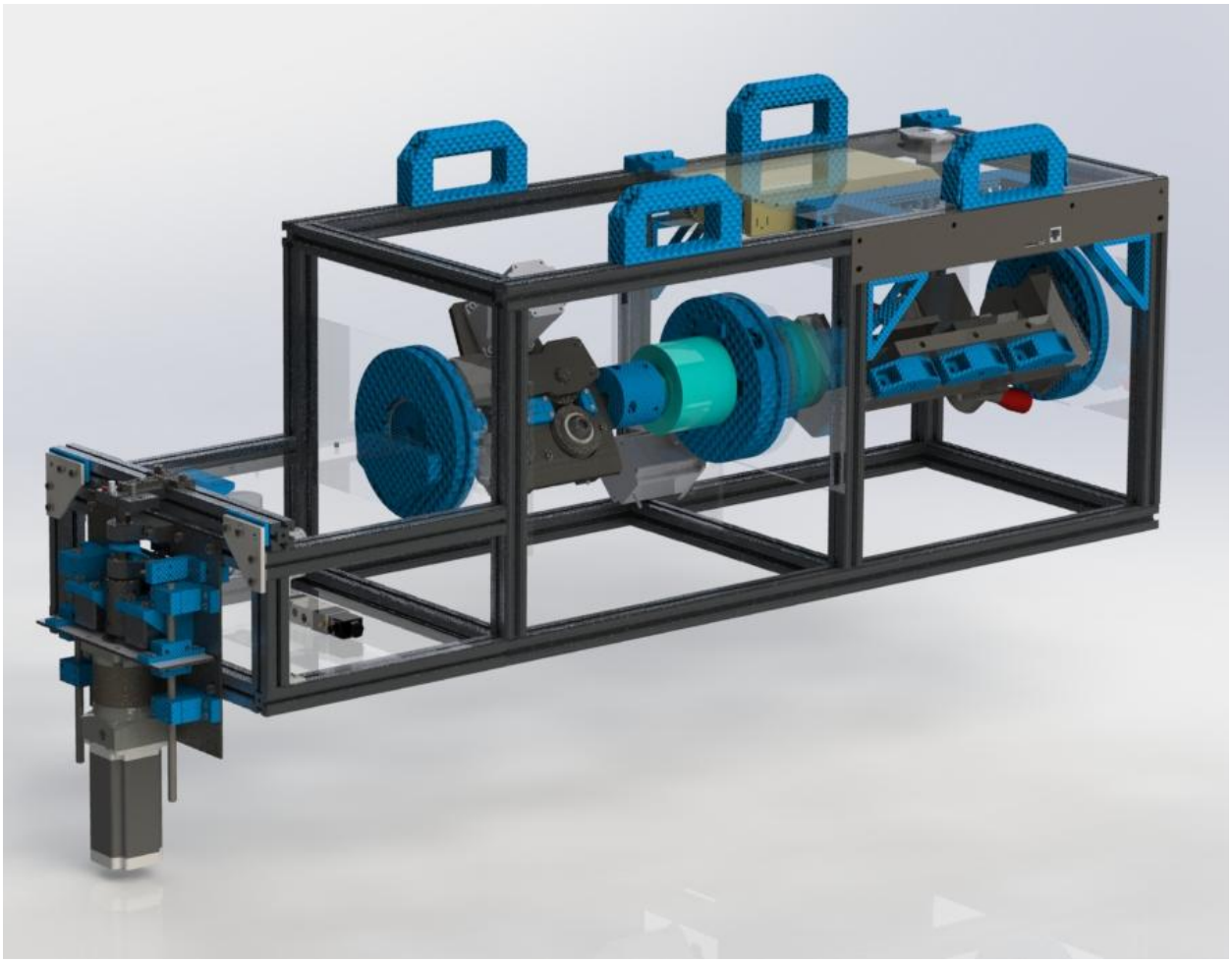


3D CNC Wire Bender

Instruction Manual

Table of Contents

Warnings

- Emergency Stops are located on top of the machine and in the web interface
- Turn power off and disconnect air supply before working on the machine (i.e. to change out parts for different wire sizes)
- Keep hands/fingers away from bend area and feed axis when the machine has power or air pressure
- Ensure bend plate bolts are secure before using the machine (lock washers not in use so bolts can back out after several uses)
- Air pressure needs to be at least 25 psi for slow bending and at least 80 psi for faster bending

Setup

Power and Air

Connect the machine to a standard 120 V outlet using an IEC cord. Connect the pneumatic fitting to a supply of compressed air within the operating range of 25-116 psi. Use the regulator to adjust the gauge pressure to the recommended value for bending speed.

Input Pressure: 25-116 psi	
Slow Bending	40-50 psi
Fast Bending	80 psi

Connecting to the machine

Router

Interfacing with the machine is accomplished over a local network. The provided tp-link router creates a local area network (LAN) with no internet connectivity. The router network credentials are:

network: MEKwirebender
password: MEKwirebender2023

Editing router settings (lab staff only)

To edit router settings, connect to **192.168.0.1** in your browser while connected to the network. The admin password is the same as the network password (**MEKwirebender2023**).

If the router is not working, reset by pressing the reset button with a pin for 10 seconds. Network name and password will return to defaults. The default password is printed on the bottom of the router.

Connecting devices

Connecting the machine

Connect the duet control board to the router directly via ethernet. (Wireless connectivity is possible with purchase and installation of duet 3 wifi module).

Connecting devices for operating the machine

Directly connect a device via ethernet from device to router. Alternatively, connect wirelessly to the network using the network credentials above.

Establishing the web interface

Using a web browser on a device connected to the network, attempt to connect to **192.168.0.100**
If connection is unsuccessful, attempt to connect to **192.168.0.101**, then **192.168.0.102** and so on.

The router will assign ip addresses starting at 100. The machine should be assigned 100 or 101 if there are only 2 devices on the network. In the case that many devices are connected to the network, connect to **wirebender.local** and send the **M552** gcode command to the board. The board will display its current ip address. Connect directly to the indicated ip address for stable performance without connection issues.

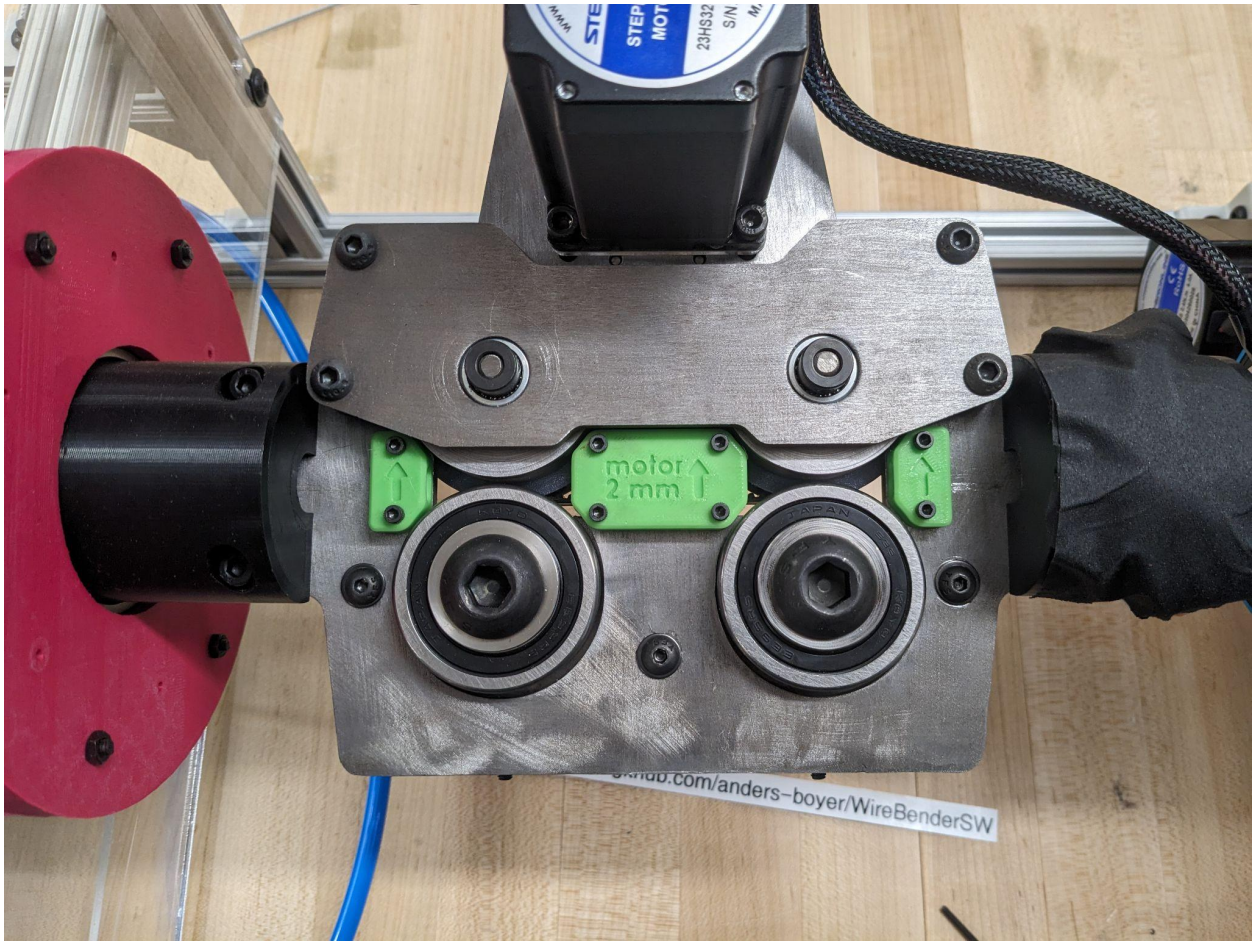
Machine setup

Bend Die, Bend Pin, and Wire Guide Installation

Select a die and set of wire guides appropriate for the wire stock diameter.
The wire feed guides appropriate for the nominal size and lower.

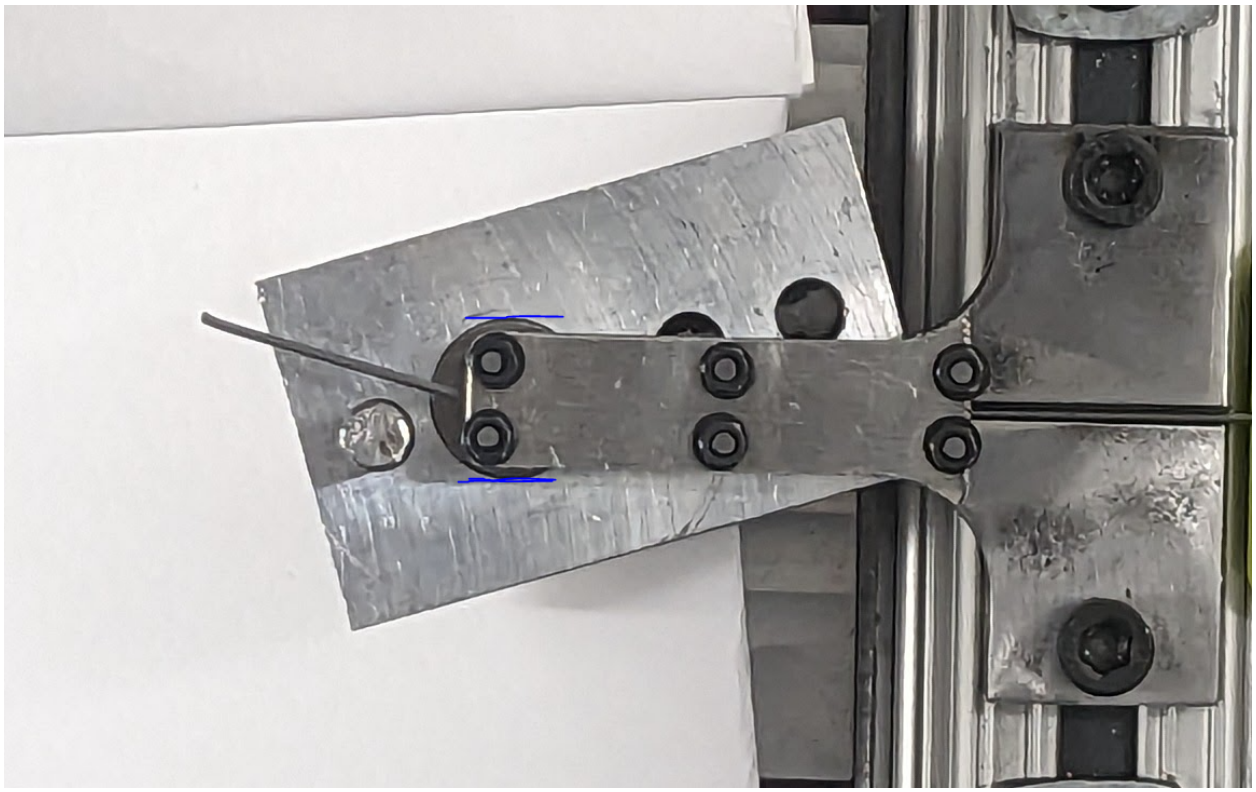
Wire size (mm)	Bend die	Feed guide	Pin location
$\varnothing \leq 0.8$	0.8 mm	1 mm	1
$0.8 < \varnothing \leq 1.0$	1.0 mm	1 mm	1
$1.0 < \varnothing \leq 1.5$	1.5 mm	2 mm	1
$1.5 < \varnothing \leq 2.0$	2.0 mm	2 mm	1
$2.0 < \varnothing \leq 2.5$	2.5 mm	3 mm	2/3
$2.5 < \varnothing \leq 3.0$	3.0 mm	3 mm	2/3
$3.0 < \varnothing \leq 3.175$	⅛ “	3 mm	2/3

Install the wire guides with the arrows facing the motor.



The bend die is installed with two M5 socket head cap screws. The holes in the die have a loose fit with the screws. Hold the die while tightening the screws and adjust its position so that the width of

the die is centered over the shaft below it. Torque the screws with the bend die centered over the shaft and installation is complete.



Installing the spool holder

Align the spool to be in the same plane as the first set of rollers in the wire straightener. PICTURE.
Orient the spool so that the natural curve of the wire is opposite to the curve that the 4 rollers will impart in the wire.
Insert the spool holder and fasten with the two M5 set screws indicated.

Loading wire

It is assumed that the spool, feed guide, and bend die are installed and the straightener is adjusted.

Open the clamps on the straightener and guide the wire from the spool to the first set of straightener rollers. Clamp the first set of straightener rollers and continue to pull the wire with a pair of pliers through the second set. Clamp the second set of rollers. Continue to pull the wire with pliers until the wire is at the pipe. Feed the wire through the pipe by pushing it in small movements with pliers. When the wire has reached the feed, pass the wire through the feed guides until it is past the most forward guide. Adjust the feed at this time to secure the wire. Use

jog commands on the web interface (X +10, X +50) while guiding the wire with your hand to prevent catching on any surface of the machine. Stop when the wire is at the tip of the bend die. The wire is now loaded.

Adjusting Straightener

Open the clamp on the first set of rollers and feed the wire into the rollers. Adjust the thumb screws so that, when clamped, the pressure on the wire is very light. Using pliers, carefully pull some wire through the rollers and check for straightness. If the natural curve from the spool is still present, tighten the second thumb screw. If the curve is in the opposite way, loosen the second thumb screw. The second set of rollers should be adjusted to be very light pressure so that no undesired curve is introduced.

Adjusting Feed

When desired straightening is achieved, feed the wire manually with pliers while the straightener is clamped. Use small movements until the wire has reached the feed. Loosen the 3 bolts on the face of the feed. Back out the set screws and push the bearing rollers down to create clearance for the wire. Using pliers continue to feed the wire until the wire reaches the forward feed guide.

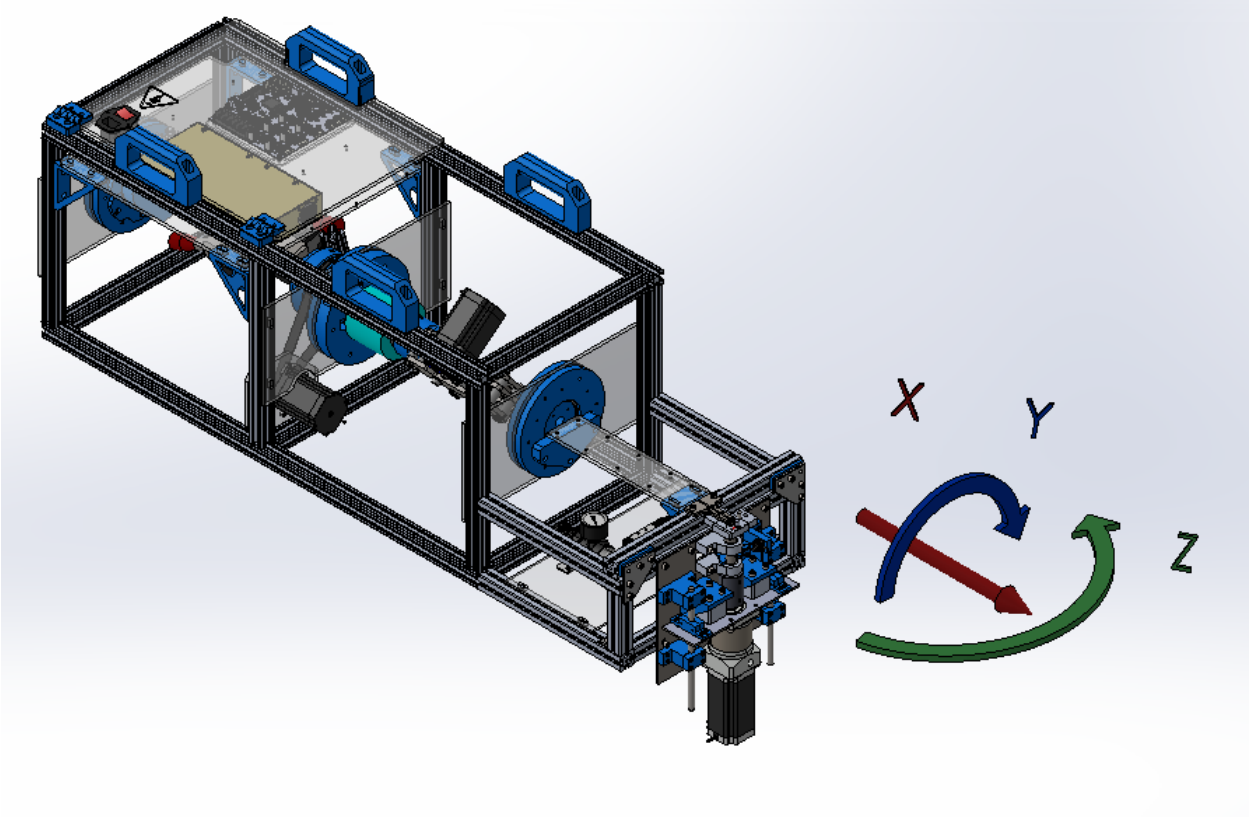
Tighten 3 bolts on the face of the feed until there is no slop in between the two plates, but the bearings can still slide. Tighten the set screws until the desired compression is achieved. Less force is needed than you think. Do not over tighten the set screws. Tighten the 3 bolts on the face to lock the bearings in position.

tensioning belts (move to new section)

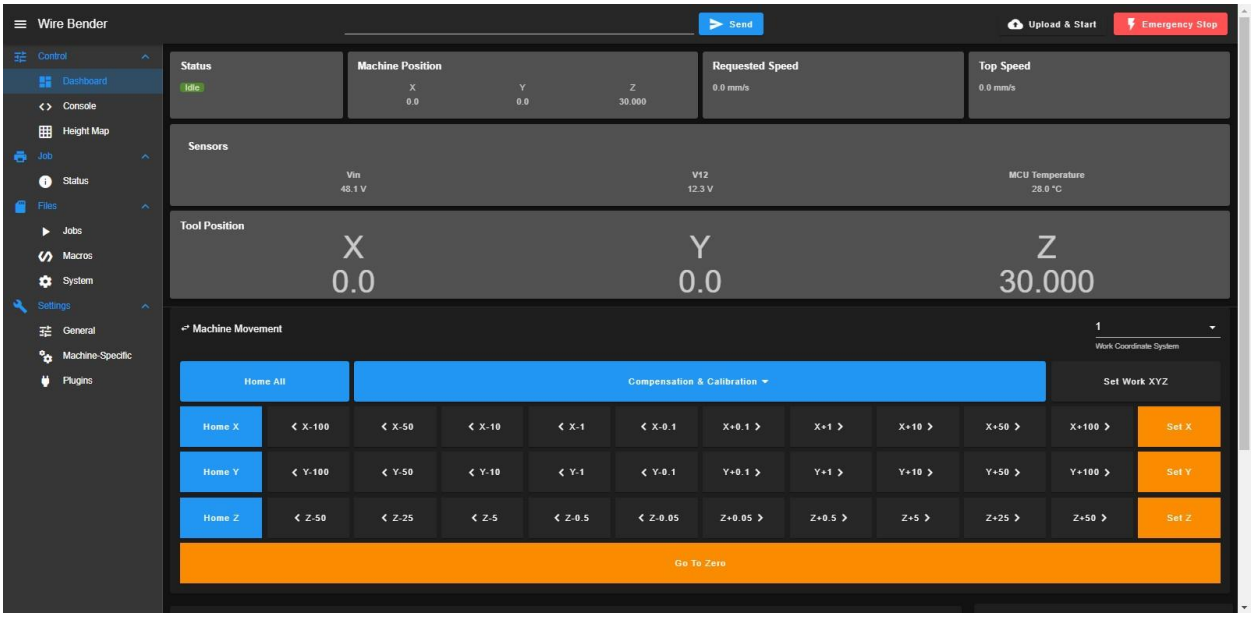
Loosen the 4 bolts on the motor mount. Using the help of a second person, hold the motor to tighten the belt and the second person will tighten the motor mount screws to hold position.

Operating the Machine

The machines axes are defined as shown



Manual Control



In the dashboard tab of the web interface are machine position readouts and jog commands. Before any movement commands can be sent, the machine must be homed. The home x, y, z, and all buttons run macros which home the axis. Home all axes when powering on the machine.

The jog buttons are useful for moving the machine during setup. X commands are useful when feeding wire or feeding an additional 10 mm after a part to create room for cutting. Likewise, moving the bender head to the side with a Z command is helpful for making room to cut the wire.

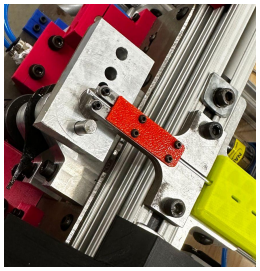
Custom macros can be written and saved to aid in the execution of repetitive moves. Two useful macros included are Bender Up and Bender Down. Running these macros will actuate the pneumatic cylinders to the up or down position.

Uploading and Executing G-code

In the jobs tab all previous jobs are stored. Right clicking on any job will give the option of running or editing the G-code. Uploading G-code can be done with the green upload button.

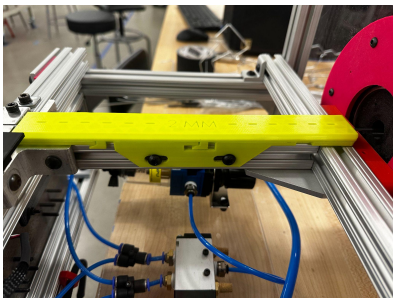
Loading Wire

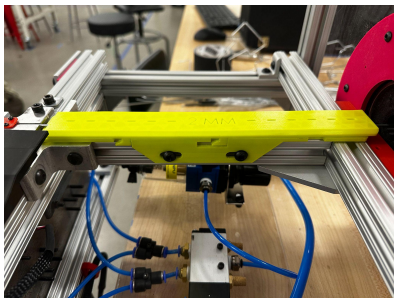
- Choose wire size
- Change following parts to the wire size chosen:
    - Bend-die - 2 allen bolts (5/32”) hold the die in place (see left image). Wire should move freely in the bend-die in and out with little side to side movement. Each gauge size is written on the bottom of the die (see right image).

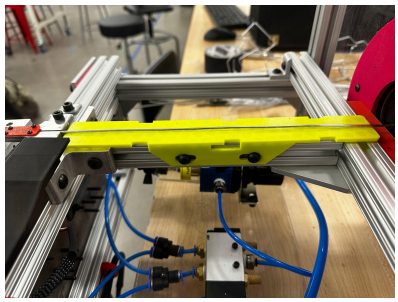


    - Wire Feed Guide - A total of 6 allen bolts (3/32”) hold the 3 guide parts that accommodate wires for the sizes printed on them.

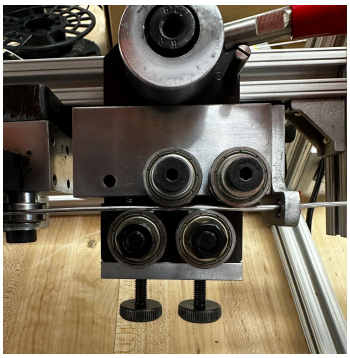
    - Bend Guide Channel - Slide to secure/unsecure guide channel. Choose the part according to the size printed on the guide.







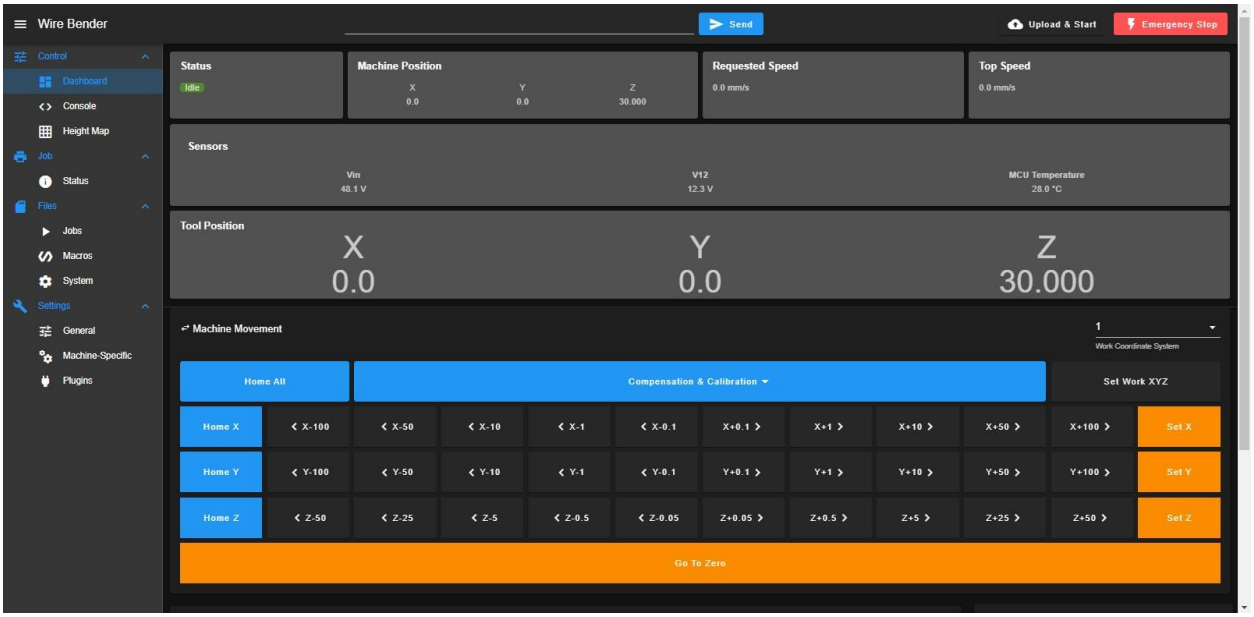
- Wire Straightener - Release straightener clamp using red handle. Feed wire through and clamp wire using the red handle again. Adjustments can be made to refine straightening of the wire using the 2 button screws shown in the bottom of the picture. (using only four rollers and not using the second set of rollers provided best results in the testing phase)



- Clamp wire in feed - Loosen the 3 allen bolts (⅛”). Adjust the 2 set screws (2.0 mm) till the wire is firmly clamped (with the power of, wire should be able to be pulled through easily with all four pulleys spinning). Once set screws are correctly adjusted, secure the 3 allen bolts (⅛”).

Connecting to the Machine

- Enter IP Address printed on the circuit cover (192.168.0.101). If the connection doesn't work enter this IP address (192.168.0.100). The 3Duet board has a dynamic IP that changes periodically but one of these IPs should work.
-



Designing a Part and Exporting a CSV

The G-Code generation software requires a 3D point cloud representation of your part with each point stored as the x,y,z coordinates in a .csv format. These points must be in order from the start of a part, to the end of the part. There are a few ways that this can be generated. For simple parts with a low number of vertices, no macro may be needed.

Things to Keep in Mind While Designing Parts

Bend Pins

There are three bend pins available for different diameter wires.

- 1st pin (12 mm) - Up to 2 mm wire.
- 2nd pin (16.5 mm) - Up to ⅛”
- 3rd pin (27.5mm) - Up to ⅛”, recommended for hardened steel over 2.5 mm

The bend pin being used will determine the number of segments that the software deletes from your point cloud, because that changes the minimum bend distance. The bender requires a certain amount of wire to be extruded from the machine so that it can make a bend without the die slipping off the previous bend. The die must be along a straight section of wire throughout the whole bend. This minimum bend distance is variable with bend angle, as sharper angles will require more wire.

Bend Radius

The minimum bend radius is 2.5mm. This is due to the physical shape of the bend dies. This is inside radius so centerline radius will be 2.5mm + diameter/2.

The bender works well with a file containing sparsely placed points, for parts with no >2.5mm radius bends. For these parts, it's recommended that you place points ∿15 mm apart for parts using the 1st pin, and ∿20 mm apart for parts using the second pin.

For a part including larger radius bends, these will need to be discretized by the software so that it can meet the minimum extrusion length requirement. A file of very closely placed points works best for these geometries.

These two concepts can be combined to generate parts which have both straight sections, and large radius bends. There are a few techniques that can be used to generate these CSVs, which I will discuss in the next section.

Video Tutorials

Simple parts

Direct Design via parametric equations

compound parts (not recorded)

troubleshooting (not recorded)

Designing Parts

Parts can be designed using a 3D sketch. 3D sketches can also be created by using convert entities on individual 2D sketches, which may be easier for planar geometries. Once you have a single 3D sketch, which contains all the lines in your part with only two unconnected segments (for starting and ending point), you can prepare the sketch to run the macro.

Exporting CSVs

Simple Parts

Simple parts include parts with no curves and a low number of vertices, which can be entered manually. For these parts it may be easiest to just design the part in SolidWorks. Then, select points to show their coordinates, and record these in an Excel file without the use of a macro.

More Complex Parts

For more complex parts, with a higher number of vertices or curved sections, a macro will need to be used. This can be found in the GitHub repository, **ExportCoords.swp**.

Only Straight Segments

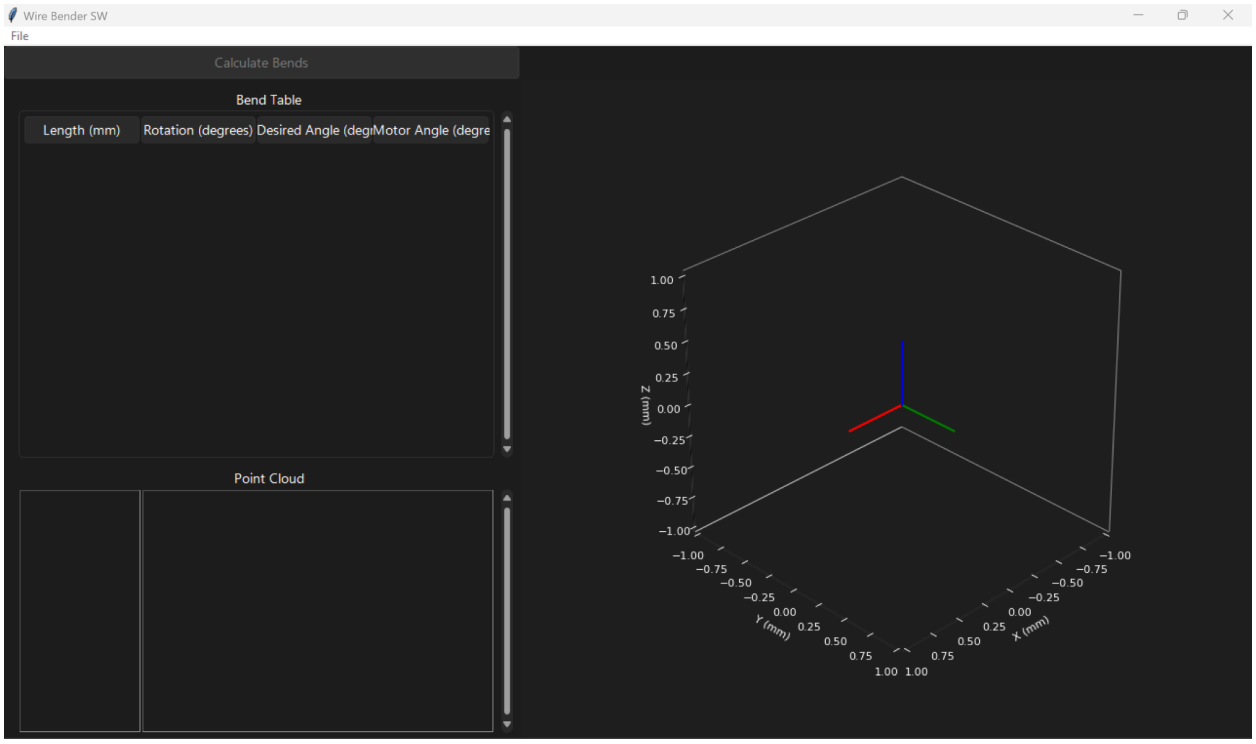
- Hide all sketches but your final 3D sketch
- Create a new 3D sketch and use the **Convert Entities tool**, choose "**Select Chain**" and select an end segment on the part
- Exit the sketch
- Select the sketch in the Design Tree and run the **Macro**

Straight Segments and Curves

- Hide all sketches but your final 3D sketch
- Create a new 3D sketch and use the **Convert Entities tool** on any straight segments
- Use the **Fit Spline** tool on any curved sections to add these to this sketch.
- Use the **Segment** tool on curved sections with "**Sketch Segments**" selected to discretize the spline.
- Create a new 3D sketch and use the **Convert Entities tool**, choose "**Select Chain**" and select an end segment on the part
- Exit the sketch
- Select the sketch in the Design Tree and run the **Macro**

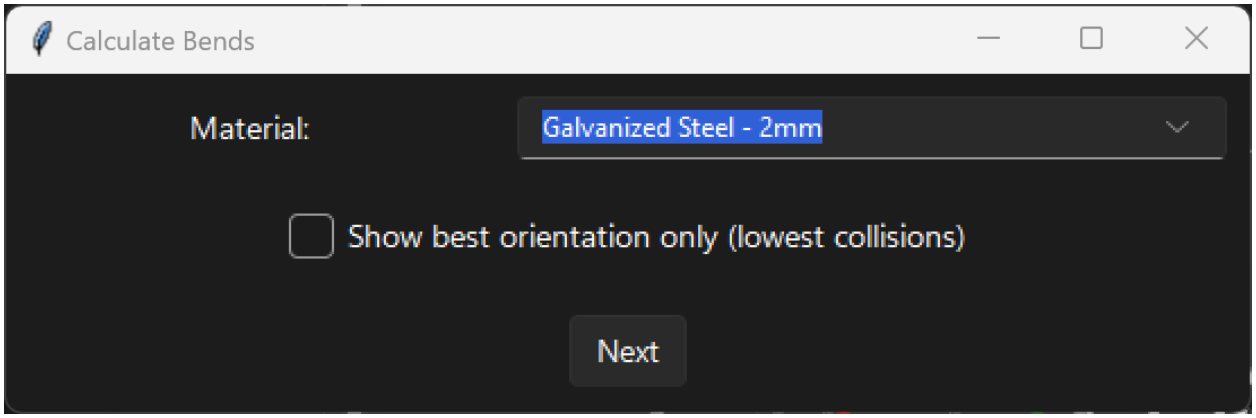
Creating G-code

The software for generating the G-code can be found in the following GitHub repo: https://github.com/anders-boyer/WireBenderSW.git. Open the WireBenderSW.exe file (you can also run the WireBenderCam.py file from an IDE like Pycharm). The following window will appear.

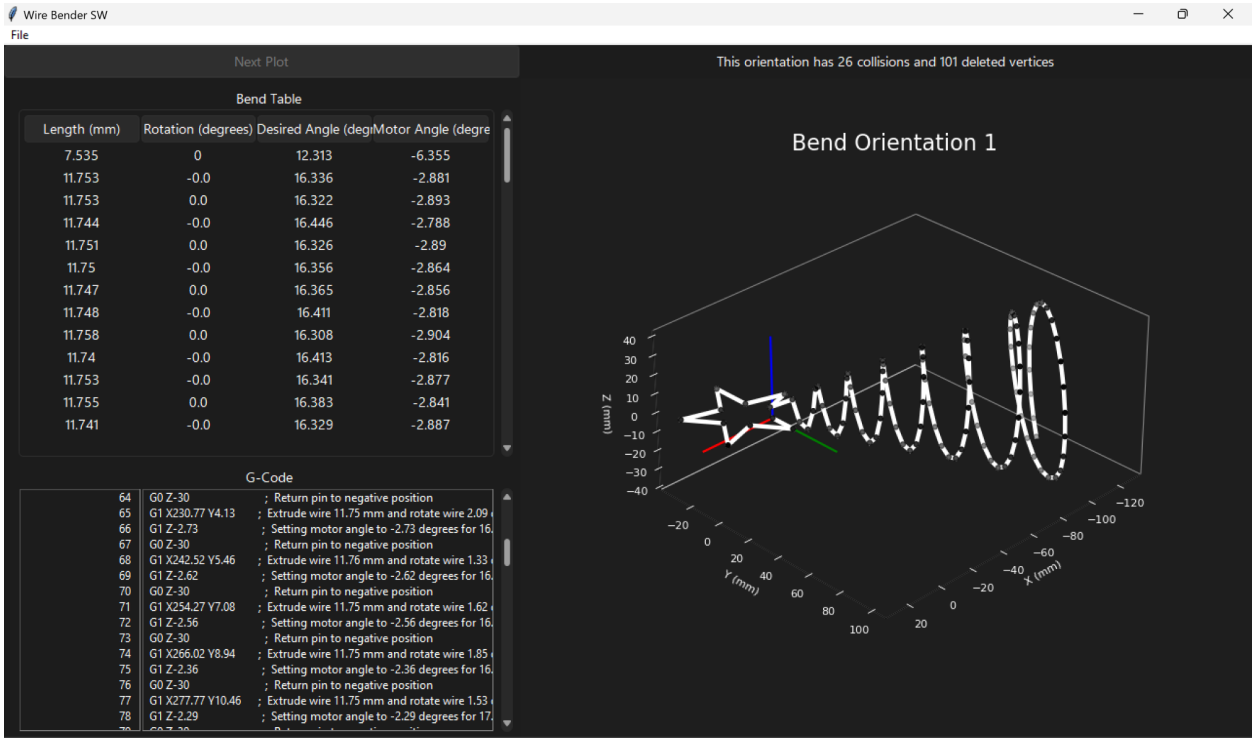


To get started click File in the top left, then select import. This is where the point cloud csv for the desired geometry is imported. Select the csv file you would like to import. The coordinate from this file will then be plotted in the graph on the right side of the window.

The “Calculate Bends" button in the top left will now be enabled (disabled until a csv file is imported). Click the “Calculate Bends" button. Select the material of the wire to be bent from the dropdown in the window that appears. If using a material not specified in the dropdown, select custom and the desired pin location.



The software will then indicate what pin location to use if using one of the specified materials. For some designs multiple bend orientations are possible. The show best orientation will show the orientation in which the final part will have the fewest collisions with the machine. If this box is not checked and multiple orientations are possible, clicking “Next Plot” which appears where “Calculate Bends” was, will show the other possible orientations. To rotate the graph, click on the graph and drag the mouse.



The bend table on the left will show the calculated lengths, rotations, angles, and corresponding motor commands for each bend required to make the geometry.

Displayed in the bottom left is a preview of the G-Code that will generate the geometry in the current orientation. This a preview of the G-Code, to export it for upload to the Duet Board, click

“File” in the top left, select “Export G-Code”, then choose a file name and location. Now the file is ready for upload to the Duet Web Interface.