Project Roark : Design Journal

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Date: January 29, 2026 **Topic:** Battery

Designing a battery is a delicate matter. It doesn't seem that there a lot of official sources on how to build your own battery pack, so I started by watching youtube videos on the topic. These are plentiful and some contain a lot of details.

Initial Objectives

I started the preliminary design with my objectives. I needed a battery that could produce around 20kw peak, with 72-92v. The controller I chose is the p24f controller from nucular. This is a well-tested controller, on the more expensive side, but it can take up to 30Kw.

Series Configuration

I chose the cells to be P42A 21700, for their abundance, low price (cheaper than P45B), and size (bigger than 18650). You can order these very cheaply on 18650batterystore.com . These cells are classic Li-ion cells with nominal 3.7v, and max 4.2v. To get 92v, one would need 22 cells in series at max voltage to get 92.4v. However, the controller i chose has a max voltage limitatin of 92v, and I am pretty confident that it would have no problem with 92.4v, but I did not want to take that risk, and I could simply drop down the voltage, without significant alterations on the performance. 21 cells in series would be awkward since 21 is 7*3 (you'll see soon that this matters), so I chose 20 cells in series at 74V nominal, and 84v max.

Parallel Configuration

The next step is to choose the parallel cells. For that i started with my output power of 20kw. 20kw/84v=238A, this means that our battery pack needs to output 238A peak. Each cell has a maximum rating of 45A, but we do not want to strain them that much to conserve battery life. A safe bet is to say that we will never exceed half of that current : 22.5A. So 238/22.5=10.5. We need at least 11 cells in parallel. I am aiming for a lighter adventure pack, and the range is not my biggest concern, so I will stay on the lower side of this. 11 is not a very nice number because it is prime, so I chose 12 in parallel.

In the end, we have a 20s12p battery. For this i needed to choose a BMS (Battery Management System), it is the device that makes sure that all the cells are drained equally. Without it the cells closer to the motor would be drained faster, which would reduce dramatically the life of the pack, and reduce performance. To choose a BMS one needs a couple things. First it needs to be for the right chemistry of cells, in our case li-ion. Second, it needs to be able to handle 20 cells in series, usually BMS are sold for a range of series connections like 8-20s. Thirdly, it needs to be rated for our max continuous current (the higher the more expensive). We aim for around 10kw continuous which entails a 10,000W/74V=138A continuous current. A good BMS for that is 150A 20s, also make sure that the BMS can handle your peak current, in our case thats around 240A (the one I chose can handle 300A peak just to be safe). Also make sure your BMS has safety protections for overcharging, overdischarge, and many others (im no expert on the matter).

Initial Objectives

To start the physical design i needed a layout. I knew i was going to use an offset pattern, to save space, but I didn't know what size/grid to use for my bike. I tried different combinations in the cad to see how all the different components would fit with different battery pack sizes. I also needed to take into account how i would connect the series and parallel connections of the cells. After many iterations (too many), I settled on a 6 by 20 pack. This made it the easiest to connect, because i would use a nickel strip with the same offset.

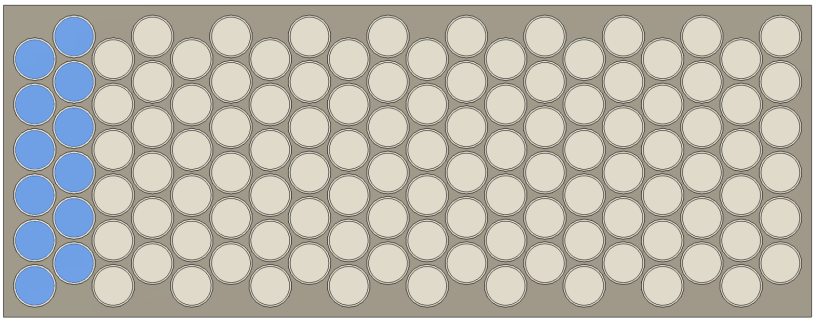


Figure 1: 6 by 12 battery config, Blue cells are in parallel

Connections

The choice of connections needs to be made carefully. It is common place to use pure nickel strip of 0.1-0.3mm thick. It is used for its high conductivity and ease of spot welding. Nickel has a low thermal conductivity compared to copper, which makes it much easier to spot weld onto the cells.

Size	Optimal	Acceptable	Poor
0.1 mm × 5 mm	< 2.1 A	~ 3.0 A	> 4.2 A
0.1 mm × 7 mm	< 3.0 A	~ 4.5 A	> 6.0 A
0.15 mm × 7 mm	< 4.7 A	~ 7.0 A	> 9.4 A
0.2 mm × 7 mm	< 6.4 A	~ 9.6 A	> 12.8 A
0.3 mm × 7 mm	< 10 A	~ 15 A	> 20 A

Table 1: Acceptable current levels for pure nickel strips

We'll start with the choice of strip for the parallel connections. We will have a max continuous current of 150A. This current will be distributed between 12 cells, so 150/12=12.5A/cell. Thus we must choose the right thickness and size to accomodate 12.5 per connection. On amazon I found some very convenient rolls of double nickel strips for this exact application (fig2). These have connections with width 8mm and 0.15mm thickness, with $0.15mm*8mm = 1.2mm^2$ of area. We can get the acceptable amount of area per amps from the table using $0.3mm7mm/15A = 0.14mm^2/A$. Thus one of our strip can accomodate $1.2mm^2/0.14mm^2/A = 8.6A$, which is lower than 12.5A we need, thus we can have two strips for a total of, $8.6A2 = 17.2A$. So we will use two layers of strip in our parallel connections. The series connections are a bit different. In my offset design, we will have 6 series connection between each group where a total of 150A continuous will travel. Thus each connection needs to accomodate 25A of current. To carry that much current with the same nickel strip would mean that we would need 3 layers, which is too much spot welding. Instead, we decided to laser cut custom pieces of 0.25mm thick copper for the series connections. Once all the connections are done, we need to cover the metal to avoid any electrical discharges. We designed a cover thats printed in two parts.

Figure 2: Double Nickel Strips

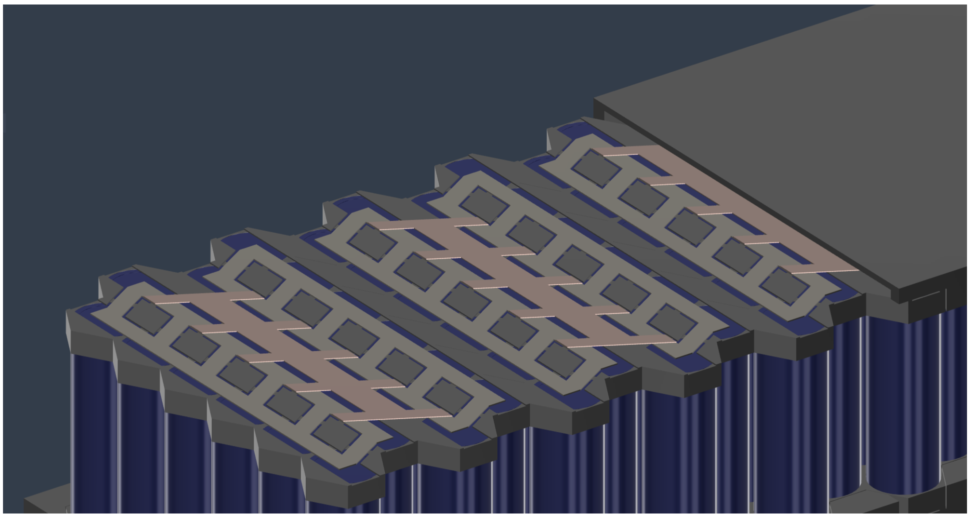


Figure 3: Connections and Cover

The next challenge is twofolded. First, the way we designed our pack is in two smaller 10s12p packs that are connected in series, and stacked. So we need to connect these two packs. This connection is going to take the full 150A, so it needs to be thick and wide copper. Additionnaly, it is good practice when designing a pack to optimize the current path. If your - and + ports are close, and there is a short electrical path between them (see fig.4), then the cells in that path will get used quicker because there is less resistance on that path. So the good way to do this is to make it so the least resistance path is actually going through most of the cells. Having a two layer pack makes that easier, as the two -and+ ports will be physically close together, but very distant electrically. We had $0.14mm^2/A$ for nickel as an acceptable value for the current density. Now copper can take at least twice as much current density (more like 4x actually), so $0.06mm^2/A$ for copper is a conservative estimate. Thus to carry 150A, we will need $150A * 0.06mm^2/A = 9mm^2$ for a copper bus.

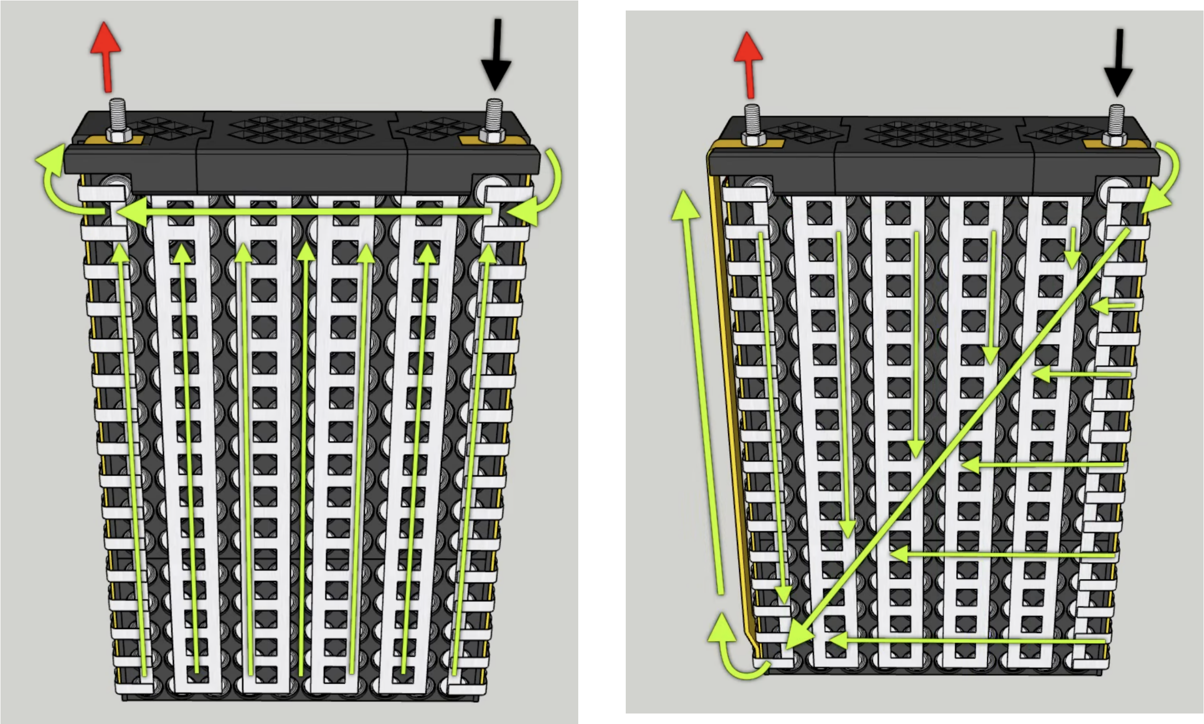


Figure 4: Left : The cells at the top get used quicker. Right : All cells get drained similarly

Date: January 28, 2026 **Topic:** Frame Build

The design philosophy of the motorcycle is form follows function, but more importantly, form follows manufacturability. This bike is like no other you have seen before, it breaks of the tradition of tubular frames, which are great for strength to weight ration, but are quite horrific for ease of manufacturing, especially at scale. This bike should be able to be made with a lathe (optional), CNC mill, tig welder, and a press brake (optionnal if you order some parts on sendcutsend). In fact, the whole bike frame can be ordered from sendcutsend, and then welded together.

The frame needs to fit the main components. These include the motor, the battery pack, the controller, the rear shock, and the gear system. In this design, the frame is made from two parallel plates of aluminum joined together by other plates. The spacing between these is defined by the width of our chosen motor (qs138), so that the motor can be directly bolted to the frame. The other components will follow suit.

i started by placing all the different components in an assembly, trying to see how they would fit together. This was a lengthy process where i had to iterate between different types of motor, battery pack configuration, and placements of all the different components. In the end, I defined some constraints :

-The battery pack needs to sit flush with whather plate is under it.

-The controller needs to be facing the wind to help with cooling.

-The lowest part of the frame needs to be low enough for a good placement of the foot pegs.

-I have a big ass rear shock, so it needs a place towards the back.

-Because I am designing this bike to be foldable, I need a shaft to go through the swingarm pivot, this shaft will be connected to the motor and to the wheel sprocket.

These constraints along with many iterations converged on a the final design. The controller is attached to the front plate, the batterypack is right behind the controller and is flush with the bottom plate. The motor and swingarm pivot are under the bottom plate, and are attached directly to the frame. Right behind the battery pack is the middle plate, upon which is attached the rear shock. All the plates will be welded together. The frame's lines are orthogonal to the front forks to maximize strength, which are angled at 27.35° (following the CRF450r).

The frame plates include the cam slots for the foldable seat along with the quick release pin for the seat. The minimize weight and maximize accessibility, the frame has two big windows to access the interior of the frame, and are covered with thinner aluminium sheet..

The motor sprocket and gear system go beyond the frame plates, and are thus covered. This cover is bolted to the frame on both sides and can be made out of composite materials, can be 3d printed, heat-formed, or even molded. It does not have any structural requirements, rather it is there to prevent the rider's feets to come in contact with the chain.

The frame connects to the front fork using a very minimalistic steering hub. It is made from an alu cylinder, with tapered ends to fit the angled bearings of the front fork, and two bent plates of 1/4" 5052 welded to the frame. The plates can supports an extreme amount of vertical force on the front forks and frame, which are the main loads the steering hub will experience.

Date: February 24, 2026 **Topic:** Swingarm

The swingarm geometry is governed by three primary constraints: frame width, rear wheel width, and the sprocket arrangement at the pivot shaft. The drivetrain layout was resolved first, since chain line and sprocket positioning dictate nearly every downstream dimension.

Construction

The swingarm is built from five chromoly steel blades, laser cut from quarter-inch plate. These can be ordered from any sheet metal cutting service ; I used SendCutSend. The five pieces are two main side plates, two joining plates, and the rear axle plate. Welding five separate flat parts into a precise 3D assembly requires a jig. Without it, thermal distortion during welding will pull the geometry out of true, and any misalignment here propagates directly into chain line error and bearing preload issues.

The rear shock pivot is not a welded fabrication but a solid block of chromoly steel, machined on a CNC mill. A welded pivot introduces too many variables at a highly loaded joint, and the machined block gives clean, consistent bore geometry for the shock hardware.

Chain Tensioners

The rear axle slot allows the wheel to be moved fore and aft to set chain tension on the axle-to-wheel stage. To make this adjustment repeatable and lockable, I machined two chain tensioners from aluminum billet on the CNC, one on each side of the swingarm. The geometry is simple enough that programming them takes very little time.

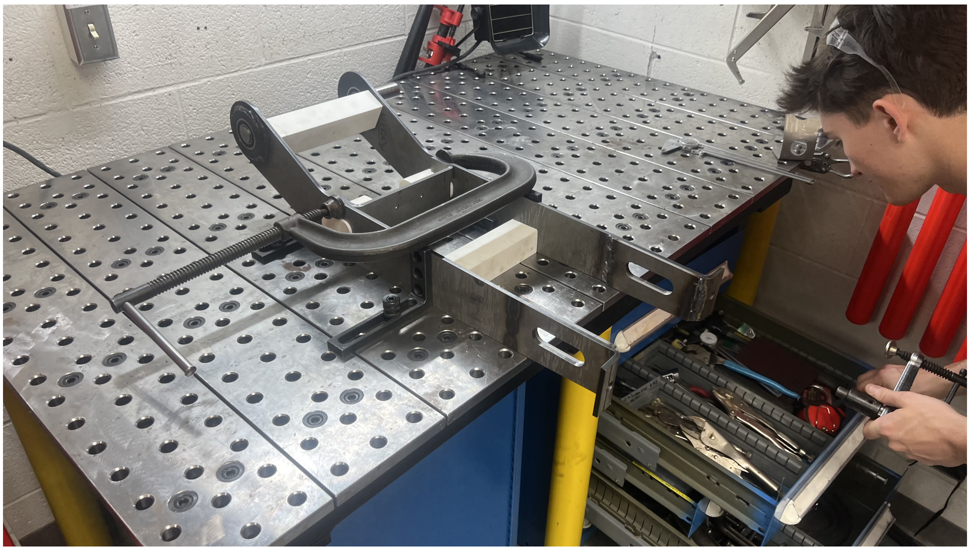


Figure 5: Swingarm jig and welding setup

Each tensioner works as follows : a bolt bears against the axle and pulls the wheel rearward when tightened, increasing chain tension. Once the desired tension and wheel alignment are set, a second locking bolt clamps the tensioner in place. The wheel axle nut is then torqued down to finalize the position. The two-bolt arrangement means you can fine-tune alignment independently on each side before committing.

Structural Design

The swingarm rotates about the pivot shaft and bearing pair. Manufacturability guided the construction method : a sheet-metal design formed from quarter-inch material with two primary bends transitioning between the pivot plane and the wheel plane.

A key structural challenge was integrating the rear shock mount while maintaining smooth load paths and bend feasibility. The solution uses a joining plate welded between the swingarm sides. The plate geometry avoids sharp transitions and limits bend severity. The maximum bend angle is 60 degrees, selected to remain compatible with thick-section forming limits and to reduce residual stress concentration.

Assembly considerations exposed another constraint. The rear shock uses a quick-release pin that must be removable without obstruction. Initial geometry restricted extraction clearance. Access holes were therefore added symmetrically on both swingarm sides, enabling direct pin removal.

Structural Validation

Structural validation was performed using FEA. Boundary conditions modeled the pivot supports and shock mount, with a vertical load applied at the axle region. The load case represents an extreme dynamic scenario:

- Maximum combined mass (bike + rider): 200 kg
- Dynamic amplification factor: 5
- Total equivalent load: 10,000 N

- Rear wheel share: 5,000 N

The aluminum configuration did not meet stiffness and stress targets. Increasing thickness was rejected due to weight and forming limitations. The material was changed to 316L stainless steel for improved strength and fabrication availability. Subsequent simulations showed localized deficiencies, addressed by introducing additional bends and longitudinal stiffening features. The reinforcement strategy mirrors I-beam behavior : increasing section inertia through geometry rather than bulk material.

Final pivot placement was tuned within the assembly. Ground clearance and sag targets drove the vertical position. Expected static sag is 30–40 mm. The pivot height was iteratively adjusted to achieve adequate clearance at zero shock preload while preserving suspension kinematics and structural margins.

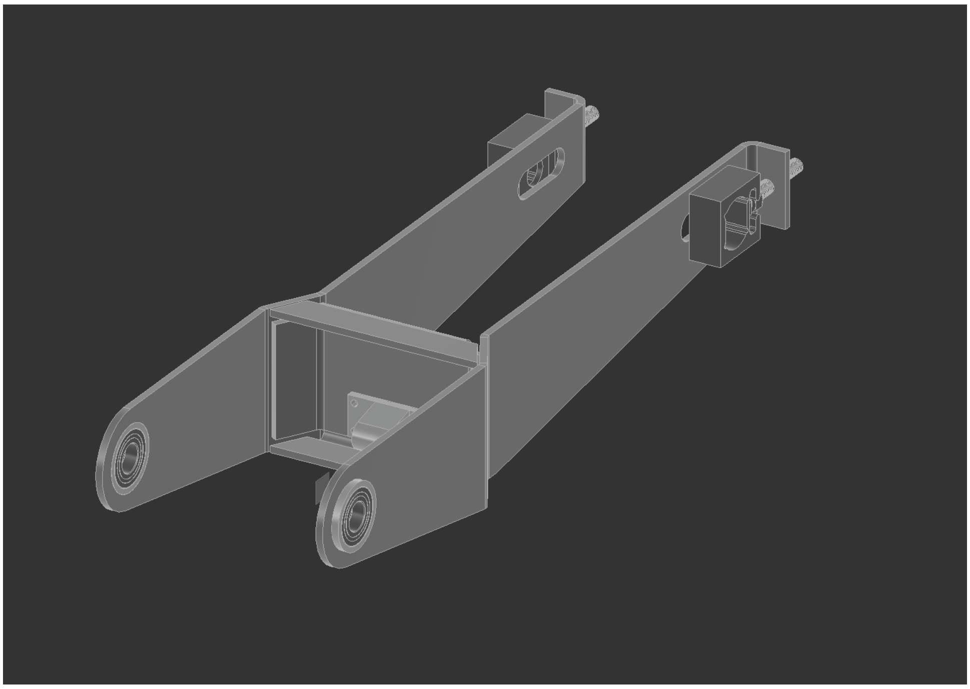


Figure 6: Swingarm

Date: March 12, 2026 **Topic:** Axle and Sprockets

Because the bike is designed to fold, the rear wheel pivots about the swingarm pivot point. This creates a fundamental constraint : chain tension must remain constant throughout the folding motion. The only way to guarantee this is to place a jackshaft directly at the pivot. The drivetrain is thus split into two stages : motor to axle, and axle to rear wheel.

Gear Ratio Selection

The target gear ratio was 7:1. The reasoning was straightforward. This is a dirtbag, so strong acceleration is the priority, while still keeping the top speed within a reasonable range. From the spreadsheet, a 7:1 ratio with the QS138 gives a peak slow-speed torque at the wheel of around 453 Nm, with a theoretical 0-100 time under 4 seconds. The rear wheel sprocket was already fixed at 49 teeth, and the motor sprocket was set to 14 teeth. To achieve the 7:1 overall ratio through the jackshaft, one needs:

$$\frac{N_{\text{motor}}}{N_{\text{axle,motor side}}} \times \frac{N_{\text{axle,wheel side}}}{N_{\text{rear wheel}}} = \frac{1}{7}$$

$$\frac{14}{28} \times \frac{14}{49} = \frac{1}{2} \times \frac{2}{7} = \frac{1}{7}$$

So the axle carries a 28-tooth sprocket on the motor side and a 14-tooth sprocket on the wheel side. Critically, these two sprockets were placed as close together as possible. This minimizes the net bending moment on the axle, which directly reduces the radial load on the bearings and thus friction. If they were spread apart, the offset forces would create a significant torque arm.

Chain Specification

All three sprockets are designed for 520 chain, the same standard used on heavy-duty bikes like the CRF450R. The chain has no O-rings. This was a deliberate choice : O-rings are there to retain grease and extend service life on road bikes, but on dirty terrain, grit gets into the O-rings and accelerates wear anyway. A plain chain is easier to clean, cheaper to replace, and lighter.

In total, the assembly requires around 160 links : roughly 100 for the axle-to-rear-wheel run, and about 60 for the motor-to-axle stage.

Sprocket Fabrication

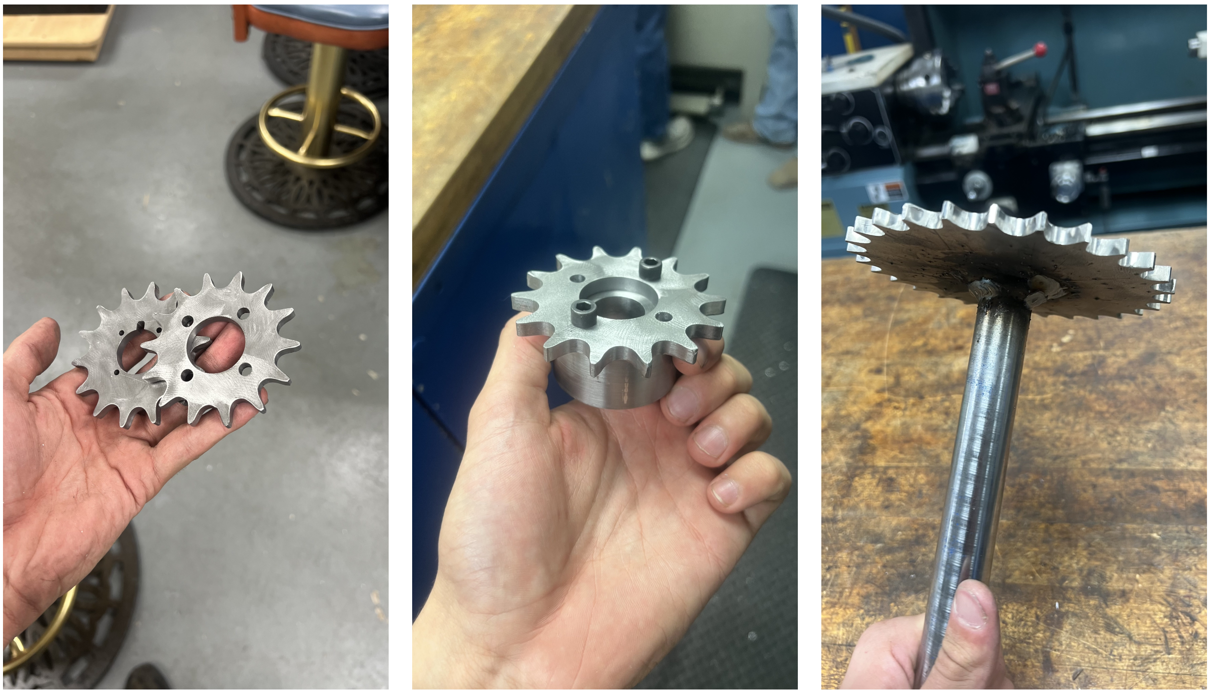
Figure 7: sprocket machining

All three sprockets were milled from 0.25 inch 4130 chromoly steel normalized plate. The choice of 4130 was driven by its machinability, strength, and the fact that it is readily heat-treatable, which gives headroom for future upgrades. In this build, heat treatment was skipped for the sake of time, but the option is there.

Motor Sprocket

The sprocket that ships with the QS138 is designed for 420 chain, which is lighter and narrower than 520. It also sits at the wrong height to clear the frame. A custom sprocket was therefore necessary.

I reverse-engineered the motor shaft and found a 10-degree taper. The custom sprocket assembly consists of two parts : a turned aluminum hub with the matching internal taper, and the sprocket itself milled from the 0.25 inch plate. The two are bolted together. Once assembled, the whole thing can also be welded for additional security, though I left mine unmodified to preserve the ability to disassemble if something needed to change. The taper gives a press fit, and a nut provides axial retention.



(a) Sprockets (b) Motor Sprocket (c) Welded Axle

Figure 8: sprockets, motor sprocket, and axle

Axle Design and Stack-Up

The jackshaft is a 1-inch diameter chromoly steel bar. The full lateral stack-up from left to right is as follows:

1. 28-tooth sprocket, welded directly to the shaft
2. $\frac{1}{4}$ inch spacer
3. Swingarm bearing
4. $\frac{1}{8}$ inch spacer (between swingarm and frame)
5. Frame bearing
6. 1 inch spacer
7. 14-tooth sprocket, keyed to the shaft
8. Retaining collar, bolted on both sides to hold the assembly axially

The 14-tooth sprocket is retained by a key rather than being pressed directly onto the shaft. The key is half an inch long, but the sprocket is only a quarter inch wide, which means the two $\frac{1}{8}$ inch spacers flanking it also needed a keyway machined into them to avoid binding on the key itself. The keyway on the shaft was machined using a $\frac{1}{8}$ inch end mill in the CNC mill, with the shaft fixtured horizontally.

Assembly Sequence

The correct order of assembly is : press the shaft (with the 28-tooth sprocket already welded on) into the swingarm, build up the stack layer by layer from the inside out, and finally press the 14-tooth sprocket onto the key.

Lessons Learned

Two things worth noting for future builds. First, when welding the 28-tooth sprocket onto the shaft, I made the mistake of running a full weld bead on one side before tacking the other. The heat from the continuous weld caused the sprocket to pull slightly out of true, resulting in a small but noticeable runout. The correct approach is to tack alternate sides progressively before committing to a full weld. Do not repeat that mistake.

Second, the sprockets were designed without a slight lead-in taper on the teeth flanks. The system works, but a small taper would help the chain seat more smoothly and reduce the chance of it riding up under load. Highly recommended for any future iteration. To be continued