Provisional Patent Application for Petal

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Notes

Title & Brief Description

This is Petal, a DIY 100-250w, mid-drive, bottom bracket integrated, brushless DC, 24-48V, 6-pole stator, 4 pole rotor, 3-phase, inrunner eBike motor.

The design takes advantage of the space around the spindle between the bearing cups, where the stator sits. It is compressed by the bearing cups to hold it in place, and fits snugly inside a standard bottom bracket tube. The stator is 3d printed (.stl courtesy r0gueSch0lar, https://www.thingiverse.com/thing:59997) for the prototype, and filed down so the windings sit neatly inside, near the cups. A channel is filed around the middle where the wires can run and be connected. The 3 cables will be bundled and exit through the cable guide screw hole.

The 3d printed PLA stator will serve as a mold for a lost wax/investment iron casting.

The windings are 22 gauge magnet wire (enamel coated copper). Rated at 1A.

The neodymium (curved, arc) magnets are attached to the spindle, either by their own strength or with epoxy (J-B weld or similar). To use bigger, stronger magnets the spindle needs to be shaved down a couple mm with a lathe.

A 3-phase controller needs to be used as it is brushless. I purchased one that came with a 500w brushless DC motor built in China. It is rated for 24-48V, and works great.

The power supply could be a standard 24-48V eBike battery. I'm using a variable Korad 30V, 5A desktop power supply here.

There should be only one cord connecting the motor and battery, and at most one more for a throttle. Hall sensors, etc. may be added in the future.

Weds. 1/15/2020 (update 5/2020):

Round two at AA a success - got the 500w motor running at low power, 6w. Step 1 complete! Here's the plan:

- take apart existing motor, understand how it works - DONE
- hook up oscilloscope, understand controller better - DONE
- learn to 3d print (tool training 3/22) - DONE
- 3d print stator model for old school bottom bracket - DONE
- learn to lost wax/investment cast/machine/CNC to produce metal/iron stator core
- embed/attach permanent magnets to BB spindle - DONE
- shave down spindle and use bigger, stronger magnets
- wind stator - DONE

- bench power supply, get spinning - DONE
- 48v e-bike battery
- cut bike frame to tabletop size
- install BB motor + controller + battery

- test w/ cranks, *torque*

- install prototype e-motor on full bike
- test prototype

- make a few working prototypes
- hand out to others for testing/alpha

- make video documenting build process
- make promo video for web

- launch website w/ video(s)
- crowdfunding/beta

- solicit investors
- patent
- form llc/startup

- refine design
- contract manufacturer
- set up direct sale on website

- release v1

Materials Required

- vintage bottom bracket w/ spindle, bearings, and cups
- 48v battery
- controller/driver
- 4 strong, curved magnets
- jb-weld epoxy
- stator iron (3d print mold, then lost-wax cast)
- copper wire

Implementation

SOLVED: nylon/metal washer possibly with notches for bearing cups to compress stator. or just design the stator so that it juts out enough for the bearings to compress on. need so that stator stays centered and fixed (non-rotating)

use cable guide screw hole for wires

Weds. 1/22/2020:

heading to AA tonight to hook up motor to scope, possibly take apart 500w motor.

Fri. 5/1/2020:

3d printed the stator, v2. This print was successful.
resources:

- printer = Prusa i3 MK3S
- material = prusament PLA (galaxy purple)
- amount = 16.64g
- cost = $.42
- time = 2h12min

settings:

- slicer = PrusaSlicer
- layer height = .20mm quality
- infill = %15
- supports = none

v2 dimensions:

- $num\_poles = 6$
- td = total diameter - 38mm $(= (1 + pr) * od)$
- od = center ring outer diameter - 21mm
- id = center ring inner diameter - 17mm
- h = height - 43mm
- pr = pole ratio - .65 $\Rightarrow$ pole length $\approx$ 6.5mm $(= pr * (od/2)$)

Pretty damn close to the specifications for the generated object file.

For v3, I'll need to have the inner diameter wide enough to fit over the races of the spindle.

- vintage bottom bracket dimensions:
- center length = 43.5mm (bottom groove to bottom groove. 45mm race to race)
- spindle diameter = 16.5mm
- square taper (small) = 13mm
- square taper (large) = 14mm
- race diameter = 21mm

standard bottom tube dimensions: inner diameter = 34mm
v3 dimensions:

- num_poles = 6
- td = total diameter - 34mm
- od = center ring outer diameter - 21mm
- id = center ring inner diameter - 17mm
- h = height - 43mm
- pr = pole ratio - .65 =¿ pole length 6.5mm (= pr*(od/2))

5:45pm: In progress.

Printed successfully. With the inner diameter exactly matching the bearing race diameter, it was remarkably tight. With a lot of force and some time, I was able to get it past. It may make sense to leave it that small with a little internal sanding or something, but I'd prefer .1mm on each side and just have an inner diameter that's .2mm bigger.

Sun. 5/10/20, 8:30pm:

Trying v4. This time, we have:

- $pole\_num$ =6
- id=21.2mm
- od=25.2mm
- $height$ =43mm

- pol_ratio =.25
- cap_ratio =1.5
- $resolution$ =400

I noticed that a problem I thought I have is not a problem. When I go to wrap the copper windings, it will bulge out a little on the sides, 1-3mm. I thought I might have to shave the stator height from 43mm to 40mm to compensate. However, there is a nice 3-4mm gap on either side between the bearing cage and the end of the cup.

Printing v4. Added a brim, turned the bed_temp up to 70c, and turned the speed down on the first few layers. Making sure to have good adhesion.

v4 printing successfully, will take 1h3m, 15.95g. PLA @ 24.99/kg =0.40.

Mon. 5/11/20: Realized that, with the bearing cups and cages, the available length for the stator 'height' is really 42mm, not 43mm. It may be that you can compress the stator, but probably only .2mm or so, which would allow for a nice snug fit.

Ordered some neodymium arc magnets from Apex Magnets.

v5 has height 42.1mm.

7pm:

v5 finished printing. It's still a little too big at 42.1mm. Will try 41.1mm.

v4 is printed. It measures:

- $total\_diam = 34.5mm$
- $id \approx 21.2mm$
- $od \approx 25.1mm$
- $pole\_length = 2.9mm$

Calculations:

Would like to calculate power. Need to know:

- wire gauge

- number of winding
- current
- strength of magnets
- geometry of setup
- number of poles = 6

$$pole\_length = 2.9mm$$

$$pole\_width \approx 5mm$$

$$AWG \rightarrow diam \rightarrow num\_windings :$$

- $19(1.8amp) \rightarrow .912mm \rightarrow 3$
- $20(1.5amp) \rightarrow .812mm \rightarrow 3$
- $21(1.2amp) \rightarrow .723 \rightarrow 4$
- $22(.92) = .644 \rightarrow 4$

Example: AWG 21, 1.2amp max power transmission, .723mm, 4 windings around pole, 6 layers.

24 loops per pole.

Too hard - need to measure. At 48v, no more than 57watt.

Tues. 5/12/20:

Printing v7, height = 41.3mm. v6 fit perfectly, but not snugly. need some compression.

Thurs. 5/14/20:

Magnets arrived yesterday. At least one set fits very nicely, no need to shave down the spindle yet, and they stick right on so no immediate need for epoxy. Going to grab some copper wire, and eventually will need to find a 48v battery.

10pm, Thurs. 5/14/20:

Found some magnet wire at "You-Do-It" Electronics Center in Needham. 22 gauge. Bought a multimeter, cutters, and wire strippers at Home Depot. Wound the stator core, and was able to generate a few mA of current by spinning the spindle.

5/16/20:

Got a nice 30V, 5A variable Korad power supply for testing. Got 500w brushless motor spinning at 25W.

6:32pm, 5/19/20:

Got some precision files to file down the notches near the end of the stator poles a bit more to better store the windings. They weren't quite fitting into the gap in the bearing cups between the bearing cages and the stator itself.

- First test w/ power, spinning: https://www.youtube.com/watch?v=SrjFXLMFxuI
- Spinning, brief: https://youtu.be/y2wRbTZY77E
- 500w motor w/ Korad, test: https://youtu.be/1-twHIf9ygM
- Generating power w/ multimeter: https://youtu.be/IRpmhwM5PVo
- Spinning by hand: https://youtu.be/fcTMyOD5his

The motor is spinning when hooked up to the 3-phase controller. Without mounting to a cut frame or the like, the axle causes the bearing cups to spin off. There may be a pair of windings wired in the wrong direction as it's doing some back and forth spinning. There are also no Hall sensors, which may be part of it. It is most likely just the vibration.

The bearing cups rubbing on the enamel coated magnet wire causes it to rub off a little and conduct on the metal, causing sparking. This can easily be alleviated by just filing the notches a bit more so that the stator completely encases the windings.