

Computer Aided Engineering Assignment

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Submission date: 30-Apr-2023 10:55PM (UTC+0100)

Submission ID: 204064370

File name: 33468_John_Gallacher_Computer_Aided_Engineering_Assignment_497865_1525086024.docx
(2.91M)

Word count: 5333

Character count: 29266

University of Wales Trinity Saint David

Computer Aided Engineering (CAE)



Researching the Strengths and Limitations of Computer Aided Engineering

ACDB5007

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21/03/2023

Declaration

The work of this report completed under the supervision of Andrew Noble. I declare this that this report is the product of my own work and is not being submitted for any other degree etc.

Signature:

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Acknowledgments

I would like to thank Andrew Noble, the lecturer at the University of Wales Trinity Saint David for the Computer Aided Engineering (CAE) module. I was provided extensive knowledge and tutorials into CAE; it's purpose, step by step tutorials and its criticality moving forward into the new age of engineering.

Abstract

This assignment was completed on behalf of the OME degree at the University of Wales Trinity Saint David. This assignment will be completed by a first-time user in the world of Computer Aided Engineering (CAE) software. The operator will create a design within CAE software Solid work before analysing the necessary components within another software Ansys. The aim of this assignment is to determine a design concept that is appropriate for a projectile hitting a target and analysis the material deformation of the projectile onto the target. Once completed the writer will be able to analyse any strengths and weakness that they have determined or researched within a CAE environment and come up with a suitable design for the scenario to be considered on an operational level within a real world scenario.

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1.0 Introduction

Throughout the years of engineering there has been a major increase in capability and resources on offer, therefore our approach in industry has vastly changed over the years. From its early stages, for example the U.S development of the Manhattan Project in which they first tested a nuclear bomb under the name “Trinity” (*See figure 1*). Despite the lack of computer power, the design was successfully completed through other means with the use of physical engineered hand drawings and tools, assumptions, scientific knowledge and prototype development [1]. This saw monumental success of the test and project; however, it took around 130,000 people to complete and over \$2 Billion for these results to be achieved [2]. This also came with criticism and the uncertainty of how the weapon would perform, based on a large amount of the engineers’ comments [3].



Figure 1- Trinity Test

Other examples of the physical tests carried out for product development are slow cooking a munition or the tensile stress applied to your cars vacuum furnace when operating, both in which will be exposed to large amounts of heat and applied forces to expensive kit and equipment. Due to the high demand in human capability, it was a group of engineers with their fingers crossed hoping their calculations and assumptions would be suitable to ensure their product or project would pass these tests.

The hands-on approach of engineering still applies but it has since evolved into a far more theoretical manner by progressing into an online platform with the use of seemingly unlimited resources. The computer has developed various programs and operating information in which we can call Computer Aided Engineering. This approach has been adopted since the early 1960's and has continued to be a critical part of engineering new products or improving existing systems [4].

This approach is used by various industries to refine product design, or to find solutions in complex situations. This is done with the use of tests such as simulation, validation and optimisation, covering all aspect of the product life up to the manufacturing stage [5].

As previously used in early engineering drawings, CAE can be looked at as an expensive Pen or pencil but far more accurate and effective. With the additional capability in solving complex calculations or problems efficiently.

1.1 Aims & Objectives

The aim of this assignment is to develop a real-world scenario by modelling and analysing it on a computerized environment.

All results and stages of this assignment will be assessed by test completion and compared with the literature to see the conflict and transparency of the results. A key objective is to determine the key strengths and limitations of CAE based on the use of the chosen software and comparison to relevant studies.

To achieve this the writer will design their own model of components and assemble them for analysis with the use of the chosen CAE tools. By determining realistic operation conditions, we can begin to conduct kinematic analysis with an additional static structure assessment on a chosen component. All these assessments and analysis will be further expanded on but will ultimately achieve a pictorial and

quantitative data into the material effects of our components. The effects of the materials can be compared with their actual withstands using credible literature to determine the validity of computerized analysis.

After these results have been achieved, a validation study will be conducted to assess the reliability of our approach and to achieve a plausible argument to determine if our results can be said to be accurate when compared to an operating environment.

From this, we will enough data will be gathered to conduct a conclusion. This will detail ways in which we can develop our component design and improve its performance. This could ultimately cause the design to be completely recreated, a potential change in material properties or simply a misuse in the software that is being used.

The conclusion will use all the aspects discussed and capture the key strengths and limitations based on the writer's experience and research. This will give the reader an insight into the key reasons why CAE is the future; with its continuous improvement in sophistication and performance [6], however acknowledging its complexity and limitations highlighted in the provided software.

2.0 Background Information

The first step of this assignment is to create a multitude of component or models to analyse. This will be completed with the use of Computer Aided Design for our product development; this concept is used across various platforms such as architecture plans, floor designs, mechanical and technical blueprints or even television special effects [7]. There is a saturated market in the software used within industry, each having similar capabilities but slight tweaks in terms of the work they are catered for. Some of the popular names can be seen listed; **Civil 3D**, **MicroStation**, **CATIA**, **Creo**, and **Siemens NX**. The software adopted for this assignment is **Solid works**, it is the most prevalent source and is provided by the University. In industry Solid works is the most used with **Inventor** being a close competitor [8].

Solid works

Solid works is renown globally and used by millions of individuals from novice to experienced engineers and designers with it being one of the most highly used systems within the market. The system has a multitude of features to maximise the accuracy of your design and to achieve the specified product requirements. One of its selling points is its ability to operate parametric design, this level of sophistication allows the operator to change any one of its components and see the holistic effects it may have on other parts of the model [9].

Despite its level of sophistication, the software can be considered easy use in comparison to its competitors and provides multiple steps by step tutorials for each of its features (*See Figure 2*). Figure 2 shows the completion of a step-by-step guide in which the operator had no previous knowledge and experience within CAE but was able to complete the design of a tool bar within a university lecture.

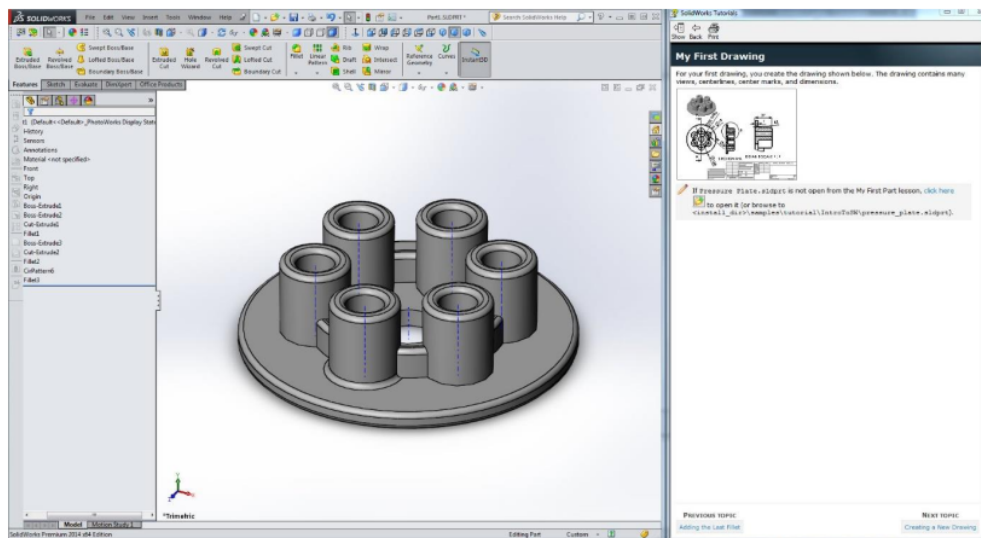


Figure 2-Step by step tutorial

The vast resources provided within the Solid works software does however only reach a certain level of complexity before it's up to the operators intuition to apply the courses appropriately. However, the community within CAE must be highlighted and admired with further step to step process from popular platforms such as YouTube or downloadable content provided at GRABCAD, this is a platform in which predeveloped designs can be directly used, manipulated, or just used for inspiration in future designs [10].

From the literature we can identify some of the strengths within the Solid works software itself this can be listed to be.

- It's 3D drawing and photorealistic capability in which designs can replicate accurately a real-life component,
- The internal library, like GRABCAD described previously again stating the ability to use previous drawings and design to increase the products delivery time,
- Automation allows for a basic drawing to move quickly into an operating phase of a component rapidly when the system is operated appropriately,
- Mistakes can be easily rectified and identified within the system, this can be traced back in your task bar,

- As there is a standard list of built components, this saves a recycle in design builds, and a faster approach in ensuring the product goes to market more efficiently and to its required standard,
- With another addition, the software allows for a holistic approach to be adopted. With the various electrical and mechanical based features for example we can begin to think about how they could potentially impact one another in operation [11].

Now some of the key features and positives have been explored and expanded within the software we can determine some of the described limitation within Solid works and CAD, these can be seen listed.

- Compatibility, Solid works is limited to various files and requires a windows computer to operate [12]. Previously CAE has been described to have seemingly unlimited resources however, each software wants to meet a certain requirement or specification in how it operates- using a multitude of platforms can cause issues with your results and potentially sabotage a design if it doesn't recognise its coding,
- Despite the system having predeveloped models and design methodology it does have limitations in it free-lance designs and can be restrictive if more complex parameters are necessary or components are to be designed [13],
- Another key limitation to note, despite having a valued community exclusively for designs and component ideas. This can be invaluable and is used globally within Solid works. However, this can provoke the operator to become complacent in their design and download a file that is not compatible or disrupt design evolution.

As we have explored some of the background information within solid works and conducted a pre use check on its strengths and limitations based on the literature. We can move onto how we will analyse our component designs; this will be done using another CAE software known as **Ansys**. This was further provided by the University and gives a wider overview into CAE software for more evidence in this report.

Ansys

In this section we will conduct some background research into the Ansys software, which was completed previously for Solid works. Ansys provides the customer to develop their digital designs and link them to simulation, real world scenarios and have a key role within business management [14]. Its capability in creating mechanical simulations with the use of Finite Element Analysis (FEA) software to perform structural analysis within on your model. These can be broken down into different types of analysis such as thermal, hydrodynamic, explicit, nonlinearities etc completed under a range of complex advance solver options.

As this report is aimed to give a basic insight of CAE at a surface level, going into the complex mathematics isn't necessary however it's Important to give the reader an insight into its relevancy. One of the examples used within CAE and Ansys is the Cholesky factorization algorithm, it derives from various matrices and is often used in quick solutions when developing Linear Algebra [15]. This example has been highlighted as similar algorithms and calculations will be used in developing the values and pictorials within the software.

We have acknowledged the methods used in Ansys mechanical operation as it resonates to our methodology further in the assignment, some of the other strengths and features of the software can be seen listed.

- Highlighted before, Ansys utilises complex calculations and interprets a variety of physics domains making it a top choice of software for industries such as automotive and aerospace. In layman's terms this provides the engineer with industry leading accuracy error % [16],
- The customization provides the user to manipulate the advance physic model capabilities,
- A picture or visual simulation is provided to the operator. This capability allows for quick identification in product operation capability, determine areas of

weakness in your design or even determine success to a business for investment.

Etc.

These are only a few of the key features that make Ansys an important feature in product design and life. However there is downfalls within its system that been highlighted from various sources, these can be seen below;

- Ansys version 2023, has its full and student version on offer. The student version is known to cause issues, due to the limit in nodes. This limits the software memory and causes operational failure when mesh sizing is far too big for the student package, essentially asking it to calculate problems greater than its memory capability [17],
- There are multiple technical issues when creating your simulations. This could see error messages within calculations, data import, and remote display issues. All these error messages are continuously updated with software improvement and list can be seen in **appendix 1**,
- Remote login issues. This has been reported by multiple operators who have developed problems when developing mesh sizes. This is information based on Ansys forums and customer dissatisfactory which will also be notified in the conclusion.
- Another problem which transcends to numerous simulations can be explained via thermal simulation. As you apply the determined heat to your product this will give you an idea on the deformation that would be created. However, this does not consider any mechanical movement and only considers the temperature in your simulation. There is ways to combat this, however for a first time user this could create difficulties and false claims when arguing operational capability.

Again, the points highlighted above are brief and give some background into the types of recognised issues or potential areas that could cause difficulties when producing a valid simulation.

From the information developed we can move onto one of the keys aims of this assignment in developing the writers own components and begin to test. Other examples will still be brought in for comparison and used for comparison, again highlighted as a key aim within the assignment.

3.0 Methodology

The methods and systems that will be applied have already been highlighted previously. First a design must be determined by the operator before the first design of this product can be achieved. In this scenario the writer has decided to construct a projectile hitting a target, this is a relevant study as it aligns with the Ordnance Munitions and Explosives (OME) degree undertaken by the student.

Tutorial

Before designing the specified scenario, another design tutorial was completed for a better understanding of the system before using the tools without a recognised guide. As seen previously with the tool bar, a finished step by step Jack Screw can be seen in *figure 2*.

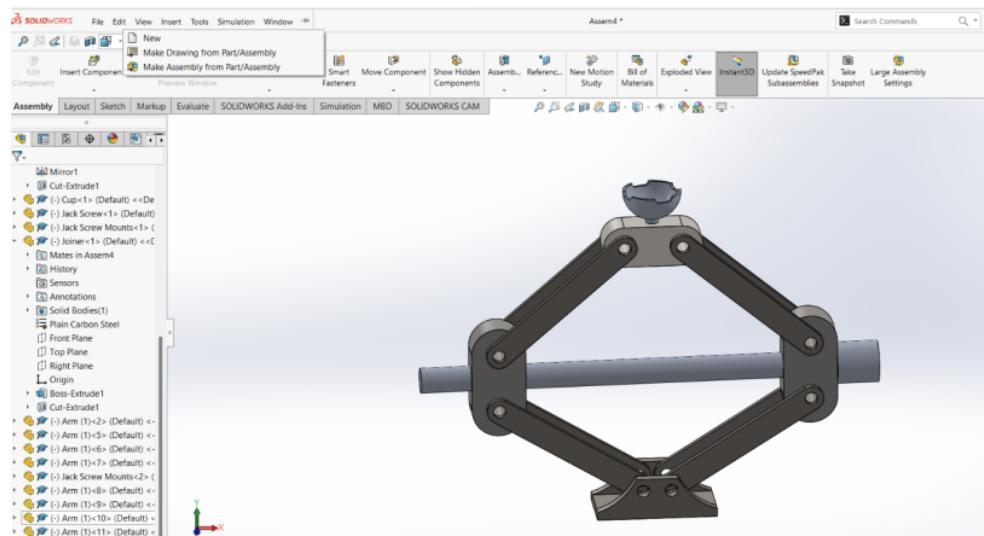


Figure 2- Jack Screw completion

Face value this looks to be completed successfully however as we transition to *figure 3* can be seen below.

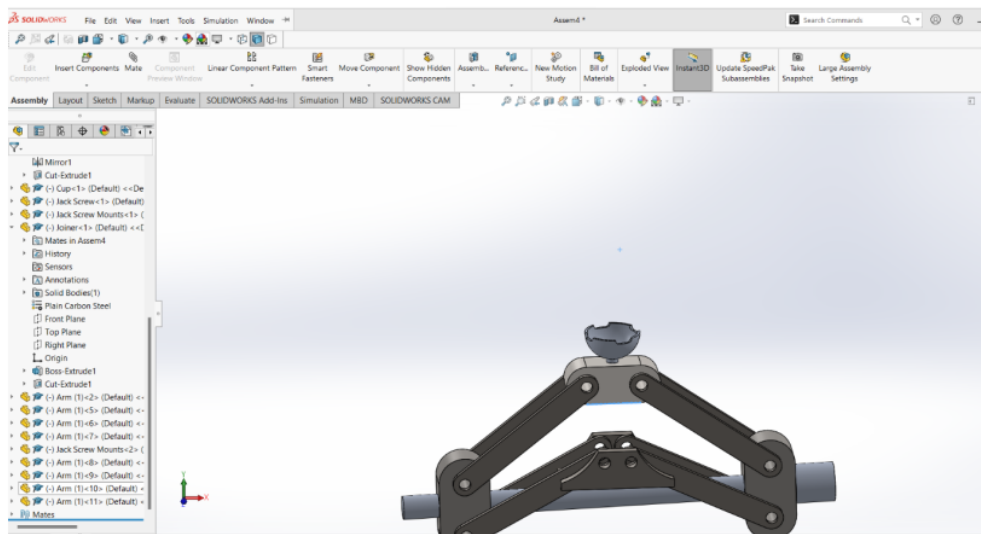


Figure 3- Software Issue

It is apparent that solid works does not consider boundaries and laws of physics within this design stage.

Despite this issue we can continue to move on to our own scenario. In recognising the issue above, it is important to set relevant parameters to avoid certain parts of your component contacting undesired areas.

Design Scenario

First step is creating our model within solid works, this will be completed by constructing both our projectile and target. The features utilised to develop this stage are as follows.

- Part- This breaks our overall component into its various sections before an assembly takes place to conjoin our products pre simulation,
- A relevant design plane will be selected as our design will be drawn in 2D before completed in a 3D format,
- Each part will be constructed using design parameters based on online measurement or pre-determined designs,
- The design tools such as Extrude, fillet, and extract etc. These are all ways to manipulate your drawings to get an accurate representation of your model with the correct aesthetic, parameters and thicknesses,

- Once both parts have been constructed and saved this will be forwarded onto an assembly, in which the components will be created as one file.

The following steps are just a brief overview for the reader, in the following pictures you can see the drawing to completion of the components created. **Figures 4&5** being the target with **Figure 6&7** showing the Projectile both showing basic drawings and completed components.

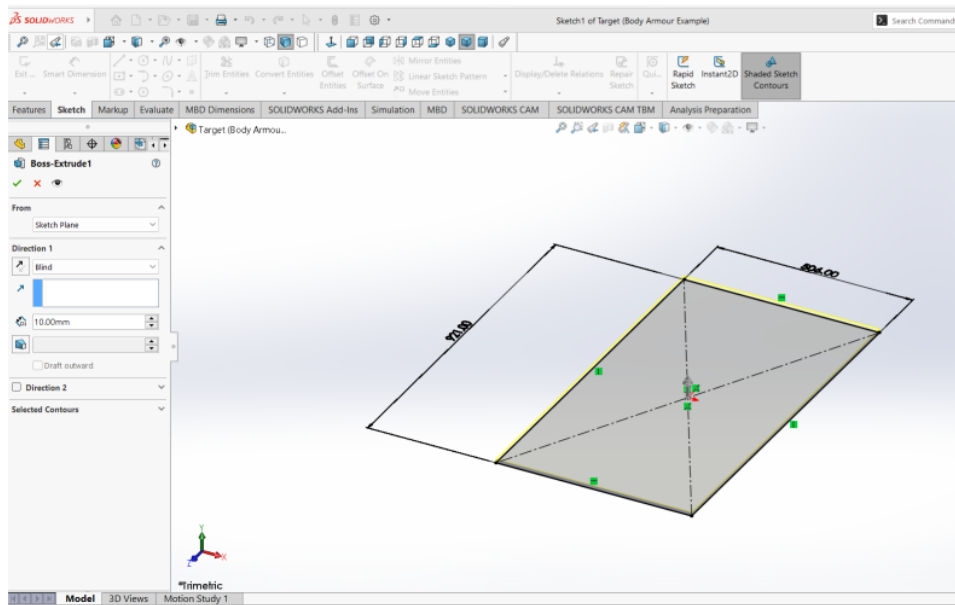


Figure 4 – Target

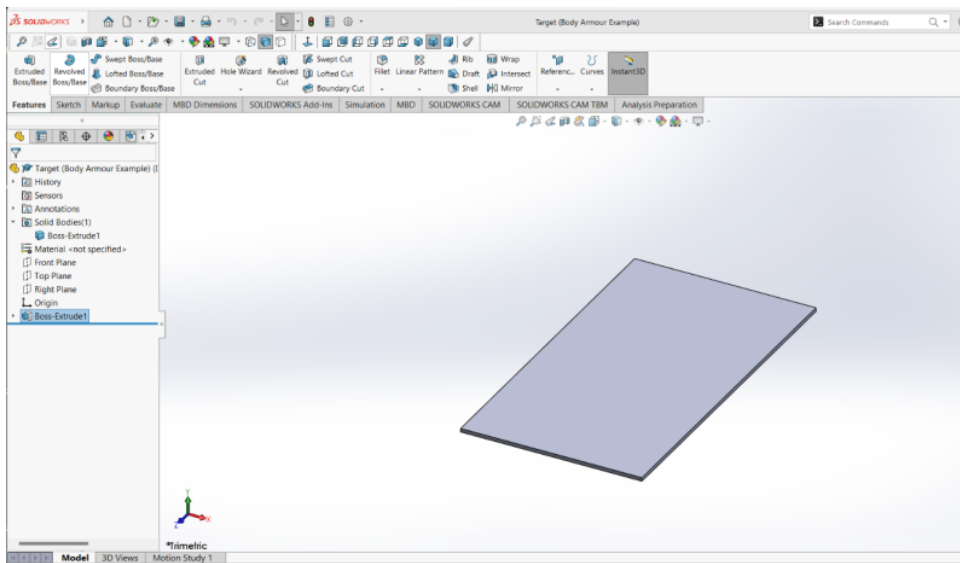


Figure 5- Target 2

The target is a basic structure; however it used the parameters based on the VPAM standards in Europe [18] and will make the results relevant to our study in trying to achieve an accurate representation of a scenario.

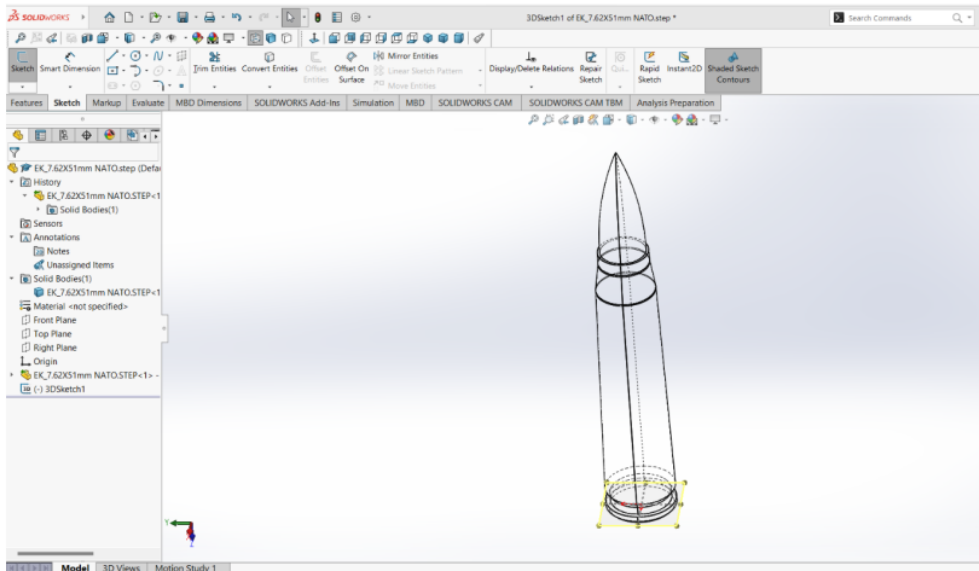


Figure 6- Bullet

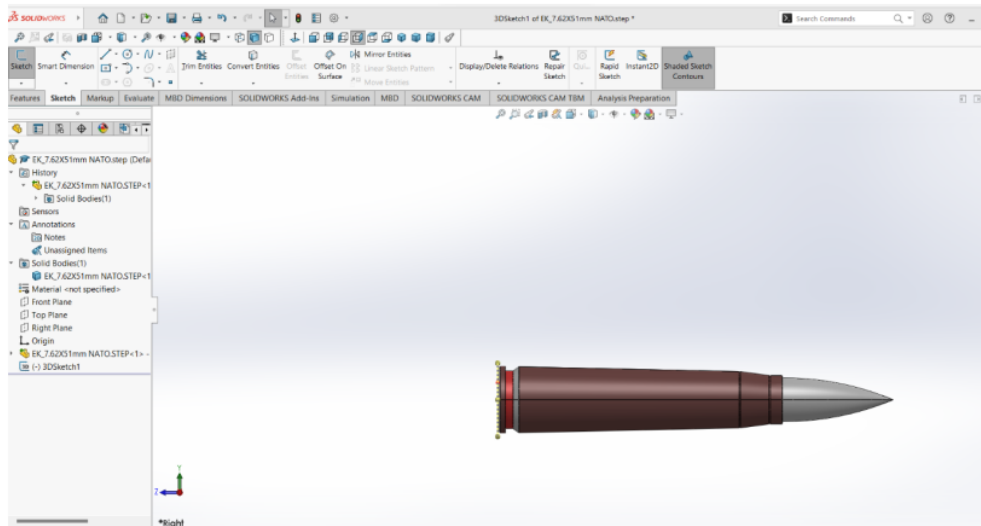


Figure 7- Bullet Finished

The final component before assembly is the projectile or in this case a bullet that is based on the 204 Ruger which is highly regarded in the munitions field [19]. For the reader, the bullet is constructed by its primer (the red band), cartridge case (brown centre) and projectile bullet front (grey front). This was completed using the mate feature in which all compartments are made individually before combining to develop the full design. Now the assembly of both fully constructed components can be completed.

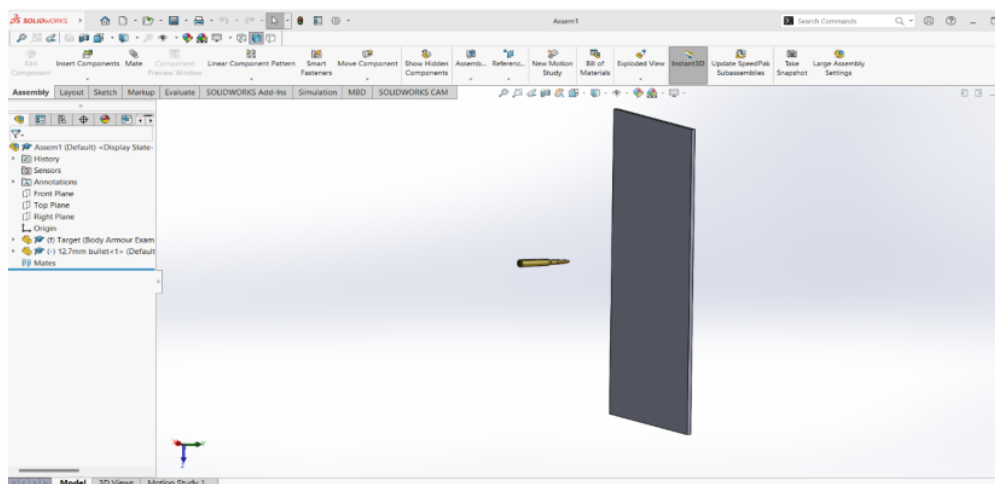


Figure 8- Assembly of component

Above is the completed assembly, essentially applying both components and determining the correct axis the components are facing to manipulate their movement in Ansys. Solid works is shown in the methodology to give the reader a pictorial into the scenario that's going to be assessed.

This is the final step before utilising Ansys for simulation, this will be shown in section 5. In using this software, an explicit dynamic study will be conducted. An explicit dynamic study is "**a time integration method used to perform dynamic simulations when speed is important**" [20]. Explicit dynamics considers a change within its environment such as high velocity impact, therefore it is relevant in the chosen scenario. This information is also applied within the simulation making it important in this study as it's considering highly transient physical phenomena. The material properties will be found on the Ansys library and the use of online material for reliability, some errors have said to be found within the library and the properties have causes simulation error in some examples. The velocity is going to be set at 400 m/s, this is an average based on the speed of this type of munition when fired.

All this data is gathered and applied to the chosen components and will give a full breakdown on the deformation of its properties once the simulation has been fully completed. From this a basic analysis into what results have been produced, if there's any errors that need addressed.

4.0 Validation

Prior to the analysis section we must conduct a validation study, this is essentially a formal way or sanity check on the results obtained and captures the percentage error between simulation and real life testing. Its aim is to reduce or eliminate the error percentage via software or human to a tolerable level. The example used can be seen below (*Figure 9*) is a beam load. In applying a load to the beam, we can determine

its maximum and minimum deformation and calculate the error percentage to consider in the results.

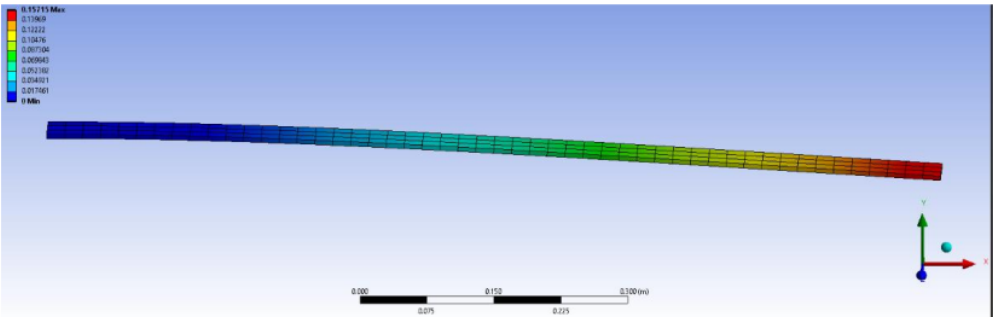


Figure 9- Beam Load

A validation was considered for the mesh sizing elements, these can be seen on the left-hand side, this identifies the suitable mesh sizes that should be used for acceptable results, as you can see the red zone highlighting mesh sizing of around 0.16 to be unacceptable and would consider this an invalid test based on them results.

Research was also conducted on validating a load increase on the component, this is represented within the table below using relevant calculations provided by Ansys online help team:

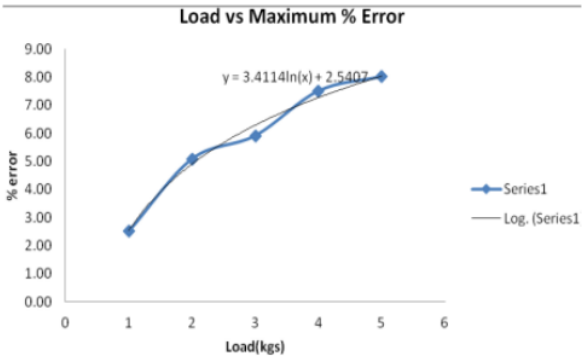


Figure 10- Validation Graph

As we take the results from the largest Maximum % it rounds up to around 8%, when compared to the acceptable standard within the literature this value is varied. Usually

around 5-15% can be considered acceptable however in some designs this could cause component failure. In this example, the writer has used engineering judgment and suggested an error rate less than 10% can be considered a valid test. So, for every 1mm of deflection applied would be 1.1825mm [20].

5.0 Results & Analysis

In completing both the design aspect and simulation section utilising both software the results can be shown.

As shown within the methodology section the writer has developed both the projectile munition designed as a 204 Ruger, with an armoured plate. This file was successfully transported over to Ansys despite the reported file issues highlighted by various operators.

The materials assigned for each component:

- Munition- Lead Projectile
- Target- Tungsten Armour

The following results can be seen from the following screenshots below:

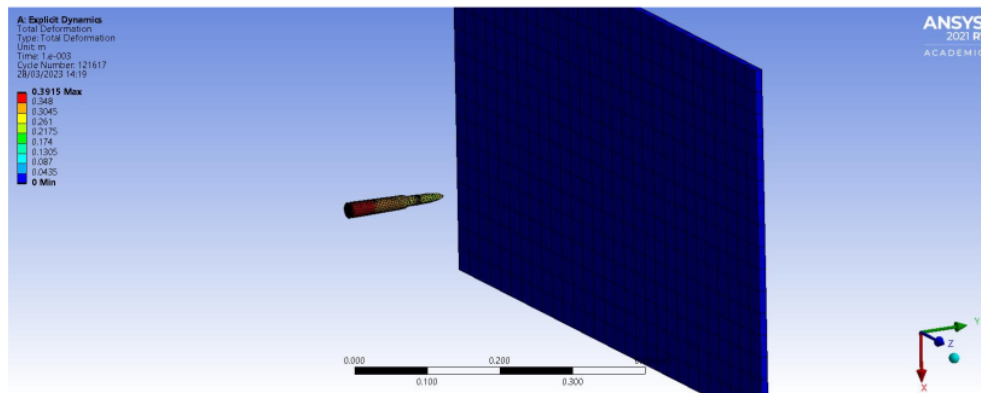


Figure 12- Simulation Step 1

The bullet is already starting to show some deformation within the cartridge, however this can be disregarded. The bullet's cartridge would not be intact at this stage, however when transferring the component from SolidWorks to Ansys the parts have become one. This can be considered an error by the operator, however should be appropriately explained in software compatibility.

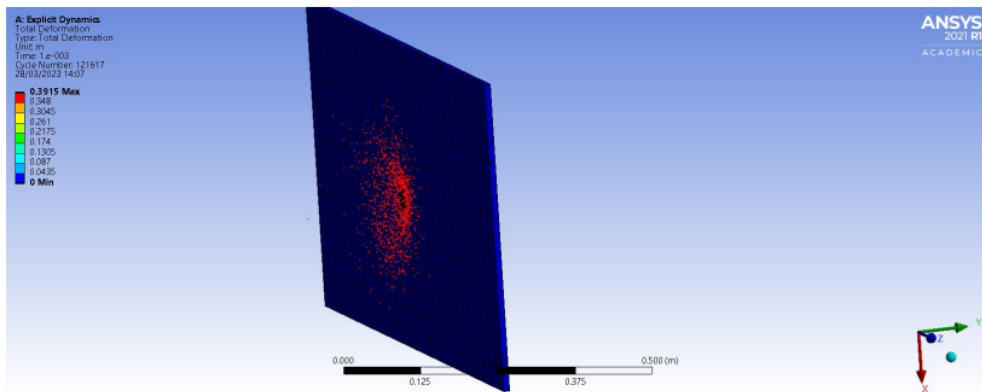


Figure 13- Simulation Step 2

Figure 13 which can be seen above shows the annihilation that has been done to the lead projectile, face value this looks like a mistake within the simulation however if we look at the transparency in material strength.

Lead has a tensile strength of around 2610 psi with tungsten having a significantly higher psi at 142,000 despite the higher velocity in lead it has no significant impact on the tungsten as its shown to be within the minimum deformation level.

Despite this basic example is shows a successful simulation and gives a good picture on what would happen if a bullet was to hit this type of armour. The red region suggesting the lead bullet would be at an unacceptable deformation $\Rightarrow$ 0.3915, while the target shows the blue section $\Rightarrow$ 0.0435 to be well in the acceptable region, therefor assuring it would operate as scoped within its environment.

However, if we wanted a munition that was more effective what design changes could be made?

Therefor the next simulation the operator created used the Ansys student version, this was to utilise remote learning which was convenient having to commute from the university. In using the same assembly however, a different set of materials and velocity change.

- Munition- Steel projectile
- Target- Tungsten Armour

In running this simulation, the following issued followed.

- Simulation time- The time for completion reached as high as 1472 hours for completion, for some examples this would be necessary but the basic principles in which were used this was far too long and disrupted this assignment completion,

From this the operator decreased the time of simulation, mesh sizing to reduce software calculations and varied the material properties.

- Mesh sizing for both target and projectile were vastly different, this caused multiple delays as the projectile had a very fine point at its end it required a very specific sizing that was not compatible with the targets,
- Despite resolving the following areas, like highlighted in the literature the student version was unable to run the specific mesh sizes for the munition (*see figure 14*). This could not be manipulated as reducing the nodes necessary would require removing a large proportion of the design ie the cartridge however this was already noted as fault within the previous simulation.

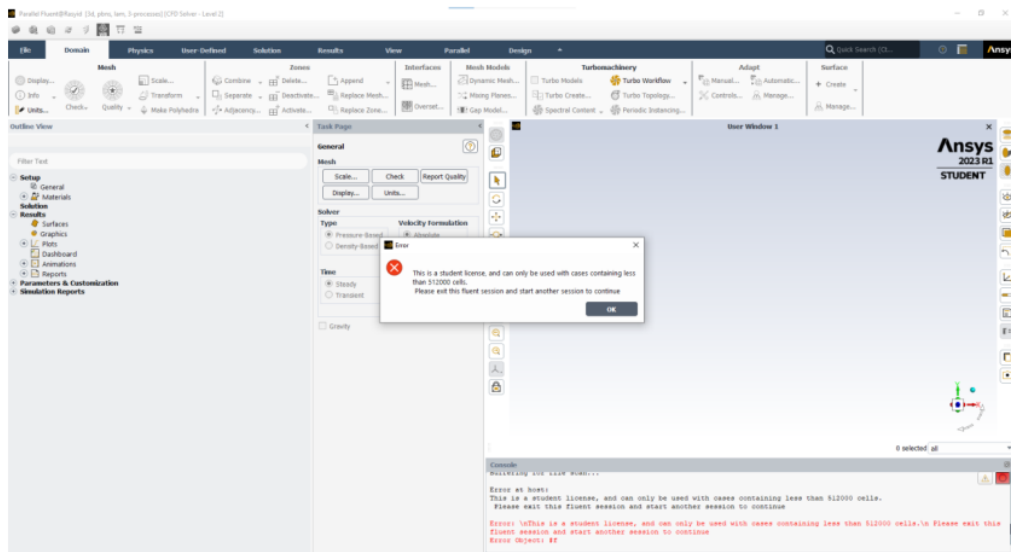


Figure 14- Error Code

In this analysis, the student version of Ansys was transparent and caused similar problems to what the forums highlighted. It would be deemed this version of the software as unreliable and only used on a get to know the system basis. Any complex simulations that need completed should not use this system. It highlights that CAE is good, however paying for the correct tools is essential.

From this the full version of Ansys was only considered. The following files were directed over, however this caused further compatibility issues. As the files had conducted analysis on updated servers it was unable to address back to an older version of the software.

New Design

From the following design multiple errors had accumulated which started back at the design stage within Solid works. This was done to eliminate any errors that had been done to reduce the errors that had been previously faced.

The new design used a smaller target to have a more specific mesh size and a projectile that's surface that could be easily calculated, dissimilarly to the pointed bullet previous which just required far to much time in completion time. That type of analysis is not necessary in this assignment.

The new projectile and target that were developed can be seen below.

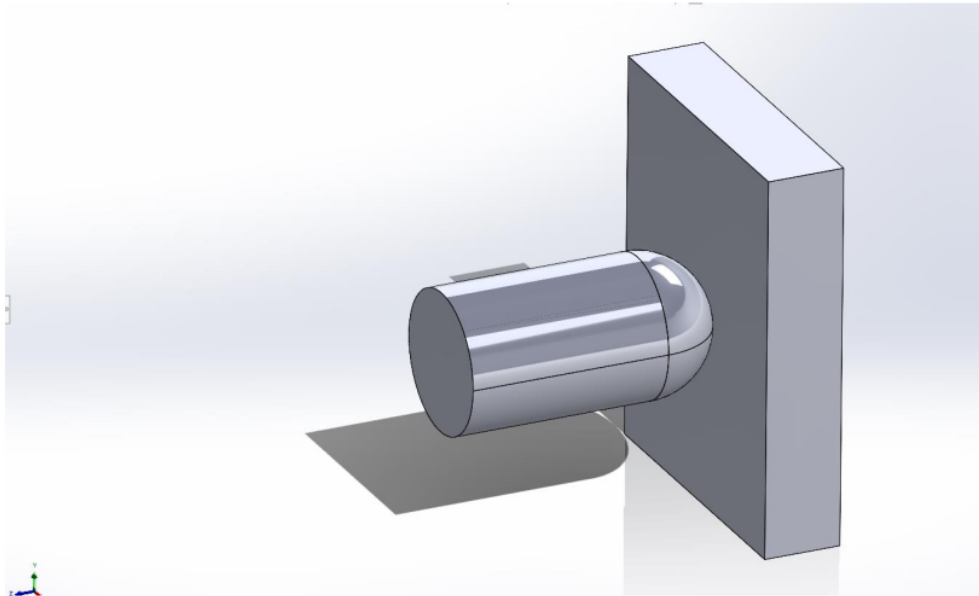


Figure 15- New Design

Its to be noted the distance from the projectile and target has been vastly reduced. This is to eliminate any wasted time, therefore decreasing the amount of calculations necessary – despite there being no impact at the start previously the software still has to take to account the distance travelled.

The design created has improved due to.

- Decreased time in simulation,
- Accuracy of results due to the appropriate mesh sizing being compatible,
- Less distance travelled, therefore faster outputs,
etc

The engineering data inputted for simulating the new design was based on the previous failure with tungsten being the main aim of impacting. The only difference being a 500 m/s impact which is more than achievable with a steel projectile. The operator decided on steel, it's a cheaper material and can apply its high tensile

strength in comparison to lead. From the following simulation an example of the energy dissipated in calculation cycles [22] as well as the initial impact (see figures 16&17).

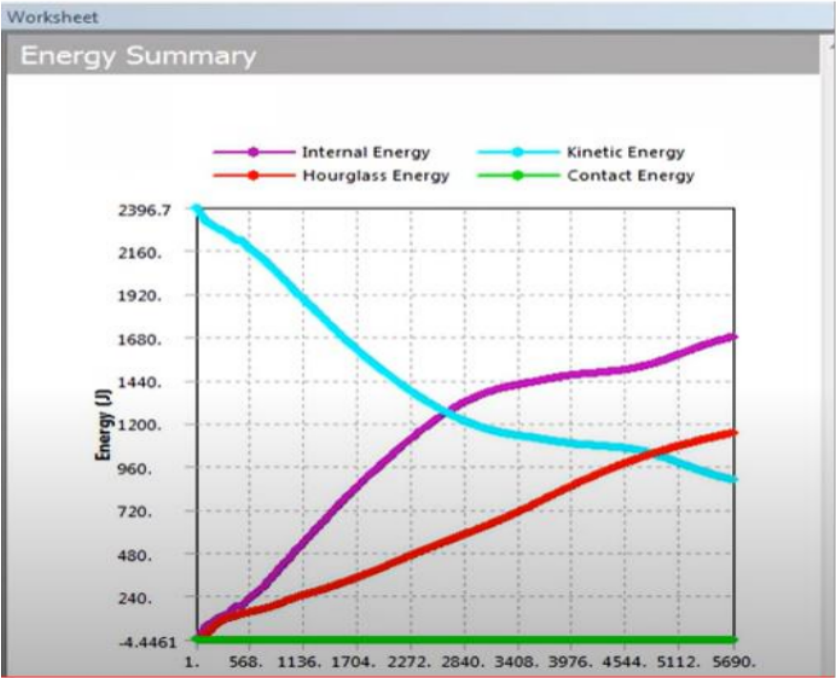


Figure 16- Energy Dissipation

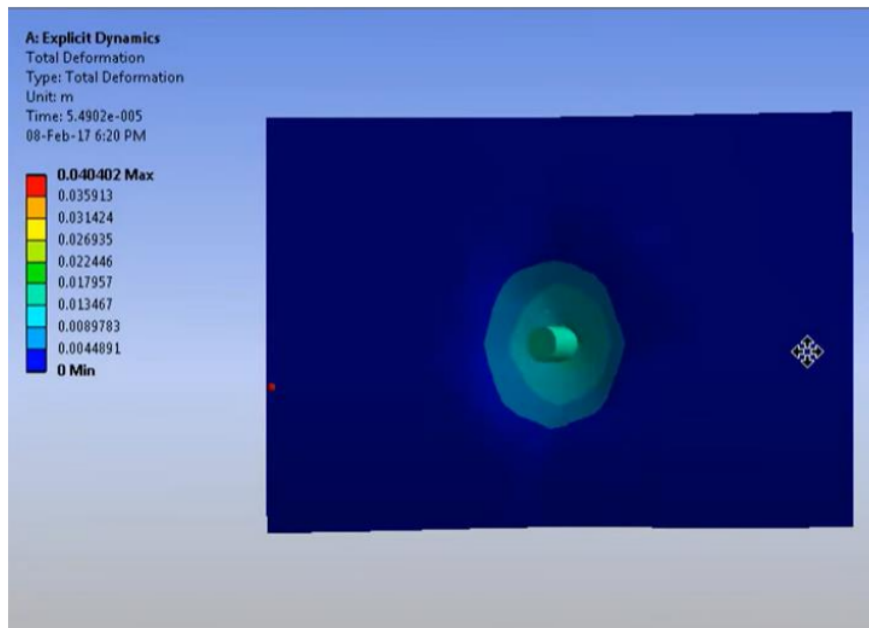


Figure 16- New Design Impact

From this simulation we can see a far more impactful energy taken place. From an eye perspective it shows the bullet impacting the target causing an impulse reaction. The design eventually causes a ricochet effect and some deformation on the bullet, however this is not detrimental to its structure like the first simulation.

The literature backs this up with tungsten being under double its tensile strength however with the added velocity and impact within a localised area this design has show to be far more reliable in terms of the projectile.

6.0 Conclusion

Now that all the relevant studies and simulations have been completed we can finally summarise CAE as a whole from the writers perspective and what the results tell us. From a first time user its apparent that CAE is a highly sophisticated tool that has too be studied far beyond the two, two week blocks provided by the university to full grasp the key concepts and mathematical methods behind its solutions. However from the time undertook using the software and reading the literature we can

complete the main objective of this report and outline some of the key strengths and weaknesses CAE. Starting from its strength.

- CAE is far more sophisticated and provides engineers with accurate results that would be nearly impossible to solve in a reasonable time limit,
- It cuts costs and time constraints vastly and can cause companies or designers etc to meet their targets way before deadlines,
- Mistakes and errors can quickly be eradicated or accounted for via an error %,
- Online tools and software's, there is so much material online and sources to help,
- The mathematical and physics integration, the software used is able to input real world scenarios and fully grasp how it would react without any sort of physical simulation,

The list could continue to expand but CAE has highlighted its excellence in the few weeks of use by the operator. However with the good there is also limitations, some of the key ones that could potentially impact performance are as follows;

- Ansys student version- This was highlighted previously in the assignment however it is important to consider the implications in using this version before creating your operation,
- Mesh sizing, as the writer was a first time user fully understanding the importance of mesh sizing and the effects it has on your results and how to appropriately manipulate it,
- Solid works assembly, despite adding a cartridge to a projectile when filed over to Ansys these two parts stayed combined as one. This makes it an unrealistic examples and caused the results of the simulation to be essentially null and void,
- With the online resources available it is important that engineers don't become numb to the idea of new concepts. CAE is a supportive tool but must not impact the way we think as innovation and evolution is just as important.

Again, these are some of the issues that had been identified in using CAE. Some were fixable however the lack of experience made this a long process for the operator. In determining the key strengths and weaknesses, developing a better munition that has a heavy impulse effect on an expensive element such as tungsten. The objectives of this assignment have been met, it is apparent why CAE is adopted as the tools on offer are remarkable.

Despite the lack of experience and time using the kit, the writer was able to develop a new scenario, design, and develop a simulation just with basic tutorials, online software and lecture communication. This shows how excellent CAE is, to make software so complex in creation however so simple in operation is a testament to the its power.

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8.0 Appendix

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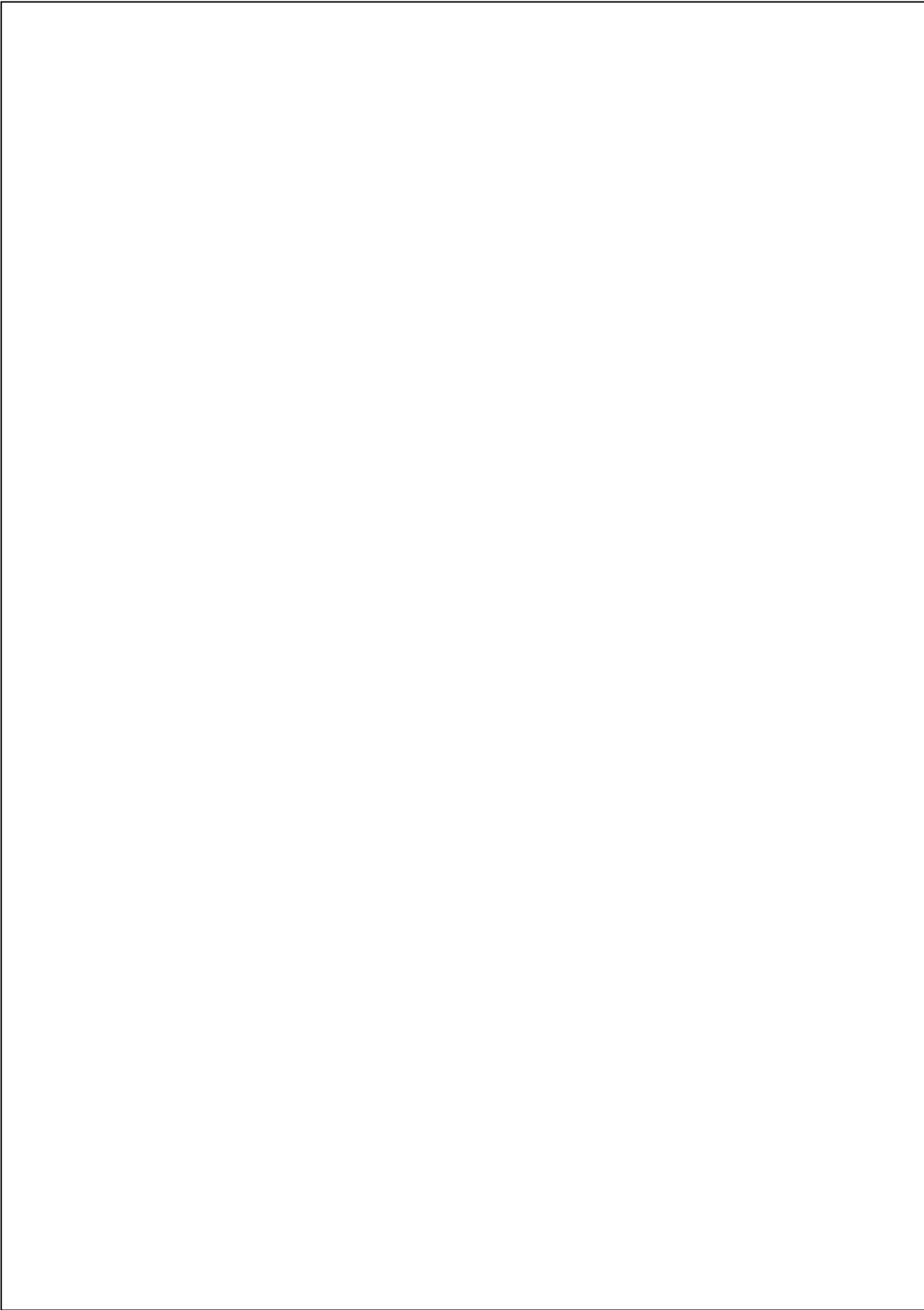
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Appendix 1

Above is the table of contents present in the Ansys error message documentation. This document highlights common error messages, difficulties in the software and a detail description of potential problems in updating the software. [ANSYS, Inc. Known Issues and Limitations](#) [21]



Computer Aided Engineering Assignment

GRADEMARK REPORT

FINAL GRADE

60/100

GENERAL COMMENTS

Instructor

The general report structure is nice, the document is well presented and the graphical information has been used well to support the discussions. The language is a bit colloquial in places, with some grammatical errors in places, but otherwise generally a good effort.

Your sections giving background information had some relevant points in them, and gave a reasonable overview of the software's being employed, but could have been a bit more targeted to some of the published limitations relating to the physics that is employed with these software's, along with how the methods of applying boundary conditions can be significantly different and important.

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