cross-sectional dimensions of working equipment	8
2.53 Result analysis.....	8
3 TASK 3.....	10
Conclusion.....	11
Appendix	12

1 TASK 1

1.1 Why companies typically carryout FE analysis alongside physical testing?

The core method of the finite element method is the discretization of the structure, that is, the actual structure is imagined as a combination of many regular elements called a finite number, and the solution domain is regarded as composed of many small interconnected sub-domains called finite elements. Each unit assumes a suitable approximate solution, and derives a solution that satisfies the conditions for the entire domain, thereby obtaining a solution to the problem. (Shengzan, 2008) Here author would give an example about a mechanical of 5 section box-type synchronous telescopic arms.

30%
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BRIEF
!

2 TASK 2

2.1 How a physical test may be correlated to an FE model.

2.2 Problem Description

A mechanical device is composed of 5 section box-type synchronous telescopic arms. After all the telescopic arms are unfolded, the length of the entire mechanical device is about 27.0m. Through the ANSYS structural optimization design, it can effectively meet the strength requirements and rigidity requirements of the mechanical devices, this can not only effectively reduce the weight of mechanical equipment, but also effectively reduce the cost of equipment.

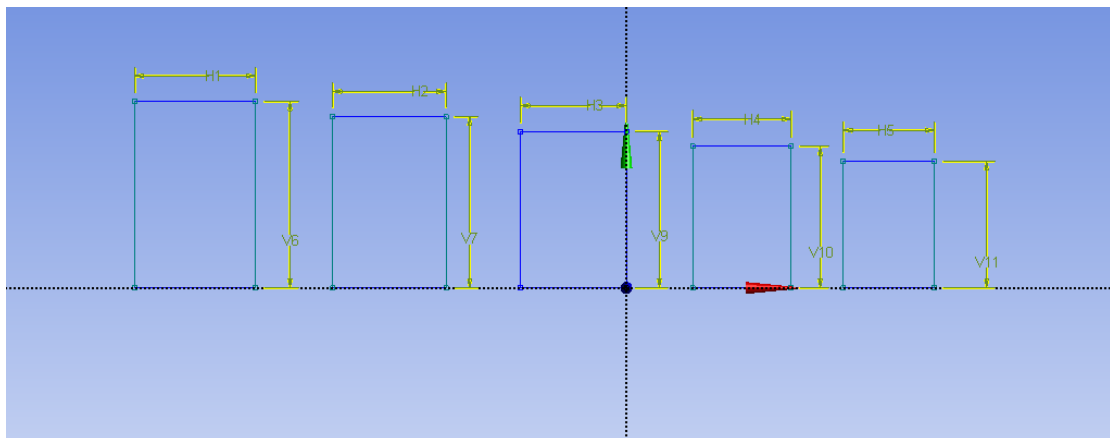


Figure 1-1 – 5 section box-type synchronous

Dimensions: 10	
☐ H1	0.26 m
☐ H2	0.244 m
☐ H3	0.228 m
☐ H4	0.212 m
☐ H5	0.196 m
☐ V10	0.304 m
☐ V11	0.272 m
☐ V6	0.4 m
☐ V7	0.368 m
☐ V9	0.336 m

Figure 1-2 – dimensions of the synchronous

2.3 Finite element analysis

2.31 Modelling

Based on the initial structure, size and working conditions of mechanical equipment, ANSYS finite element analysis software is used to model from the bottom to the top. In the modelling process, the key points are first determined, and then the line, area, and volume are established in sequence, and the solid model is finally formed. In terms of meshing, free meshing can be applied comprehensively and the grid size can be set manually.

2.32 Restraint and load handling

In the design process of the mechanical equipment, the restraint points are mainly located at the hinge position of the horn support and the base arm hinge point position. At each restraint point, it is necessary to restrain the translational auto degrees in three directions and two degrees of freedom in rotation and pay attention to the degree of freedom of mutual rotation of the centre position of the release pin. For the position of the contact point between the telescopic arm and the slider of the device, the node degree of freedom coupling can be used for simulation. In the processing module of the ANSYS finite element analysis software, enter the density and gravity acceleration of the materials required for the manufacture of mechanical equipment, and the program can directly calculate the element load factor data

into the total load and calculate its own weight. In addition, for all the attachments on the telescopic arm of the mechanical equipment, the mass can be used as a concentrated load and acted on the corresponding position.

2.33 Finite element analysis results

Through the ANSYS finite element analysis of this mechanical device, when the device is fully deployed in the horizontal position, the stress and the displacement of the end can reach the maximum value, and the stress in most areas of each joint arm position is relatively small. The maximum stress is mainly distributed at the contact position of each joint arm and sliding. According to the analysis and calculation of ANSYS finite element software, the stress value is between 132 and 277MPa, and the local maximum stress reaches 385MPa. In addition, the maximum amount of deformation is 0.55mm in the plane of the arm end luffing.

2.4 Establishment of mathematical model for optimal design

2.41 design variable

In the ANSYS optimization design process of the mechanical equipment, because the length of each section arm is determined according to the operation range before the optimization design, it cannot be changed during the optimization design process. In addition, the cross-sectional dimensions of the basic arm and each telescopic arm can be adjusted gradually according to the geometric relationship. For this, the wall thickness T_1 , width B and height H of the basic arm can be used as the optimal design variables for this time, where T_1 can be based on continuous variables consider.

2.42 Objective function

In this optimization design process, the most important goal is to minimize the volume and dead weight of the equipment in the basis of ensuring the normal function of the equipment. The larger the material volume, the greater the quality of the equipment. Then, the total volume of each arm WV_{OLU} can be used as the objective function of this optimization design.

2.43 State variables

In this optimization design process, there are two kinds of state variables, which are the stress value STRESS under component working conditions and the displacement DY of the front-end amplitude-amplification plane. In this optimization design process, in order to ensure that the design stiffness and strength can meet the actual needs, stress and displacement control should be strengthened.

2.44 Restrictions

(1) Stiffness constraints: In order to ensure that the stiffness of the equipment can meet the actual needs, the maximum deformation of the luffing plane can be used as a constraint. In the ANSYS optimization design process, in order to simplify the calculation time of the model and improve the modelling schedule and economy, there is no need to consider the influence of wind load. However, after the ANSYS optimized design is completed, the wind load still needs to be loaded to check the detection arm to ensure that it can meet the stiffness requirements; (2) Strength constraints: Through ANSYS finite element analysis, comprehensively considering the mechanical properties of equipment materials, in this project, the stress value STRESS is controlled within 375MPa; (3) Dimensional constraint conditions: comprehensively considering the relationship between the initial structural size and the size of each section arm, as well as the limiting conditions of the external dimensions of the internal cylinder of the telescopic arm, specifying the maximum value of height H, width B and basic arm wall thickness T_I . According to the analysis of this study, the height H is between 0.19 ~ 0.44m, the width B is between 0.19 ~ 0.31m, the basic arm wall thickness T_I is between 0.002 ~ 0.006m, where $I = 1, 2, 3, 4, 5$.

2.5 Optimization process and result analysis

2.51 Optimization of the thickness of each section arm

When optimizing the design of the thickness of each section arm, it is necessary to optimize the design of the thickness of the steel plate and other design variables. At the same time, it is necessary to pay attention to controlling the allowable error of the objective function within

1%, plus the initial data, through 16 optimization cycles, A total of 17 sets of data were obtained. Among them, T1 value is 4.0916mm, T2 value is 4.5119mm, T3 value is 3.0563mm, T4 value is 2.6187mm, T5 value is 2.509mm. Comprehensive consideration of the welding requirements of mechanical equipment, in the end, T1 value 4.0mm, T2 value 4.5mm, T3 value 3.2mm, T4 value 3.0mm, T5 value 3.0mm.

Table 1- Optimizing results of detection arm size

	SET1	SET3	SET7	SET11	SET14	SET15	SET17
$B/m(DV)$	0.26	0.19040	0.26370	0.19038	0.19028	0.19025	0.19025
$H/m(DV)$	0.40	0.35506	0.40403	0.34526	0.33551	0.33234	0.33253
$T1/mm(DV)$	5.0000	4.1406	4.9148	4.1329	4.0941	4.0916	4.0912
$T2/mm(DV)$	4.0000	4.5855	3.1935	4.5656	4.5149	4.5119	4.5119
$T3/mm(DV)$	4.0000	4.1643	4.1587	3.8672	3.2485	3.0563	3.0478
$T4/mm(DV)$	4.0000	4.2379	3.4588	3.9584	2.8864	2.6187	2.6618
$T5/mm(DV)$	3.0000	2.6400	2.6192	2.5897	2.5208	2.5090	2.5080
$WVOLUME/m^3(OBJ)$	0.14278	0.11314	0.13358	0.10757	0.096502	0.093583	0.093766

2.52 Optimization of cross-sectional dimensions of working equipment

After determining the wall thickness size, the cross-sectional size of each component can be optimized using a first-order method. The design variables are height H and width B. The allowable error of the objective function should be controlled within 1% of the initial volume, a total of 6 times. The optimization cycle, plus the initial value, obtains a total of 7 sets of data, and uses random search to verify to ensure the consistency of the calculation results.

2.53 Result analysis

By optimizing the design of the mechanical equipment, the results are shown in Table 2. It can determine that the total volume of the component before optimization is 0.143m³, after optimization is 0.105m³, and the volume is reduced by 26.4%. It can be shown that on this ANSYS optimization design process, in the basis of ensuring that the rigidity and strength of

the equipment meet the design requirements, the volume of the equipment material is reduced as much as possible, and a good optimization result can be achieved.

Table 2- Results analysis

parameter	total capacity	Basic arm volume	Two-arm volume	Three- arm volume	Four- arm volume	Five-arm volume
Original design	0.143	0.039	0.029	0.027	0.024	0.017
Optimization Results	0.105	0.027	0.027	0.017	0.015	0.013
Reduction ratio	26.4%	32.3%	6.2%	34.5%	39.8%	22.0%

2.6 Conclusion

In summary, the optimal design can be obtained by optimizing the design of the mechanical structure. By using ANSYS finite element analysis software for optimization design, it can simplify the calculation process and effectively improve the optimization design efficiency of mechanical equipment, so introducing finite element analysis into the design of physical experiments can more intuitively predict and represent the experimental process and results, deepen the changes in physical quantities to the experimental results, and improve the methods and processes before formulating the experimental process. Therefore, the introduction of finite element analysis in the physical experiment process can speed up the design process and enhance the effect of understanding. (Shichun, 2013)

WHILST YOU HAVE DISCUSSED THE ANALYSIS IN DETAIL, YOU HAVE NOT EXPLAINED HOW THE PHYSICAL TEST IS CARRIED OUT OR CORRELATED WELL.

DO YOU REALLY SEE NO
WORTH IN PHYSICAL TESTING?

3 TASK 3

If you think that FE analysis can (or should) ever replace physical testing.

In my opinion, the FEA test can replace the experiment. Firstly, the FEA model is verified and you have established through theoretical calculations or experiments. It is undeniable that the deviation is ubiquitous, if the results obtained by the FEA are acceptable within your acceptable range, then a series of studies are conducted in the basis of the current FEA model. And the results of subsequent studies are credible.

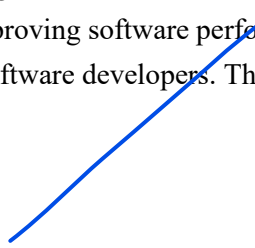
Compared with physical experiments, the better thing about FEA is that the range of setting conditions and the number of experiments are relatively flexible. That is, there is a certain advantage in the "trial" aspect: the actual operation may cause events with more serious consequences, but this situation is theoretically more required, and FEA experiments can be done better.

Although there are still many problems in the finite element analysis, the unknown new material data, and the requirements for product accuracy, but with the intensification of market competition, the product update cycle is getting shorter and shorter, and the demand for new technologies is more urgent. Numerical simulation technology is an effective means to improve product quality, shorten design cycle, and improve product competitiveness. Therefore, with the development of computer technology and calculation methods, the finite element method has become more and more widely used in engineering design and scientific research. Attention and application have become an effective way to solve the problems of complex engineering analysis and calculation. From automotive to space shuttle, almost all the design and manufacturing cannot do without finite element analysis and calculation. The extensive use of various fields such as construction, electronic appliances, national defence military, ships, railways, petrochemicals, energy and scientific research has made a qualitative leap in design.

Conclusion

This report is divided to three parts, why companies typically carryout FE analysis alongside physical testing, how a physical test may be correlated to an FE model, FE analysis can replace physical testing. The part two demonstrated FE model correlating and explain the introduction of finite element analysis in the physical experiment process can speed up the design process and enhance the effect of understanding. The operation of modelling, restraint, establishment of mathematical, design, restrictions and optimization through Ansys is more efficient than traditional physical experiments, the number of experiments can be more, there is no interference from external factors, and it is more accurate under the condition of no errors in the preparation work.

Focusing on the theoretical development of finite elements, using the most advanced algorithm technology, expanding software performance, and improving software performance to meet the growing needs of users are the main goals of FEA software developers. The fundamental way of development.



Appendix

- Shengzan, Y. (2008). *Finite Element Analysis and Experiment Study on Aluminum Alloy Wheel Structure*. Zhejiang: University of Zhejiang.
- Shichun, Z. (2013). *The influence of finite element analysis on the design of physical experiment*. Xian: Science, Technology and Agriculture Expo.
- Vyas, K. (2015, 8 7). *Design World*. Retrieved from <https://www.designworldonline.com/can-simulation-tools-replace-physical-tests-completely/>