

# Tools

My father, Christopher J. Martinez, taught me how to use most of these tools, who learned it from his father, Joe B. Martinez, and a bit from the elevator trade. I then got tips from the shop teacher on my solar car team. Lathe and mill experience was gained at the Columbia Mechanical Engineering shop and Formula SAE Team. Gaps have been filled in by internet reading, especially the OSHA log of industrial accidents. You can search by tool and see what are the most common deaths and injuries from each tool.

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# Ben Casey - Pneumatic testing kit

# Nuts and Bolts

## Practical

Nuts and bolts are going to be either Standard (American speak for imperial units) or metric. Generally each size has a standard “fine thread” and “corse thread”. Fine thread will have a higher thread count than corse thread, which means fine thread wraps around the bolt more times for a given vertical surface of the bolt.

[diagram of bolts, showing thread count]

Corse thread is adequate for most applications. Since there are less wraps, it tightens quicker, and its easier to notice when its cross threaded, which makes cross threading less likely to happen.

A note on cross threading

[insert picture of cross threading]

Cross threading is when the nut doesnt go on correctly, and instead of sliding into the first thread, it bites on to one further down. Since a large amount of force can be applied by a screw with a wrench, you can easily carve new threads by accident. This is one of the saddest things that can happen while being a mechanic, and will usually be blamed on the nefarious “previous owner” or “that idiot mechanic”. Generally you should be able to thread a bolt 1 or 2 full rotations by hand. If you are worried you don’t have the threads engaged properly. Spin left to back the nut out, and try again to tighten it. I like to rotate it left while pushing down slightly so it can hop across the thread and get seated down into the threads properly. You can usually tell a nut is cross threaded because it takes a stupid amount of force to tighten and untight, and you can feel it carving through the bolt. Sometimes though, a bolt is just old and rusty. Dirty bolts can also be continuously tough to tighten and un tighten.

Lefty loosy, righty tighty. You can also use the “right hand rule” to remember which ways nuts usually tighten. Do a thumbs down. The direction your fingers are curling is the way the nut is suppose to rotate to tighten.

Nuts are generally always hexagonal, because hexagons are the bestagons. The head of the Bolt, however, comes in many different configurations, The most common is a hexagonal head. Generally its easy to get a lot of points of contact and can be adjusted with many tools, but generally you have to access the nut from the side and cant recess the bolt unless you have a ton of space around the head.

For applications where you don't have space around the bolt head, allen heads are generally used. They are taller and have an internal hexagon for tightening. I hate them though because it is very easy to accidentally grab an allen key slightly too small and round the shit out of the hole.

## Rounding

The second most painful thing after cross threading a bolt is rounding a bolt. This happens with internal allen key bolts and external hexagonal bolts and nuts. If you use the wrong size wrench, or have it at a bad angle, or the head material is soft, you break off the sharp corners of the hexagon and round it off. It is very sad and aggravating. Its also why you try to use as many points of contact when tightening a nut, use the box end of a wrench, instead of say, an adjustable wrench. And don't use fucking pliers on a nut and bolt, you'll round it out and have to use vice grips to get it off when its fully rounded.

## Stripping

Overtightening a bolt doesn't make it take its clothes off, but if you are lucky enough not pull the bolt apart, you'll usually strip the bolt. This is when the threads of the nut or bolt fail and break off, so there is nothing to bit into anymore and the nut just freely rotates. Stripping also happens when you have a part with internal threads and you break those.

Snapping a bolt is usually when the friction on the threads is too high (or you run out of travel on the bolt so it can't move anymore, so you end up breaking the bolt in torsion.

## Torque Specs

Nuts work on friction. By tightening a nut against a surface, the surface is pushing up on the nut, forcing the threads of the bolt and the nut to push against each other, which increases the friction and prevents the nut from rotating loose. This is why a "torque" spec is usually what describes how tight to tighten a particular bolt. Since torque is just rotational force, the harder it is tightened, the harder it is to rotate, and the more friction is has between the threads, which is the same friction that prevents the bolt from loosening up. By using a torque wrench, you are essentially measuring the tightness of the threads.

One thing to keep in mind is that bolts are being stretched when you tighten the nut. You can imagine the bolt like a spring. The nut is pushing away from the plate and pulling up the bolt, and the bolt is a spring pulling the nut back down. This is useful as this is what's really generating the frictional force that keeps the nut from falling off. However, it is possible to snap a bolt this way, as the nut and threads can literally pull the bolt apart. What's also really important to keep in mind is that while the force of the bolt is usually proportionally to the force of friction, this relationship will change based on how lubricated the threads are. This means if your threads are well oiled, it will be very easy to move the nut down, and the nut displacement is what pulls on the bolt and generates the tension in the bolt. This tension is multiplied by the coefficient of friction between the threads, generating the frictional force. This means that if you overlubricate the threads, you can snap a bolt because the torque spec now puts more tension on the bolt.

[picture of thread and bolt force]

# Theory and Design Applications

[diagram of nut and bolt with forces]

Both the nut and bolt are screws, which are incline planes. The purpose of an incline plane is to reduce the force need to move something vertically, and achieves this by requiring more lateral motion. A screw does the same thing, it requires a large rotational movement for very little lateral movement, and as a result, makes the vertical force usually much stronger than the horizontal force used to tighten the bolt.

A nut and bolt also acts to transform a rotational force (torque) to a linear force.

Read Carroll Smith's "Tune to Win" and "Engineer to Win". He is very clear that the primary purpose of a bolt is to clamp two items together. For tasks such as positioning, other devices, such as dowel pins, are much better. This is very important because a bolt is often use to position parts, and to act as a shear pin. The threads on a bolt act as stress concentrators, so it is bad to the shear applied on a bolt near the threads.

This means the primary purpose of a nut and bolt is attach 2 parts, i.e. make them act and take forces as one, for something you need to take apart later. In this case, the friction on the surfaces between the 2 parts should be holding them together, not the shear force from using the bolts as a pin.

[show picture of transmission case or something]

A few good examples, using an engine as a stressed member. Crankcase of transmission. Bolting a seat to a floor. Perfect bolt application.

[show picture of fsae a-arm]

This could be done by a dowel pin with clips

Show how transmission case can use formed pins and then that helps drill the holes and screw the bolts.

# Wrenches

You should probably be using a ratchet and socket. Go use that first. If that doesn't work, then take out the wrench.

Wrenches are used to tighten nuts and bolts, and occasionally as hammers and lever arms. The goal of this article is to show good habits with wrench use so you don't damage the precious nuts and bolts on a piece of machine

Wrenches will be in standard and metric. Most cars these days, even american cars, use metric. Don't use standard on my metric motorcycle or I'll have to kick your ass.

[image of wrench with labels]

A typical wrench has a boxed end and an open end. ALWAYS use the boxed end if you can, especially when breaking a nut loose or tightening. The goal should be to have as many points of contact as possible so you don't round the nut or bolt. Boxed ends have 6 points of contact, open end has 2. It is possible to pry apart the open end with too much force, so use the boxed end whenever you can.

The open end is useful because it is angled slightly. This is for hard to reach places where you can barely get any rotation on the wrench. The idea is you turn it a little, then flip the wrench, then turn it some more, then flip again, repeat. Also some nuts need to be adjusted on a bolt that is inserted into something, so you need the open end to adjust the nut. Sometimes it can be a lot quicker to use the open end, as it slides in and out from the side. Feel free to do then when the nut is fairly loose. Still, when it's really tight, strive for the boxed end.

## Safety

I wear safety glasses all the time because I want my eyes to be beautiful and eagle sharp my whole life. I've had toxic brake fluid shoot into my eye when I overtightened a brake line with a wrench and it exploded. My damn safety glasses were on my head. I ran to the sink and poured water in my eye for 10 minutes straight.

The more immediate harm from a wrench is "busted knuckles". That's when you wrap your whole hand around a wrench and hit your knuckle on a metal piece of something while rotating it. The main advice is to push on the wrench with an open palm when breaking a bolt loose.

Gloves can be used to lessen the wear on your hands, though often this just slows you down.

The most risky thing you can do with a wrench is be in a hazardous location, such as on a ladder or in a machine room. When you break a bolt loose, you are pushing hard on a wrench that suddenly rotates. You can lose your footing and fall over, or off a ladder, or off a building, or into a

drivechain. When breaking a nut loose, always have firm footing and make sure you are not being supported by the wrench itself. Spread your legs apart so you are stable, or lean your shoulder onto a wall so you are supported while you push/pull on the wrench.

You can easily over exert yourself while trying to break a bolt loose. Get the right tool for the job. You should probably be using a ratchet/socket or breaker bar in many cases. Pull and push in ways that are natural for the body, take the time to reposition yourself and do smart moves that place force on the wrench easily instead of in a difficult manner.

Locking wrenches together

[Image of wrenches locked together]

Old trick taught to me by pops. You can pry open a wrench very easily this way and it will no longer be the right dimension. Also you can slip the wrenches out of each other and send one into your face. Don't do that.

A better way is to use a cheater bar.

## A note on adjustable wrenches

Avoid these whenever possible. If you use an adjustable wrench to work on my car, you get kicked out of the shop. It has 2 points of contact and makes it very easy to round out bolts. If your bolt assembly can be cut off and replaced when you round out the nut and can't take it off, feel free to use the adjustable. Also if this is a part that won't be serviced often, I can understand using an adjustable to carry less tools, like on an hvac job. Still, do your future self a favor, use a regular wrench.

# Ratchet and Sockets

This is the tool of choice when being a mechanic. Some of you will have a drill or impact gun to tighten and loosen bolts, but for most work a ratchet will make you work fast and not damage your nuts.

[image of ratchet and socket]

Ratchets usually have a switch that changes the direction it is going. Ratchets also have an internal mechanism, which is the typically engineer speak for a ratchet.

[show internal image for ratchet]

Ratchets have an internal pawl, which hops on the gear in the free spinning direction, and pushes on the gear in the other direction. This allows it to spin the socket only 1 way. This pawl can break if you put too much force on it. For this reason, never use a cheater bar on a ratchet. If you need a longer lever arm, get a breaker bar, or get a tiny breaker bar and put a cheater bar on that.

## Types of Sockets

Besides having metric and standard sockets. You have different sized drives, and different patterns.

[Image of sockets]

Standard size for drives are 1/4", 1/2", and 3/4" drives. All sockets you buy in america will have standard sized drives, even if the socket itself is metric.

Sockets generally come in 6 point and 12 point sockets. 6 points form better to the nut/bolt, but 12 point can more easily grab onto the head. This allows smaller rotations for really hard to reach areas.

## Adapters

You can have drive reducers, u joints, and extensions. Be careful with putting a larger drive adapter onto a small ratchet, you can break the ratchet. U-joints are great, they all you to tighten around corners. Extensions are a total necessity. Sometimes the ratchet handle would hit on your machine but with the extension you can get the socket on the head and ratchet from a more comfortable position.

## Safety



Read the wrench article. Its the same thing. The only caveat is that you have to be careful when using a ratchet with an extension and make sure you are rotating in the correct direction. With an extension, you can push into the bolt instead of pushing around it, either causing the ratchet to slip off or rotating it at a skewed angle and rounding the head. For this reason, when using the extension, I try to put one hand on the extension or on the base of the ratchet pushing it in, then other at the end of the ratchet for leverage.

# Measuring Tapes

If you want to build something that isn't shit, you need to know how to use a measuring tape properly.

[Image of measuring Tape]

Most measuring tapes will have 16ths of an inch. If you are building a part or device or car, get a measuring tape that only uses 1 unit. The type with both metric and standard can work against you when you snake the tape through parts and have the wrong units where you need to measure. This type is good for building surveys though, where the precision doesn't matter.

[Image of gradations]

When making precise measurements, try to pick one side of the tick mark and take all of your measurements from that side.

You should get in the practice of "burning an inch" or however many are needed to make the measurement comfortable. This means instead of using the end of the tape with the floppy hook, place the 1 inch mark at the start of your measurement, then when you take the reading at the other end of the tape, subtract 1 inch. This makes your measurement better.

If you do want to use the hook end, keep in mind it has play in it for a reason.

[show image of hook end]

The play should be equal to the thickness of the hook. So you can push it in so the start of the measurement is on the outside of the hook. Or you can hook the tape onto something so the start of the measurement is at the inside of the hook. When taking measurements this way, I read the to the middle of the tick mark for the measurement but I'm not 100% sure this is correct.

When you measure vertical distances, place the hook end of the tape on the ground, and push the coiled part of the tape above you.

[image of this]

Finally, the measuring tape itself is suppose to be a standard 3". So if you are measuring inside a tight space like a door way, you can place the tape against the inside of the doorway and add 3" to your reading.

[image of this.]

# Calipers

Calipers are precise measuring devices, not tools. Keep them in the case when you are not using them and don't try to pry anything with them. There are digital and manual calipers (venier calipers). We'll start with digital.

[image of digital calipers]

Clean off the jaws and zero it.

4 places to get measurements. Flat part of jaws, sharp part of jaws, jaws for internal measurements, part that sticks out base.

Treat your calipers well, do not bend them or damage the jaws.

Venier calipers work by lining up the decimal and adding this, will show image and calculation

[image of venier measurement]

# Hammers

There are many types of hammers. You got claw hammers, rubber mallets, sledgehammers, sheet metal hammers, etc. Use the right one of the job.

## Safety

Please wear safety glasses **WHENEVER** using a hammer. The pressure involved are outrageous and objects hit with hammers can explode and go into your eyes. Always wear safety glasses.

My dad taught me 2 small taps then a hard hit. When using hammers for the first time, don't swing hard. Even when experienced, start with softer hits and work your way up to harder hits. When you are doing a lot of work, generally fewer hard hits are better than a lot of soft hits. So as your skill builds up, get used to smacking nails harder.

Inspect your hammer and make sure the head isn't about to fly off. If the metal head wobbles on the wood, get a different hammer. For this reason I like to buy hammers that are 1 steel piece and the head and handle are 1 piece.

This might sound obvious, but look directly at the thing you are hitting. This will make sure you hit it **AND** protect your eyes in case it explodes. If you are looking sideways at something that explodes, bits can go around your safety glasses and get into your eyes.

Consider wearing gloves when using a hammer.

## Usage

Hold the hammer near the end, you want the weight of it to help you. Do 2 small taps then a hit. Repeat this, tap-tap-hit, tap-tap-hit. Then you get good.

Claw hammers are designed to hook into nail heads for extraction. Make sure you have the head in snugly before pulling on the handle.

[insert image of claw hammer in nail]

## Hammer Head Material

Sometimes you are hammering one part into another. Don't do this if you aren't supposed to, try to lever or push it in first. If you **HAVE** to hammer something in, make sure you don't damage the part (such as a bolt head) by smacking it with a hardened steel hammer. Rubber mallets are generally the first tool when you want to apply force to something without denting it. However, it has to be a large surface or you will damage the rubber. If you are hitting a steel or aluminum bolt head, you might want to consider using a brass hammer, or get a brass punch, or a block of wood.

You place an object between the hammer and the bolt to transfer the force, the brass/wood gets damaged, the bolt stays fine.

# Razors

Razors and exacto knives are very important tools.

Rule 1: Cut away from yourself. Make sure a finger or body part isn't in the path you path you are cutting. If it is hard to cut then the blade suddenly goes through, you end up cutting yourself very hard.

Rule 2: Blunt blades are more dangerous than sharp blades. With blunt blades, you use more force to cut objects and risk releasing that force and cutting yourself as mentioned above. Keep spare blades and replace them frequently, keep it sharp.

Rule 3: Store the blades with razor retracted or covered. This might sound obvious but at least one person has rummaged through a drawer to cut themselves, or leaned on a table that had an exposed blade.

I also wear safety glasses when I use blades cause I liek my eyes.