

BACHELORS DEGREE ASSIGNMENT SPECIFICATION

Student name:	GUO	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I declare that this assignment is all my own work and that I have acknowledged all materials used from the published or unpublished works of other people.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:	<i>Assignments will not be accepted without a signature here</i>	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	12.9
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	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	16.5
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	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)		49.9 %
	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

Advanced Stress Analysis & FEA
M6X00420

Can FEA replace physical testing?

Zhangwei Guo

1805078

22/04/2020

Contents

1	Introduction	1
2	Research about fixed brackets for external air conditioners	2
3	FEA testing process.....	6
4	Hand calculation	10
5	Comparative analysis.....	14
6	Three general questions	16
6.1	Why companies typically carryout FE analysis alongside physical testing?	16
6.2	How a physical test may be correlated to an FE model?	17
6.3	If you think that FE analysis can (or should) ever replace physical testing?	18
7	Reference.....	20

1 Introduction

In order to strengthen the understanding of the knowledge learned in the course, and to explore the role of FEA in product optimization, the author did his best to complete this report. This report focuses on verifying the accuracy and practicability of the FEA analysis by comparing the results of the FEA analysis with the calculation results. The author discusses the three tasks that need to be completed in this report through a simple optimization project on the installation of fixed brackets for external air conditioners. First of all, a certain amount of data is determined to determine the type, size, and composition of the mounting bracket, and at the same time, the installation method and quality of the air-conditioning external unit are clarified to determine the load size and loading method. Then the model for the fixed bracket needs to be built with Solidworks. The Simulation module in Solidworks was applied material, fixed loading, load loading, mesh generation and analytical solution in order to complete the FEA analysis process of the model. During this time, manual calculations for the model also need to be completed. Finally, the FEA and calculation results need to be analyzed and three tasks as follows required for the report could be answered combining the analysis results.

Questions:

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?

Keywords:

Solidworks; Finite element analysis(FEA); physical testing;

2 Research about fixed brackets for external air conditioners

There are two main types of fixed brackets for household air conditioners nowadays. But both of are using satin finish stainless steel whose Young's Modulus is 207GPa. One of them is that there is a supporting diagonal bar below the fixed plane, as shown in the figure 1 and whose simplified structure as shown in figure 2.



Figure 1. Supporting bar below in real case



Figure 2. Simplified structure of supporting bar underneath

The other one is the diagonal pull reinforcement bar above the fixed plane. The installation example and simplified model are shown below.



Figure 3. Real case and simplified model

Then the installation position of the air conditioner bracket needs to be clarified. Both of these brackets are used to fix the household air conditioner outdoor unit on the vertical wall without leaving a platform in advance.

As for why such a bracket is needed to fix the air conditioner external unit on a vertical wall, there are many reasons. One of the important reasons is that there is a connecting pipe between the indoor unit and the outdoor unit of the air conditioner. Fixing it on the outer wall can effectively shorten the length of the pipe. By shortening the length of the pipeline, it is obvious that the entire installation cost of the air conditioner can be reduced. Secondly, the working efficiency of the air conditioner can be effectively improved, and the failure rate of the connecting pipeline in the later use process can be reduced to improve the stability of the entire product. Another main reason is that the installation height of the indoor unit of the air conditioner is generally relatively high, and the height difference between the indoor unit and the outdoor unit should be controlled within three meters in order to pursue a relatively high work efficiency (Design, 2020). The installation position of the reserved air conditioner external unit in the house is generally too low under the protruding window sill, so even if the house has a reserved air conditioner external unit installation position, most house owners will choose to use the air conditioner mounting bracket to fix the air

conditioner external unit in a relatively reasonable height.

The case used in this article selects the second type of air-conditioning bracket, so its specific size parameters also need to be determined. In addition to the installation height requirements, there should be no obstacles around the outdoor unit to maintain good heat dissipation. The back and sides of the condenser should be more than 20cm away from the obstacle, and the front should be more than 40cm away from the obstacle.

For the load required by the bracket, the weight of the outdoor unit of the general air conditioner is between 25 and 50 kg. Since the load-bearing capacity of the air-conditioning installation rack should not be less than 4 times the unit's own weight, the load-bearing capacity should not be less than 200 kg (IT Encyclopedia, 2020). This type of bracket has two supports on both sides and it has a symmetrical structure, so it can be assumed that the maximum load that each bracket needs to carry is 100 kg. For the determination of the loading method and position of the load, this article uses the extreme method. Usually, due to many factors involved in the physical problem and the complicated process, it is difficult to directly grasp the change law and make an accurate judgment on it. But if the problem been pushed to an extreme state, extreme condition or special state for analysis, a conclusion could be quickly reached. The problem-solving method that pushes the problem from the general state to the special state for analysis and processing like this is the extreme method. The installation of the air conditioner external unit will generally have four bolts to fix it on the two supports of the bracket, so each bracket will have two stress points. However, the extreme method is used here to concentrate all loads at one point and assume the point at the outermost position of the bracket. As this situation is the extreme limit of the bracket in all cases, it could be used to simplify the loading method.

With all research and determine above, all the parameters of the bracket have been determined and the stretch of it is shown as follows.

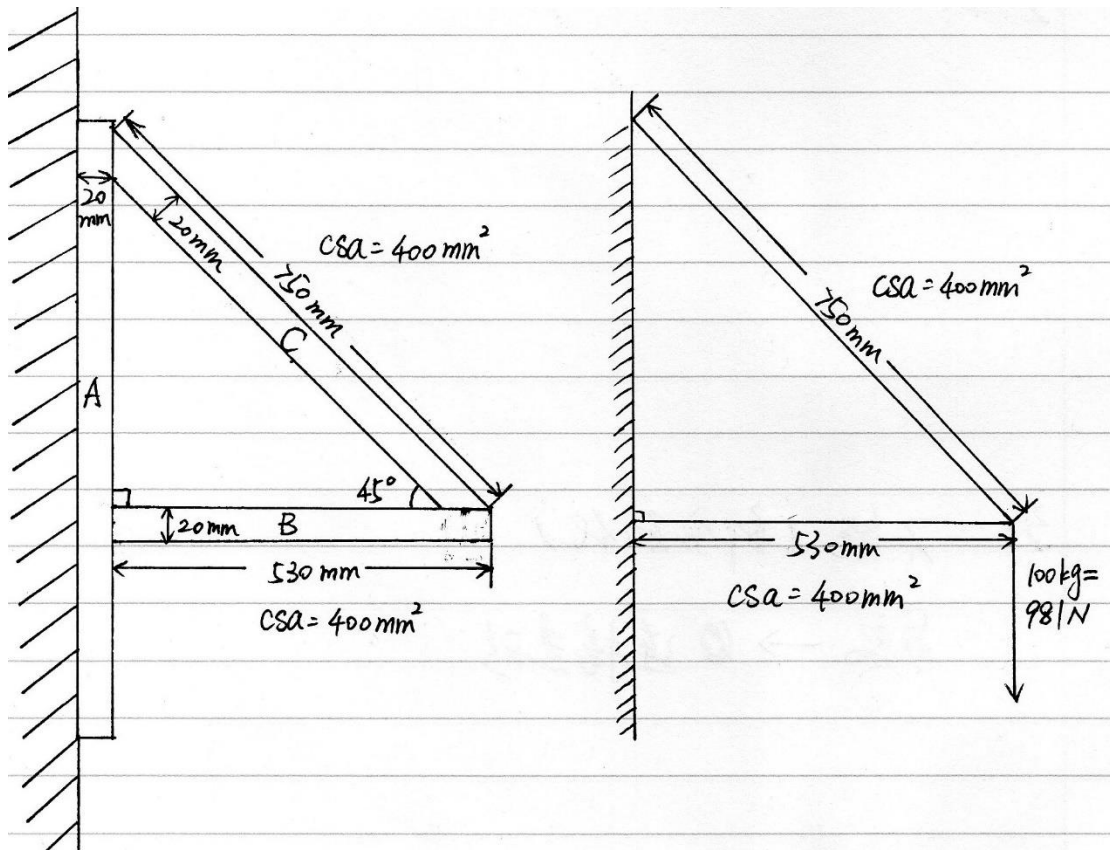


Figure 4. Stretch of bracket

3 FEA testing process

For the FEA process of the model, the corresponding solid model needs to be established using simple extruded features in Solidworks.

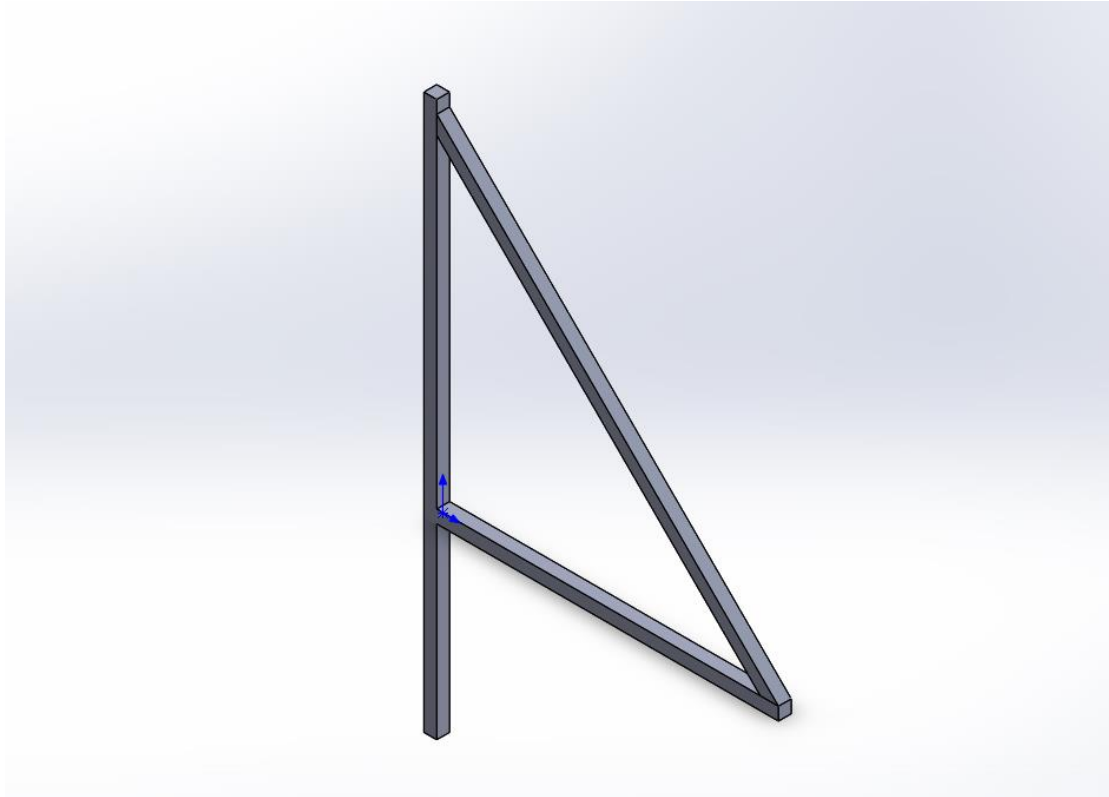


Figure 5. Solid Model

Load the simulation plug-in and establish a new static study, and then apply the material satin finish stainless steel to the model.



Figure 6. Apply material

Using fixtures to fix geometry to simulate the vertical stabilizer bar fixed on the wall.

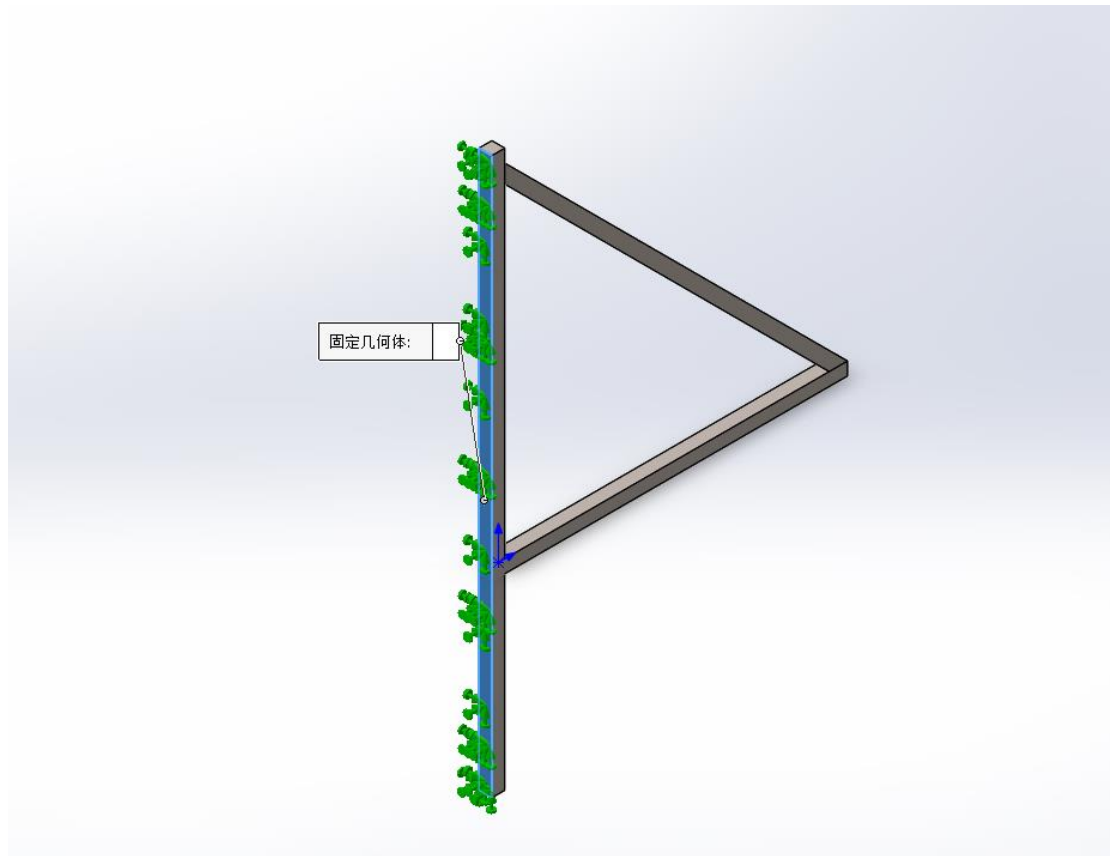


Figure 7. Fixed geometry

Then using external loads to add force, select the loading surface and applied direction, and input the magnitude of the force.

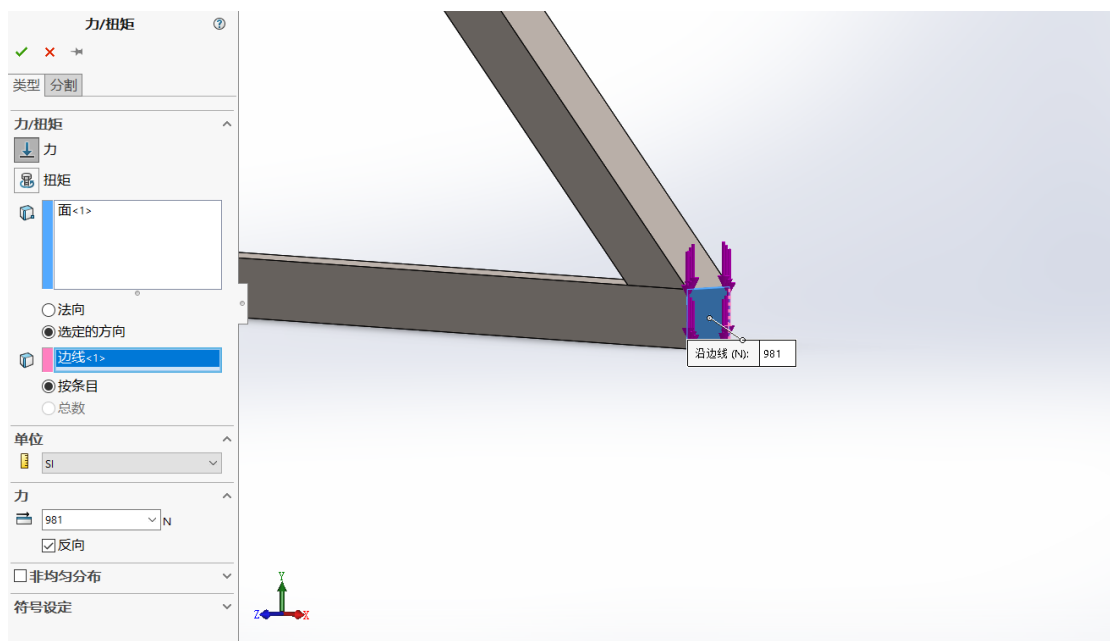


Figure 8. Load force

Determine the mesh type and element size to generate the mesh.

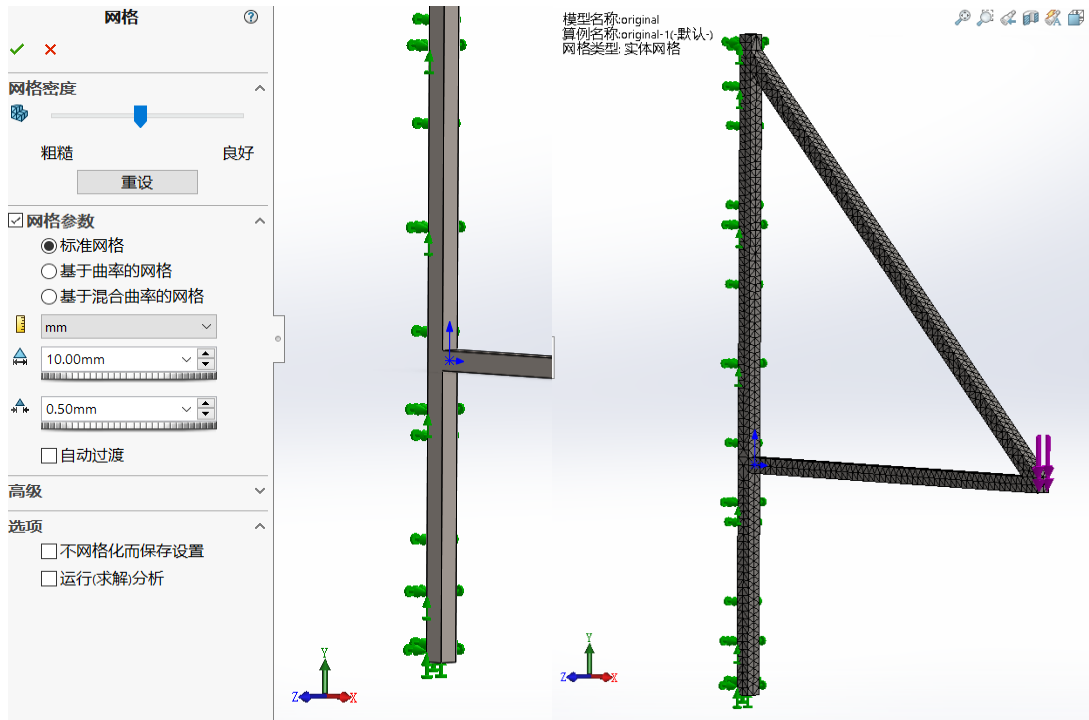


Figure 9. Create mesh

Running the analysis and view the analysis results.

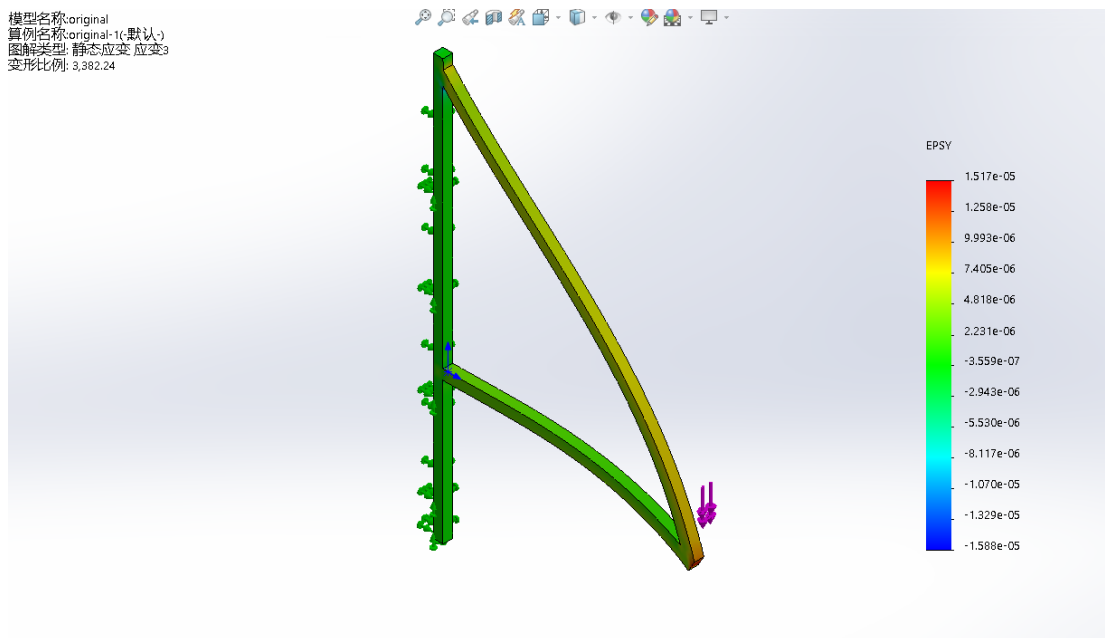


Figure 10. Review results

Change the type and element size of mesh, repeat the above FEA process, and collect analysis data for the model.

4 Hand calculation

In order to verify the accuracy and practicability of FEA simulation, manual theoretical calculation also needs to be completed. Comparing the calculations of manual theoretical calculations with the results obtained by FEA simulations, to help optimize the settings in FEA process, thereby improving the accuracy of FEA simulations and preparing for later optimization for the overall case. All the manual theoretical calculations are as follows.

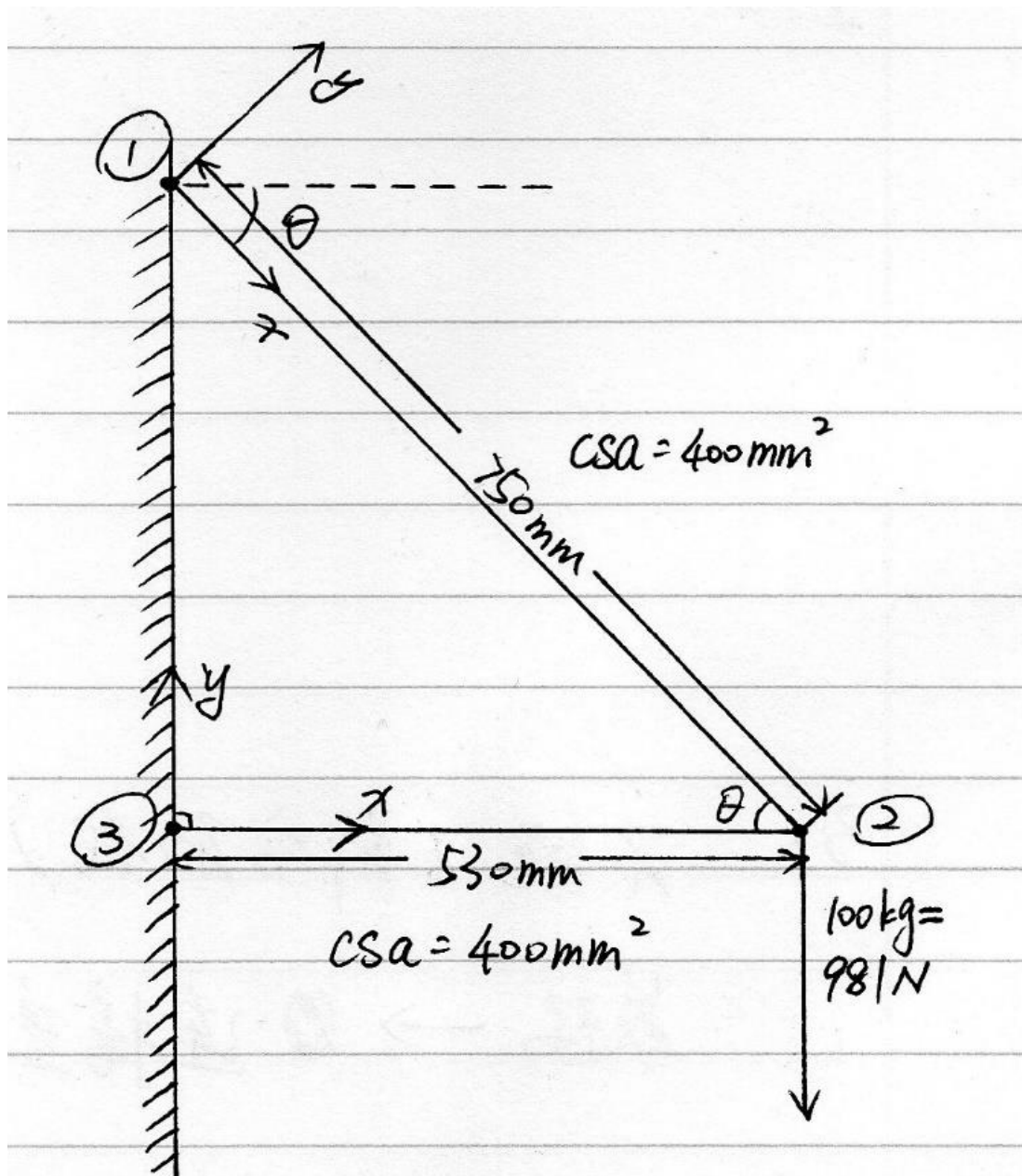


Figure 11. Page 1 of 4

First of all, to find the offset between the local and the global systems:

$$\cos \theta = \frac{530 \text{ mm}}{750 \text{ mm}} = \frac{\sqrt{2}}{2}$$

$$\theta = \cos^{-1} \frac{\sqrt{2}}{2} = 45^\circ$$

Then, stiffness matrix for first element in global

$$[K]_G = K \cdot \begin{bmatrix} C^2 & CS & -C^2 & -CS \\ CS & S^2 & -CS & -S^2 \\ -C^2 & -CS & C^2 & CS \\ -CS & -S^2 & CS & S^2 \end{bmatrix}$$

in global system, θ should be negative, $\theta = -45^\circ$

So, $\cos \theta = \frac{\sqrt{2}}{2}$, $\sin \theta = -\frac{\sqrt{2}}{2}$

$\therefore E = 207 \text{ GPa}$

$$\therefore [K]_G = \frac{E \cdot A}{L} \cdot \begin{bmatrix} C^2 & CS & -C^2 & -CS \\ CS & S^2 & -CS & -S^2 \\ -C^2 & -CS & C^2 & CS \\ -CS & -S^2 & CS & S^2 \end{bmatrix}$$

$$= \frac{207 \times 10^9 \times 400 \times 10^{-6}}{750 \times 10^{-3}} \cdot \begin{bmatrix} 0.5 & -0.5 & -0.5 & 0.5 \\ -0.5 & 0.5 & 0.5 & -0.5 \\ -0.5 & 0.5 & 0.5 & -0.5 \\ 0.5 & -0.5 & -0.5 & 0.5 \end{bmatrix}$$

$$= 110.4 \times 10^6 \times \begin{bmatrix} 0.5 & -0.5 & -0.5 & 0.5 \\ -0.5 & 0.5 & 0.5 & -0.5 \\ -0.5 & 0.5 & 0.5 & -0.5 \\ 0.5 & -0.5 & -0.5 & 0.5 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & -1 & -1 & 1 \\ -1 & 1 & 1 & -1 \\ -1 & 1 & 1 & -1 \\ 1 & -1 & -1 & 1 \end{bmatrix} \times 55.2 \times 10^6 \text{ N/m}^2$$

Figure 12. Page 2 of 4

Stiffness matrix for the second element in global,

$$\because \theta = 0, \quad \therefore \sin\theta = 0, \quad \cos\theta = 1.$$

$$|k|_G = k \cdot \begin{bmatrix} C^2 & CS & -C^2 & -CS \\ CS & S^2 & -CS & -S^2 \\ -C^2 & -CS & C^2 & CS \\ -CS & -S^2 & CS & S^2 \end{bmatrix}$$

$$= \frac{E \cdot A}{L} \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$= \frac{207 \times 10^9 \times 400 \times 10^{-6}}{530 \times 10^{-3}} \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

$$= \begin{bmatrix} 1 & 0 & -1 & 0 \\ 0 & 0 & 0 & 0 \\ -1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \times 156.2 \times 10^6 \text{ N/m}^2$$

Stiffness matrix for whole structure,

$$|K|_G = \begin{bmatrix} 55.2 & -55.2 & -55.2 & 55.2 & 0 & 0 \\ -55.2 & 55.2 & 55.2 & -55.2 & 0 & 0 \\ -55.2 & 55.2 & 55.2 + 156.2 & -55.2 & -156.2 & 0 \\ 55.2 & -55.2 & -55.2 & 55.2 & 0 & 0 \\ 0 & 0 & -156.2 & 0 & 156.2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \times 10^6 \text{ N/m}^2$$

$$= \begin{bmatrix} 55.2 & -55.2 & -55.2 & 55.2 & 0 & 0 \\ -55.2 & 55.2 & 55.2 & -55.2 & 0 & 0 \\ -55.2 & 55.2 & 211.4 & -55.2 & -156.2 & 0 \\ 55.2 & -55.2 & -55.2 & 55.2 & 0 & 0 \\ 0 & 0 & -156.2 & 0 & 156.2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \times 10^6 \text{ N/m}^2$$

Figure 13. Page 3 of 4

$$\therefore F = K \cdot \delta$$

$$\therefore \begin{bmatrix} F_{1x} \\ F_{1y} \\ F_{2x} \\ F_{2y} \\ F_{3x} \\ F_{3y} \end{bmatrix} = [K]_G \times \begin{bmatrix} \delta_{1x} \\ \delta_{1y} \\ \delta_{2x} \\ \delta_{2y} \\ \delta_{3x} \\ \delta_{3y} \end{bmatrix}$$

comes:

$$\begin{bmatrix} R_{1x} \\ R_{1y} \\ 0 \\ -981 \\ R_{3x} \\ R_{3y} \end{bmatrix} = \begin{bmatrix} 55.2 & -55.2 & -55.2 & 55.2 & 0 & 0 \\ -55.2 & 55.2 & 55.2 & -55.2 & 0 & 0 \\ -55.2 & 55.2 & 211.4 & -55.2 & -156.2 & 0 \\ 55.2 & -55.2 & -55.2 & 55.2 & 0 & 0 \\ 0 & 0 & -156.2 & 0 & 156.2 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix} \times 10^6 \begin{bmatrix} 0 \\ 0 \\ \delta_{2x} \\ \delta_{2y} \\ 0 \\ 0 \end{bmatrix} \begin{matrix} \textcircled{1} \\ \textcircled{2} \\ \textcircled{3} \\ \textcircled{4} \\ \textcircled{5} \\ \textcircled{6} \end{matrix}$$

From ③:

$$0 = 211.4 \times 10^6 \delta_{2x} - 55.2 \times 10^6 \delta_{2y}$$

$$\delta_{2y} = 3.83 \delta_{2x}$$

From ④:

$$-981 = -55.2 \times 10^6 \delta_{2x} + 55.2 \times 10^6 \delta_{2y}$$

$$(\delta_{2y} - \delta_{2x}) = -17.78 \times 10^{-6}$$

$$\therefore 3.83 \delta_{2x} - \delta_{2x} = -17.78 \times 10^{-6}$$

$$2.83 \delta_{2x} = -17.78 \times 10^{-6}$$

$$\delta_{2x} = -6.28 \times 10^{-6} \text{ m}$$

$$\delta_{2y} = 3.83 \delta_{2x} = -24.05 \times 10^{-6} \text{ m}$$

Figure 14. Page 4 of 4

It can be known by the extreme method that the maximum deformation of the model will appear at the end of the horizontal support bar, which is position 2 in the manual theoretical calculation. As shown in Figure 14, the maximum horizontal displacement at this position is $-6.28 \times 10^{-6} \text{ m}$, and the maximum vertical displacement is $-24.05 \times 10^{-6} \text{ m}$.

5 Comparative analysis

In order to facilitate comparative analysis, all FEA data and the results of manual theoretical calculations will be summarized in the following table:

Table 1- Results of Hand Calculation and FEA

No.	Type	Max Element Size (mm)	Solving Time Used (s)	Max horizontal deformation ($\times 10^{-6}m$)	Max vertical deformation ($\times 10^{-6}m$)
T0	Theoretical			-6.280	-24.05
S10	Stand	10	1	-8.685	-25.43
S5	Stand	5	6	-8.268	-25.47
S4	Stand	4	10	-8.268	-25.47
S2	Stand	2	63	-8.280	-25.49
C10	Curvature	10	1	-8.243	-25.44
C5	Curvature	5	7	-8.268	-25.47
C4	Curvature	4	13	-8.273	-25.48
C2	Curvature	2	80	-8.281	-25.49
M10	Mixed	10	1	-8.237	-25.43
M5	Mixed	5	6	-8.267	-25.47
M4	Mixed	4	13	-8.272	-25.48
M2	Mixed	2	98	-8.281	-25.49

In the table above, the number of each test shows both of the type of mesh and the maximum size of element. Judging from the results of each test, first of all, all the FEA results show good agreement with the results calculated by manual theory. Although there are still some differences, because the theoretical calculation results have completely simplified the model, but the FEA simulation analysis process has restored the true structure of the model to a certain extent. From this we can draw an analogy, the results obtained by FEA simulation analysis and the physical testing results will

also show good consistency, but on account of FEA simulation analysis only partially restores the structure of the physical model, they will also have certain differences. Secondly, analysis of the results of FEA simulation shows that the three different types of mesh have their own advantages and disadvantages. For FEA simulation analysis, the choice of mesh type and the determination of maximum element size determine its accuracy. In the case of the same type of mesh, smaller mesh cells can generally restore the model better and obtain more accurate analysis results. But smaller mesh cells mean that the computer that runs the analysis needs to be more powerful, and it also takes longer to create mesh and analysis cases. However, compared with physical testing, FEA simulation analysis still costs less and repeatability is higher.

6 Three general questions

The following three questions gradually explore the relationship between FEA simulation analysis and physical testing. First of all, the first question is why companies need to conduct FEA simulation analysis and actual testing simultaneously. It can be seen that although FEA simulation analysis is more efficient, actual testing is still necessary. Then the second question is how they interact with each other. It can be seen that the relationship between them is mutual influence and promotion rather than one-way. Finally, the answer to whether the FEA simulation analysis can replace the actual test is obviously no, so this report mainly discusses the significance of the actual test.

6.1 Why companies typically carryout FE analysis alongside physical testing?

First of all, the most important thing in product design is safety. FEA simulation analysis is limited by the models used on account of the models have been simplified to a certain extent, so there is no way to maintain consistency with the real model. It is easy to understand that these two types of models from different sources could be mismatched and the models identified from model testing are mostly complex due to the real-world mechanical structures, which is caused by different mechanisms (Wang, Zhang, & Tee, 2011). But unfortunately, modern structures have become increasingly complex. In the design optimization process of some products, every little change will have an impact on the whole, so the FEA results will be a huge different from the physical testing. This part of the difference may not have a big impact in the design and production of ordinary products, but for some high-precision or more complex products, this part of the difference will be a very important factor for investigation.

After that, the accuracy of FEA simulation analysis will be seriously affected by the quality of the mesh. It can be seen in the simple case that introduced at the beginning of the report. Regardless of which type of mesh is used, the improvement in mesh

quality can have a huge impact on the analysis results. The most severely affected by the quality of mesh is the standard mesh. When the maximum mesh element size is reduced from 10mm to 5mm, the maximum horizontal displacement is reduced from $8.685 \times 10^{-6}m$ to $8.268 \times 10^{-6}m$ with a decrease of 4.8 percent. The vertical displacement increased from $25.43 \times 10^{-6}m$ to $25.47 \times 10^{-6}m$ with an increase of 0.16 percent at the same time. Such an error is obviously unacceptable in industrial production.

In addition to the mesh quality control of FEA analysis, the time to run the analysis also needs to be considered. In the simple case in this report, for various mesh types, when the size of the largest mesh cell is reduced from 10 mm to 5 mm which is half of the original size, the analysis time increases from 1 second to 6 seconds which is six times. When the size of the largest element unit is reduced to 2 mm which is one-fifth of the original size, the analysis time is increased from 1 second to 63 seconds, 80 seconds, and 93 seconds. It can be seen that although the repeatability of FEA analysis is higher and the cost for each test is lower, in the case of high mesh quality, the analysis time will be much longer. At this time, the physical testing is relatively more straightforward and faster.

6.2 How a physical test may be correlated to an FE model?

As everyone knows, the quality of finite element model can be Inspected and upgraded by correlating the modes estimated from model testing.

The quality of the mesh could be improved through testing, whether it is to use a different type of mesh or reduce the maximum mesh cell size, it will take a lot of energy such as time, personnel, funds and equipment. However, if a physical testing is used to assist in finding the best FEA solution, the results obtained from the physical testing can be used to as a reference to quickly determine the FEA analysis result interval, and then make fine adjustments within the interval to find the best FEA solution, thereby speeding up the overall product optimization process.

At the same time, the results obtained from the physical testing can also be used as a

reference to verify the validity and accuracy of the FEA analysis. When the results of the analysis deviate significantly from the physical testing, it is necessary to analyze the FEA process and make corresponding modifications. When the gap between the results gradually becomes larger, it is obviously need to adjust the direction of program optimization. Only when their results are getting closer and closer it shows that the FEA analysis scheme is gradually improving.

In addition to the effects of the above physical testing on FEA analysis, FEA analysis also has many effects on physical testing. With the results of FEA analysis, when formulating the physical testing plan, there has been a rough reference to some critical or limit conditions, such as critical speed, maximum load, maximum inclination angle and maximum acceleration. With these reference values, the experimental variables can be directly selected in the vicinity of it, which will undoubtedly speed up the whole testing process. The results of FEA analysis can not only speed up the progress of the actual experiment, but also prevent the occurrence of harm or even damage to the subject due to the unclear critical conditions during the actual experiment.

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

For this question, the answer of the author is definitely no, or FEA can only partially replace the actual test rather than completely replace it.

First of all, before going for running the analysis, in addition to mesh quality control, it is also important to find the critical conditions of the testing. Compared with directly conducting multi-level segmented FEA testing, the physical testing may be more effective and direct to obtain critical conditions, so that some preliminary preparation work for FEA analysis can be omitted.

And then for the FEA process, as the answer in the first question says, the experimental errors observed help to illustrate the difficulty of replicating the correct boundary conditions when dealing with this sort of analysis, due to the fact that the FEA environment is usually ideal (Lake, 2018). And the accuracy of the FEA analysis

results is particularly affected by the quality of the mesh, so the accuracy is not good enough. Although slight changes in test configurations and repeat multiple tests assisted in reducing experimental errors ensuring continuity in measurements and the exclusion of non-coherent values which were not relevant (Lake, 2018), physical testing is still needed to help find very basic settings in order to speed up the entire FEA process.

In addition to the above, under high-precision settings, the FEA analysis solving time may be much longer than the physical testing. In this case, although the physical cost of FEA analysis is lower, the time cost is much higher.

Finally, after completing the FEA analysis, the authenticity and applicability of the obtained results still need to be verified by physical testing. Only when the experimental results of the FEA and the physical testing show consistency, can the accuracy and applicability of the FEA analysis be proved, and the indispensable importance of the FEA analysis in the product development and optimization process as well.

CONCLUSION?
INTERESTING ANALYSIS TO
WHICH YOU HAVE DRAWN SOME
REASONABLE CONCLUSIONS.
HOWEVER THERE ARE NO
MARKS FOR ANALYSIS, &
SOME SECONDARY RESEARCH
WAS NEEDED.

7 Reference

Appendix. (2020 年 01 月 04 日). Properties of Fuels. 检索来源: MOODLE UWTSd:

https://moodle.uwtsd.ac.uk/pluginfile.php/313892/mod_resource/content/1/Fuels%20Database.pdf

DesignHanHan. (2020 年 04 月 19 日). Notice for installation of air conditioner. 检索来源:

Baidu Experience:

<https://jingyan.baidu.com/article/c910274b39afdc8d371d2d77.html>

IT Encyclopedia. (2020 年 04 月 19 日). Precautions for installation of Gree air conditioner. 检

索来源: PConline: <https://product.pconline.com.cn/itbk/jd/ac/1712/10499776.html>

LakePagan; KelvinLuca. (2018). Modal Analysis: A Comparison between Finite Element Analysis (FEA) and Practical Laser Doppler Vibrometer (LDV) Testing. IEEE.

WangTong, ZhangLingmi, & TeeFah.Kong. (2011). Extraction of real modes and physical matrices from modal testing. Earthquake Engineering and Engineering Vibration, 219-220.