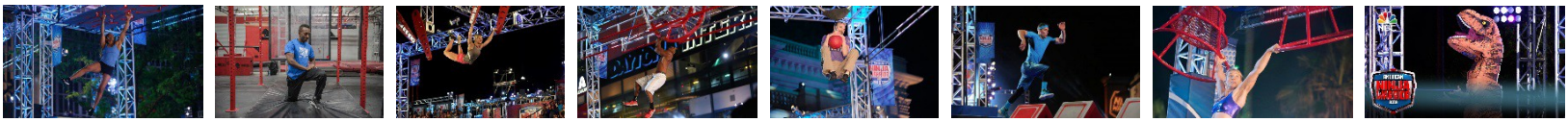

ES 2502 B'18– Stress Analysis Term Project

American Ninja Warrior Obstacle Design

Submission 4 – Combined Loading and Principal Stresses

Introduction:

This final submission will be the culmination of the project you and your team have worked so hard on this term. You will be completing a combined loading analysis and determining the principal stresses at multiple locations on your obstacle. The ultimate goal is to determine the weakest point within a component of your obstacle based on the loading applied by a user.

You have received feedback multiple times throughout the term for ways to improve you submissions. This final submission should incorporate all of that feedback to make the best possible final submission. This final submission should be a standalone document that is polished and professional. You should feel proud enough with your submission that you would be excited to show it to a potential employer as a demonstration of your technical skills. Please do not take your previous submissions, copy and paste them together, and then add on to the end. Use care when incorporating content from old drafts. Be sure copied pieces match the flow and fit in the analysis of the final submission. It is often easiest to start a completely new draft and then incorporate pieces from older submissions when appropriate.

Submission Technical Requirements:

The objective of this final project submission is to incorporate much of the technical analysis that was covered in this course into a single combined loading scenario. The order and method in which you conduct your analysis is up to you and your team. The order should be easy to follow and add to the clarity of your analysis. Your analysis should include the following technical content:

1) Determine a component within your design that experiences one of the three following combined loading scenarios:

    a. Bending and torsion
    b. Bending and uniaxial loading
    c. Bending, torsion, and uniaxial loading

    Many of you will already have this component in mind as it can likely be the component that you have been analyzing for the majority of the project.
2) Conduct a statics analysis to determine the external reactions acting on your component
3) For each of the loading types, calculate and internal loading and plot this in the form of V, M, N, or T diagrams (you should draw all diagrams that apply to your system)
4) Based on the internal loading diagrams, determine the critical section(s) within your design. The critical section(s) are the location(s) where the loads are maximum for the structure. (i.e. location along the bar with maximum V, M, N, T. These loads may be maximum at different locations along your structure)

5) If the critical section is the same for all load types, this will be the location for the rest of your analysis. If you have multiple critical sections, you will evaluate at the critical section for the moments (where M is the largest).
6) At the critical section for your component, calculate the stresses due to your applied loading at a "vertical" cut (a cut perpendicular to your member (this may be horizontal depending on the orientation of your design)).
7) Draw the distributions of stresses at the critical cross section for each of the applied loads.
8) Draw stress elements for two locations on this cross section, one at the middle of one of the sides (whichever side will have larger combined loads) and one at either the top or bottom of the structure (whichever side will have larger combined loads).
9) Using either Mohr's circle or the equations developed in class, determine the principal stresses and the maximum shear stress in the system.
10) Draw rotated stress elements for the principal stress and maximum shear stress orientations for each of your stress elements.
11) Calculate the von Mises stress for each of your elements. We did not cover this in class, and you will learn about the theory behind it later in your ME curriculum. For now, just apply the equation shown in the description section below.
12) Calculate the safety factor for your structure for your loading scenario using the von Mises stress as the applied stress and the maximum tensile strength for your material as the failure stress.

To supplement the technical content explained above, you should include comments to guide the reader through your work. You should include an introduction to the technical work to describe the analysis you are about to conduct, comments all the way through as you do your calculations, and an evaluation of your calculations at the end of your technical analysis.

Use the rubric as your guide as you go through making this final report.

Von Mises Stress:

Von Mises equivalent stress is a technique used to analyze the failure of ductile materials. The theory takes into account the effects of having multiple stresses at a given location to determine the overall effect to the material. The equation for von Mises equivalent stress is as follows:

$$\sigma' = \sqrt{\sigma_1^2 - \sigma_1\sigma_3 + \sigma_3^2}$$

Where σ_1 is your largest principal stress, σ_2 is zero, and σ_3 is the smallest principal stress (a negative value).

Teams and Team Roles For Submissions:

Submission 4: You can choose what works best for your team. You must come up with a written plan for how you will complete the final project and include this plan at the end of the draft work with the submission. I recommend one of the following work schemes, but you are welcome to develop another method that works for you:

1) work as independent subgroups on all parts of the project, swap with the other subgroup and QC/synthesize your work

   or

2) have one group serve as the lead technical group, and the other serve as the QC group

   or

3) break the project up into pieces and each subgroup does some technical work and some QC

This plan must include all tasks for the project, which person will complete each task, the date by which each task will be completed, and the actual date that the task was completed. This will serve as a checklist for your team for this submission.

Peer and Self-Evaluations: For each submission, each team member must fill out the peer and self-evaluation form on CANVAS in order for the team to receive a grade for the submission. It is highly encouraged that you work with your team mates throughout the project to give them in-person feedback on their performance in the group. These evaluations will be used as a way to assess each student's individual contributions to each of the submissions.

Deliverables:

For the final submission, you will be delivering the following content as two .pdfs. One for the poster, and one for all other content. As with submission 3, there is not template to allow for your creativity with the final submission layout. (the peer and self-evaluation will be submitted individually through a CANVAS survey).

- Written proposal from large group
    - The proposal is written to the obstacle selection committee at ANW. It may be written in terms of a traditional paper or as a letter. It should include a description of your obstacle, the ways in which people would use it, the ways in which it could be incorporated into an obstacle course, why your obstacle would appeal to the viewing audience, and other elements of your choosing. This has a maximum length of 2.5 pages.
- Technical analysis including all details described in the submission technical requirements section.
- All draft work used for the submission
- The written work plan that your large group developed for this submission and used as a check list
- Final Poster (digital submission as a separate .pdf)
    - Your poster is your chance to visually explain your obstacle to the obstacle selection committee. It should include information that would help the selection committee choose your design. This may include:
        - How your obstacle will be used
        - How your obstacle is different from others that already exist
        - Why the viewing audience would like your design
        - How the design can be portable between different cities
        - What factors you used to make decisions about geometries, materials, or other specifications
    - The poster should be visually appealing and should be clearly understood
    - Remember to think about your audience, what information they already know, and what information would they want to know from your posted to make a selection decision.
    - The poster may have dimensions of 4'x3' or 3'x4' or another size if you are making an info graphic style poster. You can make this poster in whatever program you choose, but it should be converted to .pdf for the submission
- Individual submissions of peer and self-evaluations
    - This is submitted separately on CANVAS and is not part of the team submission.

Rubric: (note: the final submission is worth 300 points, this 100 points will be multiplied by 3 when entered into your grades)

Category	Exceeds Expectations (95% ±5%)	Meets Expectations (85%±5%)	Acceptable (75%±5%)	Needs Improvement (50%±25%)
Professional Appearance (10 points)	Final submission is clean, polished, professional. Draft work is in draft form, but the overall document still appears professional	Final submission is clean, polished, professional. Draft work is in draft form but cannot be followed easily due to its integration into the overall report	Final submission is somewhat clean, but either due to messy work or poor scanning does not look polished and professional.	Final submission is not clean and does not meet a professional standard.
Poster submission (10 points)	-The size and distribution of text and graphics are balanced. -It is visually attractive in terms of color, design, and flow.	-The size and distribution of text and graphics are balanced. There are 1 or 2 problem areas -It is generally visually attractive in terms of color, design, and flow. -There are one or two problem areas	-The size and distribution of text and graphics makes the poster difficult to read. There are 2 or 3 problem areas -It is often not visually attractive in terms of color, design, and flow. -There are two or three problem areas	-The size and distribution of text and graphics makes the poster difficult to read. There are more than 3 problem areas -It is not visually attractive in terms of color, design, and flow. There are more than three problem areas.
V, M, T, N diagrams (20 points)	Diagrams are correct, fully labeled, and clear.	Diagrams have minor errors. There is 1 minor error in the calculations	Diagrams have major errors. There are 2 minor errors or 1 major error in the calculations.	Diagrams are omitted or cannot be read. There are more than 2 minor errors or more than 1 major error in the calculations.
Stress Calculations (30 points)	Calculations were error free and included plots, maximum stress, and drawn stress distributions.	Minor errors were made and/or one of the required elements was limited (plots, max stress, stress distributions).	Major errors were made and/or one of the required elements was limited or omitted (plots, max stress, stress distributions).	Major errors were made and/or two or more of the required elements was limited or omitted (plots, max stress, stress distributions).
Stress Elements (10 points)	Elements are error free. They are clean and easy to understand. They are fully labeled.	Elements have 1-2 minor error2. They are clean and easy to understand. They are nearly fully labeled.	Elements have 3 to 4 minor errors or 1 major error. They are mostly clean and easy to understand. They are mostly fully labeled.	Elements have multiple errors. They may be somewhat messy. Many labels are missing.
Evaluation of Calculations (10 points)	Calculations are evaluated for both mathematical correctness and realistic nature.	Calculations are reviewed but the values are not fully assessed relative to the reasonable nature of the values determined.	Calculations are checked, but not completely. Evaluation of the numerical solution is lacking.	Calculations are not evaluated, or evaluations is minimal.
Written Proposal (10 points)	Writing is strong, formal, and clearly conveys a logical message.	Writing is somewhat strong and/or somewhat formal and/or conveys a message but it is not completely clear.	Writing is weak and/or informal but a message, while possibly not completely clear, is conveyed.	Writing is weak and/or informal and/or a clear logical path cannot be followed.

Extra Credit: (up to +5%)

For extra credit, you and your team may use the provided rubric to grade your final submission. You must provide excerpted evidence from your submission to support your decision for each choice from the rubric.

If you choose to complete this extra credit assignment, you should include it as the final section of your submission.