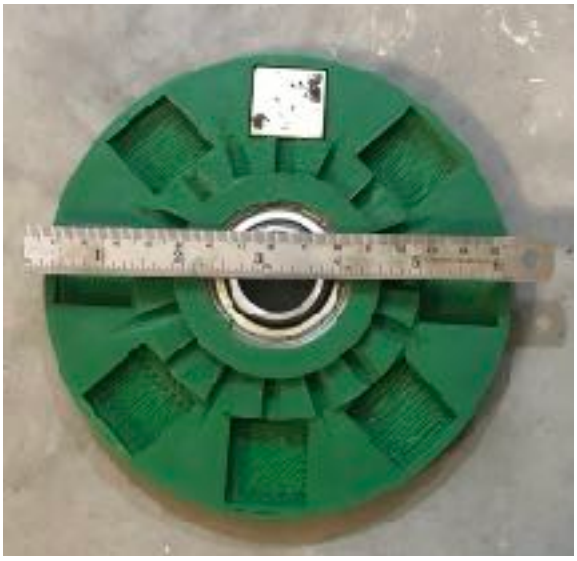
High strength, and High Strength to Weight Components
From Inexpensive FDM 3D printers using PLA

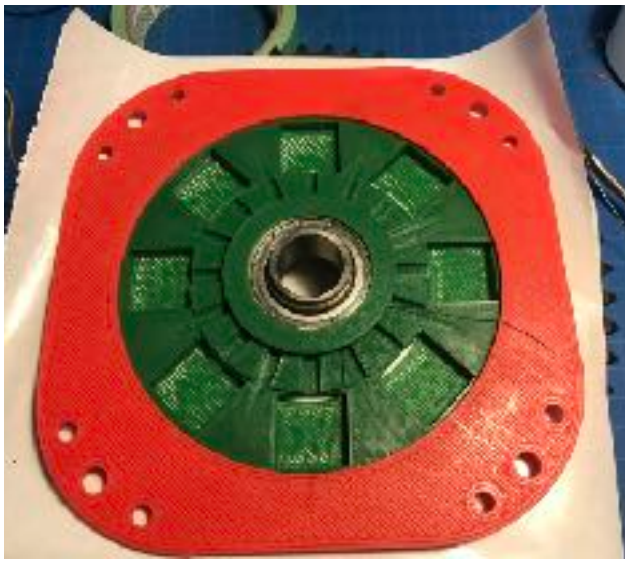
After being inspired by a number of people wrapping inexpensively printed PLA parts in epoxy soaked carbon fibre, and others using concrete and cloth wraps to join bamboo, I started to think about how I would use my 3D printer to create some PLA structures that I could try reinforcing. Yes, I know I should adjust my printers z axis, these are test parts, so I'm OK with them :-).

A week ago, the test project was decided. I am working on a 0.5-0.75 kW axial flux alternator, and need the magnet plates to be quite stiff, and not sag over time, as well I didn't want my printer to have to take days to print very heavy duty plates, which would likely sag over time anyway.

I expect the forces to be less than 400lbs, but the 200mm square plates are supported on their corners, and so a considerable bit of leverage is available to sag the centre.

I've considered a number of reinforcing materials, but one of my goals is that the alternator be fabricated just using the 3D printer, no machining, no laser cutting, just a drill in case some



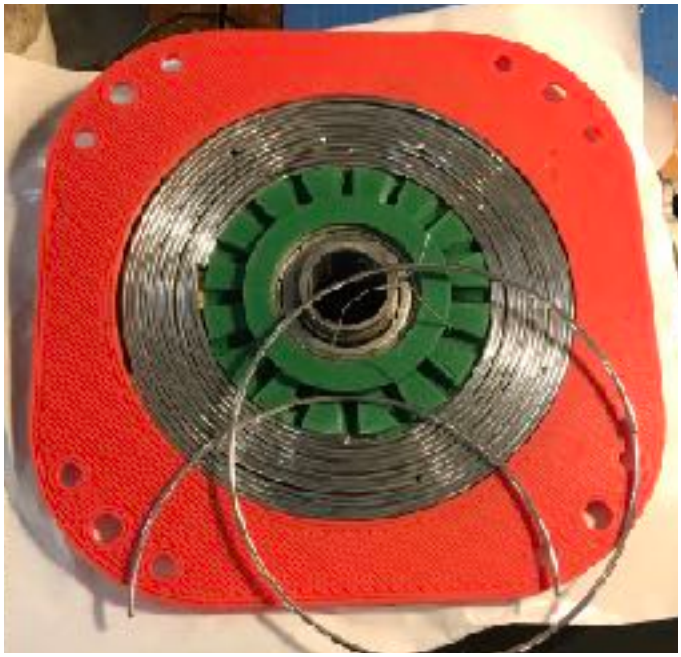


reaming needs doing, a bearing and some wire.

I designed the part in three snap together print, all to be joined together.

Assembly is begun by setting up flat steel surface (a car brake disk). Spacers are used between the brake disk and magnet array, to ensure that the magnet disk can be slid, or lifted off. At least 15mm spacer should be used, or the magnetic forces may lock it in place. The green magnet plate is then glued to the red plate and the magnets are glued in place. Using the flat steel brake disk as a glue up clamp, should help to keep the magnet array nice and flat. Brake disks can usually be found for free at brake shops.

The radial holes in the green disk, leading to the bearing shell, are channels for epoxy and reinforcing fibre. I didn't make the cutout around the bearing quite large enough to carry a wrap of wire around it, but you can see the wires in the lower right quadrant that I tried. Connecting the bearing shell, and the rest of the wire reinforcing should help keep it strong and stiff, so in the final part, I'll enlarge that space to make room.



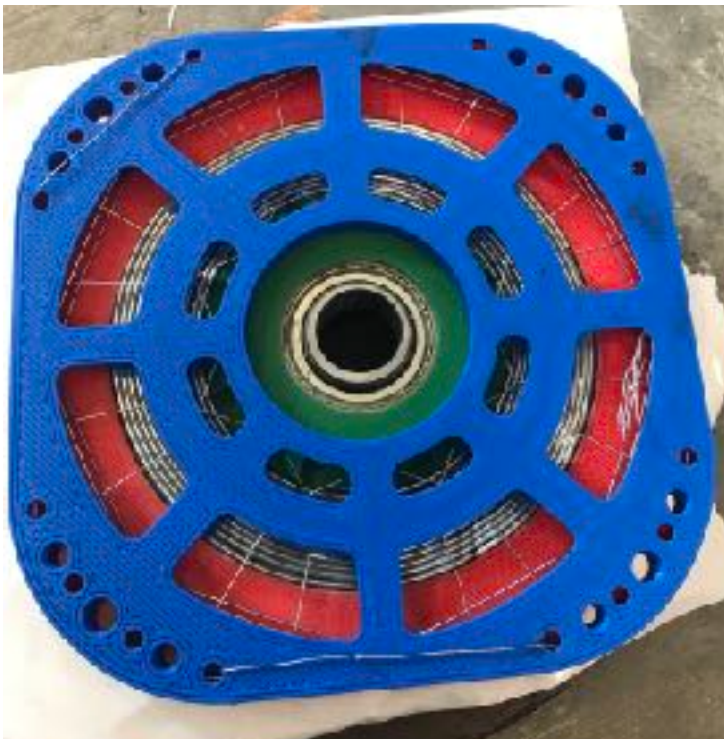
To maximize the strength of the magnetic field between this plate and the opposing plate (not pictured here), a steel ring needs to join the magnet backs. This ring isn't subject to reversing magnetic fields, so it doesn't need to be fancy steel. I've used heavy galvanized wire, about 2mm (don't know it's gage). It also will become a structural element, as it's much stronger than the PLA. As long as the magnets are glued to the disk, and the magnet disk is clamped to a steel plate with it's spacers, the wire lays down on the magnets very nicely, self clamping. It's much easier to use short rings of wire, then to try to lay the whole thing in a one piece coil. I had meant to use 2 layers of thinner wire, and think that would be a better solution, however this is a test part, so best not waste too much time getting it perfect.

In the final part, I'll probably use epoxy loaded with iron on top of the wire, to bond it all together, at the same time as I attach the blue top plate. The epoxy will be pulled between the wire and magnets, and so should create a strong ring, that will have minimal sag and should help channel the magnetic flux.

Next, I've used I've got a number of pieces of 22g galvanized steel wire as a reinforcing "fibre", and you can see how I've designed the ribs to have holes allowing me to string wire around inside the plate. I'm pre tensioning the wire a little, in the hopes of increasing stiffness.

There are lots of other possible fibres that could be used, kevlar, carbon, glass. I'm using steel wire because it's the best strength/stiffness to $. As well once I'm done my alternator winding tests with this, I may load it to destruction in my press to get a better idea of how it worked (and allow me to recover the magnets). The steel wire will be easy to separate for recycling, if it goes that way.

Here I've fitted the blue plate to the red and green plates, creating a void about 15mm tall, under the blue plate.



You can see in the blue plate, around the 3 through holes at each corner, I've got air vent holes, so that the poured in fill that coming next can fill around the bolts.

I've glued the blue disk around it's edge, and am ready to pour in my fill.

There are lots of options on fill.

I like using 2 part epoxy, and 1/4" to 1/2" chopped glass fibre. To mix it I use a piece of coat hanger, with a square loop on the end. Adjust the wire bends so that it scrapes right into the corner of your mixing buckets and ensures a good mix.

Here, I'm trying a new experiment. Super hard plaster of Paris (heavy repair 90, non sand-able, by Easy Fil, with about 50% PVA glue replacing half the water. Mixed fairly thick by hand, no chopped fibre, though that would also add a lot of strength, I didn't have any handy, and was worried it might keep the mix from flowing around bolt holes and into cavity around bearing shell.

It flowed into the shell nicely, messy, but low toxicity, no fumes, it is very nice to work with, but they aren't kidding about it not being easy to sand. This stuff sets up more like rock, than the plaster I'm used to.

I may add sand next time to reduce shrinkage and increase strength.

I tried to pour carefully, to minimize bubbles and voids. It took a lot of

tapping to get the outer corners filled, the wire timing structure on the bottom of the blue plate interferes with the mix flow, and if I'd had fibre in it, might have made it impossible to get fill into the corners.

My hope is that by doing the pour and cure, while the magnets are attached to the plate, means that it will all stay nice and flat and not distort as the mix cures.

The Assembled part.
I found that I easily scraped away the extra fill, while it was still quite wet. As it begun to set, it was time to stop messing with it. I should have taped over the through holes. I can drill out the mix easily enough though.

I'm a bit surprised to see the white mix flowing in between the bearing shell and the green magnet plate. It's almost the lowest point in the system, so it's got the most hydraulic pressure. Nice to see that if flowed down the 3d printed voids in the green part, and fully surrounded the bearing. A few pieces of wire, wrapped around the bearing and extended out to connect with the wire in the blue plate, would make this much stronger. Next time a larger toroidal void around the bearing for more reinforcing wire wraps would be a good idea.

I'm pleased with how it turned out! I may make a beam this way to test just how strong a PLA part, with a bit of plaster and some wire can be.

Or you should, and post a report on how it went!