MINI-PROJECT 8

FORGING

ME 270: *Design for Manufacturability*

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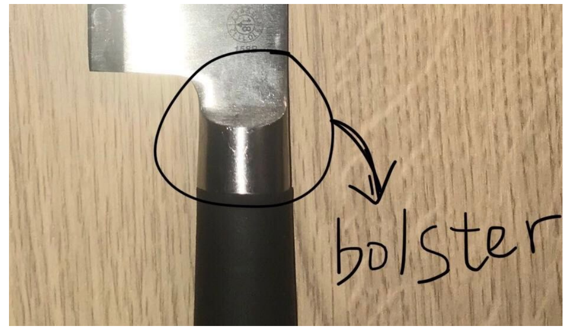
AB5_3

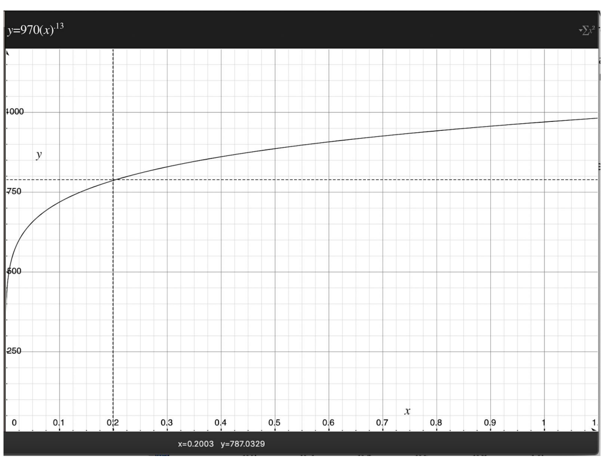
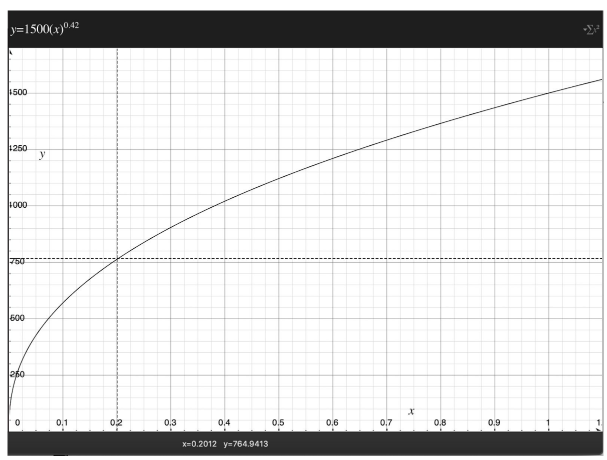
PRODUCTS



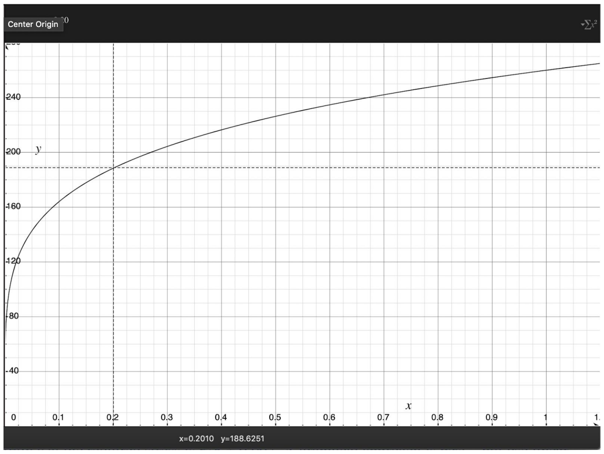
The product we chose is a chef's knife that is still in use. We can tell it is made by forging because it has a bolster between the handle and the blade. Bolster is a key feature of forged knife. Besides, it is also more heavy and less flexible than the stamped knife. A forged knife is usually made from one single piece of steel. The steel is heated and hammered/pound into its shape.[1]

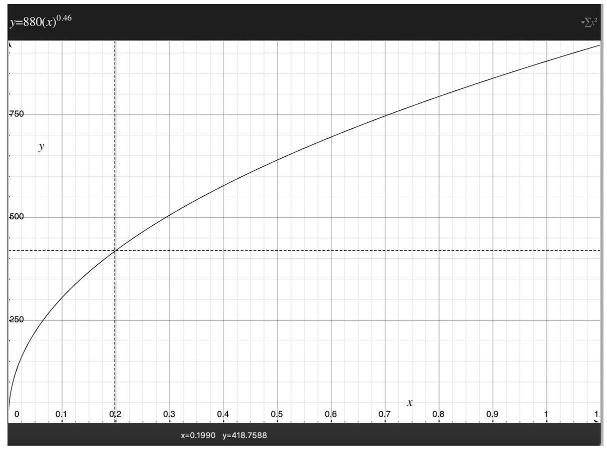
TRUE COMPRESSIVE STRESS-STRAIN CURVE

All graphs were made using the Grapher application available on Mac. The y-axis shows true compressive stress and the x-axis shows true percent of strain.

<table>
<tr><td>HIGH CARBON LOW ALLOY STEEL

</td><td>STAINLESS STEEL AISI 304

</td></tr>
<tr><td>ALUMINUM 6082-T4</td><td>BRASS (CuZn37)</td></tr>
</table>

[1] https://www.thespruceeats.com/the-anatomy-of-a-chefs-knife-995818
https://healthykitchen101.com/forged-vs-stamped-knives/





YIELD STRESS

Estimations for the stress values can be found at the bottom of the graphs displayed above.

$$\sigma_t = K \times (\varepsilon_t)^n$$

HIGH-CARBON, LOW ALLOY STEEL[2]

$$K = 970\ MPa \parallel n = 0.13 \parallel \varepsilon_t = 0.2\%$$

$$\sigma_t = 970 \times 0.2^{\ 0.13}$$

$$\sigma_t = 786.875\ MPa$$

STAINLESS STEEL AISI 304[3]

$$K = 1500\ MPa \parallel n = 0.42 \parallel \varepsilon_t = 0.2\%$$

$$\sigma_t = 1500 \times 0.2^{0.42}$$

$$\sigma_t = 762.999\ MPa$$

ALUMINUM 6082-T4[4]

$$K = 260\ MPa \parallel n = 0.20 \parallel \varepsilon_t = 0.2\%$$

$$\sigma_t = 260 \times 0.2^{.20}$$

$$\sigma_t = 188.443\ MPa$$

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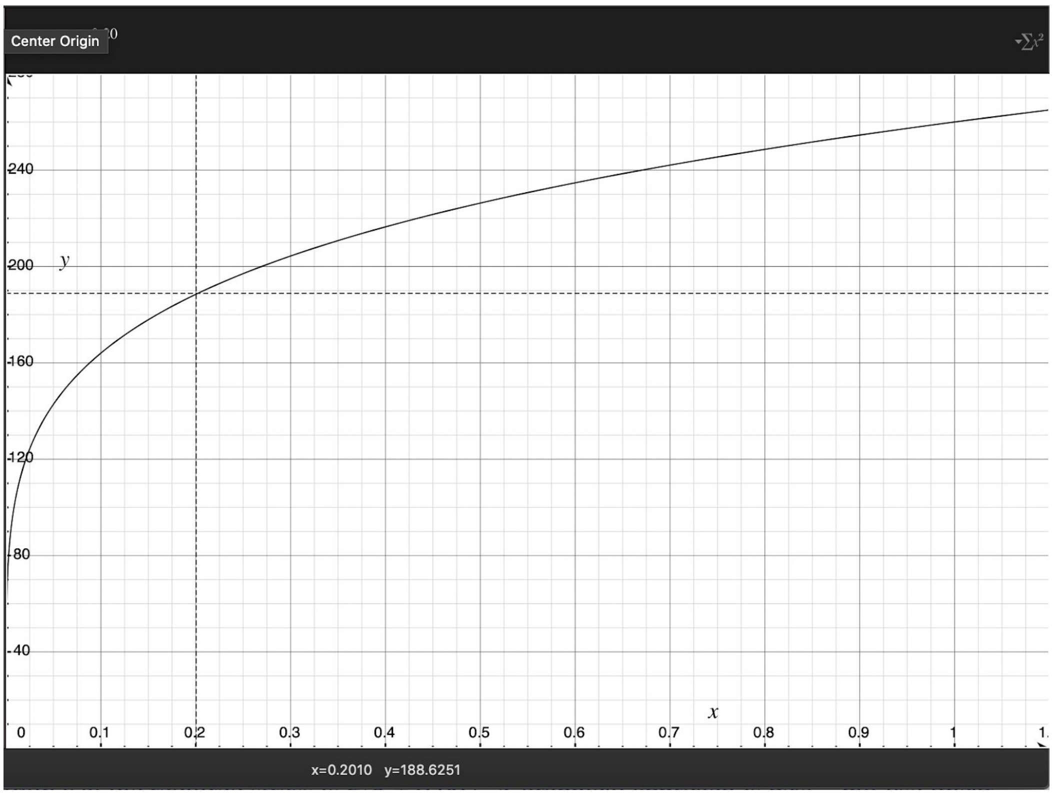
[2] https://www.jove.com/science-education/10361/stress-strain-characteristics-of-steels
[3] http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.568.3945&rep=rep1&type=pdf
[4] https://journals.plos.org/plosone/article/figure?id=10.1371/journal.pone.0181983.g006

BRASS (CuZn37)

$$K = 880\ MPa \parallel n = 0.46 \parallel \varepsilon_t = 0.2\%$$
$$\sigma_t = 880 \times 0.2^{.46}$$
$$\sigma_t = 419.717\ MPa$$

FORCES ON BILLETS OF METALS



ALUMINUM 6082-T4

$\varepsilon = 25\% \parallel \sigma = 197\ MPa$
$F = A \times \sigma = A \times 197 \times 10^6 Pa$

$\varepsilon = 50\% \parallel \sigma = 226\ MPa$
$F = A \times \sigma = A \times 226 \times 10^6 Pa$

COLD FORGING TEMPERATURES

HIGH-CARBON STEEL

$T_{solidus} = 1425°C = 1698.15\ K$ [5]

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[5] https://sciencestruck.com/melting-point-of-steel

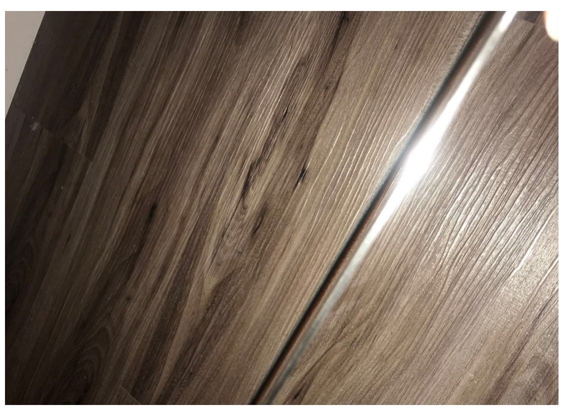
Cold forging: $0\,K < T < 679.26\,K$
Warm forging: $679.26\,K \le T \le 1358.52\,K$
Hot forging: $T \ge 1358.52\,K$

ALUMINUM
$T_{solidus} = 660$℃ $= 933.15\,K$ [6]
Cold forging: $0\,K < T < 373.26\,K$
Warm forging: $373.26\,K \le T \le 746.52\,K$
Hot forging: $T \ge 746.52\,K$

HOT AND COLD DIES[7]

Hot and cold forging, although they are different processes, produce similar parts and results. Cold forging is preferred when the metal that is being worked with is soft. In this process, because the metals being worked with tend to be weaker, the piece is tempered to increase its strength. Because of these traits associated with cold forging, it is more ideal to work with aluminum. While cold forging occurs at room temperature, hot forging requires metals to be heated to temperatures that can reach up to 1150℃. During hot forging, the lattice structure of a metal is altered which also affects the Young's modulus of the metal. Unlike cold forging, hot forging is preferred for stronger materials that have higher melting temperatures. This process is most commonly used for steel, but can be used for aluminum and copper alloys.

REMOVAL OF FLASH



There is not any sign of flash on our sample product. This product is a household knife which needs a polished or smooth surface for user to touch. Without the polishing

[6] https://www.engineeringtoolbox.com/melting-temperature-metals-d_860.html
[7] https://www.thomasnet.com/articles/custom-manufacturing-fabricating/hot-forging-cold-forging

process, users can get cut by even a small remainder of flash. Before polishing, the flash, if it exists, should be on the the thin side of knife.

COMPOSITION OF CARBON STEELS[8]

LOW CARBON STEEL:
0.05% - 0.25% carbon content
0.00% - 0.40% manganese content

MEDIUM CARBON STEEL:
0.29% - 0.54% carbon content
0.60% - 1.65% manganese content

HIGH CARBON STEEL:
0.55% - 0.95% carbon content
0.30% - 0.90% manganese content

Stated above are the carbon content and manganese content of low, medium and high carbon steels. There is a direct set of boundaries for what type of carbon steel it is and carbon content, and this pattern seemed to hold for manganese content, but there is not a direct correlation that can be found. Fittingly, a carbon steel is characterized as low, medium, or high given its carbon content.

All alloy steels have a carbon content from 0.10% - 1.00% as this is a common trait among *all* steels, not just alloy steels. The difference between steel and alloy steels is not the carbon content, but the addition of other metals that affect mechanical properties of the metal. A very common metal used in alloyed steels is manganese amongst others such as copper and nickel.[9]

ULTIMATE STRENGTH AND AUSTENITIZING

The ultimate strength if the tempering is short, will end up being too low. There are four stages of tempering martensite. During the first three stages, in this case when time is lower for these stages, the microstructure has not yet recrystallized and therefore the toughness and ductility of the material has not formed. The martensite requires a

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[8] https://www.onealsteel.com/carbon-and-alloy-steel.html
[9] https://en.wikipedia.org/wiki/Alloy_steel
10 http://www.wisetool.com/designation/tempering.htm

specific time of tempering in order to achieve the increased ultimate strength. The toughness of the martensite increases and the ultimate tensile strength decreases. (10)

QT TREATMENT AND YOUNG'S MODULUS[10]

QT treatment, also known as the quenching and tempering processes, are used to strengthen materials, typically steel. In this treatment, a metal is heated to a very high temperature, then cooled extremely fast in oil, forced air, or, most commonly, water. Young's modulus is only dependent on the atom bonding in the metal. A heat treatment, such as QT does not directly change the crystalline structure of the metal so under most circumstances QT treatment *does not* affect Young's Modulus. However, if the metal is to undergo a phase transformations, and their crystal lattice are altered, then the Young's modulus will change.

OPEN-DIE DROP FORGING[11]

With open-die drop forging implies that metal places in the die is never restrained completely in all dimensions. They also come in a wide variety of shapes although the most common are flat dies and V-dies. These parts are usually large metal components such as bars or blanks. To put their size in perspective, open-dies can produce metal parts ranging from a few pounds to hundreds of tons.

DIE LIFE SPAN

Metal type, complexity, small radii, and fine detailing, and narrow tolerances all affect the life span. The harder and stronger the metal, the more deformation it requires, the larger the radius, the more detailing, and the narrower tolerances all decrease die life span. As a whole, the more the die depricates through the production of each part, the more the cost of one part increases. Individually, larger pieces of metal and metals with very useful and rare mechanical properties, such as high strength, tend to cost more than others and directly affect part cost.

COLD CLOSED-DIE FORGING[12]

For cold forging there are multiple design considerations that need to be taken when cold closed-die forging. The first, and one of the most important is the location of the parting line. The parting line must be places on a plane that is perpendicular to the axis of die movement, typically on the x-y plane. Another design consideration is machining

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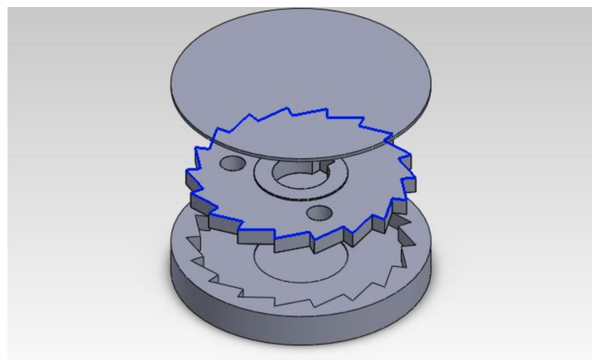
[10] https://www.researchgate.net/post/Will_the_Youngs_Modulus_E_value_change_with_heat_treatment
[11] https://www.scotforge.com/Why-Forging/Forging-101/Open-Die-Forging
[12] https://www.engineersedge.com/manufacturing/forging-design.htm

allowance. When forging a part, all tolerances, ranging from standard machining to draft angles must be accounted for when designing a mold for the part. The aalst, and also very important design consideration should be the radii at corners. All edges must be filleted to allow for metal to fill all areas of the mold, and the dimensions for these corner radii are dependent on rib height and wall thickness. Another limiting factor of cold closed-die forging is that parts should be limited to a size of 25 kg.

PARTING PLANE IDENTIFICATION



The piece that we have chosen for closed-die forging is a typical gear. Gears tend to forged in closed-dies because of this small size and need to be produced in large quantities. The image on the right is the top and bottom part of the die, with the gear produced in the middle. The parting plane would be the place where the moving die and fixed die meet which would be on the top plane of the gear.