

lecture 1

1 15

ID doesn't do one offs

Mass - anything past 500

Series - 4's, 10's, 100's, collections of stuff

Ex Maman art gallery

In house, local production

ID involves manufacture of forms

"Form follows function"

Form will follow material properties and manufacturing

Circle of 7 -> things that must be addressed in design

-> all parts of functionality

Important to be able to communicate between the bubbles within the circle as an ID'er

Form is resolution of function

Can think of it as how light splits into a rainbow in a prism

Everything in the circle has to be able to be brought together into a singular object and product

As an ID'er when you go to a meeting with everyone in the circle you have to bring to the table something they need

A broad understanding of materials and manufacturing and bringing it together with an aesthetic product with what people want

Industrial design tends to be good at explaining things through pictures

ID'ers will have to design the jigs to manufacture things

Make things efficient and easy for operators

Can spend more time designing the manufacturing than the product

Environment

Complicated topic with managers (money short term) politics toxic materials arguments with managers.

As an ID'er you have power to say no to things on ethical grounds

Life cycle chart - HP

Half psychology how much things are worth how much you want it back

All these issues come together at some point

Appropriateness

Appropriate materials process etc

Relative term - what apple thought the laptop was 10 years ago is not what it thinks now

Ductility - solid materials ability to deform under tensile stress

Malleable vs non malleable

Toughness - measure of a material's ability to absorb energy and plastically deform without fracturing

Tough vs brittle

Strength - ability of a material to withstand an applied stress without failure

Strong vs weak

Youngs modulus - a measure of the stiffness of an elastic material

Higher number the stiffer

Rubber - 0.1 - 0.2

Fibre board - 4

Diamond - 1220

Everything has this number. As an industrial designer you will have some concept of how stiff and elastic a material is

Gets weird with composites and memory metals

Other way to measure materials physical qualities is with the shore hardness scale

Three scales (oo, a, d)

Oo - super soft

Bubble gum

A - med hard

shoe

D - pretty much rigid but has some give to it

Hard hat

Will have a ball park idea how hard and soft a material is

Strain is the relative change in shape or size of an object due to externally applied forces

Stress is the internal force associated strain

Yield strength - the stress at which a material begins to deform plastically

Reaches a point that permanently stress or breaks

Every material has one

Tensile strength - max stress a material can withstand while being stretched or pulled before necking which is when the specimens cross section starts to significantly strain

Stress strain diagram

When its straight means it can come back elastically come back to its original form.
When you take the load off of it it will come back to its original shape

If you load too much it will deform permanently to a point where it will break

Yield point is the ultimate design point where it will break

Wont design to this point. Design to a proof load

DONT WANT TO DESIGN TO EVEN A CHANCE OF A FAILURE

Most consumer products are a 2:1 safety factor

Engineers will help with safety testing, ID'ers will do the user testing

Ferrous metals

Cast iron is iron ore with silica removed

- Strong but brittle

- Black rust barrier is often seasoned with oil to prevent ongoing corrosion

- Certain cast iron variants are still used in items like brake caliper housings

Iron man

- Doesn't rust in the way steel does

- Super resilient to elements

Steel is iron with impurities removed with a specific percentage of carbon added

- Many varieties of strength and ductility depends on carbon content

- Better weldability than cast iron

- Abundant but energy intensive material

Super man

- Can add diff alloys and stuff to make superman stronger

- Depending on the ratio of element with the steel it will change the crystal structure of it and how it acts

Steel will form into crystal things very quickly when it started to cool down. When this happens is O_2 can get into and will form ferrous oxide (rust)

The rust starts making this structure that are like harpoons which allows more oxygen in deeper

Not how all materials work like aluminum. When aluminum rusts it makes a very protective coating

Can be dangerous cause the harpoon shape of the rust can get into eyes and stuff

Comes in 2 diff types cold rolled and hot rolled

- Hot cheaper but flakey finish that has to be taken off after

- Cold denser and cleaner finisher but more expensive

- Cost of finishing is so much higher ID usually goes with cold

- b/c top is squished the surface is more resilient too

- Can put impressions in it too

Metal naming system

First number is the main alloy

Second is the surface treatment

Surface treatments will not prevent rust. It will mitigate it in a way.

Most of the time there will be no surface treatment (0)

Third number is the % of carbon

0-0.3% mild

0.3-0.55% medium

0.55%+ hard

Can go higher and that will be a carbide

Steel that is high carbon

So high carbon it will act as a ceramic

Associated with cutting bed and saw blades

Low carbon - mild + ductile

High carbon - hard + brittle

Hardening quenching tempering and annealing

Annealing a process of heating and slow cooling in order to toughen and reduce brittleness. This is normally done after work hardening

Annealing is similar is relieving an over all stress in the material

Tempering is a process of very controlled reheating and cooling in order to toughen and reduce brittleness of a material

This is done after quenching

Analogy

Annealing (general)

Getting in the bath tub and taking out the work stress in a material

Tempering (specific)

Getting in the bath at a specific temperature and going in for a specific amount of time and cooling at a specific time

Induction hardening - heating up with magnetic field that will eventually be dumped into a bath

Changing crystal structure of the material

Lecture 2

Glass

Glass can be tempered and annealed b/c it is a crystal structure. But has specific properties

AISI TYPE & Condition	Tensile Strength, 1000 psi	Hardness, Bhn	Impact Strength Izod,
A1010, as rolled	40-65	110-140	-
1020, as rolled	60-70	125-150	60-80
1030, quenched & tempered	75-120	180-490	-
1050, quenched & tempered	95-150	190-320	16-30
1080, quenched & tempered	116-190	220-390	10-12
1095, quenched & tempered	120-190	230-400	5-6

Note: The range of values represents differences in heat treatments

Chart to compares alloys

Tensile strength - how much strength requires before metal begins pull apart

Steel mill video - reinforces fact that steel takes **ENORMOUS** amount of energy to create and make

Biggest industries exempted in carbon footprint cement, steel, aluminum in discussion about global warming because they are seen as integral industries in a countries economy

ALLOYS

When you mix something so well you cant really tell the difference (homogenous)

Sugar + cocoa = Hershey chocolate

Composite - when you mix something but still tell the diff between the two (heterogenous?)

Cracker thing + cocoa + sugar = kitkat

Can get up to 6x the strength than regular carbon steel, but its big bucks. Balance of ID is finding which material to pick

Easiest way to make products nowadays than the olden days i.e katana

When you add something to steel it you get more than the sum of its parts

I,e $1+1 = 3$

Steel + Chromium (Chromy the robot) = increased hardenability and corrosion resistance (Stainless steel)

Steel + Molybdenum (Molly the magnificent) = increases toughness (combines with sulphur / phosphorus), used with other alloys to temper the steel, can help steel resist chlorides and salt corrosion

Molly is always good

In more than you would t

Steel + Nickel (nicky the noble) = increases toughness at higher percentages, higher strength, increased corrosion resistance, used as a coating too

Can take nickel and add steel to it to make it into a nickel alloy. Is not seen much in ID but used a lot in aerospace

Steel + manganese (manga the marvelous) = reduces brittleness, creates steel that gets harder at points of wear, creates more martensite

Used in jail cell bars. Manganese alters its crystal structure and gets harder and harder wherever it gets hacked away at

Used mostly in military and ofc jail cells. Not used so much in ID

When something impacts manganese steel it gives like butter. It doesn't crack or break, it carves/dents like butter

Steel + Silicon (Silly the springy) = increases strength, spring steel, increases magnetic properties

Steel + Vanadium (Van the vandaceous?) = increases strength and ductility, reduces grain size for a stranger material at high temperatures, contains stable carbides

Carbide = lots of carbon

Acts more like a ceramic than a steel

Steel + tungsten (Tung fu the tremendous) = remains cutting deges, referred to as a self hardening steel, part of the HSS steel

Tungsten hardens steel right away. Dont have to go through so much effort to quench steel

HSS = high speed steel

Used a lot in cutting bits and has a lot of diff alloys in it as well

Steel + Boron (boronis the bestest) = potent hardenability alloy

A little bit goes a long way

Adding a small amount = crazy diff results

Hardenes as you press it in shape while the metal is red hot

Steel + cobalt (kobels the courageous) = increases strength, hardens, heat dissipation, increases magnetic properties in large amounts with other alloys, used in stainless steel cutting bits

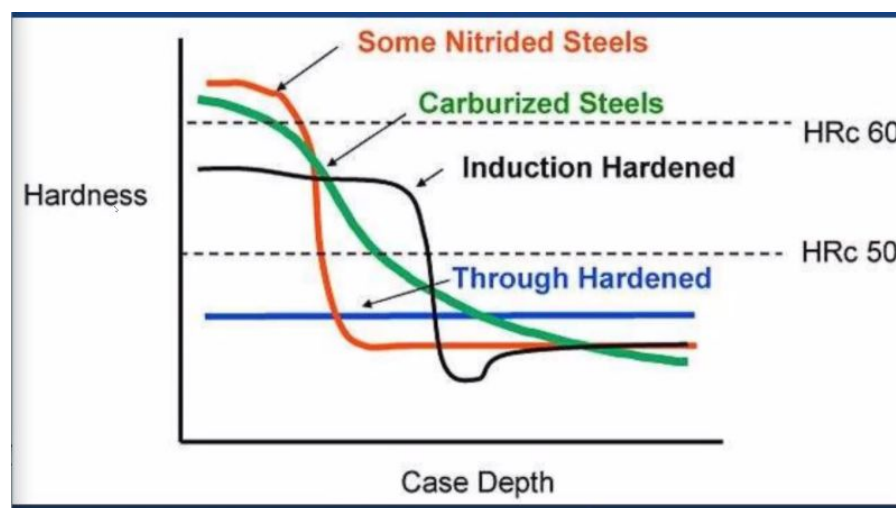
Miners die from cobalt dust back in the day

For a long time it was a unused material

When it was finally used it was found to create super magnets

Used a lot in higher end speakers

Steel + **Aluminum** (Lu the finisher) = used to assist in nitriding steel



Cutting technologies

The major four - Sheet + plate cutting (scissors), chip forming (cutting bit), non chip forming (water cutting), flame/laster

IPM = inches per minute

How fast it can cut per minute

Videos shown in class + notes of videos

Abrasive wheel cutting

Effective for cutting material. -> can basically cut anything

Issue is it heats up material a lot

Makes a messy finish. Sharp wherever it cuts

Laser Tube cutting

Precise

Heating it in such high heat wherever the laser cuts it changes the crystal structure slightly

Versatile -> can make prototype parts on the same machine that the manufacturer uses to make the final models

Takes a lot of power

Creates nasty fumes. Need good fume extraction

Two different types

CO2

Good at cutting organic material and thicker material

Not as accurate

Fibre

Really good at cutting thin material without marring the edge

Marring -> discolouring the edge

Very accurate very quickly

Can cut at different axis (crazy robot arm jumping around at diff angles and stuff)

Plasma cutting

Very quick, cheaper way to make parts that are high tolerance

Available readily. Machines are common

Waterjet cutting

an abrasive (sand) mixed with water are shot through a very very high pressure nozzle. The combination of the two basically wears through any material

Can cut 2 and 3d

Can cut ceramics and carbon fibre easily because there is no heat involved it does not wreck the part

Won't cut straight. Will cut in a cone shape

Can angle the nozzle and shoot the water down and the cut will end up being straight -> more expensive machines

Efficient but waste makes it difficult to use/ higher maintenance

Pumps, recycling water

Design Workflow

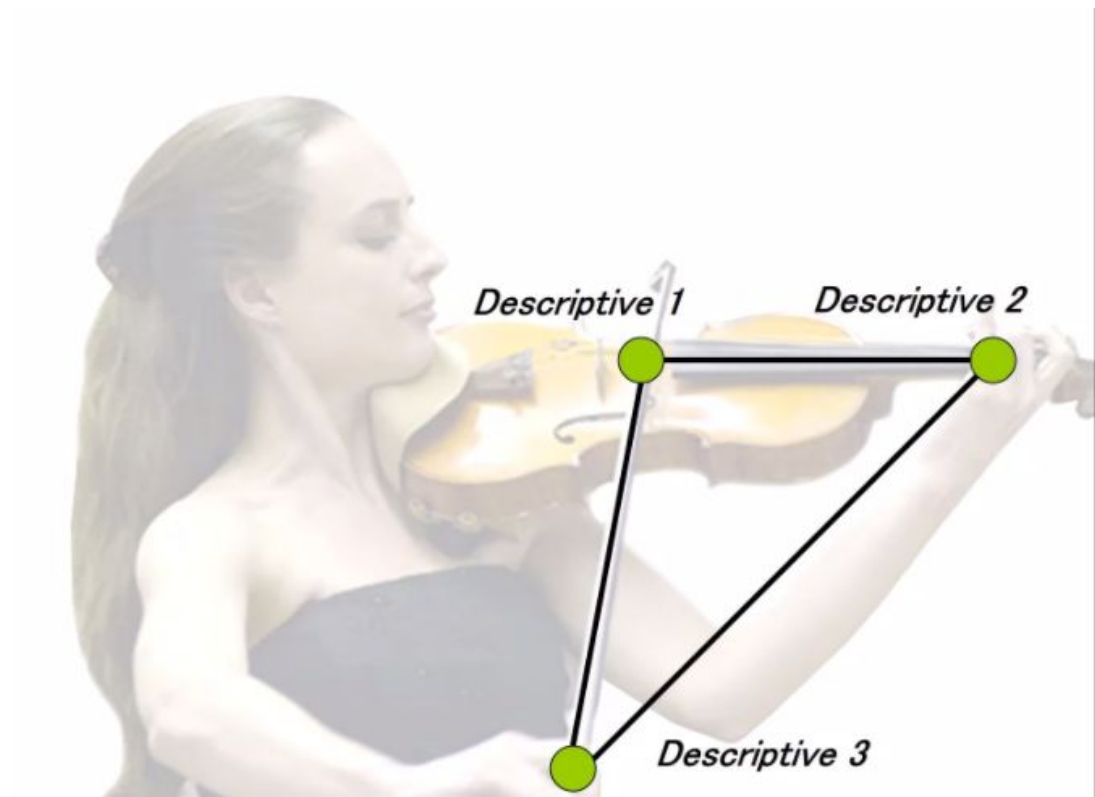
Different factors thrown at you, you feel like a one man band that has to do everything.
Realistically this is not a good way to design, MAYBE 2-3 things at once.

Easier and smoother

Imagine playing a violin.

Think of 3 descriptive words and design around it

NO OBJECT WORDS b/c itll lock you into a set idea and look



Start with a descriptive word that's general
Ex Toasting vs toaster

Mountain is a mountain -> Mountain is the descriptive word
Imagine cold windy high climbing etc

Unlearn what you have learned?

Start with loose subjective descriptive but as the project goes on you become more specific

Professionals are consulted at **Key** points

Convey the feeling you are trying to convey

Design intents -> where you are at the point of adding object points and adding dimensions

No hard details. But gives you an idea of where you are going with it

Have atleast one 3D sketch

Avoid cookie monster design

I.e do not do it last minute

Lecture 3

Textbooks -> haven books (ebook or hard copy)

De Leeuw, Series and Mass Production Technologies for Product Design

More Videos

Chip forming - routing bit / CNC

Bandsaws

Metal

Ribbon of steel that has teeth

Usually used for wood but can be found made fro steel

Steel ones are usually horizontal

Blade gets really hot so lubricant and coolant are used on it

Angle grinders

Big scary blade. Dont flex it or it can shatter

cut off disk/zip disk

Wire edm

Electrical discharge machining

Hair thin wire that shaves the material

Tiny sparks erode away material. Can be compared to plasma cutting

Biggest advantage -> doesnt matter what material it is it can cut through it with crazy accuracy (2 microns)

Sheering

scissors

Two metal blades/knives that cut material

In a lot of processes knives will break off and leave a sharp bur

A lot of times you have to deal with this or atleast deal with it in case it happens

Shaving / trimming

When cutting sheet metal can cut a large sheet or a very small tool

Notching

Starting off with a blank and notch off little parts in it

Lancing -> MIDETERM

Slicing along an edge and bending it out

Fine edge blanking - detail edge blanking

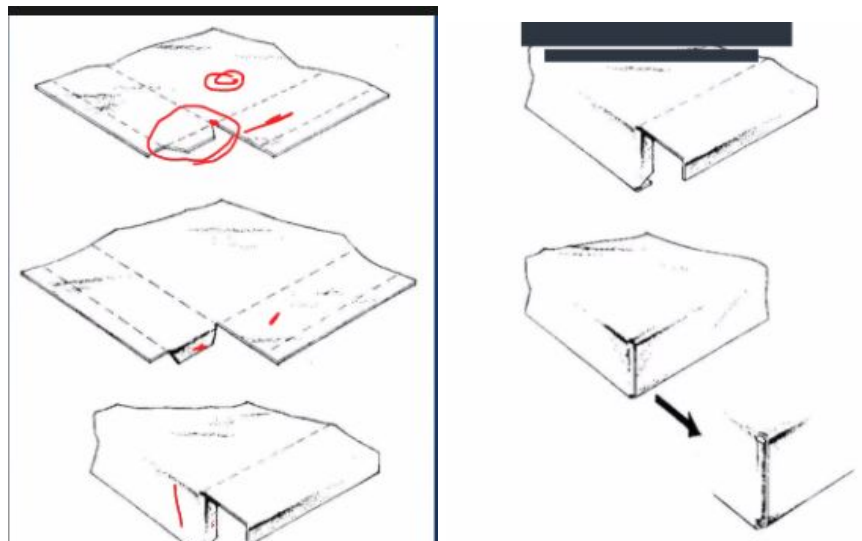
Useful for small rounded parts

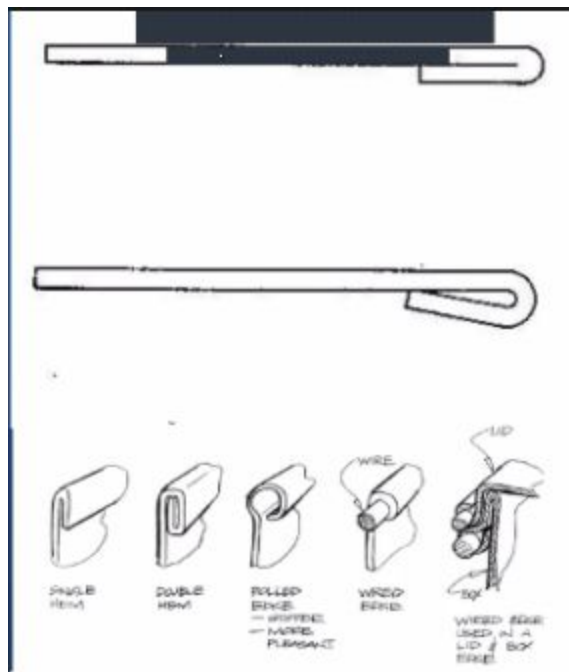
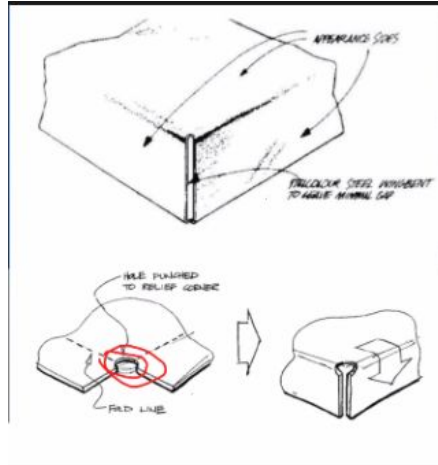
Manually deburring

Deburring sheet metal

Folding

Folding edge can fold burrs into product





Because it is hemmed over (middle one) it will never touch anyone and burrs won't be an issue

Normal bottom row on midterm

You can add diff hems together to make different parts

Good rule of thumb -> always make vent holes smaller than a pencil

Officially kids finger but pencil rule of better

Incremental sheet forming

Hold a blank and have a form and pull the blank over the form until you get roughly the shape you want

A lot of canoe hulls are made this way

Sheet metal can come in 3 types

Undeveloped

Semi developed

Fully developed

When you bend anything (tube or sheet) it doesn't bend at the radius as you think
Designers have to make jigs and devices material will bend more symmetrically
Bends will compress on one side and stretch (tension) on the other

Problem when it comes to tubing

Tube Bending

When you buy tubes they are two types, seamed and seamless

Seamed - bent to shape and welded to shape. Problem is that it leaves a little bump. Changes crystal structure and makes weld hard and difficult to cut

seamless - metal is red hot and basically extrusion

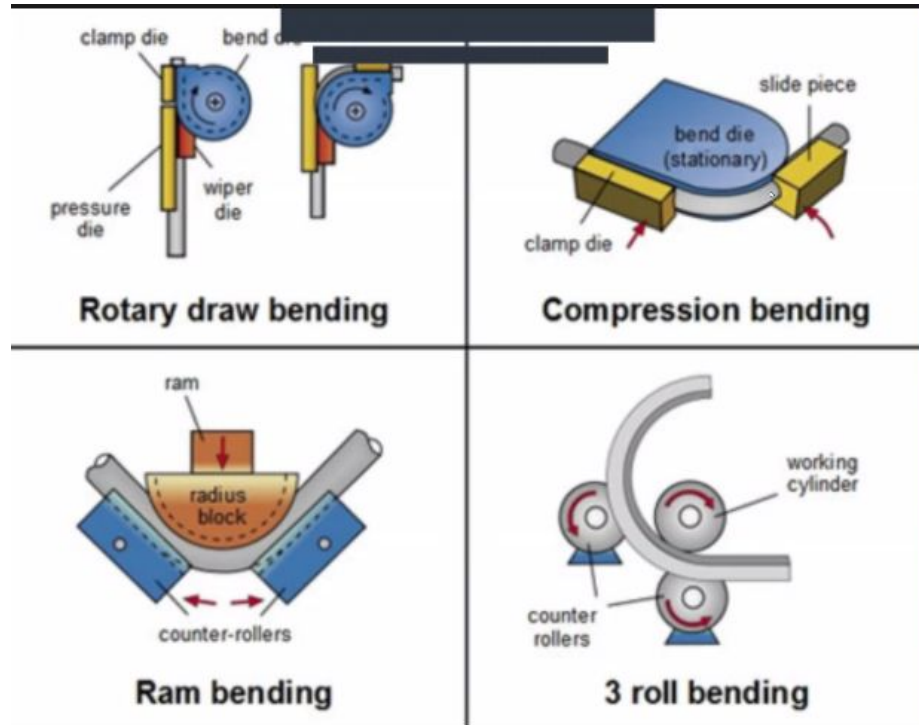
More expensive

Thin wall vs thick wall tubing

Thin wall- more often to buckle

Diameter / thickness = greater than 30

Easy bending tube = is about 15



3 roll bending

Gradually bends as material goes through

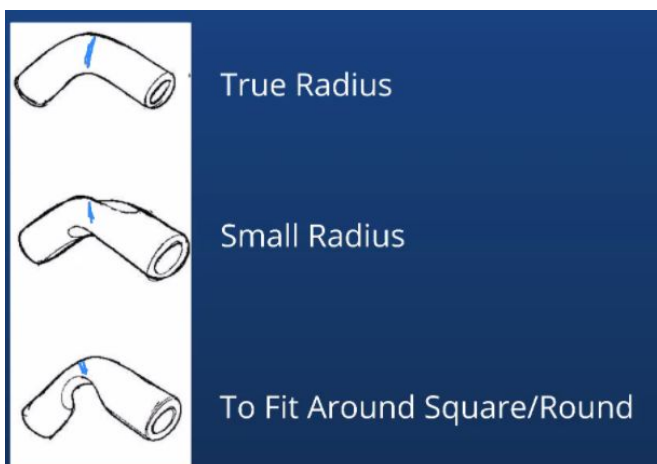
Can bend multiple times and gradually tighten the radius each time

Can get to a full circle

Compression bending

Very fast

Deliberately crushing a tube to make a radius smaller is possible but it compromises strength of piece



Small radius is weak

Smaller radius is really weak

Tube flanging

Flange - comes off and

Flaring

Trumpet

Tube expansion (swaging)/ reduction

Makes the end of the tube expanded or shrink

Fit a tube into a tube

Forming

Plastic state

Solid state

Liquid / fluid state

Accumulative

Lecture 4

Lean manufacturing -> manufacturing when putting all the machines at the same pace

Tube bending

Rotary draw bending

Most common method of tube bending and performed on rotary type bending machines

Uses bending die, clamping die, pressure die, and wiping die

Bending form rotates during bending and determines radius in which work piece is bent

Used to make bends up to 180 degrees using standard tooling and multiple/compound bends using special tooling

Compression bending

Bending form is stationary

Works well with applications in which little clamping distance is available between bends but does not control metal flow as well and impractical that requires bends that requires mandrels that require more than one bend in a work piece

Ram bending / press bending

Two supporting die have a ram pressed against the tube

The ram and supporting die are angled to match wanted contour

Require no clamping

3 roll bending

Have 3 forming rolls of approx the same diameter and arranged in a vertical or horizontal pyramid

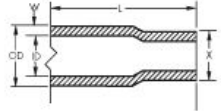
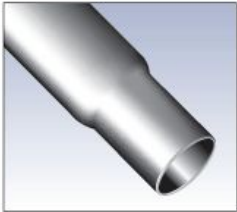
2 are fixed and adjustable center roll

All rolls are contoured to provide support and set the angle of the bend

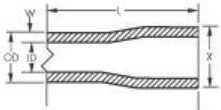
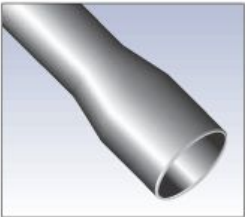
Used to process large radius tubes

Tube ending

Reduction



Expansion



Flaring

COMMON FLARE TYPES

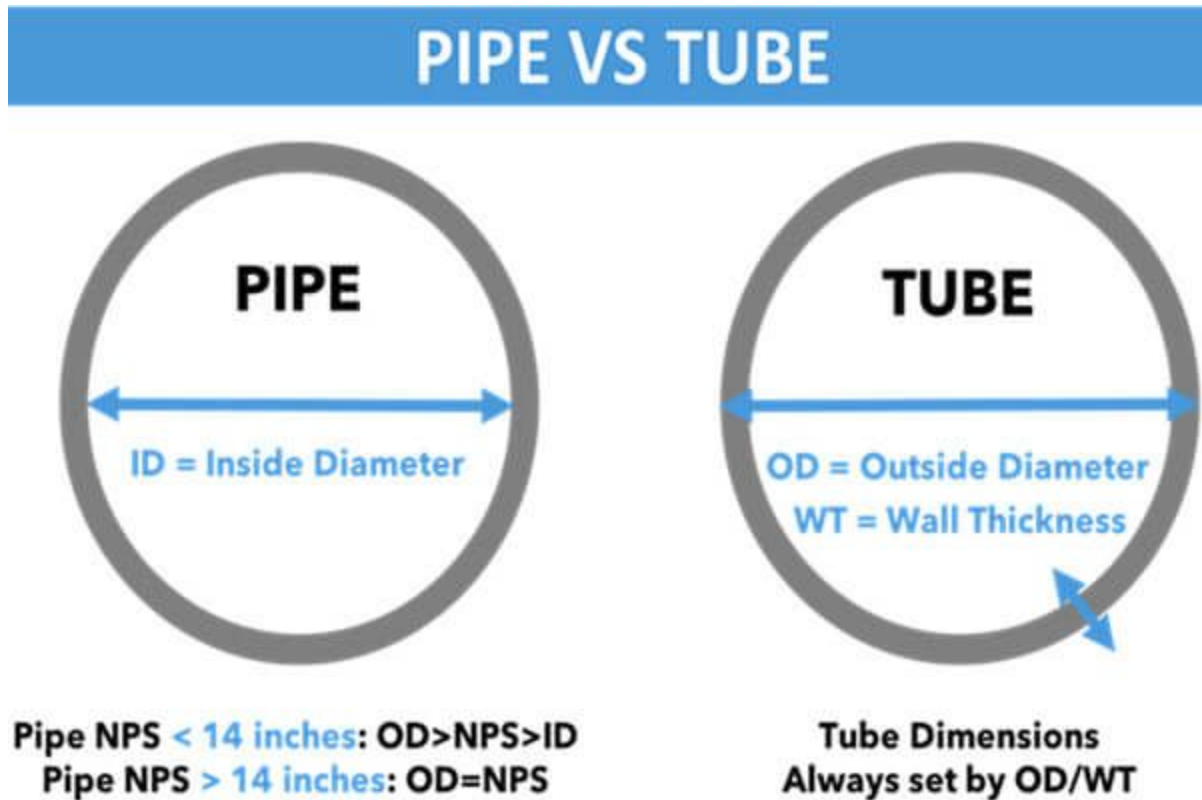


SINGLE BUBBLE DOUBLE

beading



Difference between pipe and tube *MIDTERM*



Stainless Steels

Austenitic

- Most common - cutlery
- Good corrosion resistance
- Heat hardenable

Martinitic

- Least corrosion resistance
- Tough, strong, and machinable
- Magnetic but cant heat hardenable

Ferritic

- Less ductile and less corrosion resistance than austenitic
- Magnetic
- Non heat hardenable

Precipitation

- Similar to austenitic
- Hardening process creates the hardest type

100 Series—austenitic chromium-nickel-manganese alloys

Type 101—austenitic that is hardenable through cold working for furniture

Type 102—austenitic general purpose stainless steel working for furniture

200 Series—austenitic chromium-nickel-manganese alloys

Type 201—austenitic that is hardenable through cold working

Type 202—austenitic general purpose stainless steel

300 series

302 -> tesla truck, strong but fragile to bend

303 -> relatively easy to machine

304 -> most popular

Sinks, cutlery, delorean, finishes for outdoors (brushed finish)

316 -> "surgical stainless"

Looks a lot diff. Than 304

Chrome finish to it and doesn't scratch

More expensive and does not form as easily as 304

More corrosion resistance and tougher

Higher end products

Used a lot in maritime uses / marine environments

MIDTERM

316L = 316 low carbon

Jewellery will be 316 low carbon because the more carbon content = makes it itchy

400 Series—ferritic and martensitic chromium alloys

Type 405—ferritic for welding applications

Type 408—heat-resistant; poor corrosion resistance; 11% chromium, 8% nickel.

Type 409—cheapest type; used for automobile exhausts; ferritic (iron/chromium only).

Type 410—martensitic (high-strength iron/chromium). Wear-resistant, but less corrosion-resistant.

Type 416—easy to machine due to additional sulfur

Type 420—Cutlery Grade martensitic; similar to the Brearley's original rustless steel. Excellent polishability.

Type 430—decorative, e.g., for automotive trim; ferritic. Good formability, but with reduced temperature and corrosion resistance. Indoor appliances

Type 439—ferritic grade, a higher grade version of 409 used for catalytic converter exhaust sections. Increased chromium for improved high temperature corrosion/oxidation resistance.

Type 440—a higher grade of cutlery steel, with more carbon, allowing for much better edge retention when properly heat-treated. It can be hardened to approximately Rockwell 58 hardness, making it one of the hardest stainless steels. Due to its toughness and relatively low cost, most display-only and replica swords or knives are made of 440 stainless. Available in four grades: 440A, 440B, 440C, and the uncommon 440F (free machinable). 440A, having the least amount of carbon in it, is the most stain-resistant; 440C, having the most, is the strongest and is usually considered more desirable in knifemaking than 440A, except for diving or other salt-water applications.

Type 446—For elevated temperature service

409 -> most famous b/c cheapest

430 -> appliance steels

Harder and does not scratch as easily
magnetic

440 -> higher end cutlery

Within 440 there are 4 different grades (440A, 440B, 440C, and 440F)

500 Series—heat-resisting chromium alloys

600 Series—martensitic precipitation hardening alloys
601 through 604: Martensitic low-alloy steels.
610 through 613: Martensitic secondary hardening steels.
614 through 619: Martensitic chromium steels.
630 through 635: Semaustenitic and martensitic precipitation-hardening stainless steels.
Type 630 is most common PH stainless, better known as 17-4; 17% chromium, 4% nickel. 17-4 PH is more magnetic and a little tougher. More common in laser cutting recently due to non-browned edges.
650 through 653: Austenitic steels strengthened by hot/cold work.
660 through 665: Austenitic superalloys; all grades except alloy 661 are strengthened by second-phase precipitation.

900 Series—austenitic chro-moly
904 - like 316 but even more corrosion resistance (more moly!) for marine applications

Duplex - half austenetic / half ferritic
Type 2205—the most widely used duplex (ferritic/austenitic) stainless steel grade. It has both excellent corrosion resistance and high strength.
Type 2304—lean duplex stainless steel. Similar to 2205 for strength but with lower pitting corrosion resistance due to low Molybdenum.

630 -> 17-4

Doesn't brown when laser or plasma cut. Very popular now, obscure before

904 -> they added more moly and now it doesn't really rust in a maritime environment

Duplex -> special

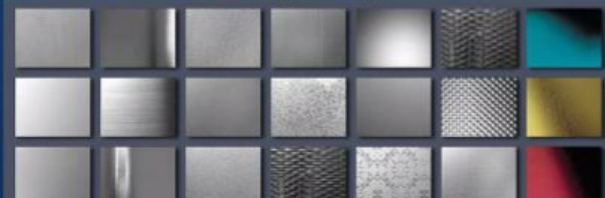
Crystal structure is half and half

Used in very very hard surfaces that are also corrosion resistant

2205 -> good calipers

Stainless steel surfacing

No. 0: Hot rolled, annealed, thicker plates
No. 1: Hot rolled, annealed and passivated
No. 2D: Cold rolled, annealed, pickled and passivated
No. 2B: Same as above with additional pass-through highly polished rollers
No. 2BA: Bright annealed (BA or 2R) same as above then bright annealed under oxygen-free condition
No. 3: Coarse abrasive finish applied mechanically
No. 4: Brushed finish
No. 5: Satin finish
No. 6: Matte finish
No. 7: Reflective finish
No. 8: Mirror finish
No. 9: Bead blast finish
No. 10: Heat colored finish—wide range of electropolished and heat colored surfaces

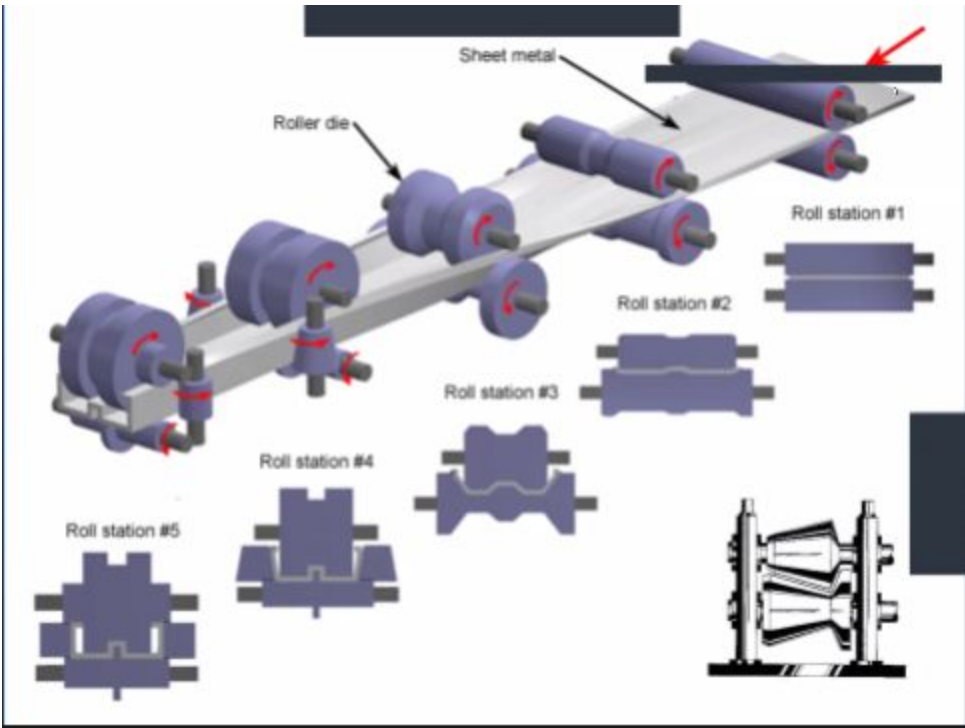


Gauge -> thickness of material

Gauge	Thickness
10	0.141 in
11	0.125
12	0.109
14	0.078
16	0.063
18	0.050
20	0.038
22	0.031
24	0.025
26	0.019
28	0.016
32	0.010

Roll forming

Think of it as a series of round dies that spins. As the steel sheet goes through to rounds it until it is shaped and becomes the final product at the end of the line



Lecture 5

Spin forming

Put a blank onto a lathe and gradually form it. One way of making pots and pans.

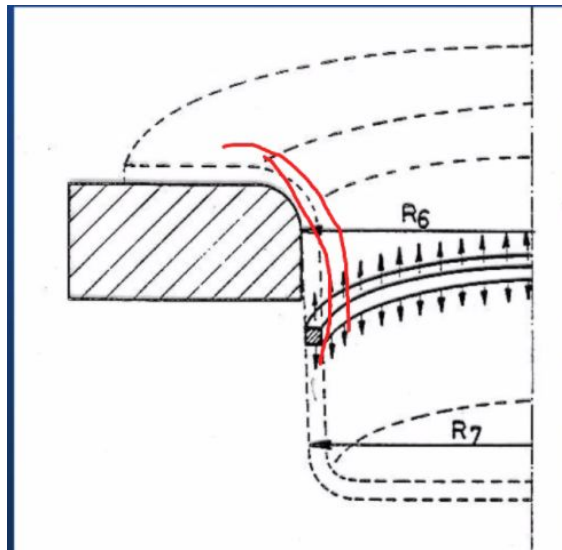
Deep draw

What competes with spinning. Different process but similar

Punch and a ring/die

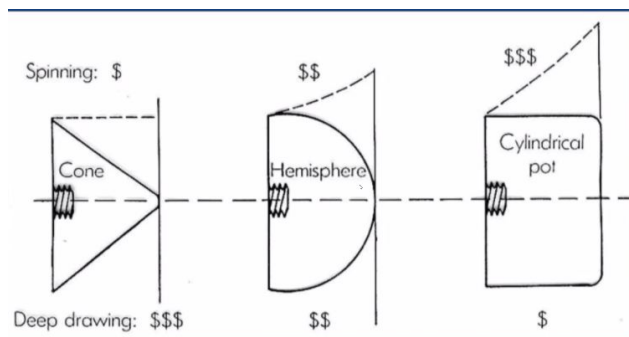
Blank and punch goes down and forms blank into die

Forms u form shapes. Ripples at edge depending on material. Flat blank gets drawn over die edge and stretches into hole



People guess the shape of blanks because of how material stretches and compresses. Recently software has become powerful enough to guess the form of the blank

Also called press forming



ALWAYS ON THE Midterm - how is a bbq made?

Steel disc -> lubed with soap -> put into a press that stresses a disk (deep drawing) into a big bowl -> bowl is trimmed -> spin bbq bowl while automated roller flanges the rim -> piece the bowl to make holes for ventilation -> welding guns fuse metal couplings to the bowls to serve as attachments for bbq's legs -> load handles into fixture that welds handles to sides -> at another station they weld hands to bbq lids that lets cook control temp -> parts hosed down with soapy water -> once dry they are finished with a dusting of a glass powder -> put into a furnace (848 celsius) -> furnace bakes glass dust into an enamel finish that protects parts

Punch machine makes dampers from aluminum -> simultaneously cuts shape and embosses logo/tm -> damper allows control of air to grill -> nylon grips are put on handles and installs dampers onto lid

Consumer assembles

Usually canoe video is in the midterm. Aluminum canoe video

Made with the same stretched aluminum process made for shaping aircraft wings

Strong silent type -> resists cracking when it comes against a rock or any other underwater object

Aluminum is too soft so elements like magnesium nickel and silicon are added are added to give it the needed strength

Electric shears cuts aluminum to length -> put over a mould of the hull -> clamp metal to hydraulic system -> pulls and stretches aluminum alloy sheet -> to the mould and it conforms to its shape -> moulded sheet needs trimming -> trimmed with a template placed over contoured section -> clamped into place and etched pattern onto aluminum -> cut with shears following pattern -> two halves form hull -> bake hull halves at 200 celsius for 8 hours -> heat strengthens aluminum and adds rigidity -> two halves are aligned -> clamps are lowered -> crank squishes two parts together -> parts are welded together -> hand clamps tacks two rounded ends together and welds together -> link end welds to the bottom

Team positions aluminum keel along the bottom of the seam -> reinforce in the inside with a T bar -> drive rivets along the T-bar hull and keel to secure assembly -> they install guards to bow and stern with rivets -> they protect end welds -> brace base of canoe from inside with aluminum ribs

Equip rim with aluminum gunnels -> pound with mallets to improve fit -> worker rolls paint on inside to prevent it becoming slick

Test -> transfer to a tank of water and clamp 450 kg of weight onto the canoe -> check for leaks

Cross bars and bench seating are added to complete fabrication

Lecture 6

Machining + Forming

Aluminum

Reason its lumped into machining and form is b/c is great to machine and form.

Goes hand and hand in ID -> easy to form and cut, doesnt rust

A lot easier than steel

Super available in crust

Comes in sheets can be extruded can be made into products and structure

Aluminum is 4x cost of steel pound per pound

Issues with laser cutting

Can be superformed

Some of the alloys can be formed to really nice shapes and cast really nice shapes

$\frac{1}{3}$ elastic modulus of steel

Unlike steel most aluminum can stress out over time through continued fatigue

Steel can take more continued stresses than aluminum

Controversy over new boeing737

Highlights problems with aluminum

Big connection points on inside of the plane

What happened is -> high strength high alloy aluminum -> they put bigger engines on it. Every Time it takes off loaded and lands etc the wings bend up and down

As it bends up and vibrates it gets fatigued out and work hardens

What's been happening is that they designed this part for a smaller engine but they put bigger engines on it and didn't redesign and the 737's are wearing out prematurely.

Common issue with aluminum planes. This is common on aluminum planes because once they get to a certain amount of hours they have to retire the plane because the wing sections have stressed out that they can't trust them anymore

Famous cases where wing falls off mid flight

Glass cement and aluminum are the same density

Wrought alloys

Aluminium - Wrought Alloys



1000 series are essentially pure aluminium with a minimum 99% aluminium content by weight and can be work hardened. Excellent corrosion resistance (good for chemical storage), good workability, low strength, not heat treatable. Can be arc welded, but difficult. Used in electrical components too.

Can be laser cut but takes a lot of energy and powerful lasers because it reflects so much light

Things are changing as fibre lasers are can be improved

Can be cut with other methods because it is so soft

How its made -> aluminium

Red sand (bauxite) -> electrolysis (a lot of electricity to separate aluminium from sand) ->

Don't use aluminum with food. Relationship and aluminum and alzheimers



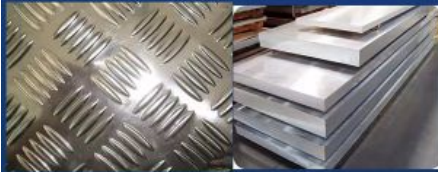
2000 series are alloyed with **copper**, can be precipitation hardened to strengths comparable to steel. Formerly referred to as duralumin, they were once the most common aerospace alloys (due to high strength to weight), but were susceptible to stress corrosion cracking and are replaced by 7000 series in high performance applications. Some 2000 alloys are arc weldable. Heat hardenable.



3000 series are alloyed with **manganese**, and can be work hardened. Good workability, moderate strength. Generally, not heat treatable. Good for higher temperature applications like radiators, powerplants. Moderate strength means there are better alternatives for structural purposes. Not heat hardenable. Weldable with variety of different filler aluminums.



4000 series are alloyed with **silicon**. They are also known as silumin. Use in high-end automotive engines - racing. Generally, not heat treatable (although some exceptions), but weldable. Good at higher heat applications.



5000 series are alloyed with magnesium. Good corrosion resistance and arc weldability, moderate to high strength, not heat treatable. Highest strength for non-heat hardenable Al. alloys. Very formable at lower temperatures (super-forming). Used in marine applications a lot due to salt resistance. Many different alloys in this series - some not good for high heat.



6000 series are alloyed with magnesium and **silicon**, are easy to machine, and can be precipitation hardened, but not to the high strengths that 2000 and 7000 can reach. Good formability, machinability, weldability, corrosion resistance. Heat treatable.



7000 series are alloyed with **zinc**, and can be precipitation hardened to the highest strengths of any aluminium alloy. Moderate to high strength, heat treatable. Most of these alloys are not arc weldable, but there are a few exceptions (7005).



8000 series is a category mainly used for **lithium** alloys. Under development - only aerospace applications at the present time. Good corrosion resistance, high strength low weight. Can be TIG welded. Not seen in product design yet.

Aluminium Treatment (i.e. 6061-T6)

- F As fabricated
- H Strain hardened (cold worked) with or without thermal treatment
- H1 Strain hardened without thermal treatment
- H2 Strain hardened and partially annealed
- H3 Strain hardened and stabilized by low temperature heating
- O Full soft (annealed)
- T Heat treated to produce stable tempers
- T1 Cooled from hot working and naturally aged (at room temperature)
- T2 Cooled from hot working, cold-worked, and naturally aged
- T3 Solution heat treated and cold worked
- T4 Solution heat treated and naturally aged
- T5 Cooled from hot working and artificially aged (at elevated temperature)
- T51 Stress relieved by stretching
 - T510 No further straightening after stretching
 - T511 Minor straightening after stretching
- T52 Stress relieved by thermal treatment
- T6 Solution heat treated and artificially aged
- T7 Solution heat treated and stabilized
- T8 Solution heat treated, cold worked, and artificially aged
- T9 Solution heat treated, artificially aged, and cold worked
- T10 Cooled from hot working, cold-worked, and artificially aged
- W Solution heat treated only.

Precipitation hardening

T -> most common T6

Artificially aging aluminum

Alloys like migrating to the surface. Over time alloys migrate and go to the surface of aluminum. Engineers described it like precipitation (like rain). They collect at the surface and make the aluminum harder

If you heat up aluminum at 200 degrees. It allowed alloys to migrate to the surface faster.

They don't want alloys in food stuff because once the aluminum heats up the alloys will get to the surface and then into food

