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MMAE 445 Bracket Midterm Report

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Introduction

This report documents the complete design, analysis, documentation, assembly setup, and manufacturing programming process for the MMAE 445 Midterm Exam. A major focus of this midterm was understanding how design modifications influence strength, manufacturability, and overall performance, particularly when comparing Bracket P1 and P2. The assignment required the creation of two bracket designs, Bracket P1 (#98461) and Bracket P2 (#98462), using SolidWorks for modeling, analysis, drawing creation, and assembly with soft jaws, and Mastercam for CNC programming. Both parts were modeled from provided blueprints, analyzed using Finite Element Analysis (FEA), detailed in fully annotated 2D drawings, assembled in a 5-axis soft jaw setup, and prepared for machining through toolpath programming. The following sections describe the workflow, key decisions, results, and engineering observations.

3D Modeling

The objective for the modeling was to create 3D models of Bracket Quiz - P1 (#98461) and P2 (#98462) using SolidWorks.

P1:

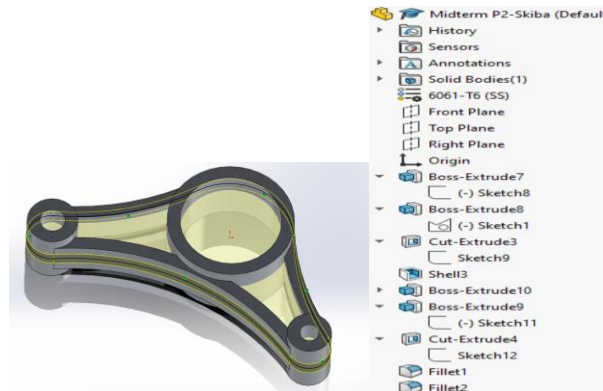
The process to create P1 is shown in the screenshots below.



The model was created first with a sketch and extrusion of the 3 cylinders on the part. Each cylinder was dimensioned to the correct position according to the reference geometry. Following that, an outline of the whole part was sketched and extruded. Then the holes were cut in the cylinders to an edge thickness of .125in for the shell to line up properly. Then the shell command was used to cut the inside of the part. The cylinders were then filled again to a solid then recut to get the correct hole size. To finish P1, the edges were rounded using a fillet.

P2:

P2 followed the same steps as P1, except an extra extrude and fillet were necessary. Before the final cut, an extrude of the whole outline of the part was added, because the shell only left the part with outside walls. After all previous commands, an extra fillet was added to include the extra fillets in P2. There were other changes from P1 to P2 as well. For P2 all extrusions came from the plane and went in both directions. There were also so dimensional changes. The screenshots below show the new extrude added along with the process of creation.



Discussion:

There were many differences between P1 and P2, most of which contributed to the strengthening of the final part. The main physical differences between P1 and P2 include P2's taller cylinders, its symmetry on both top and bottom, its thinner large cylinder hole diameter, and more fillets. These changes were made to strengthen the part and the loads it can support. P2 was also lighter due to it having a smaller volume (see below screenshots).

<p>Mass properties of Midterm P1-Skiba Configuration: Default Coordinate system: -- default --</p> <p>Density = 0.10 pounds per cubic inch</p> <p>Mass = 0.10 pounds</p> <p>Volume = 0.98 cubic inches</p> <p>Surface area = 14.75 square inches</p> <p>Center of mass: (inches)</p> <p>X = -0.23 Y = 0.23 Z = 0.23</p> <p>Principal axes of inertia and principal moments of inertia: (pounds * square inches)</p> <p>Taken at the center of mass:</p> <p>Ix = (0.82, 0.01, 0.40) Iy = (0.82, 0.01, 0.40) Iz = (0.82, 0.01, 0.40)</p> <p>Ixx = 0.82 Iyy = 0.01 Izz = 0.40</p> <p>Ixy = 0.00 Iyz = 0.00 Ixz = 0.00</p> <p>Moments of inertia: (pounds * square inches)</p> <p>Taken at the center of mass and aligned with the output coordinate system:</p> <p>Ixx = 0.82 Iyy = 0.01 Izz = 0.40</p> <p>Ixy = 0.00 Iyz = 0.00 Ixz = 0.00</p> <p>Moments of inertia: (pounds * square inches)</p> <p>Taken at the output coordinate system, using positive tensor notation:</p> <p>Ixx = 0.82 Iyy = 0.01 Izz = 0.40</p> <p>Ixy = 0.00 Iyz = 0.00 Ixz = 0.00</p>	<p>Mass properties of Midterm P2-Skiba Configuration: Default Coordinate system: -- default --</p> <p>Density = 0.10 pounds per cubic inch</p> <p>Mass = 0.09 pounds</p> <p>Volume = 0.91 cubic inches</p> <p>Surface area = 13.75 square inches</p> <p>Center of mass: (inches)</p> <p>X = -0.21 Y = 0.21 Z = 0.21</p> <p>Principal axes of inertia and principal moments of inertia: (pounds * square inches)</p> <p>Taken at the center of mass:</p> <p>Ix = (0.82, 0.01, 0.40) Iy = (0.82, 0.01, 0.40) Iz = (0.82, 0.01, 0.40)</p> <p>Ixx = 0.82 Iyy = 0.01 Izz = 0.40</p> <p>Ixy = 0.00 Iyz = 0.00 Ixz = 0.00</p> <p>Moments of inertia: (pounds * square inches)</p> <p>Taken at the center of mass and aligned with the output coordinate system:</p> <p>Ixx = 0.82 Iyy = 0.01 Izz = 0.40</p> <p>Ixy = 0.00 Iyz = 0.00 Ixz = 0.00</p> <p>Moments of inertia: (pounds * square inches)</p> <p>Taken at the output coordinate system, using positive tensor notation:</p> <p>Ixx = 0.82 Iyy = 0.01 Izz = 0.40</p> <p>Ixy = 0.00 Iyz = 0.00 Ixz = 0.00</p>
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FEA Studies

The objective was to conduct static stress analysis using SolidWorks Simulation.

Setup Summary:

Material: 6061-T6 Aluminum (Yield Strength = 275 MPa)

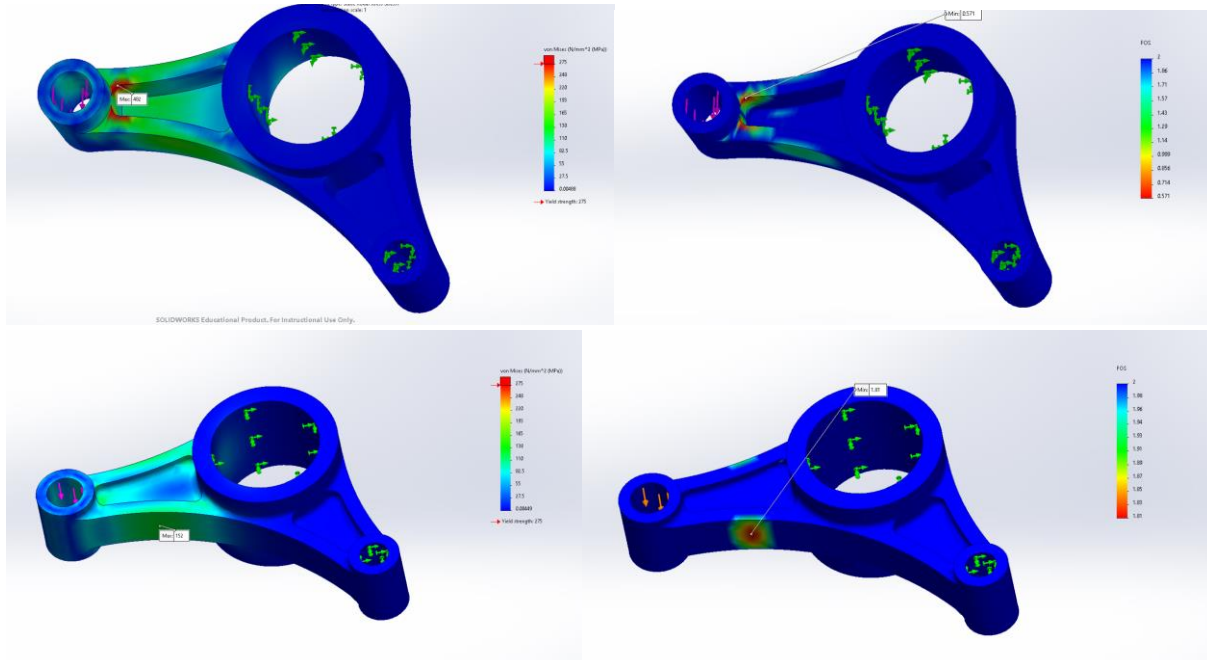
Fixtures: Fixed 0.875" and 0.250" thru holes.

Load: 500 lbf applied to 0.312" hole, directed along the top plane (IPS).

Mesh: Default solid mesh, generated and saved as .stl.

Results:

Parameter	Bracket P1	Bracket P2
Max Stress (MPa)	482	152
Min Factor of Safety	.571	1.81
Weight (lb)	.1	.09



Discussion:

Bracket P1 exceeds the yield strength of 6061-T6 (275 MPa), indicating that the design would plastically deform under the 500 lbf load. In contrast, P2 remains well below yield and maintains an FOS of 1.81. The FEA shows that P2 experiences lower stress concentrations due to improved fillet geometry and load path distribution. Its higher factor of safety indicates a more robust design. The weight difference suggests that the material was moved and removed

strategically to increase strength. Overall, changes were made in order to improve stress distribution to increase the strength of the design.

2D Drawings

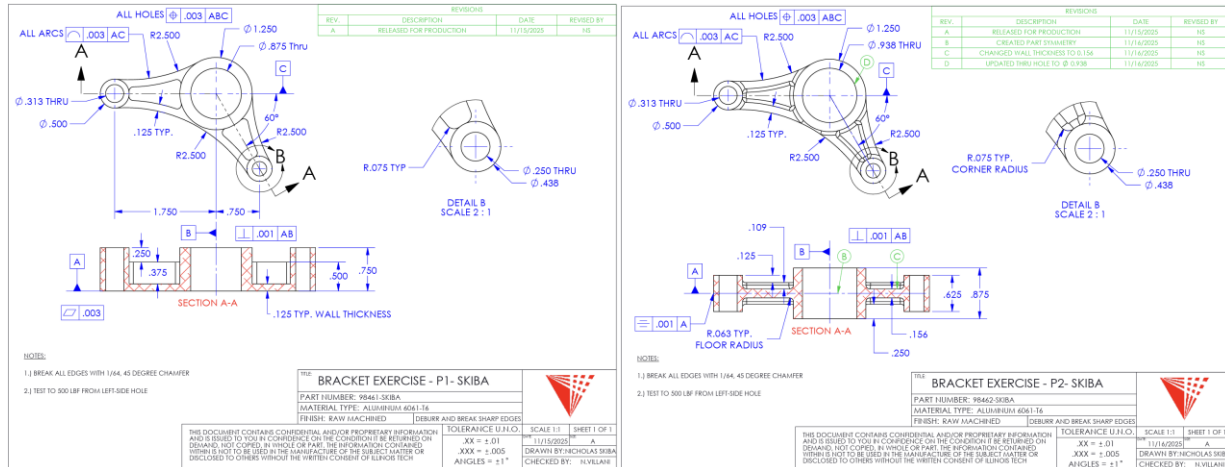
The objective was to create fully annotated 2D drawings for P1 and P2. Features included in these 2D drawings are:

- Proper layers, title block, and revision table
- Views including front, section, and detailed views
- GD&T symbols
- Dimensions per provided blueprint

Discussion:

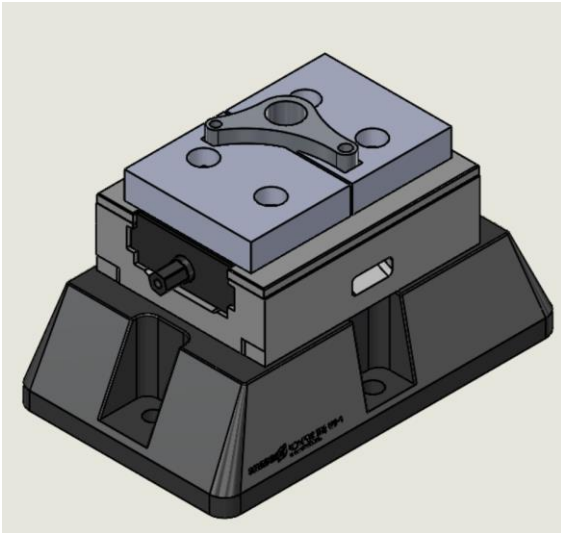
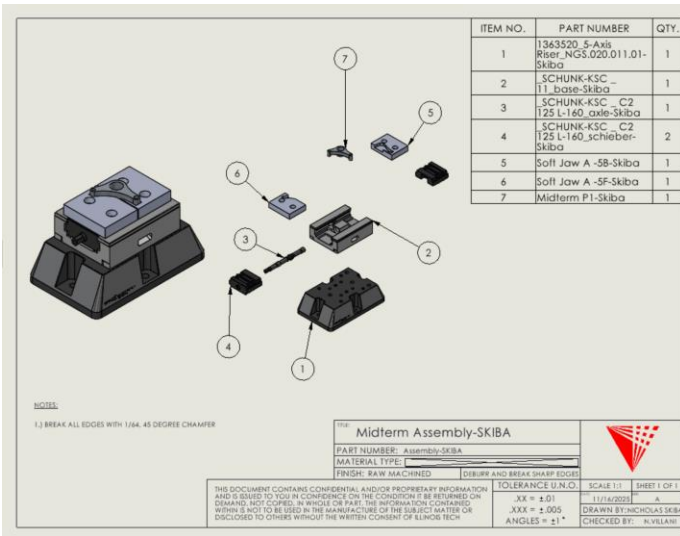
The views and overall layout for both P1 and P2 were about the same. They both included front, section, and detailed views. Those views were the only views needed to display all of the key features of the parts. The section view provided easier views into the part, which was needed because of the shell. The front view provided most of the main details of the part, which were dimensioned. The detailed view provided a zoomed view of the smaller part of P1 and P2, which can help us see the dimensions of those smaller parts more clearly.

GD&T symbols for P1 include profile of a line, position, flatness and perpendicularity. The profile of a line was used for the dimensional tolerances of the arcs. The position was used for giving tolerancing details of the position of the holes. The flatness was used to say that the bottom of the part was flat, and to say the tolerances of the bottom of the part. The perpendicularity was to show the tolerances of how straight up and down the holes can be. P2 had the same GD&T symbols as P1 except instead of flatness, it had symmetry, which says the part must be symmetrical across a certain plane, with a specific tolerance. The GD&T tolerances are tighter than the title block tolerances, to ensure the critical features are as precise as possible. Also, the revision table includes what was changed from P1 to P2 in order to help understand and find the changes. The screenshots of the drawings are below.



3D Assembly

The objective was to assemble the bracket in the 5-Axis Vice and Riser with Soft Jaws. This was done by first mating the soft jaws with a 0.0625" gap using a distance mate. A 0.0625" gap ensures proper clamp force without over-constraining the bracket. Cutting the jaws in-context ensures perfect conformity to the part geometry and eliminates misalignment during machining. Then the P1 bracket was inserted and constrained relative to the soft jaws. Then pieces of the soft jaws were cut out to match the profile of the bracket. Below is the assembly with P1 in it along with the exploded view and callouts to identify the parts.



Parent-Child Relationship: In SolidWorks, a parent feature is a feature in which other features (child) depend on. So, changing a parent feature would make a change in the child feature. For example, an extrude is a parent feature to a shell which is a child feature. A child feature is built on a parent feature, and it is dependent on a parent feature. Understanding these relationships is essential for avoiding rebuild errors, maintaining design intent, and enabling efficient parametric modification.

Programming

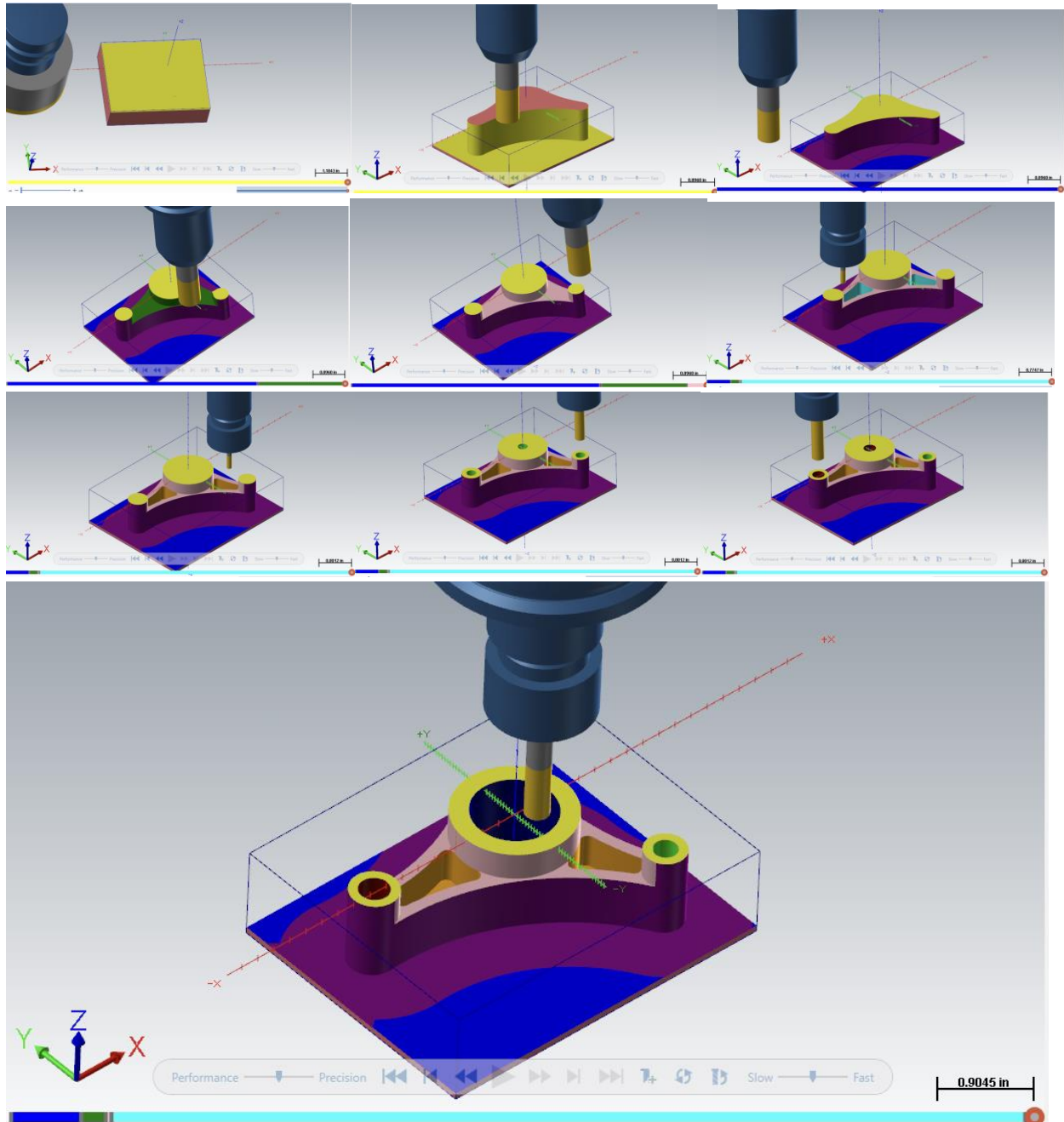
The objective of the programming part is to create CNC programs in Mastercam for both parts. The setup for each part is as follows:

- Stock Material: 3.75 x 3.00 x 1.00 inches
- Tools: From provided tool library

- First Operation: Stock setup, roughing, finishing
- Second Operation: Soft jaw setup, finish pass, and verification
- Verification: Verified toolpaths using Color Loop simulation.

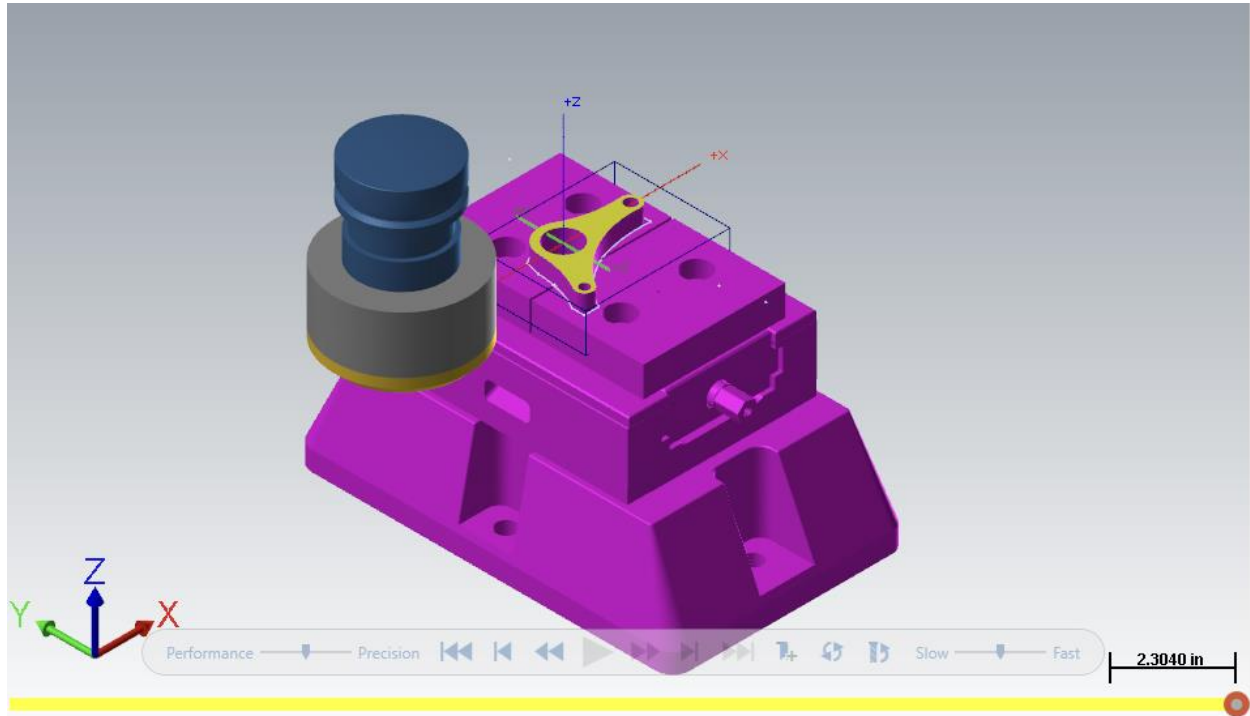
P1-First Op

Below are screenshots of P1 first operation. This is in order from left to right going down. The last operation is missing but it looks the same as the second to last one as it is a finishing operation.



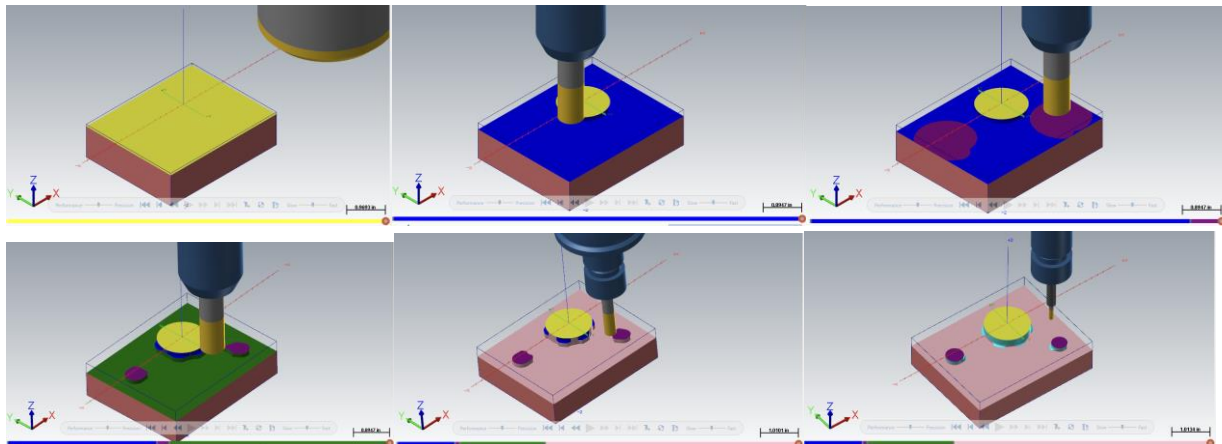
P1-Second Op

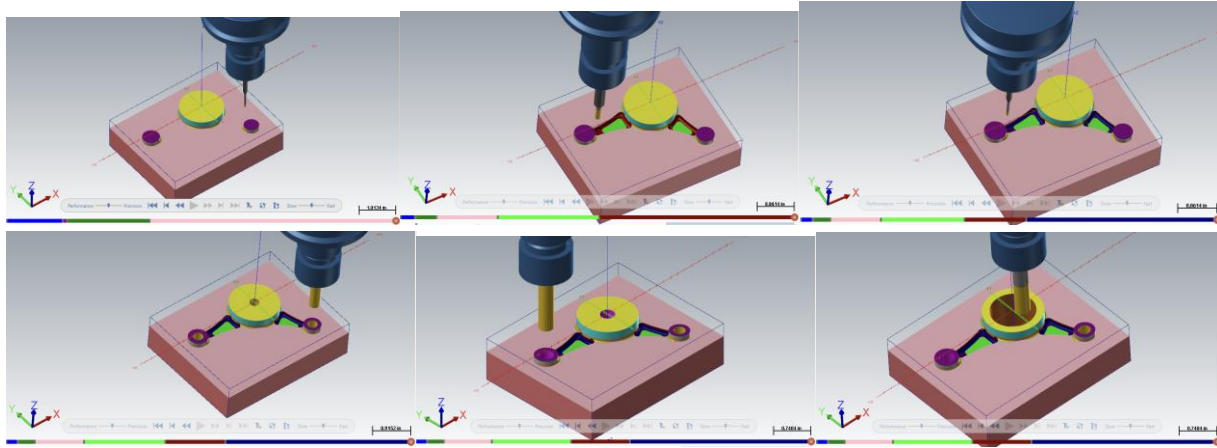
Here is an image of P1 second operation. It is a face mill. There is one more operation, which is a finishing endmill, which looks the same as well.



P2-First Op

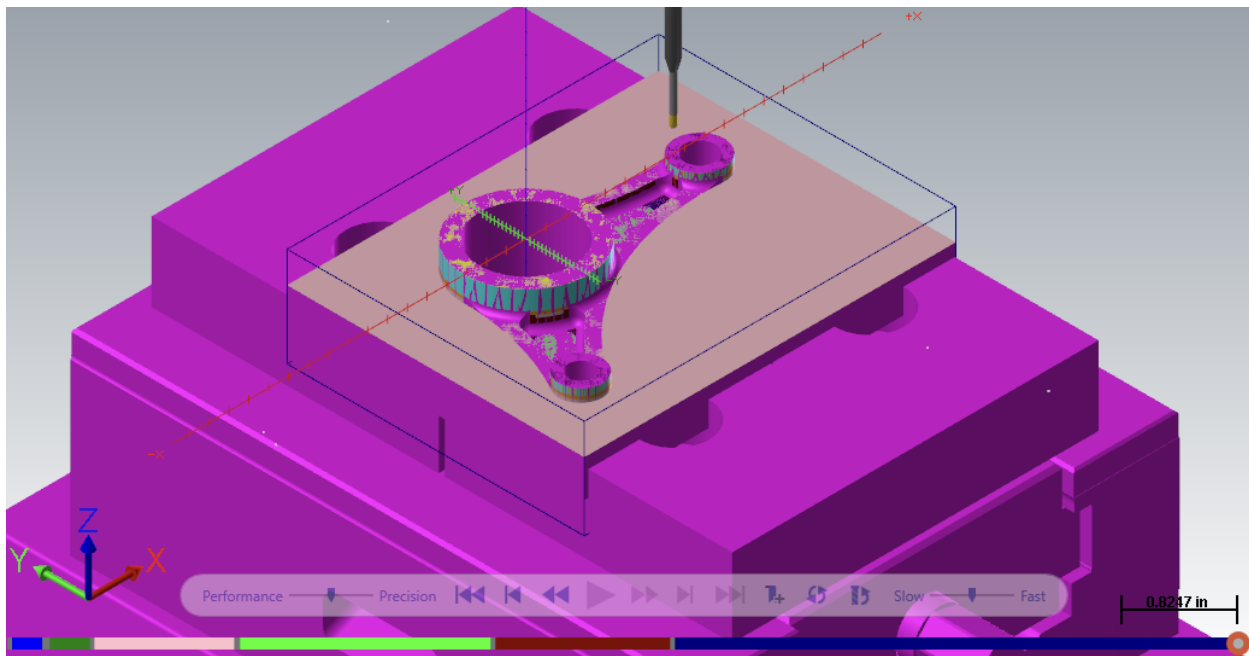
During P2 when trying to cut around the outside of the part, it said that there was a duplicate chain and I could not cut it. The first operation cuts for P2 can be seen below.





P2-Second Op

The second operation looks the same as the first operation with the work holder as well. Also, it is not supposed to have the dynamic cut that cuts around the bracket and does not include the drills.



Discussion:

Using a mix of dynamic endmills and dynamic ball mills, we can get a pretty good result, where only a small portion of the pocket has ridges. With this, all the fillets can be cut as well. P2 uses a 0.125" ball end mill, which has a cutter radius of 0.0625". This radius directly determines the smallest floor radius the tool can produce, so the floor radii in the part are 0.0625" TYP. However, when the ball mill cuts an internal corner, the tool contacts the material higher on its spherical surface and cannot physically reach the sharp intersection of the vertical and horizontal surfaces. Because of this geometry limitation, the effective radius in an internal corner

becomes larger than the tool radius. This results in the corner radii measuring 0.075" TYP instead of 0.0625". In summary, the floor radius equals the tool radius (0.0625"), but internal corners naturally become larger (0.075") because the ball end mill cannot cut directly into the corner.

Conclusion

This project provided a complete workflow experience from CAD modeling through simulation, documentation, assembly design, and CNC toolpath generation. The comparison between P1 and P2 demonstrated the importance of design iteration: P2 achieved lower stress, higher factor of safety, and reduced weight while improving manufacturability. The FEA results confirmed a stress reduction and significant improvement in safety margin. The creation of 2D drawings reinforced GD&T and drafting skills, while the assembly and machining programming sections strengthened the understanding of fixturing and setup strategies. Overall, this midterm integrated key concepts in product design, structural analysis, and manufacturing engineering. This project strengthened my understanding of how CAD design intent directly affects manufacturability and structural performance. The integration of simulation and CNC programming reinforced the importance of designing parts that are both strong and machinable.