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Team F: ADD_IN

Teammates: Nikhil Baheti, Dan Berman and Astha Prasad

ILR02

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I - Individual progress

My goals during this week where mainly to experiment with a bent nozzle coupler and to start preliminary calculations to find the required specifications for our rotary stage. I also did an experiment of printing with an added mass to make sure it will not cause problems.

1.1 - Nozzle coupler:

I used the nozzle coupler in Figure 1.1 below, which was designed by Nikhil, to test if the nozzle can print at an angle and that the filament can rotate inside without kinking or breaking. The results were okay for the first couplers, I then tried different surfaces and results where very good with an internal heat shrink tube between the filament and the coupler's surface. The final nozzle will use PTFE which offers much better qualities, most of which is less friction. This experiment enabled us to confirm that the filament can spin inside the coupler and the nozzle's cold part, which greatly mitigates the risks of filament kinking being a problem in the future.

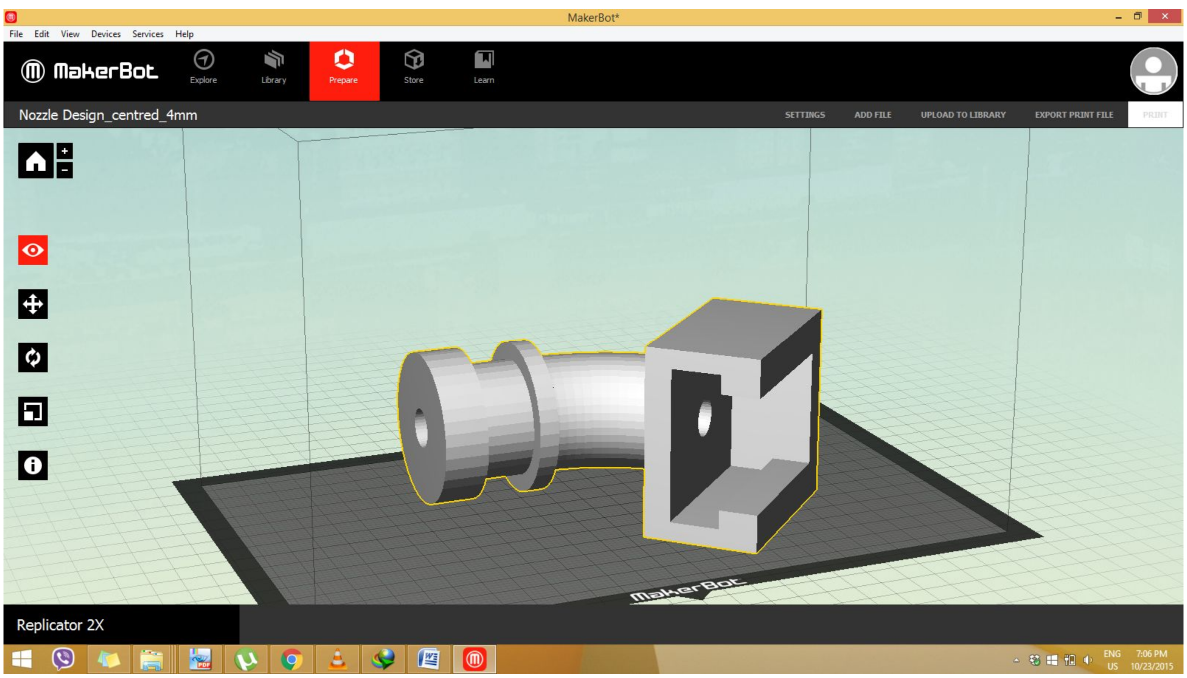

Figure 1.1 Nozzle coupler - final iteration (size increased for this caption)

1.2 - calculating required rotation speeds:

For this part I was interested in finding out the required speed for the rotary stage based on the printer's speed for the X/Y axes. The ratio of rotation speed to extruder movement speed is variable, with a maximum when printing around a point, which represents the worst-case scenario. Practically speaking this happens when printing around a rod or screw that is of very small radius, or when going around a corner, which is equivalent to going around a single point.

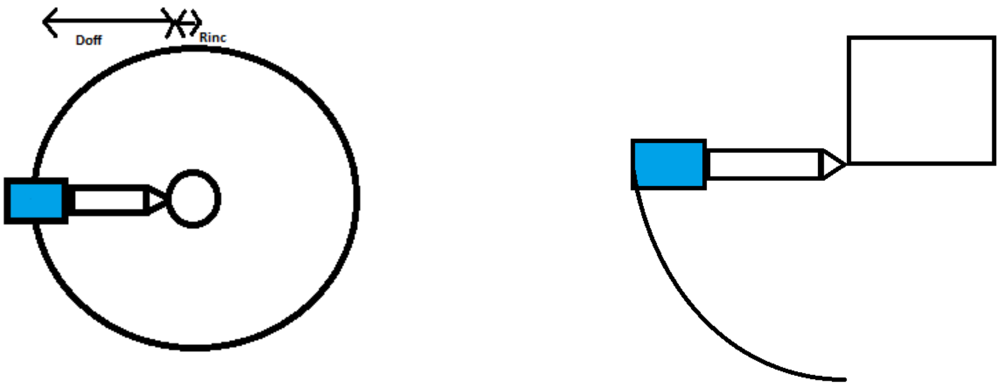

Figure 1.2 illustration of maximum rotation speed configurations

In our current printer, the typical printing speed is between 80 - 200mm/sec. While typical travel speeds of X/Y axes are between 100 - 250 mm/sec on the manufacturer's website. But the printer is rarely moving at max speed while printing, especially in arcs or circles, since max acceleration also comes to play, and these numbers seem far from the reality, so I tried to calculate the actual speed of the printer through experimenting. The traveled distance for the extruder in X/Y is: (Doff+Rinc) * θ rad. Assuming a 40mm offset(current coupler value) and 0mm Rinc. The extruder will travel around a circle of radius 40mm while the R joint rotates by 360°. So I designed a simple cylinder with 0.5mm wall thickness and 40mm radius to check the time it takes to print, and I made sure the printer does each layer in a single rotation. To remove timing lost in heating and setting up, I varied the height of the cylinder and checked the substraction. Illustration of the cylinder is in Figure 1.3.

Estimate to print 500 layers, duration: 0:43:13

Estimate to print 250 layers, duration 0:22:20

=> 20 mins53 secs for 250 layers =>5 secs /layer
=> required rotation speeds: Wmax = 72° /sec

Of course, the offset for the final design might be different, but the required speed is always inversely proportional to that offset and can be found easily.

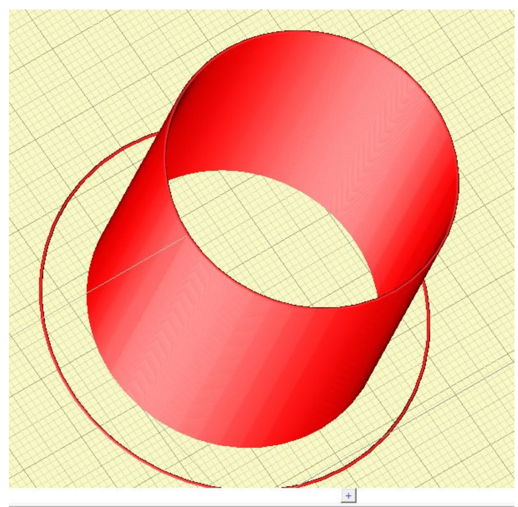

Figure 1.3 test cylinder

1.3 - calculating required repeatability of rotary stage:

Repeatability is one of the biggest risks of our project. It is imperative to precisely position the nozzle tip, and the added offset in our nozzle tip acts as a multiplier for the error, making it essential to reduce the offset and also to select a high-end rotary stage. Our goal is to be able to position the nozzle tip up to a +- 20 microns resolution, which is consistent with most desktop 3D printers and should results in a good print finish. For that, assuming a 40mm Doff, we need a rotary stage with repeatability of: 0.02 mm *360°/Doff*2*pi **= +-0.03°**

For our use, minimum positioning is less important than repeatability, because as long as the position of the nozzle tip is known it can be compensated by the X/Y axes. So a high-end stepper motor might also be used, since steppers usually have repeatability of 3 to 5% of a single step, that means a stepper with 600 steps per revolution and 5% repeatability would be enough for Doff = 40mm. And once again the required repeatability is inversely proportional to Doff.

1.4 - Printing with added mass on extruder:

Our added degree of freedom will certainly increase the mass of the extruder, and we identified that as a risk since it is commonly known that heavier extruders have more backlash and are less precise. To check that issue I tried printing the same part with and without an added mass, as shown in the Figure 1.4. The added mass was a NEMA 17 stepper motor, which should be close enough to what we will actually add, i.e., a smaller stepper but with mounts and bearings.

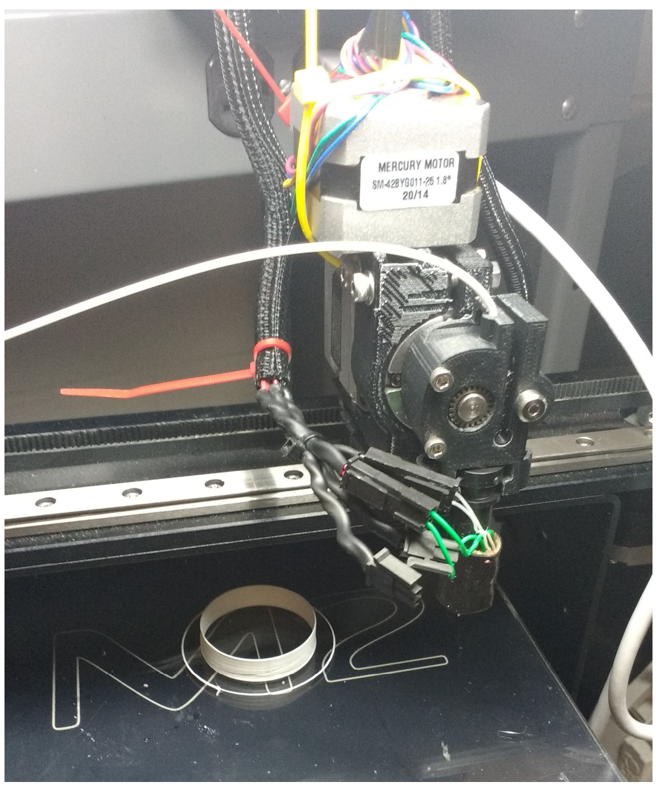

Figure 1.4 Printing with mass on extruder

II - Challenges

Not many challenges were met during this week. The only one was getting the coupler to fit perfectly with both the nozzle and the extruder, and have the holes aligned for the filament to go through. That took many iterations and redesigns but was finally achieved.

III - Teamwork

During last week I mostly worked with **Nikhil Baheti** on the nozzle part. As he would design and modify each iteration of the nozzle coupler and I handled the printing and post processing. **Astha Prasad** and **Dan Berman** who handle the software side of the project managed to get the matlab script to add insertion layer. Also **Dan** , as a mechanical engineer, helps us with questions related to the nozzle design, and **Astha** did all the work on the website.

IV - Future Plans

The future plans for next week are to start designing the first prototype of the nozzle, so I will order materials and me and Nikhil will start designing the bent heat break and nozzle head on solidworks. After that Dan will help us machine it in the shop, during the following week. We will also be designing our rotary joint mount on the extruder, which will be part of the CAD 3 assignment, and Dan and Astha will keep improving the Matlab script and learning about slic3r.