Pearson BTEC Level _ Higher Nationals in Engineering (RQF)

Unit 37: Virtual Engineering

Unit Workbook 1

in a series of 1 for this unit

Learning Outcomes 1, 2, 3 & 4

Virtual Engineering

1.1 Engineering Design Fundamentals

Within any organisation, a design engineer has a key role to play in delivering a product or service to the end customer. They have the responsibility of researching and developing new ideas and/or modifying existing products in order to make improvements. When implementing a new design process the design engineer must listen to the requirements of the customer, whilst considering the limitations and requirements of manufacturers, suppliers, fitters, software, testing procedures and end users. The purpose of a design engineering process is to produce a product/service that is fit for purpose and fulfils the original requirements of the customer.

1.1.1 Standards & Regulatory Compliance

In order to ensure that all engineering products meet certain levels of quality and are safe to use and operate, there are sets of standards that have been refined over time to provide engineering laws and practical constraints, representing good practice across the entire spectrum of engineering.

There are currently different sets of standards depending on the discipline of engineering and the country in which the are being applied. Generally, in Europe engineering companies conform to EN (European Norms) standards. In the U.K. some companies comply with EN standards and some with British Standards (BS), whilst others comply with a mix of both. In America there are a set of standards known as ANSI (American National Standards Institute), whilst ASTM (originally the American Society for Testing & Materials) and ISO (International Organisation for Standardisation) are both standards organisations which operate globally.

1.1.2 Capabilities & Limitations of Computer-Based Models

In order to comply with regulations, companies often use computer-based models to test their designs before they actually go into production. Imagine a boat manufacturer requires a bow post to be designed for a new boat, and in order for their product to pass regulations this bow post must be capable of withstanding a certain 'pull force'. Rather than just designing a bow post, having it manufactured and then immediately having it physically tested, the company can perform virtual tests on a computer model of the post to determine if the design is likely to pass or fail the physical test. In doing a virtual test, this gives the designer valuable information about whether or not their design is fit for purpose. If the design fails this virtual test then the designer can make changes to material, design or method of fixing/manufacture and then retest the design until it passes. Alternatively, if the part that has been designed is over-engineering then potentially some costs could be saved by removing excess material, simplifying the design or using a less expensive material.

Of course, a design engineer can use manual calculations to predict the physical performance of a product they are designing; however, this can be very labour intensive, may take a lot of time and is susceptible to human error. Using computer-based models increases speed, accuracy, reliability, adaptability and reduces the space required for storing records. Although there are many advantages to computer-based models, there are several limitations; computer systems have zero IQ and are therefore only able to perform specific tasks that they are programmed for, computer systems are also unable to make decisions requiring human evaluation skills, finally a computer is unable to use common-sense or logic as a human is able to.

1.2 Design, Analysis and Simulation Tools

Depending on the industry or the context in which an engineer is operating they may need to use different computer-based design, analysis and simulation tools.

1.2.1 2D and 3D CAD

Within a professional company, when there is a requirement for a new product it is highly likely that it will be designed using Computer Aided Design (CAD), without this it will be difficult to communicate the details of the design to a supplier. Whilst a detailed drawing can be produced by hand, it is far quicker to use CAD and it also makes it easier to rectify mistakes or make changes to designs. There is a full explanation of capabilities and limitations in the previous section.

There is a plethora of different CAD software packages that can be used for professional design, as such there are also many different file formats but generally they can usually be transferred from one package to another.

2D CAD is used to produce technical drawings and is frequently utilised in the production of building layouts, floorplans and electrical schematics. 3D CAD is generally used to produce three-dimensional models of parts and assemblies that can be manipulated in 3D space and then used to produce 2D manufacturing drawings for manufacture. It is used by engineers, product designers and architects to produce a vast plethora of different products and structures.

CAD has developed massively since it’s conception in the early 1980’s and is continuing to improve by offering a better user experience through more intuitive operations and ease of access.

1.2.2 Finite Element Method

The finite element method, sometimes referred to as finite element analysis (FEA) is used in order for engineers to predict the behaviour of systems and parts, typically in the areas of heat transfer, electromagnetic potential, fluid flow and structural analysis. These systems can be static or dynamic and one, two or three dimensional. To predict the behaviour of a system, the finite element methods looks at it in terms of a number of algebraic equations rather than the system as a whole. The problem is divided into a large number of much simpler parts, known as ‘finite elements’ and brought together at the end of the process to give an overall answer.

With regards to structural analysis, FEA is used very frequently in functions such as calculating the failure point of parts and structures when put under load. In order to make a simulation of a structure, a ‘mesh’ is created which consists of a huge number of small elements, which when added together make up the structure overall.

These individual elements produce known values at each corner and these points are called nodal points or nodes. When each individual element and node has been worked out, the mesh can be converged, and an overall result obtained. If a more precise overall result is required then the mesh can be refined, which is essentially reducing the size of each individual element to reduce errors in calculations.

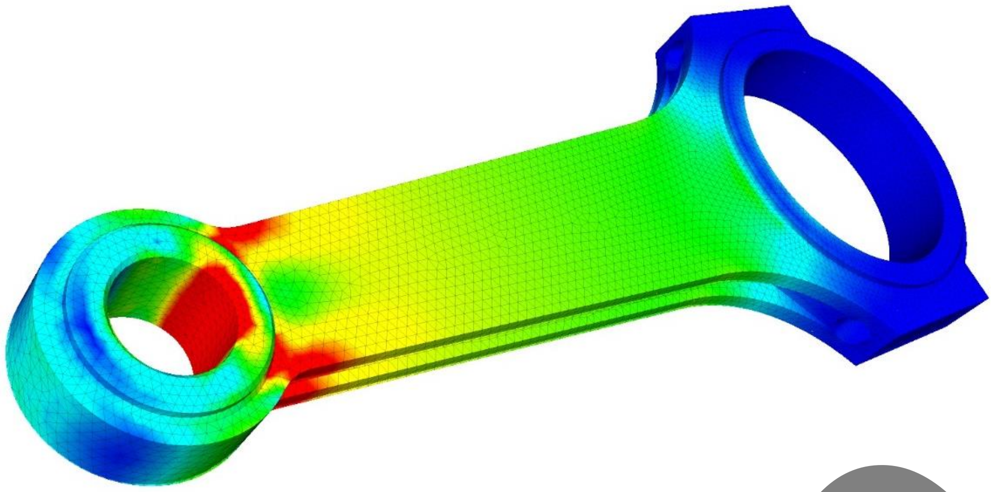

Figure 1.1: *FEA Simulation of a Connecting Rod with Visible Mesh*

The mathematical form of FEA is a complex and time-consuming process, therefore computer-based models are used to predict this behaviour, the visualisation of the end product is also very effective at quickly communicating issues in design to the designer(s).

As with any prediction, the results cannot be guaranteed to be exactly 100% accurate. It is therefore prudent to check the results of the simulation against historically similar systems; experienced engineers usually have an idea of the expected results and can therefore identify erroneous simulation results. Simple hand calculations can also be carried out to confirm simulated results on more simple systems such as single beam deflection. The same simulation can also be carried out by another engineer and/or using different software to confirm the simulation results are accurate.

1.2.3 Computational Fluid Dynamics (CFD)

CFD involves analysing fluid flow using computational methods and producing simulations of the flow of liquids or gases and how they interact with boundaries and/or solid objects. This technique uses the same method as FEA of creating a mesh in order to analyse a sold part/assembly, however it applies fluid flow principles to determine the outcome of the system.

There are various different software packages that can be used to simulate flow and mechanical systems, professional organisations often use one overall software provider for 3D design as well as simulation so that the 3D model can be easily migrated to the simulation area. There are also many pieces of software that are devoted to simulation solely and 3D models in various formats can be imported into these simulation programmes to be analysed.

CFD is used extensively in Heating, Ventilation and Air Conditioning (HVAC) applications such predicting air flow of a new as air conditioning systems within a building. It can also be used for aiding the design of exhaust and diffuser systems, as well as analysing air flow relationships with vehicles, buildings an even a bird in flight. There are a huge number of uses for CFD and, as it is an incredibly powerful tool to simulate heat transfer in fluids it can be used to simulate real life situations highly accurately.

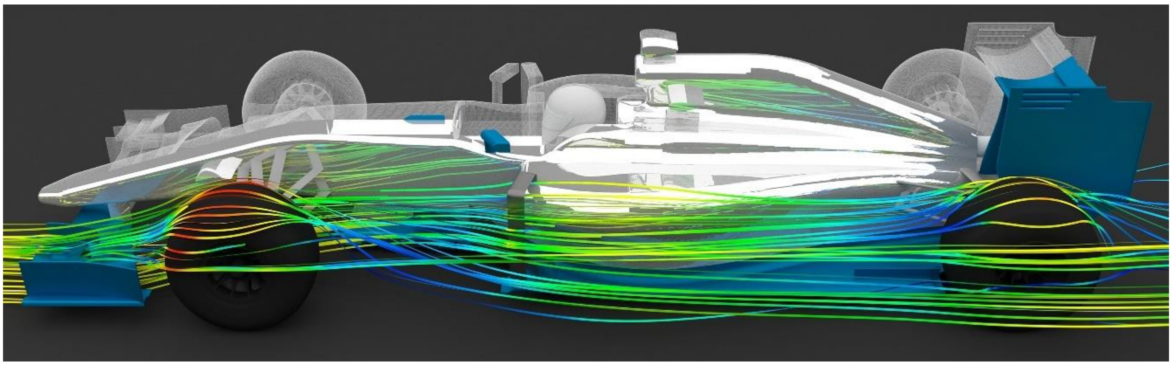

Figure 1.2: *CFD Simulation of Airflow around a Formula One car*

The best way to become familiar with these computer-based models including CAD, FEA and CFD is to practice using them as frequently as possible.

Challenge

Register with Simscale (https://www.simscale.com/) and complete the Solid Mechanics Simulation (FEA) and the Fluid Flow Simulation (CFD) tutorials (https://www.simscale.com/tutorials).

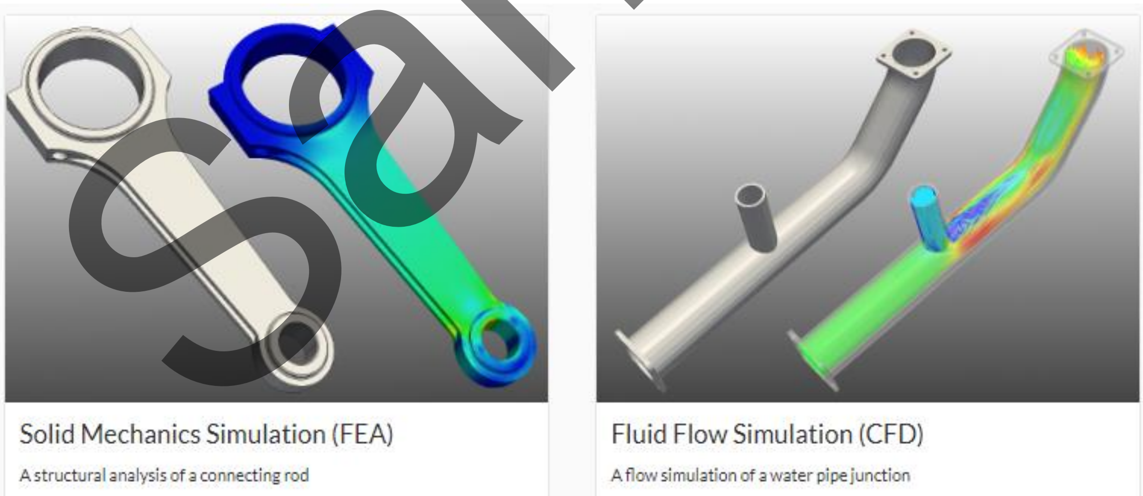

Figure 1.2: *Simscale Tutorials*

1.3 Interpretation of Results & Determining Faults

Once a simulation has been conducted, we are presented with some results that require interpreting, remember that just because the simulation has presented a set of results it does not necessarily mean these results are reliable.

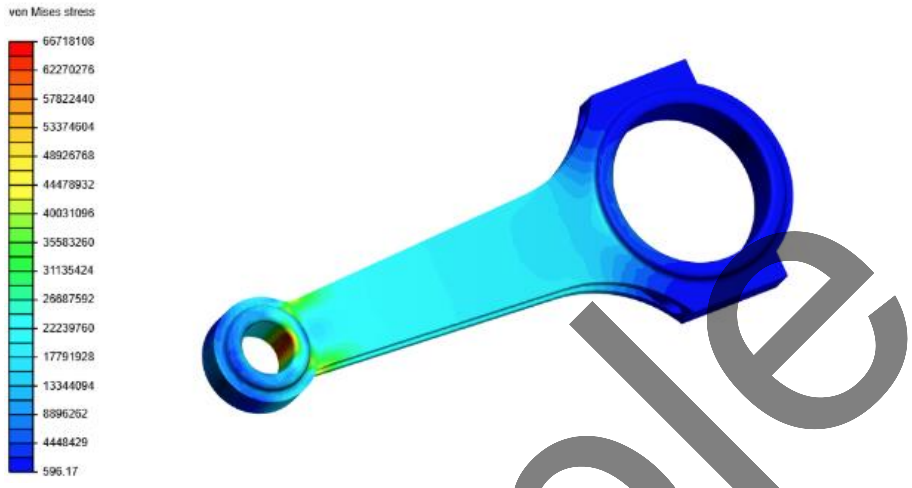

Figure 1.3: *Von Mises Stress Results*

In the example of a solid mechanics simulation, there are a large number of different types of loads to apply to a part and there are also many different results that the simulation software can be made to display. In general, in structural analysis, areas in red indicate a higher value of stress, whereas blue areas indicate lower stress areas. By just glancing at the results of the above von Mises stress simulation, an engineer may assume that the part is performing well as the stresses are appearing in the areas one would expect. However, it is very important to actually check those stress values because there may be some values that exceed the yield stress of the material. A useful tip is to change the settings of the simulator so that values of von Mises stresses above the material yield stress are highlighted in a different colour. This will then show exactly where the part is likely to yield, and an engineer can then change some properties of the part to mitigate this yielding.

In addition, where a part has areas of zero radius (sharp corners) occasionally these will lead the simulator to deliver erroneous results because it attempts to solve for infinity at these areas. In order to defend against these kinds of errors, it is always a good idea to rerun the simulation with a different mesh size and check that the results are similar.

Simply presenting a colourful image of stress or deflection is not a full explanation of the results, it merely shows where the relatively high stress regions are located, it can be useful to tabulate and/or graphically represent the results obtained.

The same principles of interpreting results and determining faults can be extended to CFD and used in much the same way as with stress analysis and heat transfer.