

Introduction:

This report is to highlight some of the key issues found with in CAE and CAD designs throughout the engineering industry and how engineers overcome and deal with these issues. It will have a view on the analytical approach of calculations and the CAE calculations to signify the differences between both. A look into thermo-mechanical, deflection and how the analytical calculations differ, also why they differ.

Also, validation of how accurate CAE calculations will be shown to highlight how accurate these tools can be for the engineering industry, this saves time and money for engineering firms as it saves having to perform these tests manual which in hand would reduce the number of materials used, time in specialist labs and does not require the use of specialist machinery to analyse if any deformation or changes have occurred throughout testing.

Throughout the validation calculations, comparison to published engineering papers will be shown to express how accurate the software can get to mathematically proven results. This can often be found to be lower than 1 percent which proves extremally accurate and to be a trusted form of research.

The final part of the report will include a CAD assembly under analysis using ANSYS software to view the changes reported when a material is changed, this software is quite powerful and fast in producing results which will include the thermodynamic changes, the deflection of the material and the stress and strain cause on other materials due to the density changing.

Validation Test Case:

To validate how accurate Ansys a CAE software can be, this test will be performed to compare the difference in calculated values to a simulated case and a fundamental mathematical calculated case. This will be done via calculating the total deflection experienced through a metal beam placed under a uniform load at one end. Thermal conditions will be applied also at an ambient temperature to ensure accuracy.

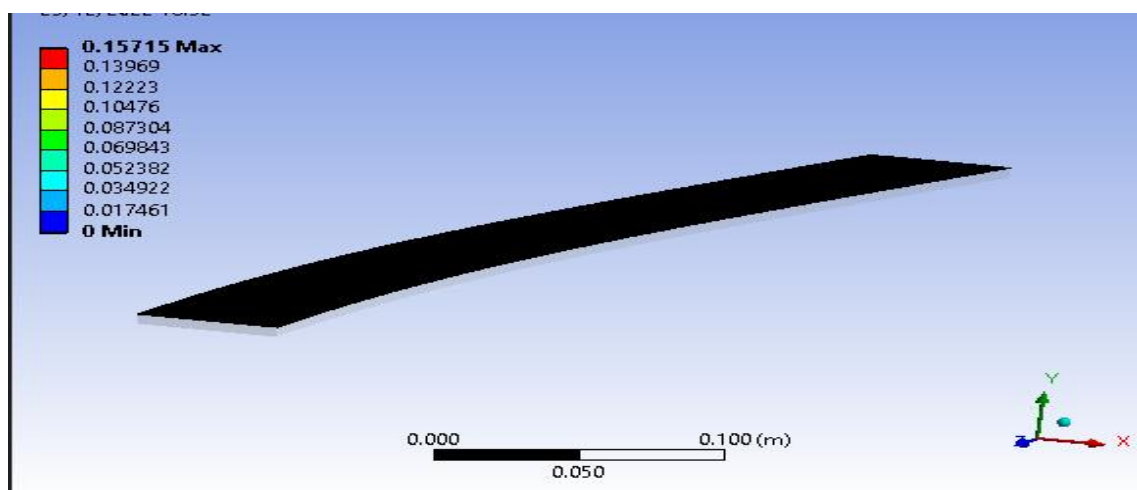
The aim of validation is to prove that this testing can provide an accurate result to within a small inaccuracy percentage, ideally below 1 percent. If proven correct, this then proves to be an especially useful piece of equipment to test items via simulation as an engineering report can account for a 1-2 percent of error as that is exceedingly small. This could result in much cheaper testing to rule out materials, types of material bonding and many other situations.

Below is a validation example that has been calculated fundamentally which will be compared to a simulated calculation to show the difference in accuracy.

Results

Structure File	Surface Stiffness Type
0016.01	Standard
0016.02	Without Tension

Surface Stiffness Type	Analytical Solution	RFEM 5	
	$u_{z,max}$ [mm]	$u_{z,max}$ [mm]	Ratio [—]
Standard	157.143	157.130	1.000
Without Tension		157.150	1.000



Results:

Above shown are the hand calculation results and the simulated results performed via a basic static structural study within the Ansys software. The mathematically calculated results are done following physical and structural laws that the simulated calculation would have followed also, The Mindlin plate theory is used in the mathematical calculation as well as Isotropic linear material model.

To maximise the accuracy possible when using a CAE software, its especially important to ensure all details have been inputted correctly such as the material properties, material dimensions, what solver type has been selected to process the simulation and the geometry of the design. It is particularly important to do so as an example of this is using a pre-selected material within the software, this is due to most engineering cases using different forms of materials such as different formulations for an alloy they are intending to use. Therefore, it is important to input as much data gathered on the material such as the Youngs Modules, Poisons ratio and its shear ratio. By adding in these values when inputting data for a custom material it will allow the software to calculate all other relevant parts of information that is required, however all this data must be inputted using the correct units and values as even one mistake will cause a significant difference in results.

This outlines the process that manufacturers would follow which is the FEA process. This process is now a crucial part of engineering design as it consists of virtual testing, a reduction in prototyping, reduces the risk of the need for any recalls due to product failures and the final design can be assured of success which reduces the need for expensive testing machinery.

Result Comparison		Percentage difference
Fundamental (mm)	Simulated (mm)	0.0045%
157.143	157.15	

Analysing Results:

Above are the results of both which shows a percentage difference between the hand calculated result and the simulation calculated result to be less than 1 percent at a value of 0.045 percent which is an exceedingly small difference.

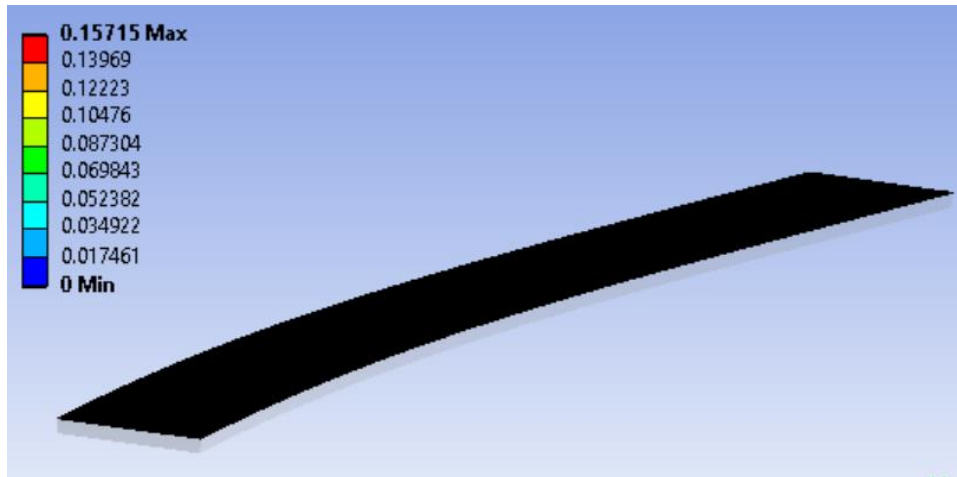
This Validation case proves the point that the simulation software can produce an extremely accurate simulation so that an engineer can validate that their study is accurate to below one percent when studying a static structural case. This in form then backs up the reason engineering cases are done via FEA processes rather than going straight in for product testing in a lab and using expensive materials and equipment.

However, there are few issues with using CAE testing, one of those being the initial starting costs to purchase the software licenses, multiple computers that are powerful enough to process these simulations in a timely manner and a CAE analysis expert. This can also be a very time-consuming process due to altering mesh sizes to see if accuracy improves when compared to hand calculations, this is due to issues arising sometime with complex shapes such as a suspension arm as an example, this is due its awkward shape and having to change the mesh sizing and re simulating to get the ideal accuracy required, as the smaller the mesh gets the more processing power that's required as it's analysing a smaller element across the design to see if there is any difference. However, sometimes when reducing the mesh sizing to get a more accurate result it may go the opposite way, it may produce different scenarios that are not anticipated. This is where the aim is to get a fine balance between computing processing time and percentage difference in results.

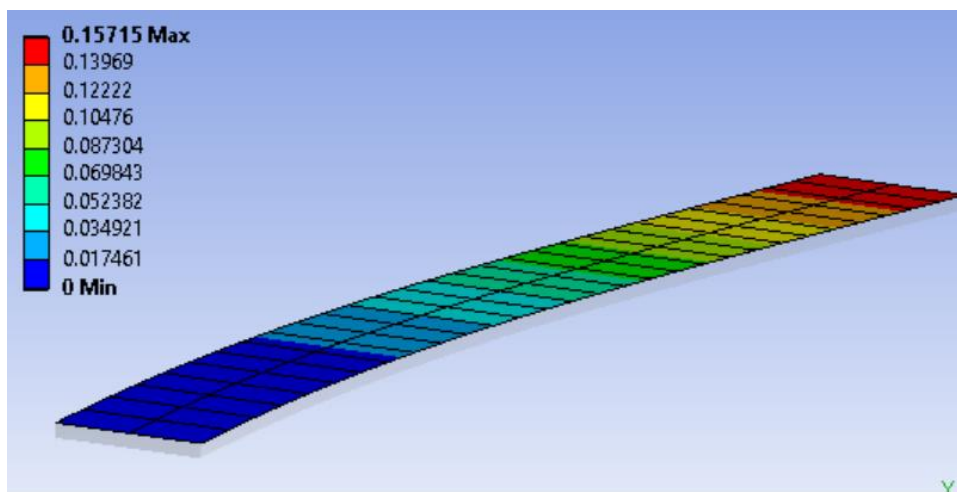
Mesh independence studying is one form of ensuring an accurate result. Mesh independence is the point at which when refining the mesh produces a very minimal change in results, therefore proving that reducing the mesh size and increasing the need for longer processing is not required as it has reached the point where its results are within the allowable percentage difference between the hand calculated result. This process is done to ensure when changing the mesh size to a very refined study that there are no drastic changes in results to prove the study has reached mesh independence.

Below is a comparison of how the result has the possibility of changing due to the mesh sizing and whether it has reached mesh independence.

Below are the results of a simulation with the mesh refined to 0.035mm.



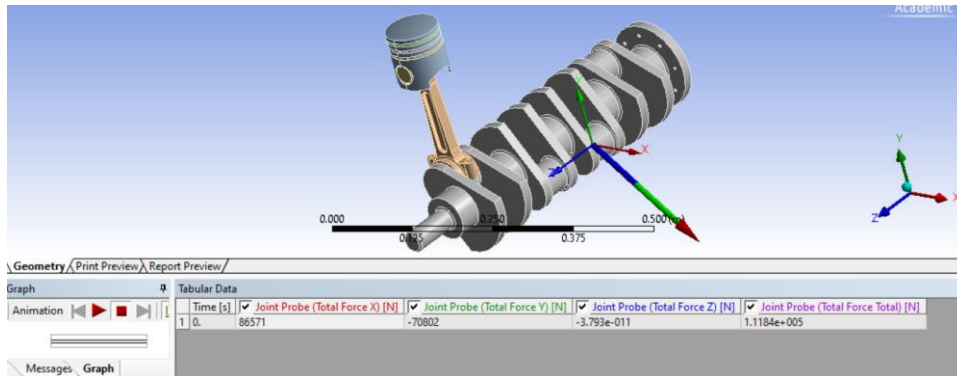
Below are the results of a simulation with the mesh refined to 0.015mm.



After the original results and both results above at 3 different mesh sizing's with 0.010mm difference between all it is apparent that mesh independence has been reached, where the change in mesh sizing has no implication to the results of the simulation, with mesh independence being acquired it is proven that the percentage difference between the hand calculations and the simulation is confirmed to be at 0.0045 percent which proves to be extremely accurate.

After validating this simulation, it is now ready to use for another design as its proven to be below 1 percent accurate.

Kinematic Study:



Above is a kinematic study based on a rotating piston in an engine of a 4-cylinder vehicle. The parameters have been set at 3,500 RPM (revolutions per minute) where the analysis will focus primarily on the forces experienced by the bottom end bearing, this is done using a realistic materials and sizing, the material of choice was copper as this is a quite common choice for the internal materials of a bottom end bearing.

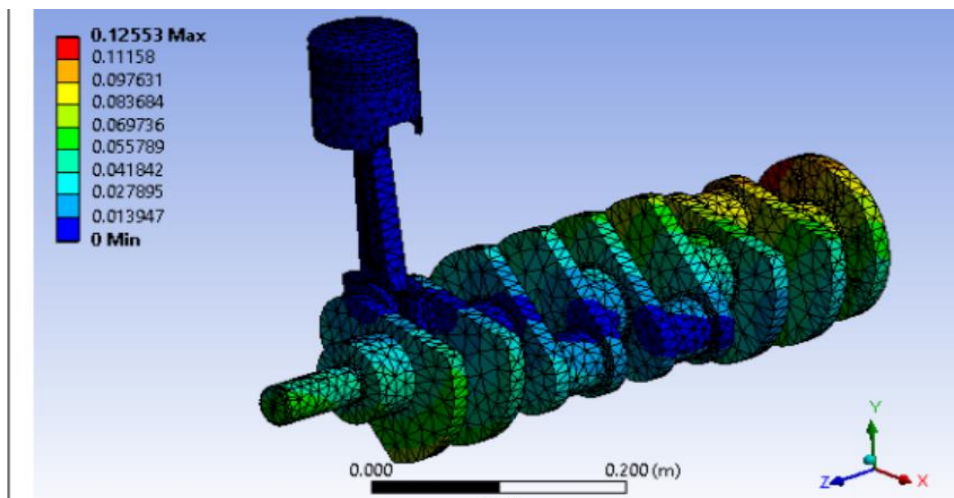
The simulation was setup to provide a revolving motion of the crankshaft where the bearing would be in contact with the crankshaft all throughout the cycle to provide a realistic result. The simulation was run to analyse how much force would the bearing receive when the engine is running at an optimum rpm for testing.

Another force was added to ensure as much accuracy as possible when testing, this was a pressure force at the top of the piston to mimic operating conditions, this force was set to 130 PSI or 896318Pa which is a realistic compression ratio for a 4-cylinder inline engine.

After running the simulation and having errors with the contacts being incorrect for this set up, they were then amended to suit this analysis, after figuring that out the simulation then solved correctly to produce 3 different results in different axis.

The main result was the X axis as it was set to rotate in that direction as that would provide the up and down motion, it calculated that the bearing would absorb a force of 86,571N per cycle, this would be down to the shear force throughout the combustion cycle as the bearing that is under analysis is the last point for the force to travel to so it would experience the total shear force.

The solver also calculated forces in both other axis as this is relevant for when the combustion cycle is on its way back toward TDC where it found in the Y axis a force of -70,802N which this effects the corners of the bearing where it would meet the upper shell bearing.



Above is a static structural study that also includes thermal conditioning and a pressure load set at the crown of the piston. This study calculates the total deflection of the whole assembly to view if any deflection will occur during a standard combustion cycle where temperatures, forces and loads will be present to provide a realistic result.

From the analysis above it shows that the piston and conrod face no deflection as they are awfully close to the dark blue shade which shows a value of 0 in the image above.

However, it does show that there is little deflection throughout the crankshaft, the temperature condition for this was set at 105 degrees C as this is an operating oil temperature for an engine, and toward the end of the crankshaft it shows that there is a maximum of 0.12553mm of deflection.

To ensure this was correct the mesh sizing was tested at 0.1mm, 0.250mm and 0.400mm which are increments of 0.150mm to ensure the result was correct, after re solving using these results it seemed apparent that mesh independence had been reached with very minimal if any changes in value at all.

The reason a deflection analysis is performed is to analyse how the bearings will wear over time as crankshaft deflection can determine whether there is any miss alignment in bearing positioning, therefore causing premature engine failure, this is a very standard test when it comes to engine design as manufactures must ensure bearing placement is withing tolerance.

It seems from these results the analysis has picked up a misaligned part in the assembly, this is evident as there is far more deflection present as the end of piston 4's location of the crankshaft, this could be very slightly misaligned which is causing the deflection.

This proves the usefulness of CAE software, as an example of its usefulness is proving that a part amongst the assembly is fitted incorrectly which saves a significant amount of money if an automotive manufacturer just prototypes an engine with components miss aligned as it would fail earlier than anticipated. The software calculated this before it could happen.

Summary:

After showing all the benefits of using CAE and FEA processes to produce engineered future concepts rather than prototyping there is however some issues that do arise from this. One issue is the initial costs to get started using this, as to run most CAE software's a computer with incredibly good internals is required due to the demand on memory capacity, processing power and graphical abilities is needed, all these combined are not cheap, especially when a lot of them are required in an engineering office, these are needed as most standard desktop computers could potentially process the simulations required, however they would consume far more time doing so which in business terms costs more money again. This is where the question is asked whether it is worth using CAE over prototyping and testing, as most large manufacturers have access to all the materials and machinery required to do prototype testing prior to CAE becoming more mainstream.

A quite common issue that is found throughout just using CAE in the automotive industry is unexpected NVH issues, this can lead to substantial amounts of recalls on vehicles, an example of this is the EGR (Exhaust Gas Recirculation) failure on most diesel-powered BMW vehicles produced over the last ten years, any failure in design can lead to massive costs in trying to find a solution then implementing the solution.

Another issue found throughout the industry is not noticing issues early on. For instance, a design engineer may have made a slight miscalculation prior to using CAE like one found in the final simulation produced above where the final shell bearing was miss places, this can cost a large amount of time trying to find the issue as the software will not give you an indefinite answer. Issues like this can cause product failures or even a product that is released to the public that is unsafe or not suitable for its use.

However, with all the issues that can be found using this software, after purchasing the licenses and the hardware required this does prove to be a worthwhile investment for businesses especially now when material costs have drastically increased.

CAE software's have benefited the automotive industry drastically as it can provide insights early on into projects on how a component will behave, last and makes design alterations quite easy and affordable, it also makes designs easier to transfer from internal teams, such as the materials team and the design team due to them being digital, both are able to analyse and make decisions based on the software's results. It also requires a lot less effort to produce a prototype, there is no need to create moulds, send them off to third party part manufacturers or produce in house, all the testing that is needed is embedded in the software ready to analyse the next component.

The software also allows the use of varied materials and the ability to input your own material specification if all boundaries are filled in as required, this allows the use of different forms of alloys to be used for body panels etc, this allows the manufacturers to narrow down what material they desire to use based on the results produced.

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