AME 485 – Aerospace Structures

Project 4

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Part 1

1. Analyzing the valve, the fixed support and pressure locations are determined in the following images.

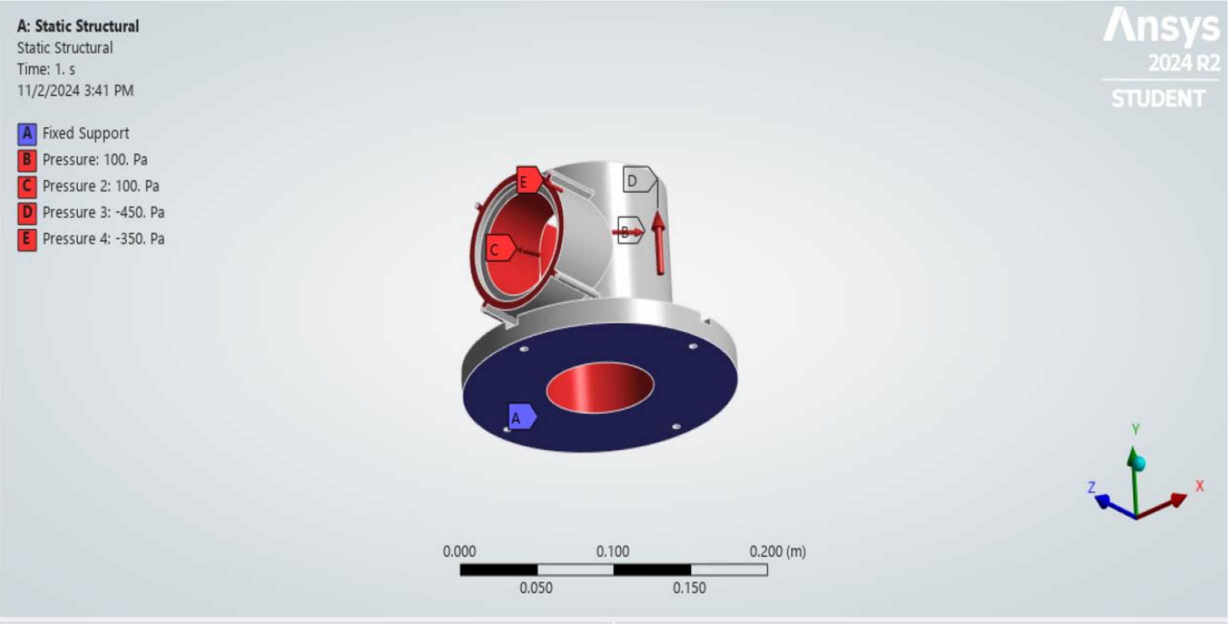


Figure 1: Pressure is determined for each location and the fixed support is placed on the bottom of the valve. B and C both have pressure gradients of 100 Pa while D has a pressure of -450 Pa and E has a pressure of -350 Pa. Values are taken from the YouTube tutorial.

Part 1

1. Analyze the valve, image of the mesh on the part.

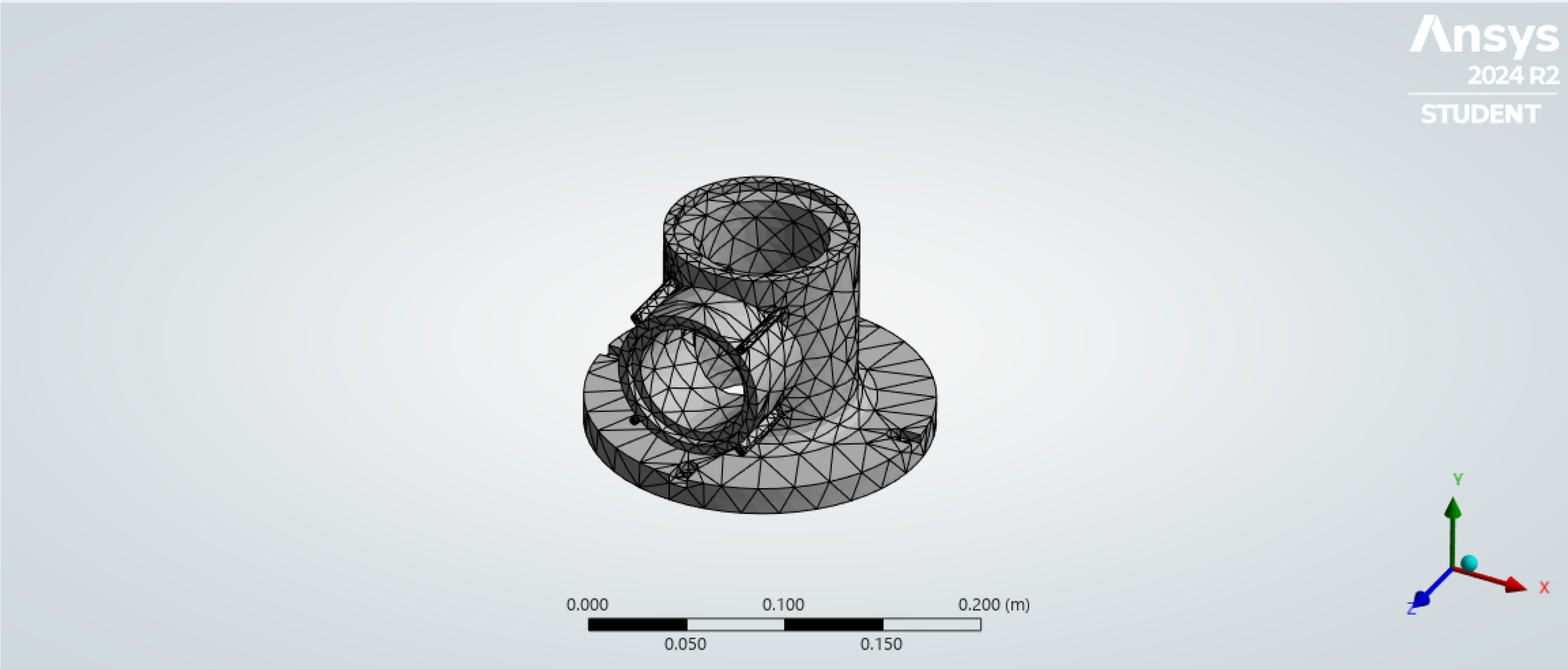


Figure 2: The mesh was determined to be 0.02 as 0.002 was too small for the ANYSYS student license.

Part 1

1. Analyzing the total deformation of the valve.

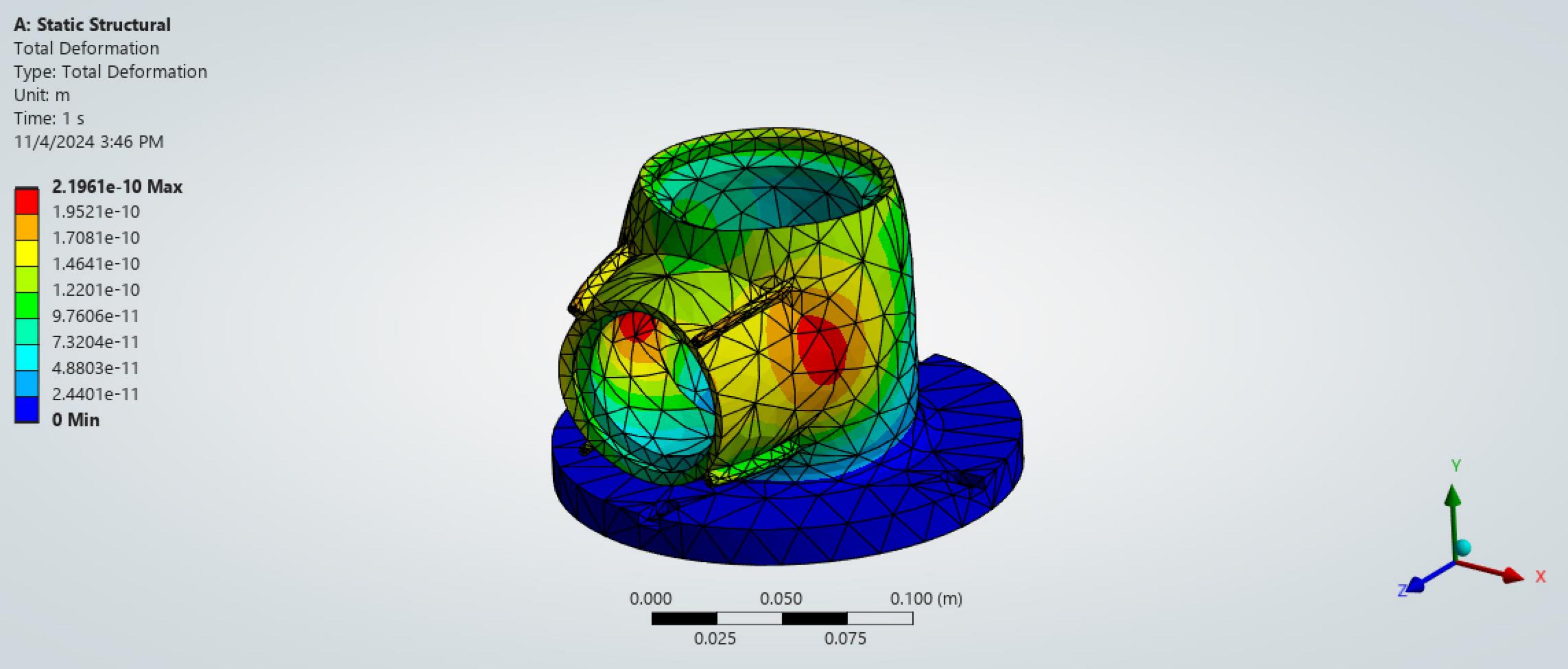
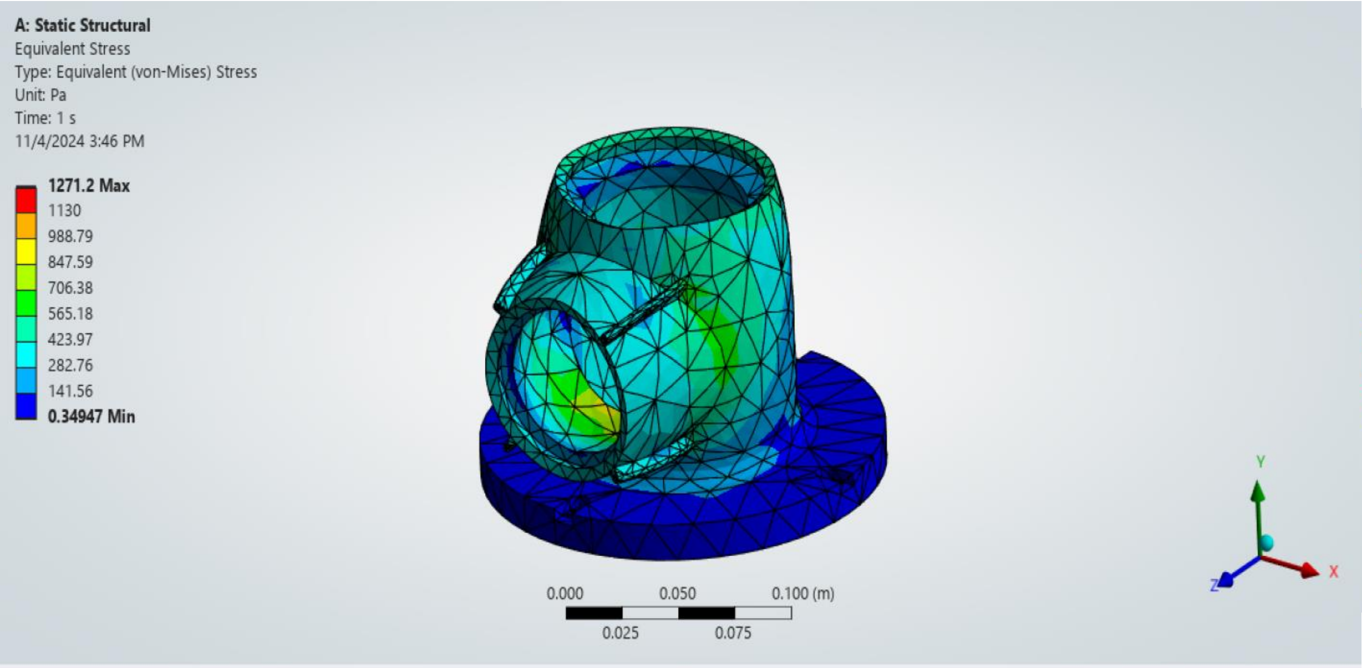


Figure 3: The maximum total deformation is 2.1961e-10 located where the exit hole meets the main body of the part. The fix point at the bottom of the valve has 0 deformation.

Part 1

1. Analyzing the Equivalent (von-Mises) stress in the valve.



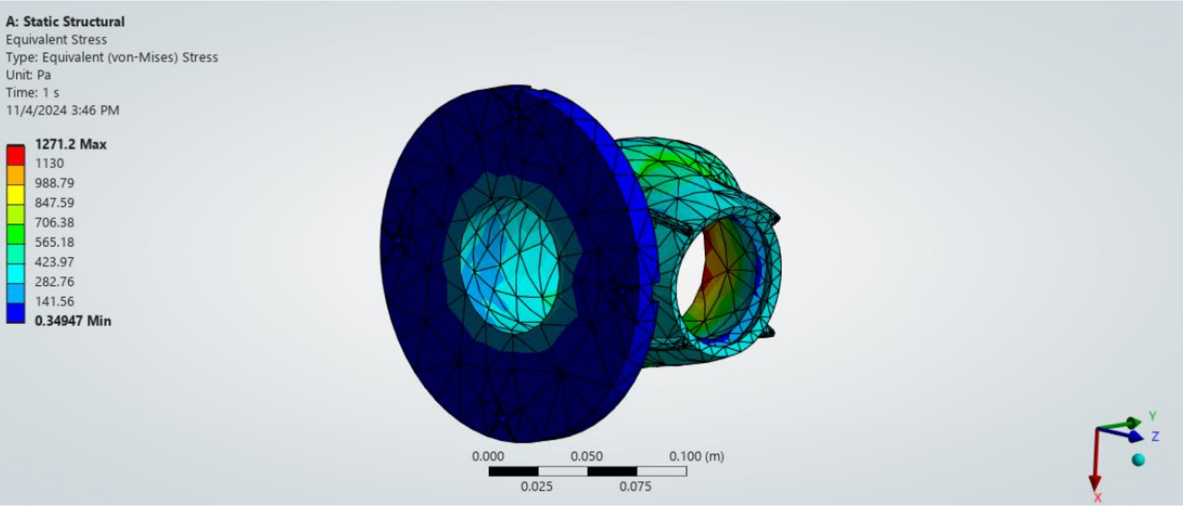


Figure 4: The maximum equivalent stress is 1271.2 Pa in the interior of the valve while the lowest equivalent stress is located at the fixed point (base of the structure)

Part 1 – Iterating Ansys Internal Pressure

1. Looking at the MMPDS-08 at Table 2.3.1.0 (g_1) S-allowable for AISI 4135 the yield stress for >0.188 Thk is 70 Ksi.
   - A factory of safety of 2.5 (70/2.5) means that the stress should not exceed 28 Ksi (0.19305 Gpa).
   - From the simulations changing the pressure values from the images above, the max von-Mises stress on the valve was 0.19299 Gpa form an internal pressure of 15.182 Mpa.
     - These results show that with a factor of safety of 2.5 the maximum allowable internal pressure is 15.182 Mpa and is slightly off the the known factor of safety value by 0.00006 Gpa.

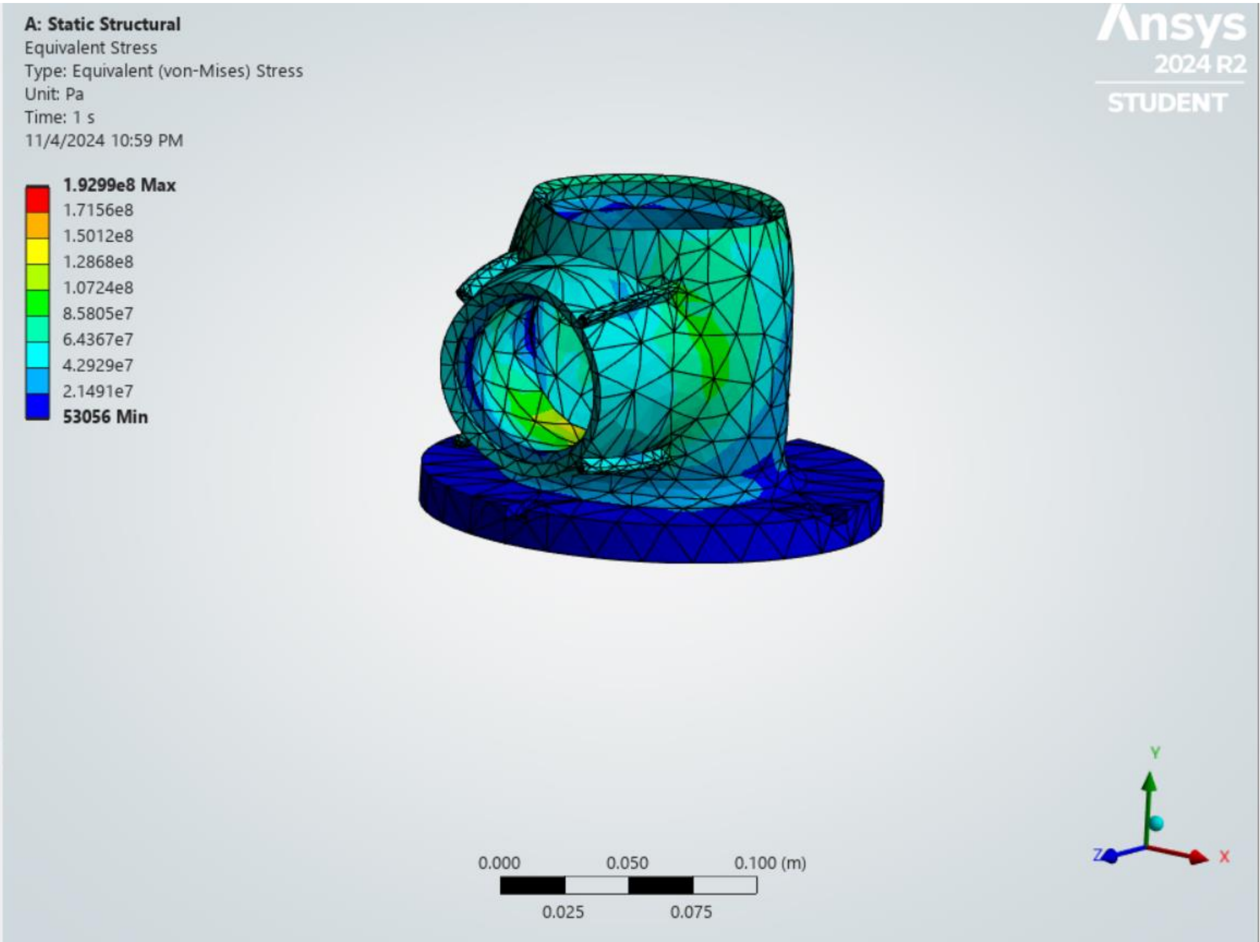


Figure 5: The internal pressure was iterated until the maximum allowable stress was found before breaking the factor of safety.

Part 2

1. The average is calculated to be 104.4 Ksi, the standard deviation is 9.45 Ksi (Excel), and the K-factor was found in lecture slides using a $n = 5$.
   - $K_A = 5.741$
   - $K_B = 3.408$

   The allowable stress is:
   - A-basis = 50.15 Ksi
   - B-basis = 72.19 Ksi

   With a 1.5 factor of safety, the margin of safety is:
   - A-basis = -0.44
   - B-basis = -0.20

   - No, the design does not have adequate margin, this does not mean total failure instead, the design does not meet the specified safety factor requirements and should be redesigned.

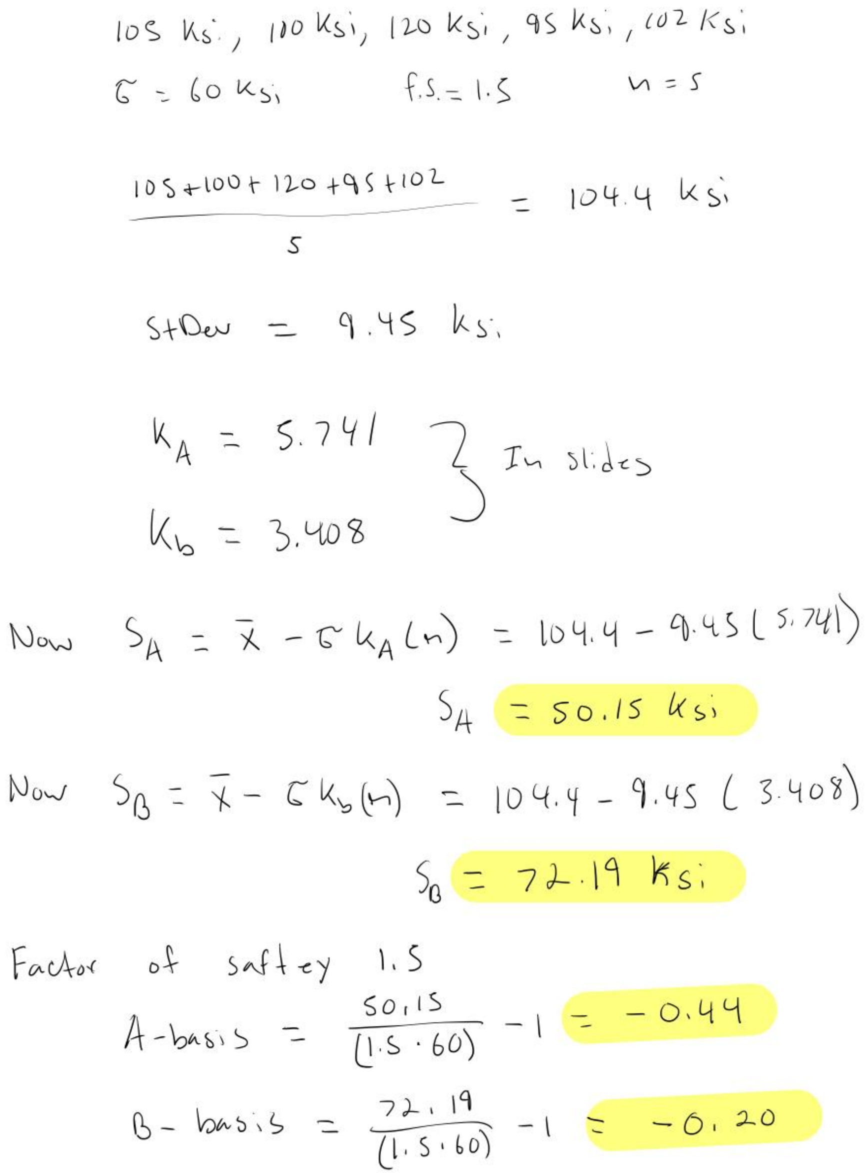


Figure 6: Image of my work and calculations done on an iPad. The average strength, slandered deviation, and K-factor are all mentioned.

Part 2

2.

Materials	Key differences	Key advantages	Key disadvantages
Aluminum	Used in over 80 % of structures. Typical alloys can be configured for specific applications. High strength vs weight, readily available, low cost, ductile, easy to machine, high buckling strength vs. weight. Alloys are used in primary and secondary structures.	Cost advantages, weight advantages, workability and machinable, corrosion resistant.	Low strength vs. volume, poor resistance to galling and wear, high coefficient of thermal expansion, welding can reduce its strength. Surface is susceptible to stress-corrosion cracking, pitting, crevice corrosion, and galvanic corrosion of not anodized.
2024 – T3, T351, T42, T81	Solution Heat treated, cold worked, and naturally aged to a stable condition	Optimal fracture toughness, slow crack growth rate, and fatigue life. High strength in tension.	Thickness effects transverse properties including SCC.
2324 – T3 2224 – T3	10 % Improvement in strength over 2024.	Increased fatigue and toughness.	Precise possessing to maintain properties, more expensive and hard to find, limited formability compared to other alloys, prone to SCC.
7075 – T6, T651, T7351	Different aluminum alloy – high strength for compression. Solution heat treated and them artificially aged	Good SCC resistance, T7351 has better fracture toughness than T6	Hard to weld, 2024=T3 has low fracture toughness
7050 – T7451	Solution heat treated and stabilized, good for thick sections	Better properties that 7075-T7351 in thick sections	Not good in non-thick regions
5000 series	Used primarily in honeycomb cores and structures. Low to medium strength. Cooled from an elevated temperature shaping process and them artificially aged.	Easily welded and corrosion resistant.	Not that strong, limited to a maximum use temperature, some alloys require specific tempers to provide resistance to stress-corrosion cracking and exfoliation
6000 series	Low to medium strength. Common for stiffness critical designs.	Easily machinable and weldable.	Welding reduces strength.

Part 2

2. CONT

Materials	Key differences	Key advantages	Key disadvantages
Nickle Alloys	High resistance to corrosion and oxidation, good mechanical properties under various temperatures, used in extreme environments.	Corrosion resistance, high temperature performance, used in some electrical applications, wide range of applications – welding, controlled expansion, coatings, shape memory effect, thermal control. Mainly used in plating's. hot corrosion resistant, resistant to deformation and fracture under stresses and temperatures. Excellent cryogenic properties.	Ferromagnetic and needs care in some applications. Under thermal cycling, the protective oxide layer may crack or spill. Very expensive, difficult to machine, heavy.
Titanium Alloys	Lightweight with good strength to volume ratio, low density, good high temp performance, chemical resistance. Ti6Al4V is the most common alloy.	Good corrosion resistance, fatigue resistance, great strength properties, easy to machine and shape, can be welded and joined properly.	Not all alloys are weldable, and a protective atmosphere is needed to reduce degradation, some metals and processing chemical can degrade the properties by inducing hydrogen embrittlement, reducing fracture toughness, inducing stress corrosion, the fatigue life is reduced by fetting, relies on protective coatings, hard to produce, limited availability, prone to corrosion. Low CTE compared to aluminum.
Steel	Widely used, very available, alloying produces a wide range of applications with improved performance.	Low cost, can be heat treated or mechanically worked, can be machined easily, wide range of compositional and mechanical surface treatments are available, low alloy steels can resist SCC.	Very heavy, stress corrosion at high temperatures, low alloy steel don't resist corrosion well, some have ductile-brittle transformation, some exhibit poor weldability, prone to corrosion in atmosphere and from acidic aqueous solutions, Higher strength steels are also prone to SCC in seawater and other chloride solutions.

Part 2

2. CONT

Materials	Key differences	Key advantages	Key disadvantages
Stainless steel	Have alloying additions that specifically provide a continuous, adherent, self-healing oxide film that reduce the risks of corrosion.	Corrosion resistant, oxidation resistant, creep resistant, good toughness at low temperatures, strength can be increased by cold-working, properties are retained at low temperatures, can be heat treated to be very strong and still have a high corrosion resistance.	When heat treating have to be careful of SCC, need careful cleaning, susceptible to contamination, some grades are susceptible to hydrogen embrittlement.
Magnesium	Lightest structural metal, can be machined and casted.	Used for stability and high heat capacity, same strength to weight ratio as aluminum	Poor ductility, poor resistance to corrosion, suspectable to catching fire during machining
Beryllium	High stiffness and strength at low density, high melting point.	Thermal and electrical conductivity is great, can absorb radiation.	High cost, toxic, can be brittle, not weldable.
Composite	Made from two or more constituent materials, lightweight and high strength.	Can be tailored for high stiffness, high strength and extremely low CTE, low density, good in tension.	Costly, for low production volume, requires long development, strength can depend on individual workmanship, laminated composites are not as strong in compression, brittle, can be hard to attach.
Graphite	Good thermal and electrical conductivity, has lubricating properties.	Lightweight and high strength, high temperature resistance.	Brittle and can fracture, hard to work with, has very limited tensile strength.
Copper	Established materials in electrical, electronic assemblies, and bearings.	Used in wiring, electrical/electronic subsystems, used as a matrix phase in some reinforced metals, not suspectable to vacuum issues, radiation doesn't affect it,	Not all copper and copper-based alloys are acceptable to space environments. Cold worked brass alloys are sensitive to stress corrosion cracking, susceptible to SCC, surface oxidation, some sealants and potting compounds are corrosive to copper.
Fiberglass	Made from glass fibers in a resin matrix formation, has good corrosion resistance.	Lightweight, high strength to weight ratio, good thermal and electrical insulation.	Less durable, limited resistance to atmosphere, can degrade quite easily.

Part 2

3.

Hydrogen embrittlement – When an engineering material absorbs hydrogen atoms, causing it to lose its ductility and become brittle. This in turn causes the material to prematurely crack or fracture before its estimated/normal yield strength.

Corrosion – A process where an engineering material (typically metal but doesn't have to be) reacts with its surrounding environment over its lifespan, leading to changes/deterioration in the materials properties. The reaction of the engineering material with its environment can significantly alter the material properties and can compromise its overall performance.

Stress corrosion cracking (SCC) – When a material is subjected to corrosion and suffers the overall effects that lower its performance and deteriorate its properties, is then also subjected to tensile stress. This combination can lead to the formation and prorogation of cracks, resulting in failure much faster than if the material was not corroded.

Galvanic corrosion – When two or more dissimilar materials are in direct electrical contact within a corrosive solution or atmosphere, galvanic corrosion occurs. This electrochemical process leads to preferential corrosion of one metal, known as the anode, while the other metal (cathode) remains protected. Basically, GC is when one metal corrodes preferentially when it is in electrical contact (this is based on the electrical potential difference b/w the metals). Environment can also play a factor in this phenomena.

EXAMPLES OF GALVANIC CORROSION NEXT SLIDE

Part 2

3. Looking at the Galvanic corrosion chart in the slides shared to us during lecture we can tell what metal couples are dissimilar and similar. In a corrosive environment such as in salt water these are 5 examples of material pairs that can lead to galvanic corrosion.

- Magnesium and Lead – Mg is more anodic than lead thus, in a corrosive environment, Mg will corrode faster.
- Aluminum and Titanium – Al is more anodic than titanium thus, in a corrosive environment Al will corrode faster.
- Steels (carbon low-alloy) and Zinc – Low carbon steel is more anodic than zinc thus, in a corrosive environment low carbon steel will corrode faster.
- Copper (high Hi Monel) and Brass (Pb-Bronze) – Copper is more anodic than brass thus, in a corrosive environment copper will corrode faster.
- Magnesium and Nickel Cobalt – Magnesium is more anodic than Nickle-cobalt thus, in a corrosive environment magnesium will corrode faster.

These examples are taken from the lecture slides, there are several other combinations.

Part 2

4. AZ31B Magnesium Alloy Plate is titled AMS 4376 in the MMPDS handbook. The measurements are all in Ksi.

Mechanical properties	Definition
F_{tu} (Ultimate Tensile strength)	Max stress material can withstand without failing (breaking/fracturing)
L (Longitudinal direction)	Measured values along the length of the material (x-direction)
LT (Transverse direction)	Measured across the width (perpendicular to the longitudinal direction)
F_{ty} (Tension yield strength)	Stress when the material begins to deform
F_{cy} (Compressive yield strength)	Yield strength of the material under compressive forces
F_{su} (Shear ultimate strength)	The maximum shear a material can withstand before failure
F_{bru} (Bearing ultimate strength)	Ability of the material to resist deformation
e/D (edge distance ratio)	Hole center to edge distance over bolt hole diameter
F_{bry} (Bearing yield strength)	Stress measurement where the material yields in a bending test

Mechanical properties	Definition
e % (Elongation)	Measure of ductility. Permanent (plastic strain) increase in gage length, measured after fracture
E (Modulus of elasticity)	Measure of the stiffens of the material
E_c (Compression elastic modulus)	Modulus of elasticity in compression
G (Modulus of rigidity)	Measure of a material response to shear stress
μ (Unit lateral deformation/unit axial deformation)	Identifies the Poisson's ratio in uniaxial loading
ω (density)	Physical property of density. Weight per unit volume in this case lb/in^3
$C, K,$ *and* α (Physical properties)	Physical properties of the material, considered to apply to all forms and heat treatments unless otherwise stated

Part 2

5.

Material	Process	Definition of Process	Aircraft part	More Information
2024 Aluminum 7075 Aluminum	Sheet	Rolled flat to various metal thicknesses	Fuselage skin, fuselage frames, rib and spar webs, control surface, and pressure domes	Sheets have good grain orientation
7075-T651 Aluminum (upper wing skin), 2024-T351 Aluminum (lower wing skin), 7050-T7451 Aluminum (spars)	Plate	Rolled flat to various metal thicknesses	Wing and tail skins, monolithic spars and ribs, various fittings	Grain orientation can be a problem
7075-T6511 Aluminum (upper wing stringers), 7075-T73511 Aluminum (lower wing stringers)	Extrusion	Metal is forced through a die a high temperatures to create a desired shape. Often requires further forming and machining to achieve final specification.	Stringers, rib and spar caps, stiffeners	Grain aligned in the lengthwise direction
6Al-4V Titanium (landing gear support) 15-5 Stainless Steel PH13-8Mo Cres steel bar	Forging	Impact or pressing material into shape	Large fittings, large frames and ribs, odd shapes, landing gear support, wing to body attachments, flap tacks	Control grain orientation, residual stress can cause warpage problems, requires a lot of tooling, high strength
A356 Aluminum A357 Aluminum 347A Stainless Steel 410 M Stainless Steel 421 M Stainless Steel Cobalt 6	Casting	Pouring molten metal into a die to form desired shape	Nacelle, engine components, propulsion components (valves, etc.)	Lowers part and fastener counts when the shape is completely molded, has poor fatigue and damage tolerances properties, very expensive, has a lot of porosity
Graphite/epoxy fabric aramid/phenolic honeycomb Fiberglass/epoxy fabric corrosion barrier	Composite	Laying fibers and resin to two materials to create a strong material.	Fuselage, wings, tail, control surface	Lightweight, High strength to weight ratio, resistant to corrosion, hard to form into small complex parts but good for large parts