FEA Taught the Industry Way

Dr. John L. Irwin, Michigan Technological University

As Professor for Mechanical Engineering Technology at Michigan Technological University, Dr. Irwin teaches courses in Product Design & Development, Statics and Strength of Materials, Parametric Modeling, and Senior Design. Research interests include STEM education, where as PI for Improving Teacher Quality grants (2010 & 2013) he has developed and implemented professional development courses for K-12 science teachers to implement inquiry-based learning while utilizing computer simulations and 3D printing in their classrooms to help solve engineering problems.

Dr. David Michael Labyak, Michigan Technological University

David Labyak is an Assistant Professor in the Manufacturing and Mechanical Engineering Technology Department at Michigan Technological University (Michigan Tech), teaching in the area of Solid Mechanics.

FEA Taught the Industry Way

Abstract

Finite Element Analysis (FEA) can be taught as theoretical, application oriented, or preferably as a combination of these. It is beneficial to include a laboratory component dedicated to the application of FEA principles while becoming familiar with the user interface of typical FEA software. This is especially true for an engineering technology curriculum that requires graduates to be familiar with the modern tools used in industry, but is common in engineering curriculum as well. The unique topics examined in this paper are the methods used to teach FEA to develop skills for accurate analysis and reporting of results in a format required by industry professionals.

Common modeling errors are discussed in this paper, such as element selection which can greatly affect the outcome of the analysis. Too often, a new analyst will apply meshes to the model without understanding why proper element selection is important. With FE software being easier to use, more and more people will use default elements without understanding how the elements behave. Proper element selection can make a model solve quickly and with a higher degree of accuracy. Improper element selection can affect the solution time and final results. This paper also outlines the FEA result reporting requirements and suggests methods used to develop meaningful post processed plots to best visualize results.

The assessment results from a student self-reflection survey of the industry relevant requirements of the FEA course support the intended course competencies and student outcomes. The student responses to the open ended question for the "biggest takeaway from the course" show that the highest frequency of response is that FEA is important, there are important steps, and that FEA is an incredible, effective, and helpful tool for mechanical engineers. The industry partner feedback survey responses verify that the student FEA report content, procedures and result formatting is comparable to the expectations in their industry.

Background Information

The Finite Element Method (FEM) uses numerical computation to predict the effects of force, pressure, heat, fluid flow, vibration or other physical effects on products. Finite Element Analysis (FEA) is generally performed by computer programs using the NASTRAN solver originally developed for NASA now integrated into a number of software systems. FEA can shorten the product design process by indicating where and at what level a product may fail prior to the building of a prototype. The building of a prototype that is tested until failure or evaluated using strain gage testing is required for validation, but predictions using FEA software can reduce the number and iterations of physical prototypes necessary. FEA is a tool for the mechanical engineer or designer that can be used during most phases of the product development process. FEA can be used for feasibility of initial design ideas, evaluation/testing phase to measure the worthiness of alternative designs, and during the final stages of design to optimize the design solution.

Depending on the industry, FEA can be used for different purposes. For instance, while designing industrial equipment, it is often necessary to design and test many versions of a system and/or components. Watson and Joshi [1] describe FEA methods used on a steering column mounting bracket design of an on-highway construction vehicle that integrates Design of Experiments (DOE) with traditional CAD and FEA tools in a concurrent manner called DRIVE (Design Refinement by Iterative Virtual Experimentation). Another industry where FEA can be very useful is in the design of automated manufacturing equipment, welding fixtures, and end of arm tooling in robotic work cells. For example, some studies [2], [3] indicate that FEA can be used to analyze the cutting and clamping forces in certain fixture layouts, then these results can be used to optimize the fixture design. These few studies and many more illustrate the wide uses of FEA in diverse industries, but the element mesh selection strategies and/or industry standard formatting of results are not discussed here. It seems there is little research of effective strategies to communicate FEA results based on a particular industry standard.

Being accomplished at using FEA software is a general requirement for most manufacturing and mechanical engineering positions, especially in the automotive, aeronautic/aerospace, military, and for that matter any transportation industry due to requirements for lightweight and strong structures that remain within industry standards for safety and reliability. The largest employers for initial positions of graduates from the Manufacturing and Mechanical Engineering Technology (MMET) Department at Michigan Technological University over the past 10 years are General Motors, Leidos, Ford and FCA. Given that three of the top four employers are automotive companies it is imperative that an understanding of FEA methods be included in the BS Mechanical Engineering Technology (MET) degree program curriculum.

Students are first introduced to FEA early in their coursework during an introductory Computer Technology Applications course, applications of FEA are reinforced in Statics and Strengths of Materials course, and FEA software is again used in Product Design and Development capstone course. The required courses typically use examples of tetrahedral meshed 3D CAD models solving for structural load stress and deflections. In Statics and Strengths of Materials courses FEA is used to reinforce the basic concepts of stress, strain and deflection as described in the research [4], [5].

Becoming “very” proficient in FEA requires a specialized course which is provided as a 4000 level technical elective in the MET curriculum at Michigan Tech. This FEA course is taught using an industry-based teaching approach. Through the years the MMET faculty that have taught and developed this course have themselves been employed for engineering companies utilizing FEA software. The faculty member who developed the initial version of this course consulted at Meritor Simulation and Development Engineering, Troy, Michigan, where he developed and implemented training for engineers in the product design and manufacturing tooling departments to utilize FEA software more efficiently. Much insight into the industry standards and requirements for reporting FEA results was gained through this experience. The current faculty member teaching this course had experience as a senior engineer at Great Lakes Sound and Vibration, Inc., Houghton, Michigan, serving as the lead analysist for all FEA and CFD related projects. Projects he was in charge of were for the commercial and defense industries (Army and Navy).

CAE and FEA Methods Course

The technical elective course, Computer Aided Engineering (CAE) and FEA Methods, is delivered in a 3 credit format with 2 hours of recitation and 2 hours of lab during a 14 week semester. The course topics are as follows:

- Application of Design-Simulation (FEM)
- Application of Advanced Simulation (FEM)
- An understanding of Motion Simulation (Multibody Dynamics)
- Introduction to Advanced Simulation, Computational Fluid Dynamics (CFD) & Electromagnetism (EM)

Additionally, some of the ABET student outcomes demonstrated and/or reinforced in this course are the following:

- an ability to apply knowledge, techniques, skills and modern tools of mathematics, science, engineering, and technology to solve broadly-defined engineering problems appropriate to the discipline;
- an ability to apply written, oral, and graphical communication in broadly-defined technical and non-technical environments; and an ability to identify and use appropriate technical literature; and
- an ability to conduct standard tests, measurements, and experiments and to analyze and interpret the results to improve processes.

One of the course competencies is for students to develop an understanding of the industry requirements for providing an accurate and complete set of results for an FEA study. As stated by authors, [6], [7], [8] FEA is most effectively delivered using a combination of understanding the concepts of FEA fundamental theory and understanding the common commercial software. The commercial software used for the majority of the course is Siemens NX version 12 using the simulation applications. Additional software used for some projects is the Altair HyperMesh structural analysis software.

The software used in the course was chosen to give the students exposure to a couple of different software platforms. As in industry, analysts are often exposed to different types of analysis tools. Exposing students to different platforms helps the students understand the functionality of commercially available software packages. In the case of linear static analysis taught in this course, the pre-processing and post-processing techniques are quite different between software packages, however, the solvers are inherently the same. This is an important teaching point for students to understand the same problem, set up identically in different programs will yield the same results.

Initially, the students tend to migrate towards the software package that looks easiest to use. If the students are accustomed to windows-based menu options, they tend to like using Siemens NX. If they prefer using a more traditional style of command options, they tend to use HyperMesh. Both software platforms perform very well with setting up analysis problems and both have very good post-processing capabilities. After exposing students to the two software packages, they ultimately choose the software package that aligns with the methodology of formulating a problem.

Although this course has topics ranging in many CAE analysis tools, this paper is restricted to structural analysis, and specifically the competencies related to; 1) element selection, and 2) reporting results. The course is comprised of a recitation and lab. During the recitation, the finite element method is taught so the students learn how the software calculates displacements and stresses. Understanding how to formulate a stiffness matrix, how boundary conditions are treated, and what degrees of freedom are available for a specific node is essential for appreciating how the calculations are performed by the software. This helps the students understand the importance of element choice as it relates to the analysis results.

The laboratory portion of the class is set up using a series of instructional labs and assignments. The instructional labs are designed to expose the students to finite element software. Students import geometry, mesh the model, define properties, apply boundary conditions, create a solution set and then solve the model. Once the model is solved, the students learn how to display the results properly. They end up using a variety of element types and mesh densities during the semester and learn how the different elements react. As typically seen in an industrial setting, element selection and element performance are common errors in finite element analysis. Laboratory assignments reinforce the instructional labs and help the students learn how to display their results in a logical manner by writing a lab report. Excerpts from student reports are available in Appendix A and B for examples of the format and content for the student project reports.

Data Collection Methods

The presumption is that skills for accurate analysis not only come with many years of experience, but that there are certain teaching methods that can help develop an FEA mindset for students. The common understanding that “junk in = junk out” has very much proven to be accurate, but students need to understand what is “junk”. The theoretical understanding of restricting a body from rigid body motion, and the type of elements to use for meshing are examples of concepts being assessed. The results from the student self-reflection survey of the industry relevant requirements of this FEA course may provide formative feedback for continuous course improvement. Along with student self-reflection, industry partner feedback is intended to validate that the reports that students have developed in class are relevant to industry requirements.

To provide feedback for the course offered from 2018-19, a survey of previous enrolled students was conducted in fall 2019. The survey was administered by email to 22 students, which was the total number of students enrolled in two semesters of the course. The number of responses to the survey was just 36.4% (N = 8). Even though this is a small sampling, the course should be fairly fresh in the memories of students having either just finished the course or having completed the course the year prior.

The survey instrument consists of seven questions, three ranking type questions and four open-ended questions. The survey was sent via email to students December 3, 2019 and they were asked to complete the survey by Dec 13, 2019. The ranking questions were intended to determine how well students understood the importance of certain concepts, and to rate their level of accomplishment on FEA tasks. The open-ended questions provide the students the ability to expand on the advantages of certain FEA methods and to describe their biggest takeaway from the course. The self-reflection survey instrument is available in Appendix C providing additional detail.

A select number of industry representatives were chosen to provide feedback on the format and quality of the student lab reports from the CAE and FEA Methods. The industry representatives are engineering managers familiar with reading and providing feedback on FEA analysis of structural projects. The industry survey questions were rankings of quality of sections of the report and an open-ended question related to what was good as well as what could be improved upon. The industry perspective survey is available in Appendix D providing the question format administered by email during the month of January 2020.

Results of Student Self-Reflection Survey

Question 1: Rank order the following FEA principles you think would be most beneficial in industry applications. Use the scale: "Somewhat Critical = 1" "Critical = 2" and "Very Critical = 3".
The results are a very close rating of "Element Selection and Behavior" and "Displaying and interpreting results of FEA for reports" which were rated lower than "Recalling commands specific to the FEA software" given there are many software packages that can be used to perform FEA.

RANK	CHOICE	WEIGHTED RANK
1	Element selection and behavior	1.86
2	Displaying and interpreting results of FEA for reports	1.88
3	Recalling commands specific to FEA Software	2.13

Figure 1: Question 1 Results

Question 2: Rank order your most accomplished element meshing principles learned in this CAE & FEA Methods course. Use the scale: "Somewhat Accomplished = 1" "Accomplished = 2" and "Very Accomplished = 3".

Results show a very clear rank order of the three areas showing that students presumably practiced several modeling techniques and "understanding the effect of shear locking with 3D elements" less than the other element meshing techniques.

RANK	CHOICE	WEIGHTED RANK
1	Understanding the effect of shear locking with 3D elements	1.38
2	Uses of 1st order tetrahedral vs. 2nd order tetrahedral elements	2.00
3	2D element selection and 3D element selection	2.50

Figure 2: Question 2 Results

Question 3: Rank order the sequence of steps to consider for output of accurate FEA results. Use the scale: "First to Consider = 1" "Second to Consider = 2" and "Third to Consider = 3".

Results show a fairly close ranking order of two items, but the last ranked item "interpreting constraints from structure diagrams as pinned, roller, etc" was ranked last.

RANK	CHOICE	WEIGHTED RANK
1	Applying nodal degrees of freedom for 1D, 2D, and 3D elements	1.75
2	Applying proper boundary conditions	1.88
3	Interpreting constraints from structure diagrams as pinned, roller, etc.	2.38

Figure 3: Question 3 Results

The remaining questions 4-7 are open-ended. The results are provided in table 1 as a summary of the most common responses. Question 4 asks students to list the "advantages of importing certain file types (geometry) into a FE pre-processor". The results show that the highest frequency of response has to do with making FEA easier by reducing time and effort in different ways. Question 5 asks students to comment on "utilizing convergence to reduce error in FEA". The results show that the highest frequency of response is providing accurate FEA results. Question 6 asks student to comment on the advantages of post-processing data, displaying the results clearly. The results show that the highest frequency of response is providing understanding of the results through visualization techniques. Question 7 asks student to comment on the biggest take-away from this CAE & FEA Methods course. The results show that the highest frequency of response is that FEA is important, there are important steps, and that FEA is an incredible, effective, and helpful tool for mechanical engineers.

Table 1: Responses to Open-ended Questions

#	Common Responses	Frequency
4	“**reduce** overall preprocessing time”, “**easier** to create desired geometry”, “mesh the model much more **quickly and easily**”, “**easily** determine certain conditions”, and “hand-calculations would be **too cumbersome/difficult”**	5 out of 8
5	“proper **solving**”, “**not create errors** within the analysis”, “achieve **more precise results**”, “to get more **accurate results**”, and “to ensure the **correct mesh size**”.	5 out of 8
6	“simple to **understand**”, “**understand** and read the answers”, “to **visualize** mechanical behavior”, “**view the results** of your model”, “easier for people unfamiliar with FEA to **understand results**”, “results into a **universal image**”, and “Provides a **visual for presentation**”.	7 out of 8
7	“FEA and CAE are **important**”, “….are the most **important** parts of FE modeling”, “**incredible** in terms of displaying complex information”, “very **effective** tool”, “….are **important** to defining a proper analysis”, “very **helpful** tool”, and “more **importantly** how to interpret and utilize the results”.	7 out of 8

Results of Industry Survey

Two company representatives were asked to assess two sample FEA reports from students enrolled in the Fall 2019 CAE and FEA Methods course. The FEA reports are available in Appendix C for additional information. The industry survey results indicate that there are certain areas of the FEA reports that be improved upon. For instance, company A representatives rated the reports using a 1-5 scale as 3 (Good), and had some suggestions for improvement (see Table 2).

Table 2: Industry Survey Responses company A

Industry/Survey Question	**Comments**
Company A/ Concerns about the FEA reports	“… should be noted that the increased weight and potential cost incurred by adding more materials. Adding mass and thickness is only one solution where stiffness may be an option.”
Company A/ Concerns about the FEA reports	“… the overall report organization (Key Elements) Start with a table of contents i. Problem statement Executive Summary of results (1-2 sentences) ii. Model Setup Loads, Boundary conditions, Elements, Material Properties iii. Analysis Results, Correlation to hand calculations

	iv. Conclusions/Recommendations All pictures/graphs should be labeled and referenced in the body of the report (Student 1 does a good job)"
Company A/ Concerns about the FEA reports	"Both reports seem (to be) using first order element. In the industry, 2nd order is the standard for the accuracy. StudentLab#1: The jack model can be set up to symmetry. For the product, it seems buckling analysis should be also performed. In addition, the report did not show the elements, so not sure if the mesh is good enough at critical locations. In addition, showing stress at locations of constraints and RBE2 is not recommended unless there are enough test correlation done. StudnetLab#2: Again, using 1st order element is not recommended, especially there are many TRI elements. Need to change all TRI elements to QUAD. Same for the tetrahedral element to Hexahedral element for the 1st order element. The report does not clearly describe materials on all components."
Company A/ should sections be omitted?	"All areas are relevant and should be kept in the report."

Two company representatives from Company B were asked to assess the same two sample FEA reports. The industry survey results indicate that there are some areas for improvement, but also indicate they meet the quality of reporting in their business. Representatives rated the reports using the 1-5 scale as 5 (Excellent) and 4 (Very Good). Suggestions for improvement are listed in Table 3.

Table3: Industry Survey Responses Company B

Industry/Survey Question	**Comments**
Company B/ Concerns about the FEA reports	"… Liked seeing extra analysis and hand calcs, but I would have added other components, so that you could get the whole picture." "Element quality checks, important to familiarize with industry standards: Jacobian > 0.7, etc."
Company B/ Concerns about the FEA reports	"Have the students suggest an appropriate FS (factor of safety) and material that meets this FS. Maybe have students simply change materials and compare stresses in new material to old to answer the question – Does material change stress levels in the part? This would help them understand that stress levels are a result of geometry not material properties, a common misconception."
Company B/ Concerns about the FEA reports	"Bearing Load: Pin loading stand should be a semi-circle to avoid tensile forces in RBE2 elements. Maybe mesh both ways to demonstrate differences in results."
Company B/ should sections be omitted?	"I thought it was all relevant – wouldn't omit anything."

Conclusions & Recommendations

The student survey results revealed anticipated results for the majority of the reflective inquiries. For instance, students rank “element selection and behavior” and “interpreting and displaying results” topics as approximately equally critical to understand, but the highest ranked item was “recalling FEA software commands”. This result indicates the understanding that FE problems can be analyzed by a variety of software packages, and understanding the modern tools used in industry applications is very critical. Conversely, an unanticipated response was that students ranked “interpreting constraints from structure diagrams as pinned, roller, etc.” as last in the sequence of steps to solve FE problems. This is contrary to most projects which require interpretation of the constraints from the structure diagram, which usually requires creating free body diagrams, prior to applying the constraints to a FE Model. Students surveyed either misunderstood the reflective question, or this may indicate that more emphasis in the course should be directed towards interpreting structure diagrams and creating free body diagrams prior to starting an FE Model.

The industry perspective survey responses verify that the student FEA report content, procedures and result formatting is comparable to the expectations of the industries polled in this study. It is recommended that further responses from a wider variety of industry representatives would validate this conclusion. As would be anticipated from any company, additional sections may be added to each report, consistent with their specific company requirements. An industry representative recommended a format for comprehensive reporting that will be used as an example to improve student lab reports in FEA courses.

Student and industry responses related to first order and second order element selection is a topic of some contention. The interpretation from the student responses are they are less accomplished at “first order and second order tetrahedral element selection”, and “2D and 3D element selection”. One industry response argues that second order element selection should always be used for increased accuracy in results. Students are introduced to many types of meshing and solving techniques in this FEA course emphasizing the advantages and disadvantages of each. An introduction to different types of elements is a key role in understanding the interaction of different element types. This is one area where experience can play a role in correct element choice at the start of the analysis project.

The student must understand the compromise that is made in computing time over accuracy. For instance, some FE solutions are required for a designer to generalize the level of stress in a part to optimize the model by adding or eliminating material, while other FE analysis is performed prior to physical testing to accurately predict stress to assist in setting up validation physical testing procedures requiring more accurate results. Students must also understand how first order elements behave when used with second order elements. Adding an additional lab exercise that requires students to model using 2D, 3D, first order and second order elements on various scenarios is recommended. The time to solve, number of elements, percent accuracy in comparison to theoretical results can be reported with a recommendation for the most appropriate method to use in various scenarios.

Acknowledgements

Thank you to representatives from Company A providing industry perspective survey responses; Dr. Brian Wang (FEA manager), Leonard Jenaway (Chief engineer) and Company B for responses Zach Bustos (Engineering Manager), Sam Hanson (FEA Lead Analysist), and Erik Kocher (Project Manager).

References

[1] C. M. Watson, "Design Refinement by Iterative Virtual Experimentation (DRIVE): A Methodology to Solving Engineering Design Problems," MS thesis, College of Science & Technology, Morehead State University, Morehead, KY, 2015.

[2] N. Parmar, "Design of Fixture: A Review," *International Journal of Advance Research and Innovative Ideas in Education*, 2(3), pp. 1992-1995, 2016.

[3] Z. Ahmad, T. Sultan, M. Asad, et al. "Fixture layout optimization for multi point respot welding of sheet metals," *Journal of Mechanical Science and Technology*, 32, pp. 2967, 2018. doi:10.1007/s12206-018-0553-6

[4] J. L. Irwin, S. S. Mehendale, "Simulations and Manipulatives used to Better Understand Graphics, Statics & Dynamics Concepts," *In AJ Hamlin (Ed.), Engineering Design Graphics Journal, Greenville: ASEE Engineering Design Graphics Division*, 82(2), pp. 9, 2018.

[5] J. L. Irwin, "Utilizing Parametric 3D Solid Modeling to Illustrate Statics and Strength of Materials Concepts." in *Proceedings of the 2018 ATMAE Annual Conference, Kansas City, Missouri, November 7-9. 2018*, ATMAE, 2019. pp. 146-152.

[6] R. Shih, "The applied finite element analysis course at Oregon Institute of Technology." In *Proceedings of the 2007 ASEE Annual conference and Exposition, Honolulu, Hawaii, June 24-27, 2004*, American Society for Engineering Education, 2007.

[7] R. L. Roberts, "Teaching Finite Element Analysis for mechanical undergraduate students," Doctoral dissertation, Wentworth Institute of Technology, Boston, MA, 2019.

[8] J. L. Irwin, "Three-way Comparison Used to Reinforce FEA Solutions." In *Proceedings of the 2008 ASEE North Midwest Section Conference, Platteville, Wisconsin, October, 2008*, ASEE North West Section, 2008. pp. 10.

Appendix A: Excerpts from Student Report 1 provided to Industry Representatives

Report 1 – Problem Statement Section

A jack stand base, like the one shown in figure 1 is commonly by mechanics to support automobiles during repairs. The stand in question is rated for supporting a load of 6,000 lb. This stand base is composed of 0.25 inch thick A36 steel. The modulus of elasticity of the material is $29.7e^6$ psi, and the poissons ratio is 0.29. The mass density of the material is $7.34e^{-4}$ lb-sec^2/in. The finite element analysis of the 0.25 inch thick stand will be completed to show that the stand will withstand the rated load.

For comparison, we will be analyzing a 0.125 inch thick A36 Steel jack stand under the same loading conditions. We will determine if the 0.125 jack stand will be able to withstand the load without failure.

Within the report, findings of the analysis will be presented along with supporting hand calculations.

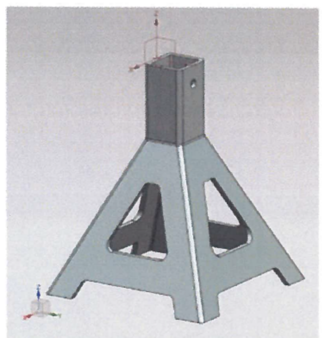


Figure 1: A36 Steel Jack Stand Base

Report 1 – Final Results Section

The next FE analysis was conducted on the model with the 0.25-inch thick cross section with shell elements. The stresses can be seen to be below the yield strength of the A36 steel. This analysis backs up the rated load of 6000 lbs. for the designed jack stand base. The maximum stress value from the FE model can be seen below in Figure 6.

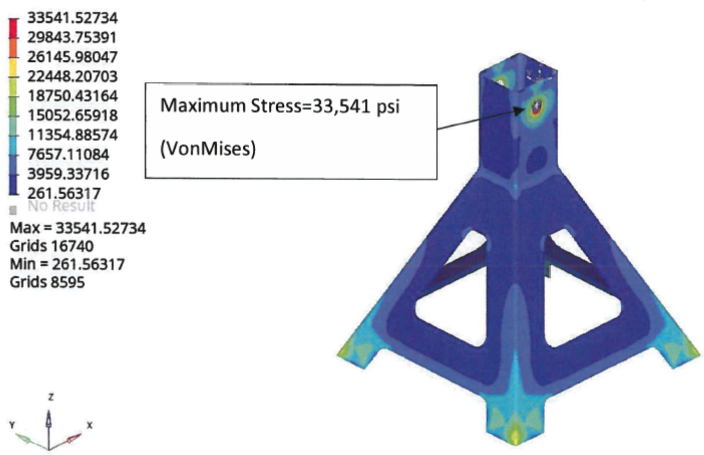


Figure 6: VonMises Stress Results for 0.25-inch thick Jack Stand Base

Report 1 – Summary Section

Based on the findings presented in the report, it is recommended to use a 0.25-inch thick plate for the jack stand base. The 0.125-inch thick plate is not recommended as the maximum VonMises stresses found in the analysis are far over the yield strength of the A36 steel material. The 0.25-inch plate jack stand base can support the 6,000 lb. load. The factor of safety for the 0.25-inch-thick plate is just over 1. This can be improved by using 0.375-inch plate.

Appendix B: Excerpts from Student Report 2 provided to Industry Representatives

Report 2 – Problem Statement Section

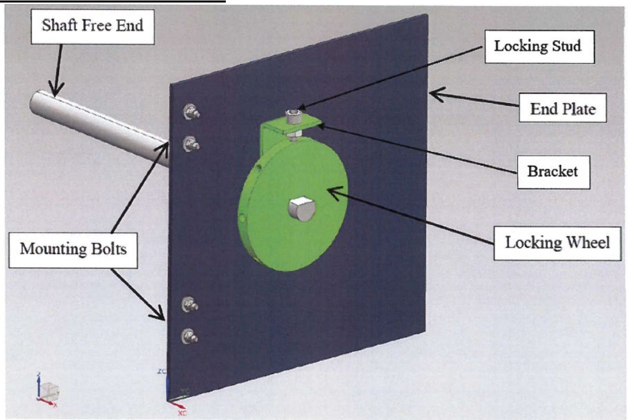


Figure. 1.

Figure. 1. Shows an assembly of shaft, end plate, locking wheel and a bracket. A torque of 9000 lb-in is applied at the free end of the shaft. The locking wheel showed in the figure is used to prevent rotation. The material used for the shaft is SAE 4140 steel, the End Plate is made from 6061-T6 Aluminum and the Bracket is made from 1060 steel. The analysis of the above design is done against the applied torque to see it the respective materials can withstand the resulting stresses and deformations. If not, the design should either be changed, or stronger materials should be used for the same design. The simulation is done using a variety of elements- solid, shell, beam and rigids used for different components.

Report 2 – Constraints Section

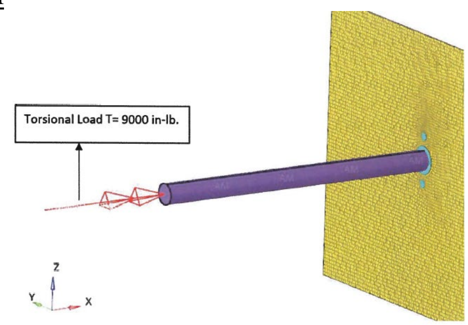


Figure. 14.

A torsional load of 9000 in-lb. is applied at the free end of the shaft along the X-axis as shown in Figure. 14.

Report 2 – Calculations Section

Shear stress in the torqued shaft

T = torque = 9000 lb-in

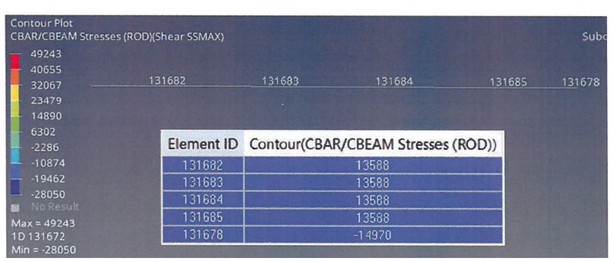
c = radius = 0.75 in

$J = \frac{\pi d^4}{32} = 0.5 \text{ in}^4$

$$\tau = \frac{T \times c}{J}$$

$$\therefore \tau = \frac{9000 \times 0.75}{0.5}$$

$$\therefore \boxed{\tau = 13,500 \text{ psi}}$$



Appendix C: Student Self-Reflection Survey Instrument

MET4660 CAE & FEA Methods
Student Self-Reflection Survey of the Industry Relevant Requirements

1) Directions: Rank order the following FEA principles you think would be most beneficial in industry applications. Use the scale: “Somewhat Critical = 1” “Critical = 2” and “Very Critical = 3”

_______________ Element selection and behavior
_______________ Displaying and interpreting results of FEA for reports
_______________ Recalling commands specific to FEA Software

2) Directions: Rank order your most accomplished element meshing principles learned in this CAE & FEA Methods course. Use the scale: “Somewhat Accomplished = 1” “Accomplished = 2” and “Very Accomplished = 3”

_______________ 2D element selection and 3D element selection
_______________ Uses of 1st order tetrahedral vs. 2nd order tetrahedral elements
_______________ Understanding the effect of shear locking with 3D elements

3) Directions: Rank order the sequence of steps to consider for output of accurate FEA results. Use the scale: “First to Consider = 1” “Second to Consider = 2” and “Third to Consider = 3”

_______________ Applying proper boundary conditions.
_______________ Applying nodal degrees of freedom for 1D, 2D, and 3D elements.
_______________ Interpreting constraints from structure diagrams as pinned, roller, etc.

4) Open ended question: Answer in 30 words or less.
Advantages of importing certain file types (geometry) into a FE pre-processor.

5) Open ended question: Answer in 30 words or less.
Utilizing convergence to reduce error in FEA.

6) Open ended question: Answer in 30 words or less.
Advantages of post-processing data, displaying the results clearly.

7) Open ended question: Answer in 30 words or less.
What is your biggest take-away from this CAE & FEA Methods course.

Appendix D: Industry Perspective Survey Instrument

ASEE FEA Paper - Questions for Industry

Email language

Dear XXXXX,

I am contacting you because I would like you to review a couple of recent student reports from the the CAE and FEA Methods course in the MMET Department. The purpose of the review is to evaluate the quality, completeness and relevancy of the reports. The results of student surveys in this course along with your review will be used to improve the course content, and will also be submitted to an engineering education conference to be considered for publication in their annual proceedings.

Please respond to the following prompts by email:

1) How would you rate the quality of the FEA report in comparison to industry standards that you are familiar with in your business? (Please comment)

1 = Poor

2 = Fair

3 = Good

4 = Very Good

5 = Excellent

Comment:

2) What concerns do you have in regards to completeness of the FEA project reports?

3) In your opinion are all sections of the report relevant to the understanding of the analysis, or should sections be omitted?