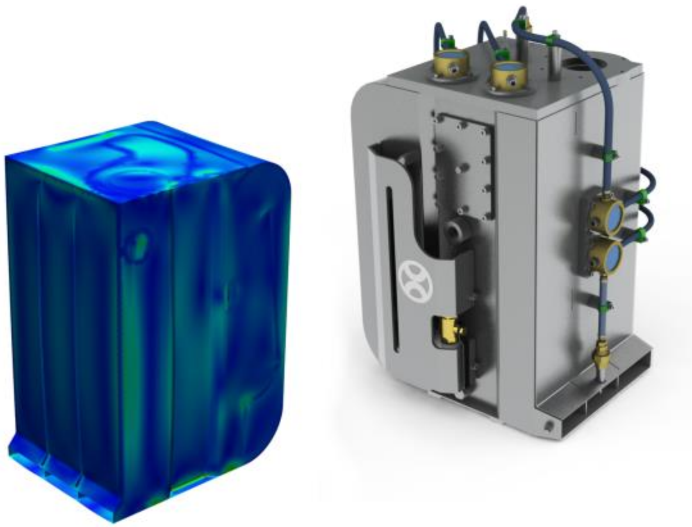
CALIBER DESIGN
ENGINEERING | ANALYSIS | MECHANICAL DESIGN

Why Use FEA?

An introduction to Finite Element Analysis



HOW TO GUIDE

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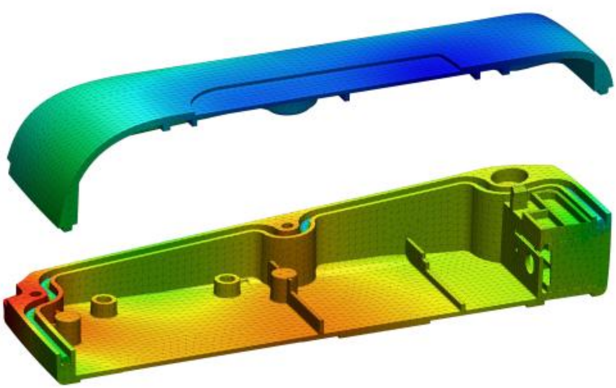
Introduction

This is a How To Guide for product developers and their managers. It explains Finite Element Analysis (FEA) in plain language: What is it? Why use it? What are the benefits for product development and for business?

With FEA, basically you can road test your design before going anywhere near a production facility. Do these parts fit together? What impact will freezing temperatures have on this part? How will my design handle intense vibration? Questions like this can be answered, and your design tweaked and re-tested—all virtually! This way, the expensive process of physical prototyping is only done when you have confidence in your design.

Adding FEA to your product development process will invariably result in quicker development times, reduced development costs, and a more robust and reliable product … all good for the bottom line!

If you'd like to discuss how FEA could benefit your project and bottom line, please get in touch!



What is FEA?

Finite Element Analysis (FEA) is a method of analysing how a part or assembly will perform over its lifetime. FEA enables you to predict potential design issues and therefore minimise risk to your product, profits, and your business.

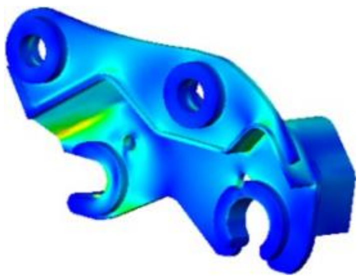
With FEA you can test the impact of varying conditions (stress, vibration, buckling, fatigue, creep, heat, etc) on your design. It is a powerful simulation tool used alongside the likes of CFD (computational fluid dynamics) and motion analysis.

By including FEA as part of your product development process, you can simulate the effects that real world extremes will have on your design before you've created a physical prototype. This virtual prototyping saves you substantial time and cost by minimising the number of physical prototypes required.

These days FEA is being used in virtually every engineering discipline: aerospace, automotive, biomedical, chemicals, electronics, energy, geotechnical, manufacturing, and plastics industries all routinely apply Finite Element Analysis.

Some common FEA packages include Cosmos, SolidWorks Simulation, Femap, Nastran, Ansys, and Abaqus.

FEA can be used to optimise the performance of a new product, verify an existing product, or modify a product for a new condition.



What are the benefits of FEA?

What would it be worth to your business if you could predict potential failures prior to getting your product to market? How would that affect consumer perception of your product? How would less warranty claims affect your cash flow?

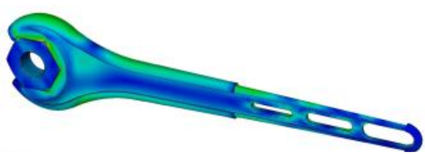
What if you could halve or even quarter your prototype and testing costs? How much quicker could you get to market? What impact would that have on your bottom line?

Would it be helpful for you to know if your structure or product can withstand working loadings? Will permanent deformation occur? Will buckling or vibrations ever be a problem? Can material be reduced to save costs?

FEA is a crucial step that you can easily add to your development program. It will save you time and money by highlighting problems and finding solutions during your product design phase, before any material is ordered or before you even contemplate 'cutting steel'!

FEA can also be used to:

- check your design is on track during the design process.
- check calculations, when hand calculations are too difficult.
- optimise stress, mass, heat, etc to get the best results before the manufacturing stage of the project.
- understand structural behaviour and therefore remove uncertainty in the design phase.



FEA types & applications

There are many different types of analysis supported by the finite element method. Below is an explanation of the main types of FEA and their applications:

LINEAR OR NON-LINEAR

All analyses can be classed as being linear or non-linear. Whenever the ‘initial conditions’ change during an analysis, non-linearity exists.

Imagine you are blowing up a balloon; as the balloon fills its diameter rapidly changes. The balloon material stretches significantly, becoming thinner and stiffer. Hence the effort required to inflate the balloon changes as it is inflated. A non-linear analysis can take this into account while a linear analysis cannot.

Linear analysis have the ability to be directly ‘scaled’ … for example, if the load is doubled then the results (stress, deflection, etc) will simply double. The use of this knowledge can significantly reduce the number of FEA analyses that need to be undertaken.

STATIC OR DYNAMIC

Are the loads applied slowly or fast? (Like snow loading on a roof or a cellphone dropping to the ground?) When loads vary rapidly with respect to time, the mass and stiffness of the structure start to have an influence on the results. Using the example of a cell phone dropping; the heavier the phone is, the greater the structure needed to support it.

COMPARATIVE OR ABSOLUTE

Does the analysis need to provide ‘accurate’ results or is a percentage change all that is required? You may have an existing successful product with uncertain loading conditions that you would like to change. For example, it might be a coil spring from a car suspension. Without knowing anything about the load that the spring undergoes on the car, with a comparative analysis it may be possible to see whether design changes to the geometry (for example) are going to improve or reduce the performance of the unit.

FEA types & applications

There are many subtypes of FEA. These are explained below:

- **Vibration and Impact:** These are types of dynamic analysis that can be used to assess how a product will perform. For example, will the car steering wheel vibrate while driving? Would my product survive a drop onto floor from one metre up?
- **Buckling:** A length of wire can hold much less load in compression compared to tension due to a phenomenon called 'buckling'. It can occur in any object that is relatively thin/narrow in one direction, such as beams and sheet-metal parts. FEA can be used to predict the load at which an object will partially or fully buckle.
- **Contact:** This non-linear technique analyses the effect of parts contacting each other. For example, a car crashing into a flexible safety barrier or a bolted 'friction-grip' joint.
- **Fatigue:** FEA is a powerful tool for assessing the complex effects of cyclic loading (fatigue) on components. A product life can be estimated in years and areas likely to crack highlighted.
- **Heat transfer and Thermal Deflections and Stresses:** FEA can be used to calculate the effect of heat on a components strength and temperature distribution.
- **Creep and Relaxation:** A lot of engineering materials will tend to gradually stretch over time and can eventually rupture in a process called 'creep'. This is a key consideration for most plastic designs and is highly influenced by temperature. FEA can predict this behaviour.

What type is best for me?

Talking to an FEA expert is the best place to start!

- **Static studies** are cost effective and acceptable for most general engineering scenarios. Structural, vibration, fatigue, heat, flow, etc are common types of analyses that can be run.
- **Non-linear studies** are more complicated and expensive to perform. If you are looking for analysis of deforming structures, complicated contact conditions, creep etc, then you may need to take this route.
- **Solids, shells and beams** are all mesh (or element) options in a general FEA package. In general, beams should be used for frames and section structures, shells for sheet metal components, and solids for complicated geometry.

All options have their pros and cons as well as limitations, so make sure your analyst is competent and has done their research!

How does FEA software work?

Knowing exactly how FEA software works can be confusing, but the basic workflow is as follows:

1. Create geometric model
2. Define finite element model (create mesh with FEA software)
3. Define operating environment (apply forces, constraints, etc)
4. Compute structural response (stress, deflection, temperatures, etc)
5. Review and interpret the results
6. Re-design as necessary and repeat until satisfied

What do I need to know?

In order to incorporate FEA into your design, you need to have:

- A GOAL – What are you wanting to achieve (improved strength, reduced mass, etc)? **If your goals aren't clear then the FEA process is pointless!**
- GEOMETRY – Models or dimensions of your design and material properties as appropriate.
- CONSTRAINTS – A good understanding of how the system is interacting with its surroundings (is it bolted, welded, sliding, etc).
- LOADS – What are the magnitudes and how are they to be applied?
- RISK ASSESSMENT – What risks are associated with this product? How important is it to get the design right?
- AN ANALYST – An experienced analyst can develop realistic loads and constraints. They are also more likely to give you results you can rely on.

What do the plots mean?

Understanding results means not only looking at the result plots, but also reading the analysis report (if you have one).

It is easy to create a result, but takes skill and understanding to create a result that is accurate.

Check that the constraints and forces make sense, read the assumptions, check the hand calculations, and then decide whether the conclusions are representative of reality.

Are the results correct?

It's easy to create a stress plot and put it into a report. But is it right?

- **Engineering calculations should never be neglected!** Validate your FEA results to make sure they are correct!
- Applying constraints and forces differently can cause wildly varying results. You need to look past the final plot and think about whether the conditions applied to the model are accurately representing the real world scenario.
- A good analyst knows how and why they are setting up the FEA analysis. Experience and engineering judgement are the most important factors for creating the most accurate analysis.
- Physical testing is a great way to check your boundary conditions and results!
- If you have your analyst increase the deformation scale 100x, does the deformed shape look as expected?

Are the results correct ENOUGH?

Picture you are the manufacturer of mid range, low production run mountain bikes. You want to asses whether a small design change to an existing, successful product is going to increase or decrease the durability of the design. In this case, it may be appropriate to run a quick comparative analysis with some representative design loads.

If the new design is weaker than the current design, you may choose to avoid the design change or to tweak the design to improve its strength, regardless of whether the analysis is providing 'exact' results or not.

In a different scenario … you might manufacture bespoke high-value racing bikes for Olympic competition. In this case, a failure could both injure the athlete and significantly damage your brand, it may be prudent to analyse the bike in great detail . The challenge is to:

1. Avoid 'paralysis by analysis'
2. Get the 'level' of analysis correct. What corresponding level of risk are you prepared to accept?

What are the common traps?

FEA has played an important role in the design and analysis of mechanical products for decades, however it has been prohibitively expensive. Now that FEA tools are incorporated into the best CAD software, it is a much more affordable and accessible option.

We must caution you: FEA must be used with care. FEA produces fantastic colour plots and it can be difficult to notice that you have made a mistake. It becomes a case of rubbish in=rubbish^2 out.

Here are some other common traps:

- Thinking the answer is right before checking the scale is the easiest trap to fall into!
- Incorrect restraints are easy to apply and can significantly change the final result. Also, view results near restraints with caution as it takes an experienced analyst to get valid results in these areas.
- A coarse mesh is a very easy way to understate your stresses whilst an overly fine mesh may take days to solve. Making sure the mesh is appropriate for your model is a skill that comes with training and experience.
- Bad assumptions can mean the analysis is doomed from the start. Make sure that the research has been done and the assumptions make sense. If the analyst wasn't given the full story, they might be assuming something completely wrong with the setup.
- FEA is not a substitute for final physical testing. It should be used to minimise testing required, reduce development costs, and accelerate time to market!

Quick Summary

FEA is a crucial step that you can easily add to your development program. It will save you significant time and money by highlighting problems and finding solutions during your product design phase, before any material is ordered or before you even contemplate ‘cutting steel’!

Here are some key points to remember about FEA:

- ☐ Engineers use FEA to simulate how a product will respond to expected loading conditions in real world situations.
- ☐ If you are designing a new product, you should consider how to embed FEA into your design cycle.
- ☐ With FEA, you can test your design for stress, vibration, buckling, fatigue, and heat BEFORE prototyping.
- ☐ There are many types of FEA. Which type to choose depends on your product, the materials involved, how it will be made, and how it will be used.
- ☐ If you have decided you want an FEA done on your design, make sure you approach an experienced analyst and be clear about what you want to achieve. A goal is essential.
- ☐ Rubbish in = Rubbish^2 out. Don’t let the pretty pictures fool you. FEA results are easily misinterpreted and should be backed up with hand calculations and physical testing.
- ☐ The software may have got cheaper but the skill required to do an accurate and reliable FEA hasn’t changed. Career analysts are few and far between, but worth their weight in gold.

Get it right before you cut steel!

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