How to Reduce Stress in Parts

Week 2 Lecture

https://tinyurl.com/ybe759hc

What this lecture and guide cover:

Lecture:

- Stress - revisited

CAD Guide:

- Renaming features
- Sweeps
- Chamfers/ Fillets
- Symmetry
- Projection
- Reference Geometry

What makes “good CAD” with these features?

Same as good sketches:

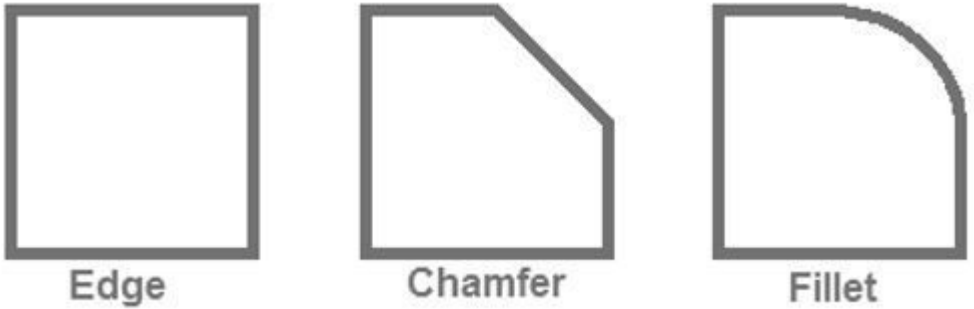
- Responsive
  - Dynamically adjusts to design changes
- Simple
  - Features, and the sketches that govern them, should be their own
  - Used correctly, these features can often cut the amount of work you do in half
- Robust
  - It won’t break when changes are made

Sweeps

- “Sweeping” a cross section across a specified path
- Makes things like pipes, some frame elements, and v-belts CAD-able
    - You could technically do it in a series of very painful extrudes, but this simplifies the process

Fillets and Chamfers

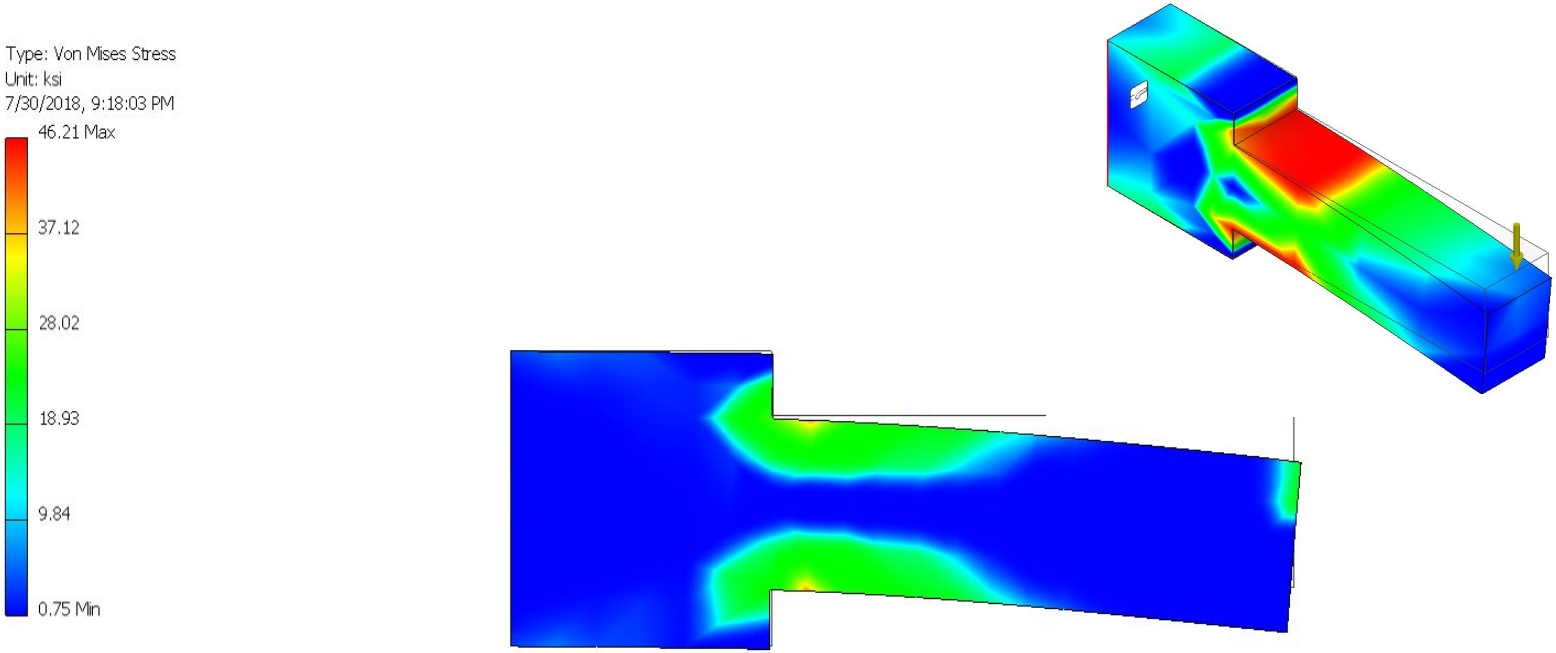
- Fillet:
  - Rounded edge
- Chamfer
  - Angled edge



Why fillets and chamfers are good: CAD

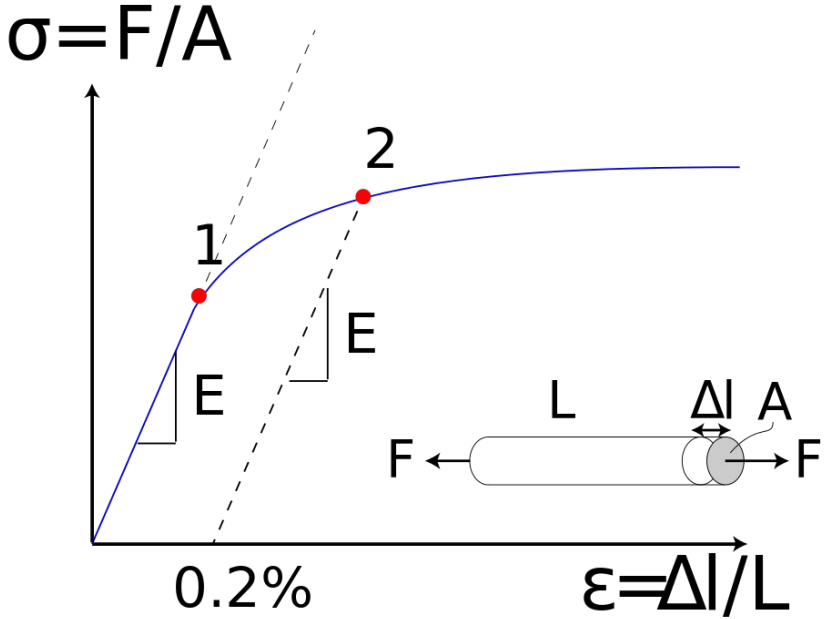
- Filleting and chamfering parts as a feature is much better than as a sketch
  - Doing it in the sketch means you will have to add a ton of constraints and dimensions to get the sketch fully defined
  - Sketch becomes super messy
  - Using the feature makes it a ton easier to modify the chamfer/fillet later on in CAD
- You can do variable radius fillets
  - Think of where an airplane wing meets the fuselage
  - This is nearly impossible to get right in a sketch
  - Organically shaped parts

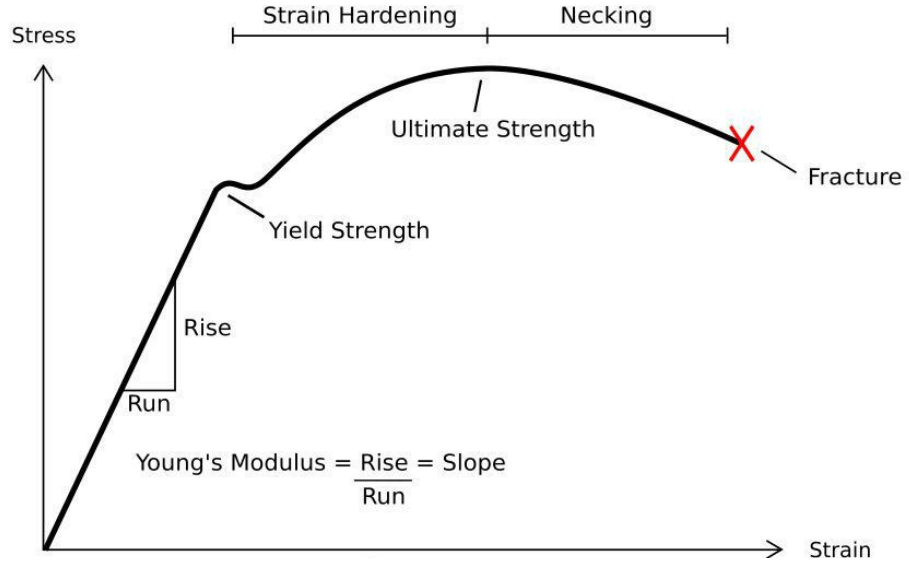
Why fillets and chamfers are good: application



- This stainless steel yields at ~42 ksi, so this part will fail

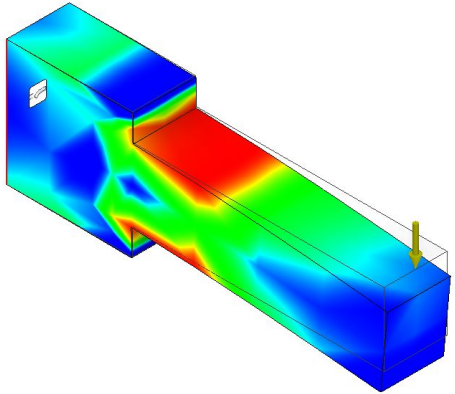
Stress and Strain (a reminder)

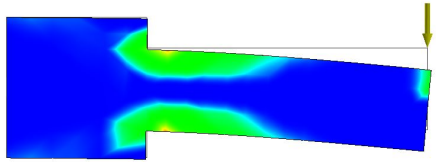


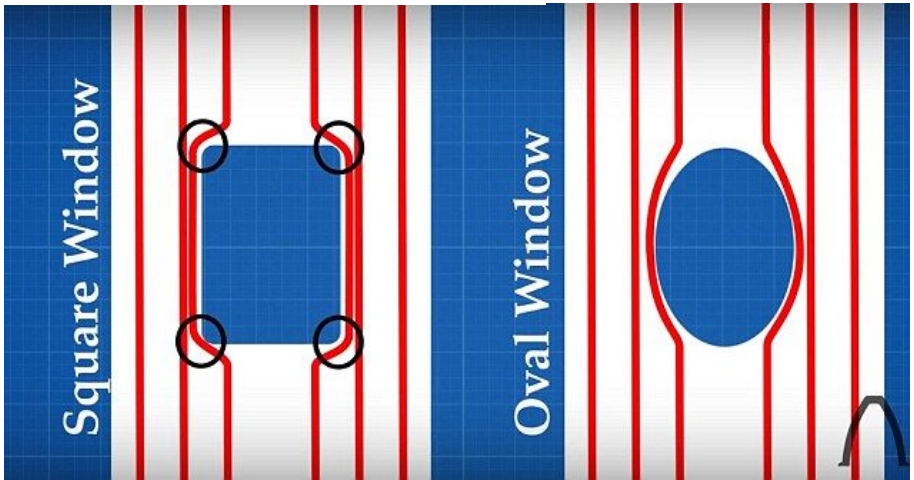


Stress Concentration

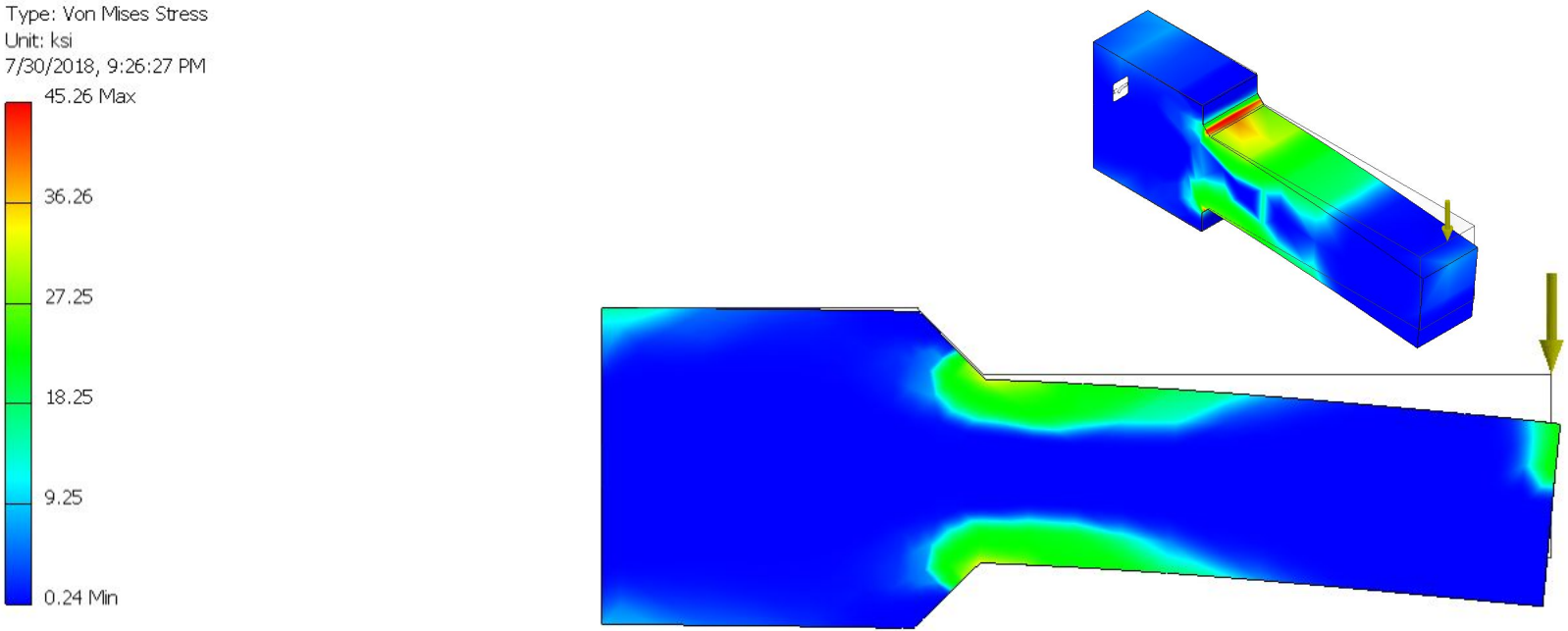
- Stress will concentrate where the rate of change of cross sectional area is greatest
- Location and magnitude is therefore largely dependent on feature geometry
- Airplane windows used to be square, which caused a lot of problems - often fatal







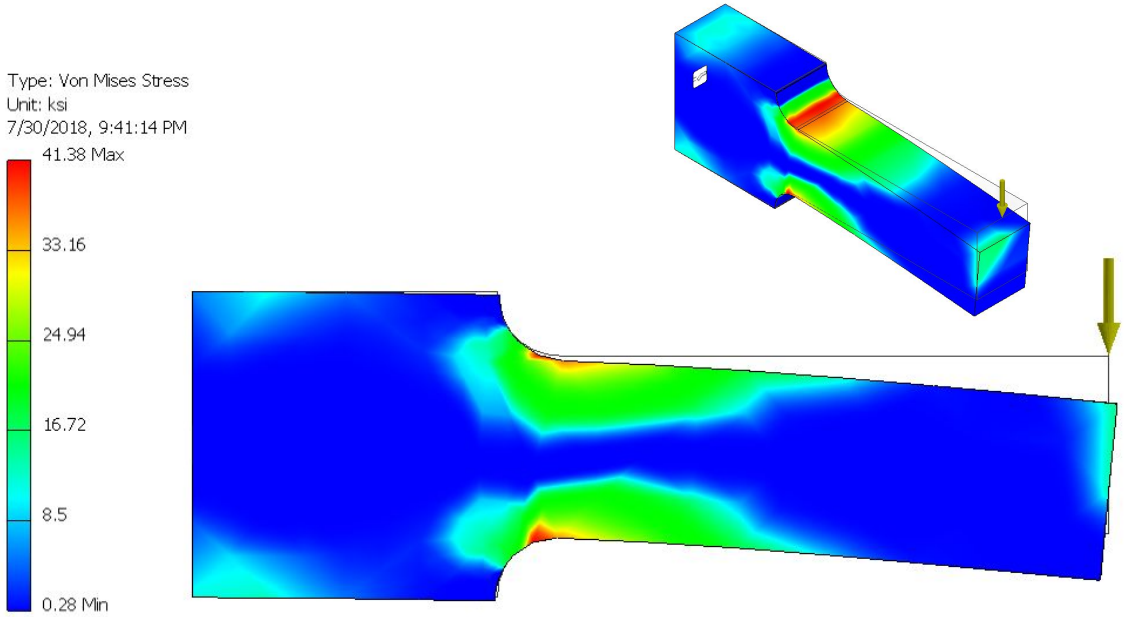
Let’s exert the same force on a chamfered part!



- Well the max stress is lower, but the part still fails
  - In general, chamfers are not great at removing concentrations
  - In fact, they usually make things worse!
    - More corners, more places for stress to concentrate

Well… Chamfering wasn't ideal… What to do now?

- Fillets are your friends!
- They most efficiently reduce stress concentrations from corners without making huge design changes



- Easy way to strengthen load bearing elements
- Part no longer yields!!!

Safety Factors

- Ideally, you do not want the max stress of a part to be just under the yield stress
  - Very close to plastic deformation and failure
- Examples of safety factors:
  - Buildings and bridges - around 40
  - Airplanes - 1.5
    - Low due to weight constraints
  - Broken things < 1
  - Chamfered part in previous slide - 1.02
- Engineers define a “Safety Factor” that describes how close a part is to failure
  - Allowable stress usually elastic limit or fatigue limit

$$F.O.S. = \frac{\sigma_{allowable}}{\sigma_{max}}$$

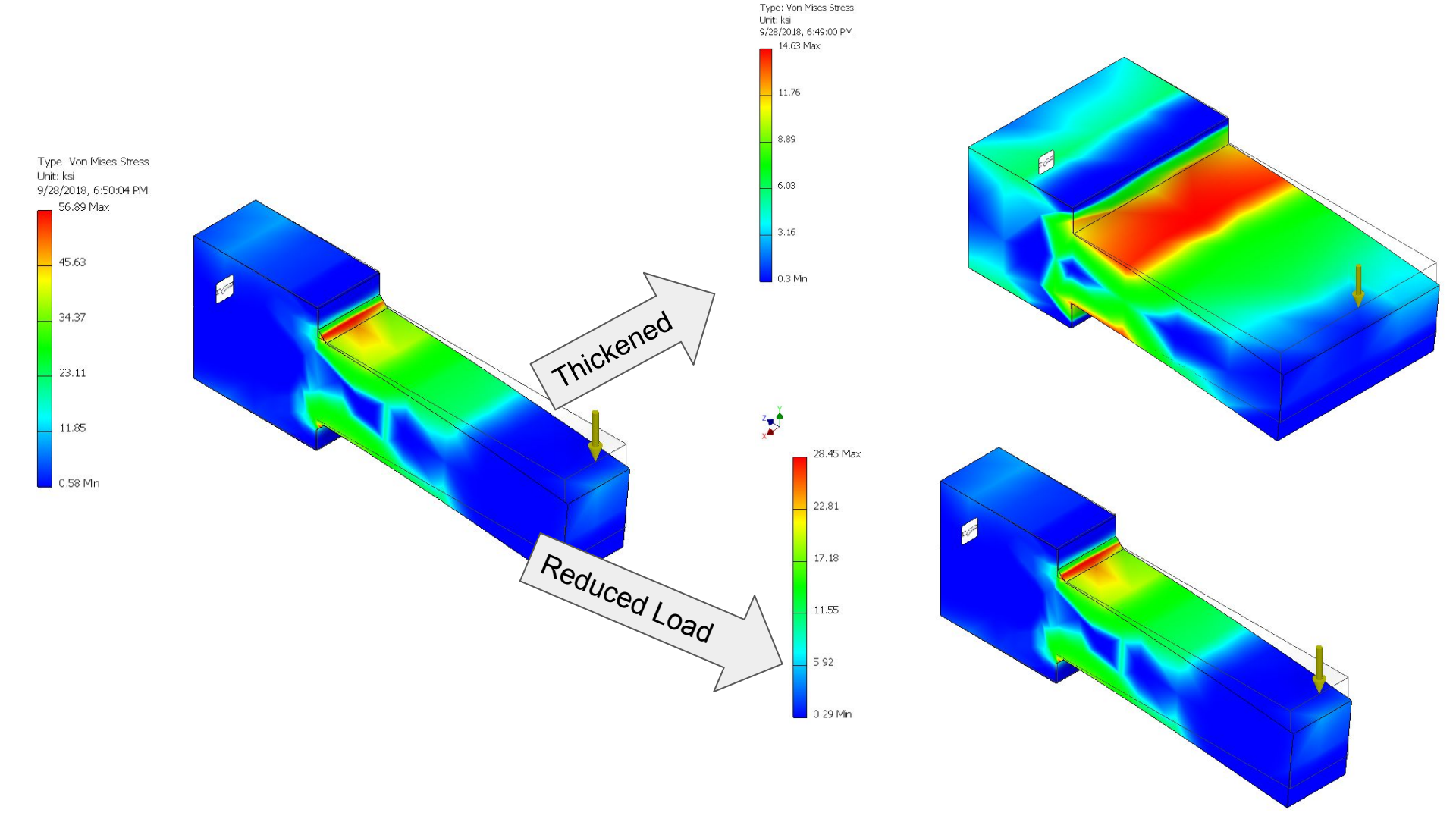
Increase the Safety Factor!

- Let’s say that the part you just made has a safety factor of 1.02
- In order to improve the performance, you can:
  - Choose a stronger material to increase the allowable stress
  - Reduce the load
  - Make the part thicker
    - Remember: Stress = F/A

Stronger

Name	Yield strength (elastic limit) (MPa)
Nickel-based superalloys	300 - 1.9e3
Low alloy steel	400 - 1.5e3
Titanium alloys	750 - 1.2e3
High carbon steel	400 - 1.16e3
CFRP, epoxy matrix (isotropic)	550 - 1.05e3
Stainless steel	170 - 1e3
Medium carbon steel	305 - 900
Nickel	70 - 900
Tungsten alloys	525 - 800
Silicon nitride	600 - 720
Zirconia	500 - 710
Cast iron, ductile (nodular)	250 - 680
Silicon carbide	400 - 610
Age-hardening wrought Al-alloys	95 - 610
Commercially pure titanium	270 - 600
Alumina	350 - 588
Boron carbide	350 - 560
Tungsten carbides	335 - 550
Bronze	100 - 500
Brass	95 - 500
Nickel-chromium alloys	365 - 460
Zinc die-casting alloys	80 - 450
Cast iron, gray	140 - 420

Weaker


Type: Von Mises Stress
Unit: ksi
9/28/2018, 6:50:04 PM
56.89 Max
45.63
34.37
23.11
11.85
0.58 Min
Thickened
Reduced Load
Type: Von Mises Stress
Unit: ksi
9/28/2018, 6:49:00 PM
14.63 Max
11.76
8.89
6.03
3.16
0.3 Min
28.45 Max
22.81
17.18
11.55
5.92
0.29 Min

Quiz Time!

Why are fillets good?

Helps reduce stress concentrations, makes parts machinable, ~~and makes things look nicer~~

Give a real life example
of fillets being useful

Airplane windows and sharp corners, but other answers acceptable