T-RAX Metal workshop study material

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Credits

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General workshop rules

It is very important to adhere to the workshop rules while in the metal workshop. As the machines can be very dangerous if used without care, and there is a possibility of damaging the equipment.

In the metal workshop it is mandatory to adhere to the clothing rules. The following is required in the workshop:

- Safety glasses, normal glasses are fine
- Hearing protection, when machines are running
- Correct clothing, this includes
    - Pants that extend past your knees.
    - A short sleeve t-shirt, or rolled up sleeves (Exception to this rule is when welding, when welding, full covering fireproof clothing should be worn. A good alternative is the welding overalls that is available in the workshop).
    - Safety shoes (available in the FUSE-box).
- No hanging jewelry
- Tied up hair if you have long hair

You are never allowed to work alone in the workshop. Anyone else that is joining you must have completed the necessary T-RAX metal course to be allowed into the workshop.

You are not allowed to use gloves when working with any rotating tools or machines in the workshop, which only leaves the plate cutter and welding where gloves are allowed.

You are not allowed to perform any maintenance on the machines, this is done by the daytime personnel, if a machine is broken, scan one of the QR-codes in the workshop and fill in what is wrong.

Open flames are not allowed in the workshop. Meaning that you are not allowed to use burners or similar anywhere in the workshop.

Bringing and using a water bottle into the workshop is fine as long as it has a sealable lid.

Payment for material can be done in the rapid prototyping workshop next to the laser cutter.

Workshop layout

The metal workshop consists of two main areas

The first area that you enter upon entering the workshop is the cold or cutting area of the workshop, this area houses all of the machines that cut material. In there you should always wear short-sleeved shirts (or rolled up sleeves) and no lose clothing. Straight ahead from the entrance you will find a “office” where you will find safety glasses, as well as a locker with drills and measuring equipment.

The second area is the hot work area, this room houses all welders and grinders. This is the only room where you are allowed to weld or grind. While working in this area it is important to always close the door, as the ventilation will work badly if the door isn't closed. On the far end of the room you will find a locker with welding gloves, angle grinders, TIG electrodes etc. When welding it is of utmost importance that you pull the yellow UV-blocking curtains out as good as possible. Since without these not only will you hurt the eyesight of the people working in the workshop but also people passing by or studying in the hallway.

Drill Press

The drill press is used to drill holes, and is of great help when making threaded holes.

General use

It is absolutely forbidden to use the drill press as a mill, in other words, never do anything that does not have completely vertical forces in the machine. As neither the machine or the tool holder are designed to take forces from the side, it will lead to the machine breaking as well as danger as the tool (drill chuck) could fall out while running.

Always make sure to have the workpiece securely fastened while drilling.
When using clamps you should always use a minimum of two clamps together with a scrap wooden board under the workpiece so that you won't drill into the table of the drill press.
You can also use a vise to secure your workpiece, make sure that you always have something supporting the workpiece. This is usually accomplished by using parallels.
Remember that the vise is not dialed in, which means that you can't be sure that turning one wheel will lead you parallel to the workpiece.

In the workshop there is usually one drill press with vise mounted and one without a vice mounted. This is the preferred setup since it allows for fast access to both clamping and using a vice, and as such you should always put it back in this setup if you have moved around the vise.

When drilling you should always use cutting fluid to cool and lubricate the drill.

Step drill

When drilling holes in thin sheets of metal (up to …mm) you could use a so-called step drill to make sure your hole is completely round. If you use a regular drill the holes tend to get oval.

Cutting speeds

When drilling it is important to always use the right spindle speed to make sure that you do not wear out or break the drills prematurely. To calculate the speed that you should use you will need to use the following formula:

$$n = (V_c \times 1000) \div (d \times \pi)$$

Where n = Chuck speed in RPM V_c = Cutting speed for the desired material in mm/s d = drill bit diameter in mm

The formula is listed on signs close by the drill presses, but make sure to memorize it. The signs also include cutting speeds for most normal materials.
Since the drill presses have geared gearboxes it is not possible to get the exact desired speed, because of this you should always round down, never up (i.e if the calculated value is

599 and you can choose between 600 and 440, you should pick 440) this is to decrease the wear on the drills.

For drills with varying diameters (countersinking drills etc) you should calculate the value for the biggest diameter used, it is also recommended to lower the speed a little extra, since these drills usually are less stable than normal spiral drills.

Threading

Cutting threads in the drill press is done using a thread tap, these are available in the most used sizes from M3-M12. Before cutting the thread with the thread tap you will need to drill a correctly sized hole for the thread to make sure that you get the full thread profile. This is accomplished by drilling a hole with a diameter of the size of thread minus the pitch of the thread for a M6 with a pitch of 1 mm this would be:

6 - 1 = 5 mm

Meaning that you should drill a 5 mm big hole to be able to cut the thread. Many sets of taps come with matching drills, but these can of course be lost or misplaced. To find the size of the tap you can usually read on the shank of the tap, and it will say something like M6x1 meaning that it is a metric size 6 mm tap with a pitch of 1 mm.

When you have drilled your hole it is advised to not move the table and drill another hole, but to stay at the same location as finding the hole correctly again can be cumbersome and lead to the tap getting threaded off axis. This can lead to a bad thread and the tap snapping off. It is best to simply switch out the drill and insert the tap, and then carefully turn the chuck by hand until you have made sure the tap is cutting straight. After this you loosen the chuck and attach a tap wrench to turn it the rest of the way. When threading it's important that you break the chips. You will notice that as you turn the wrench it will give an increasing resistance to turn, to break the chips you simply turn the wrench backwards until you feel a slight “click” in the tap. You can then continue turning forwards. You should always make sure to use threading grease when cutting threads, just a small drop on the tip of the tap is enough to lubricate.

> *tip: Taps are available in multiple stage variants, where you have 2 or 3 versions that cut semi-finished threads. These are good since they lower the risk of snapping the tap, and have much lower cutting forces which is crucial when cutting larger thread sizes.*

Horizontal Metal Band Saw

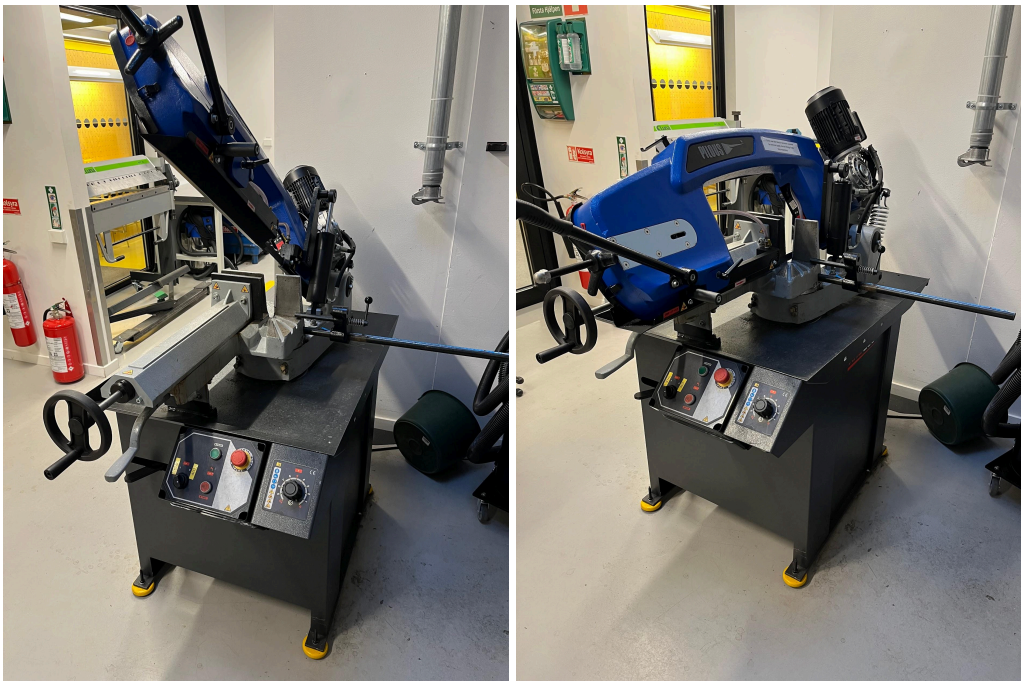


Figure 1: Horizontal Metal Band Saw

Use

The horizontal metal band saw is used to cut workpieces from long pieces of stock.
It uses cutting fluid to lubricate, cool and extract chips. The machine works by sawing while the machine drops the blade, giving a stable cutting force. When cutting stock it is important to always have as many cutting teeth as possible cutting at the same time, this means that rectangular stock should lie down while cutting.

Feed

The feed mechanism (dropping of the blade) is fully hydraulic, meaning that the saw does not need to be running for the blade to drop. Due to this it is important to always make sure that the feed is turned to zero whenever you're not cutting. If you fail to do so, it could result in the blade crashing into the stock that is in the machine.

figure 2: Horizontal metal bandsaw feed rate control

Feed Rate

The feed rate can be turned multiple turns to open the hydraulic valve more, this increases the rate at which the blade drops. When turning the knob to zero it is important that you do NOT tighten it, this will only lead to the plastic cover slipping and making the indicated numbers off. When cutting the knob should be turned to the number 5.

Figure 3: Horizontal metal bandsaw controls

The controls have two different speeds stål (steel) and alu (Aluminium) It also has stop, start and emergency stop.

Swivel the bandsaw

Figure 4: Swivel lock

To swivel the band saw the lock needs to be opened, it can then be turned. It is important to remember that the band saw can start cutting into its own base in certain swivel degrees. When using swivel it is therefore important to always stop the machine right when the stock has been completely cut through.

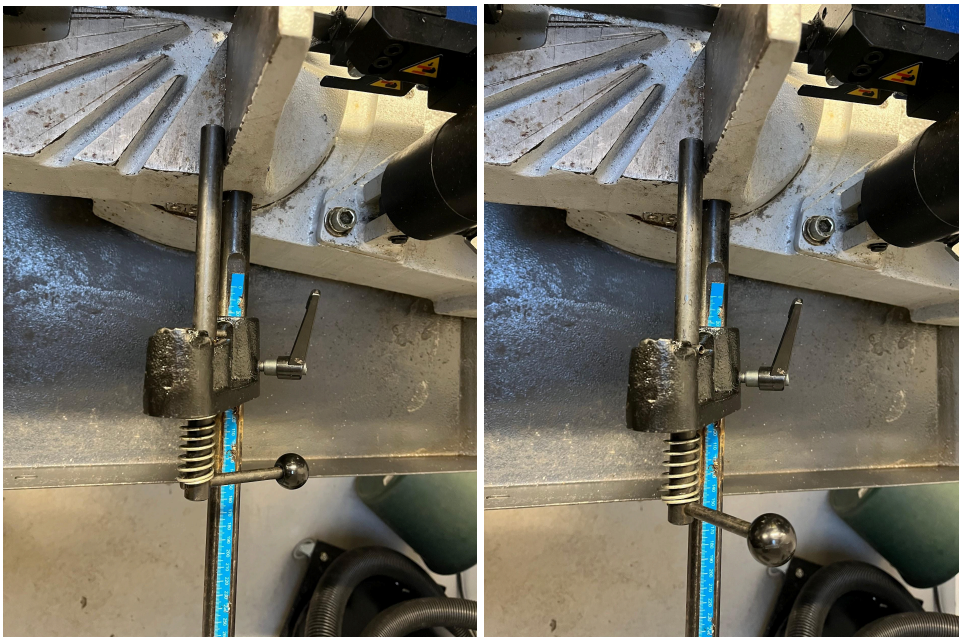


Figure 5: Length stop engaged (left) and up while cutting (right)

The length stop has two different modes, it can be flipped up or down, this feature is meant to make sure that you can keep the same measurement between cuts, while still not pinching the blade. The lever is flipped away from the operator when putting in a new piece and then flipped towards the operator during cutting.

Figure 6: Horizontal band saw fast clamp lever (White closest to the camera)

The saw is equipped with a fast clamping mechanism, to use this you turn the clamping wheel until the stock is slightly clamped, you then turn the wheel half a turn back. When this is done you can simply use the fast clamping lever to clamp the piece securely. This along with the length stop can be used to great advantage when cutting many similar pieces of stock.

Figure 7: Blade support (black square running along blade)

Depending on how wide the stock youre cutting is, the support might need to be changed, the small black lever situated next to the support unlocks the support and allows you to move it back and forth. If this support has been moved back and you're trying to cut a small stock. Then you might have a problem where the back of the support will interfere with the clamping wheel. This will lead to the blade not being able to drop any longer. To fix this simply move the support in longer.

Figure 8: Horizontal metal bandsaw door

The door next to the saw is used when cutting long materials, it can also be used to get bigger pieces of material into the workshop. It is allowed to be opened only when cutting long pieces. It must at all other times be both closed and locked, as anyone can open the door if you fail to lock it.
Failing to lock the door leads to termination of access to the workshop.

Vertical band saw

Figure 9: Vertical Band Saw

General use

The vertical band saw is used to saw through most kinds of material available in the workshop, especially if you have plates that are too thick to cut in the plate cutter.

The controls you are allowed to use are the red and green off and on buttons to the right, these are used to stop and start the band saw. The buttons to the left are used to weld the saw blades, which members are not allowed to do.

When cutting with the band saw it is very important that you do not reverse while the machine is on. If you reverse, the blade will skip off its driving wheels and the machine will be out of service until the daytime personnel has fixed it. So to get out of a cut, you first have to turn off the machine and let it come to a complete stop before pulling the workpiece backwards.

It is also good to remember to not pinch the blade, when turning, the machine has a possibility of pinching if the turn is too sharp. A better alternative than turning in the saw is to simply make a series of small straight cuts and then grinding down the rest of the turn on the belt grinder. This will also lead to a much better result.

Figure 10: Blade support (Green) blade support wheel (Black above the support)

When cutting, the blade support should be as close to the material as possible (without pinching it). To change the height of the support the wheel on the right should be loosened and then the support can be moved up and down with one hand.

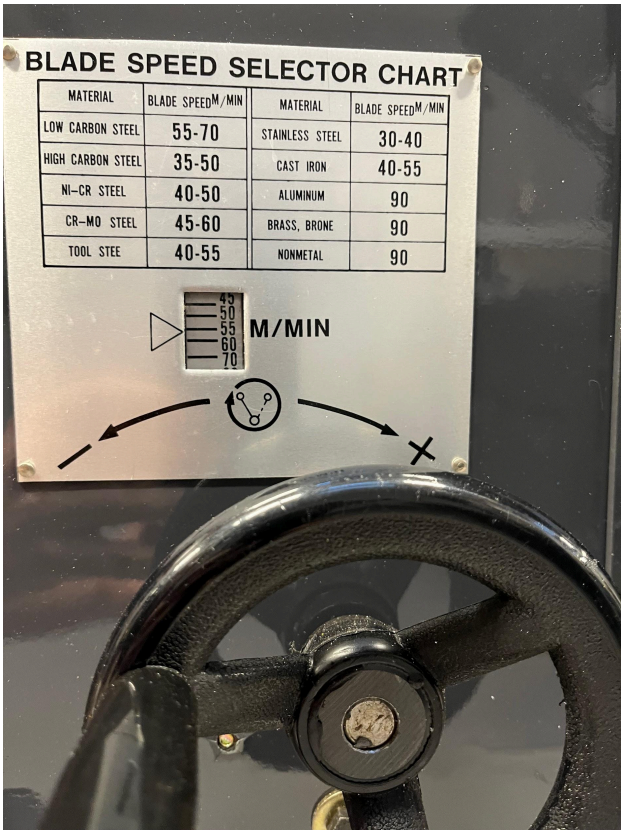


Figure 11: Blade speed chart for the vertical band saw

You are allowed and encouraged to change the blade speed to match the material you are cutting. For reference all the steel (except stainless steel) that is available to buy from T-RAX is low carbon steel, and thus the wheel should be turned until the indicator is somewhere between 55 and 70 when cutting it.

Belt Grinder

Figure 12: The belt grinder in the FUSE metal workshop

The belt grinder can be used to grind steel. The belt grinder should not be used to grind aluminum, as aluminium and steel dust can create thermite.

When grinding it is very important that you do not grind things in such a way that they risk going in between the rest and the belt. You should also not grind against the turning direction of the blade, meaning, since the belt moves downwards, that you should not angle your workpiece up when grinding. If you angle the workpiece up it will lead to very unstable grinding, and the possibility of hurting yourself, since the workpiece can “catch” on the belt which can throw it across the room in the worst cases.

Figure 13: Examples of incorrect ways of grinding.

There is one exception from this rule, which is grinding TIG electrodes. As the TIG electrodes are really difficult to get grinded well otherwise, and they also have really low mass, leading to the risk being very low when grinding them.

When grinding it is especially important to remember that you are not allowed to have gloves or long sleeved shirts on while using rotating equipment. Since you will often go between the welders and the grinder, leading to a risk of forgetting.

Sheet metal Cutter

General use

The sheet metal cutter is used to cut sheet metal. It makes very clean and nice cuts very fast, which makes it ideal for cutting out smaller pieces of sheet metal from a big piece. It makes very sharp edges and you should therefore always make sure to deburr all the edges that have been cut. This also includes the big sheet that you put back in the material stand.

Cutting sheet metal

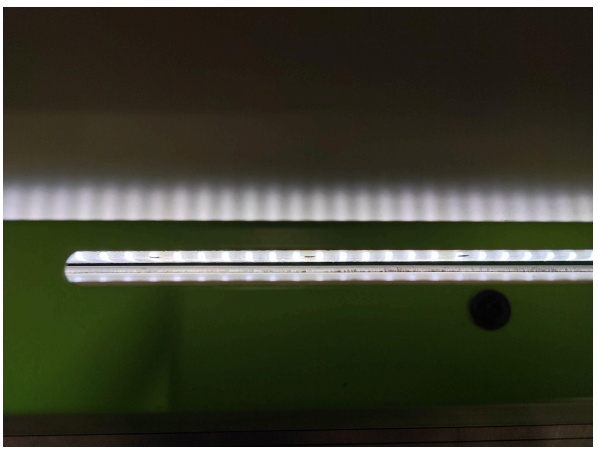
The sheet metal cutter can at max cut 3 mm of mild steel, 4 mm of Aluminium and 2 mm of Stainless steel.
You do not have to make any changes depending on the material you are cutting. The important settings that the machine has is the length of the cut, which can be entered on the touch screen.

When turning on the machine a warning symbol sometimes appears. To get rid of it you press on it and the green check mark afterwards.

A good tip is that you can always cut the inverse measurement, so that you don't get as big of a piece falling into the bin.
When changing the length of the cut it is important that you do not have any sheets in the machine, as this can cause the machine to push the sheet out into you which can be dangerous.

When cutting longer sheets it is possible to pull up the support, which are a couple of metal square tubes that the plate rests on while cutting, this setting is usually set to auto, meaning that when a long length is entered into the touch screen the machine will use the support by itself. This setting can be found under the “SNABB INST” menu.

You can also look through the slits to cut parts manually



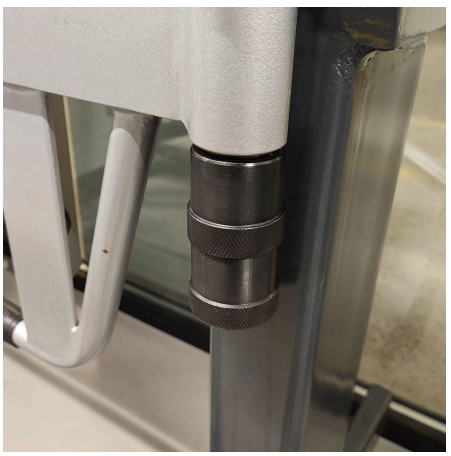
You are not allowed to cut any types of net or round bar in the plate cutter.

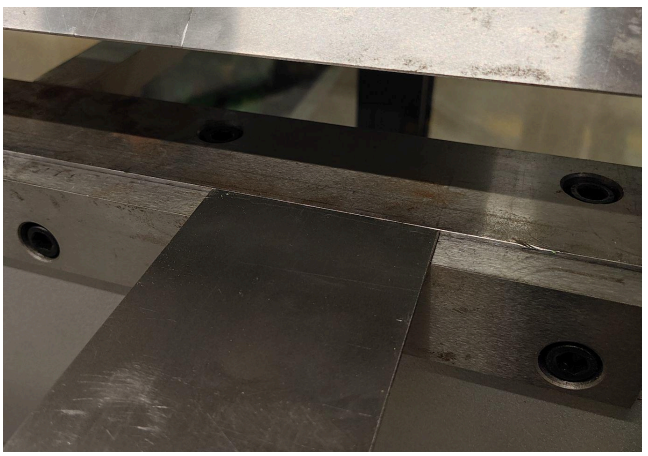
Sheet metal bender

The bender is used to bend sheet metal. It can bend sheets of the following thickness: mild steel 3 mm aluminium 4 mm stainless steel 2 mm.

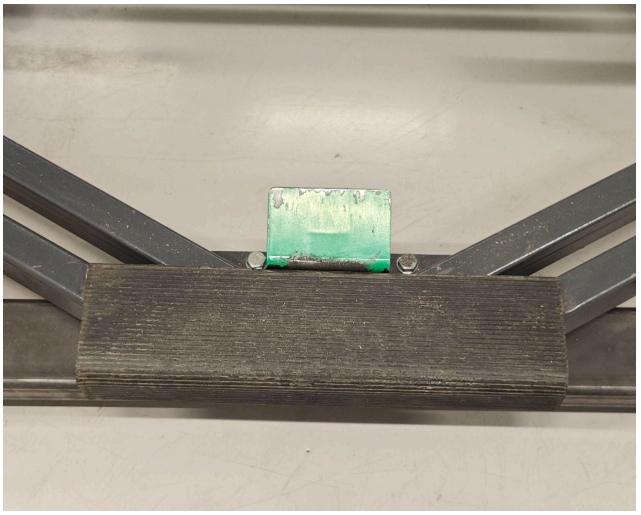
When trying to bend a corner the teeth on the bender can be removed, which allows bending without sides clashing with the teeth.

Before bending it is important to set up the machine correctly, to do this you start by putting your sheet on one side of the bending support. You then turn the screw on the bottom of the machine on the same side that you put your sheet until it is flush with the stationary part of the bender. You then move the sheet to the other side and repeat the same steps. The sheet should now be flush with the stationary part of the machine. This makes sure that the bending radius will be correct for the thickness of the sheet.

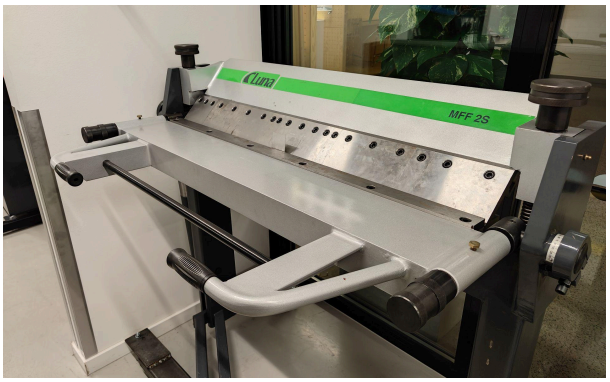


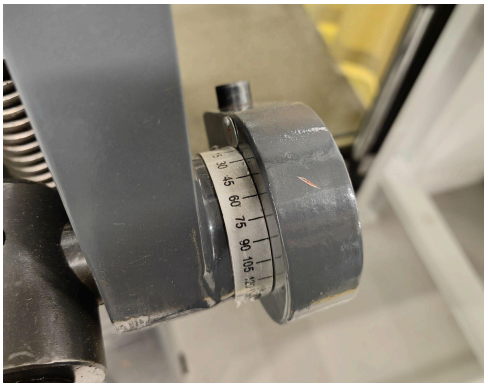


You then put your plate on the stationary part of the machine and push down the locking bar with your foot. Here you will have to feel if the plate is firmly fixed when the lock on the locking bar has clicked. If not, or if the bar can't be pushed all the way, then you will need to turn both screws at the top of the machine until the plate is fixed firmly.



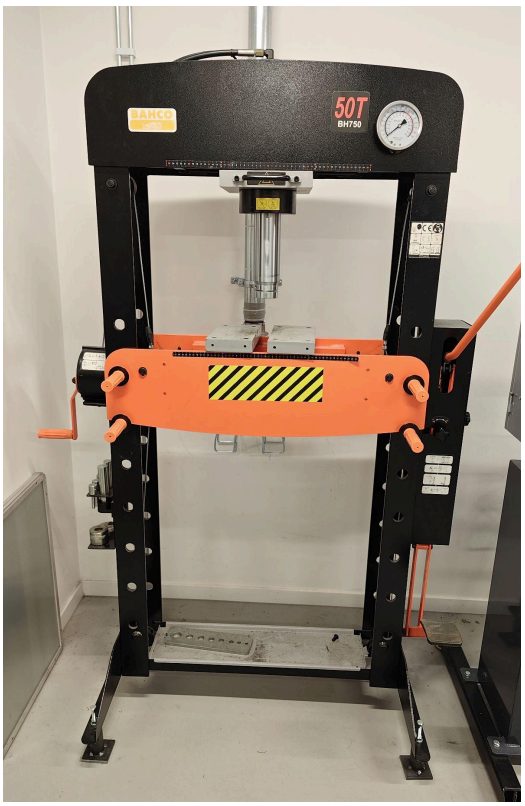
When the machine is set up and the plate is clamped into the machine it is as simple as lifting the bending bar with your hands until the plate is at the angle you want. Remember that the plate will spring back a little bit when you stop bending, and you might have to go a little over the wanted angle to get it correctly. Remember that it is difficult to unbend the sheets when they have been bent.





When bending corners, you always need to have reliefs in the corners, as without them the plate will buckle and shear in the corners, as well as possibly damage the teeth of the machine. This is usually done by drilling an approximately 8 mm diameter hole on the intersection of the bending lines. A rule of thumb is to at least have a relief diameter twice the thickness of the sheet, and making sure to round up.

Hydraulic press



The hydraulic press is used when you want to achieve really high pressing forces, usually when pressing parts with press fit tolerances together. It can also be used to get press or heat fits disassembled in some cases and can be used to straighten out things that have bent.

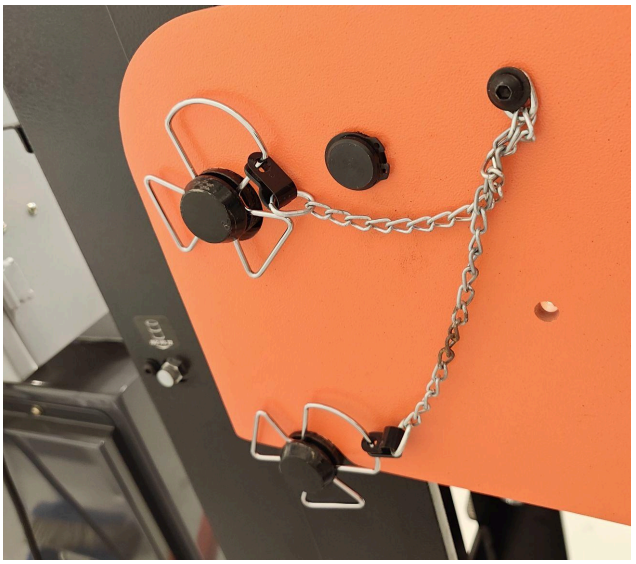
It is important to always make sure that the risk for misaligned pressing is minimized, as this can lead to parts being shot out with really high speed. To reduce the risk of this it is both good to try to reduce the stick out length of the hydraulic press as well as the height of the workpiece being pressed.

There are two different valves on the press. On the front of the press there is a valve that when tightened it will allow you to start pressing, while loosened it will release the pressure and make the piston retract.

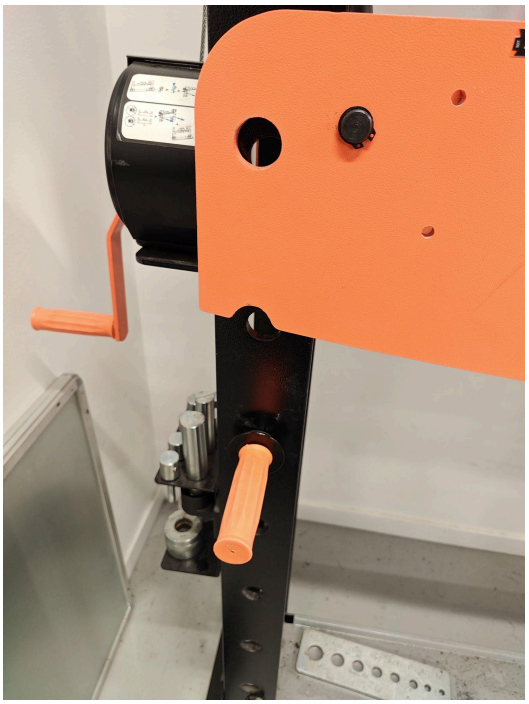
On the right side there is another valve which allows you to select between fast travel and pressing mode.

For most pressing, using the fast travel mode will do fine, and will make sure that you don't press too hard, which is much safer. The pressing mode allows you to get a lot of hydraulic leverage and the pressure can be increased easily.

To change the height of the table of the press you first must loosen the cotter pins on the back of the table



you can then remove the big axles that support the table. Try to always have one pair of axles below the table when moving it, as the wire can get a little tangled which can lead to the table suddenly falling a bit.
When the table is at the height you need then you just put back the lower axles and lower the table onto these. Then insert the rest of the axles and reinstall the cotter pins on the back (One of the pins on each side reaches both axles while one only reaches one).



It is then very important that you make sure that the wire is loose and not taught. If the wire is taught and you start pressing the wire will immediately snap off and the press is broken. This is because you will then press with the full force on the wire and not the axles.

Angle grinder

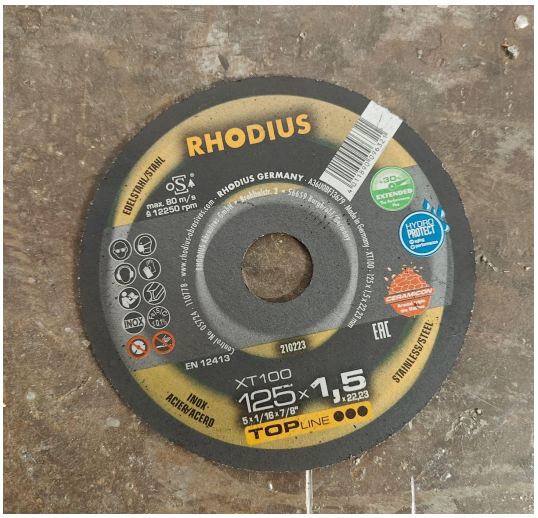
The angle grinder is a very versatile tool, using abrasive plates to cut through material.

When using an angle grinder it is important to adhere to the normal workshop rules, meaning that you should not use any gloves or long sleeved shirts etc. Use of the angle grinders is only permitted in the hot work section of the workshop.

There are three different types of grinding wheels we have in the workshop, these are:

- Cutting wheels
- Grinding wheels
- polishing wheels

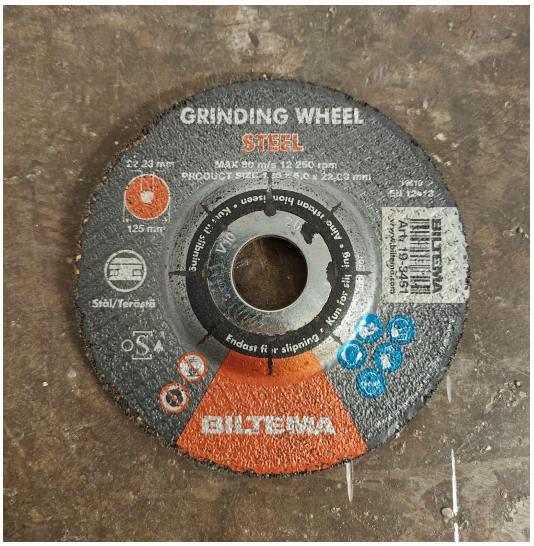
Cutting Wheels



Cutting wheels are used when cutting, and only when cutting.
If you try to grind with a cutting wheel the risk of the wheel exploding and sending sharp debris all around is very high. Therefore you should never grind with one. Always make sure that you are grinding at a right angle to the material so that the disc does not experience any side forces as these can break the wheel.
Also make sure that the disk is not cracked before starting to cut, as this increases the risk of the disk exploding

When using a cutting wheel it is required to wear face protection.

Grinding Wheels



Grinding wheels look alot like cutting wheels, but are much thicker. These are used when doing rough grinding and trying to get away alot of material. Face protection is also required when using a grinding wheel.

Polishing Wheels

Polishing wheels are used when polishing or grinding. Polishing wheels leave a pretty good surface finish but do still remove alot of material, and for most grinding jobs done in thin sheet (less than 5 mm) polishing wheels will usually give plenty of material removal.
Face protection is recommended but not mandatory when using a polishing wheel.

Other

There also exists a few extra attachments for the anglegrinder, one of the most used ones are the steel brushes. These are very good both when getting a surface ready for welding as well as cleaning up welds. The steel brushes dont have alot of material removal, and will thus remove most loose surface contaminants.

Welding

Hot work room

When in the section of the workshop that is designated for hot work, it is important that you always make sure to close the door, this is to make sure the ventilation works as intended in the room, also remember that this room has its own power and you will need to start it before most machines will work. The welding tables available are very nice if you need to build a fixture. When a fixture is not needed you should always use an aluminium cover sheet to make sure that you do not damage the table.

TIG-Welder

General use

The TIG (Tungsten Inert Gas) welder is a welding technique where a torch is used to heat up the material and material from a rod is manually added to the melted metal to form a weld. This is the kind of welding recommended when you are not welding normal steel, since you do not have to make many changes to the machine to weld, for example aluminum. It is also a welding technique that allows for much finer control of the results.

Basic technique

When TIG-welding the goal is to form a melted puddle of metal, which you then push in front of the torch while adding filler material with your other hand. When this puddle connects

between two parts, the parts will be welded together. As with any other arc-welding process (Electrical welding) there needs to be a continuous circuit for the current to flow, this is achieved through connecting the negative clamp to a metal surface touching the workpiece, usually the table upon which the workpiece is placed.

Filler Material

TIG is the go to welding technique when welding materials that are not mild steel, for example aluminium or stainless steel. When welding different materials it is important to use the correct filler material. The three main ones we have are steel (copper colored wire) stainless steel (silver colored wire, stiffer than aluminium and the package should say 316) and aluminium (silver colored wire).

Electrodes

There are two main electrodes available in FUSE, these have either green or golden tips (do not grind away the coloring) the green tips are used when welding aluminum and the golden tips can be used for pretty much every material. The electrodes are available in a couple of different sizes as well, and matching collets and gas lenses are available to match.

When welding you should not be dipping the electrodes in the melted metal, this can of course happen, and when it does happen you need to grind the electrode in the belt grinder, this is the only time that it is allowed to grind against the turning direction of the belt. You grind the electrode by holding it upright and lightly resting the tip against the belt while turning it around. The goal is to make a pointy tip. Remember that grinding should not take a lot of time, and the tip does not need to be perfect.

Machine settings

The TIG-welder has a lot of settings, the five buttons on the top can be clicked to switch between the different modes pictured next to the LEDs above them. A lit up LED means that that mode is currently engaged. We will go through these settings button by button:

First button, welding type: Switches between TIG and MMA (Stick) operation of the machine. It is possible to do stick welding, but we prefer consulting the board before as it can be very messy. This mode is otherwise always in the upper mode, meaning TIG mode.

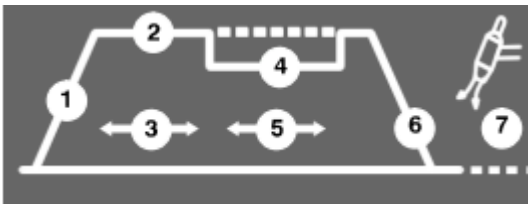
Second button, power type: Switches between the power delivery, AC, DC and pulse. This button is set to DC when welding steel. AC is used when welding aluminium and pulse can be selected to alternate between high and low current.

Third button, ignition mode: Switches the way the torch is ignited, this is mostly a legacy feature, the top mode is used to make the ignition work automatically and is preferred. The

lower mode is manual mode which requires scraping the electrode into the metal to ignite it, this is not recommended.

Fourth button, 2-step 4-step switch: Switches between trigger settings, 2-step to the right, means that the machine will weld while the trigger button is pressed in. 4-step, to the left, means that the trigger should be pressed and released to start welding and then pressed and released again to stop welding (nice for longer welds).

Fifth button, set current mode: switches the way the current is set. The top mode allows you to set a current value with the rotary knob on the right of the machine. The middle button allows you to set two values using the preset buttons on the bottom of the machine while the lowest mode lets you use a footpedal to sweep between zero current up to the value set in the top mode.



The lower indicator buttons allows you to switch between adjusting the following values as indicated by the figure above

1. Slope up - the time it takes the current to go from zero to max usually set to 1 s
2. Welding current (AC and DC, max current used in pulse) - approx 30A per mm
3. Pulse max current time
4. Pulse low current
5. Pulse low current time
6. Slope down - The time it takes for the current to drop from max to zero current when stopping the welding, usually set to 1s
7. Gas post purge - The amount of time the gas will continue flowing after ending the weld, usually 4-5 s

There are finally three more LEDs after the post purge LED, these being:

AC polarity shift
AC frequency
AC duty cycle

These last three are usually not needed, and of the three the frequency is usually what is changed if needed.

MIG-Welder

General use

The MIG-welder is the simplest way of welding metals. It is possible to weld different materials with the MIG-welder as well (Not aluminium since the machine does not allow AC current), but welding different metals requires changing of the spool as well as in some cases changing the protective gas used (Can usually be done if a project really requires it, otherwise use TIG). It works very much like a hot glue gun but for metal. It feeds metal wire automatically that is also current carrying. This means that you just point the gun to where you want to weld and press the trigger.

Settings

The MIG-welder only has a few different settings, from top to bottom, then left to right:
Post purge: Makes the gas run for a small amount of time after welding has stopped.
Creep start: Lowers the wire feedrate at the start of welding, can help with ignition stability.
2-step/4-step switch: Switches between trigger settings, 2-step to the right, means that the machine will weld while the trigger button is pressed in. 4-step, to the left, means that the trigger should be pressed and released to start welding and then pressed and released again to stop welding (nice for longer welds).
Feedrate: sets the feedrate of the wire.
Fine step current control: Allows for fine adjustment of the current.
Power switch: powers the machine on and off
Coarse step current control: Allows for big jumps in current control.

The machine has a handy guide with recommendations for the feed and current settings depending on the thickness, material and protective gas used. In the MIG the protective gas is argon blended with CO2.