CSC293 CS Improves 3D Printed Manufacturing
FDM 3D Printing

Sreepathi Pai
Sep 6, 2023
URCS
Outline

Printer Operation

Problems

Software Operation
Outline

Printer Operation

Problems

Software Operation
Filaments (common) or pellets (high throughput) of some polymer (plastic) are “melted” and extruded into layers.

- PLA
- ABS / ASA
- Nylon
- PETG
- TPU
Different polymers have different print settings

- Bed plate temperature (70°C for PLA, 100°C for ABS)
- Melt temperature (200°C for PLA, 230°C for ABS)
- Chamber temperature (cool for PLA, 60°C for ABS)
- Print Speed (slow for TPU)
- Flow rates (100% for PLA, 92% for ABS)

All these settings are set in the Slicer
Extruder

- The extruder pushes the filament into the hotend
  - Or pulls it out
- Direct drive: extruder pushes directly into hotend
- “Bowden”: extruder is much further away (e.g. back of printer)
- On the printer you’re using:
  - Direct drive
  - Voron Clockwork 2
- User actions:
  - Increase/Decrease tension
  - Release Filament
Hotend

- The hotend heats the filament to its “melting” temperature
  - Usually 230°C for ABS
- Maintains a temperature gradient
  - Assisted by the hotend fan
  - If the fan fails, emergency!
- Maximum temperature and flow rate of hotend limits
  - What materials can be printed
  - How fast the printer can print
- No user actions
Nozzle

- Extrudes melted plastic under pressure
- Diameter of nozzle varies:
  - common 0.4 mm
  - Fine detail – smaller diameter
  - Fast printing – bigger diameter
- Usually brass, but can be made of steel, and other materials
- Two popular standards V6 and MK8
- User action: Switching nozzles

Source: [www.prusa3d.com/product/nozzle-e3d-v6-0-4-mm/](http://www.prusa3d.com/product/nozzle-e3d-v6-0-4-mm/)
Cooling

- Hotend fan (below)
  - always on when hotend is heating or above 50°C
- Part cooling fan (above)
  - Mostly on for PLA, off or low for ABS
  - Usually switches on automatically for “bridges”
- No user actions

Source:
https://vorondesign.com/voron_stealthburner
Print Bed

- Provides a level surface for printing
- Part must adhere to it when printing
  - And release after printing
- Achieved through:
  - heating the plate to glass temperature
  - using a removable PEI plate
- User actions:
  - plate removal and replacement
  - plate cleaning using soap (not IPA!)
- Always remove parts after bed has cooled down to around 50°C
  - They should pop out easily without needing PEI plate to be removed.
Enclosure/Chamber

- Maintains chamber temperature
  - Reduces warping in ABS
  - Inhibits cooling for PLA!
- Keeps pollutants inside
  - Microplastics
  - VOCs
Positioning

- **Homing**: Print head locates a known position along X, Y, and Z axis
  - **Probe**: Print head locates print bed
- **Z-tilt**: Print bed is leveled so it is level wrt to print head
- **Bed mesh**: Records bed imperfections and adjusts while printing
General Warnings

- Burns
- Cuts
- Fumes
- Electric shocks

Machines are replaceable, your body parts are not.
Outline

Printer Operation

Problems

Software Operation
The first layer is the layer of plastic directly on the print surface.

Printed slower compared to the rest.

Common problems:
- Partial adhesion (cancel and reprint)
- Too less adhesion (cancel, add Skirt, Brim, Raft, and reprint)
Warping
Warping – contd

- Parts of the print pull themselves off the surface (usually at the edges)
  - Uneven cooling
- Worst case: part topples while printing
- Bad case: part is warped and can’t be used
- Good case: part has warps, but is functional
- Ensure:
  - Chamber is heated before printing
  - Cooling is not too much (esp. for ABS)
Clogs (contd.)

- Filament jams inside cool part of hotend preventing extrusion
- Various methods, almost all involving dismantling the print head
- No specific cause, random occurrence
  - Except for “heat creep”, when the hotend fan is insufficient

Layer Shifts – contd.

- Printer is open-loop
  - It does not monitor its position continuously
- Thus, it can lose track of its position
  - Usually due to the print head hitting an object (e.g. toppled object)
  - Or due to poor construction (e.g. too short drag chains)
  - Many others
- This causes layers to shift during printing
Spaghetti
Spaghetti (contd.)

- Filament is extruded into free space instead of on top of previous layer
- Might be due to toppled object, layer shift, etc.
- Causes buildup of spaghetti, blobs, etc.
Blobs

- Blobs usually due to incorrect nozzle tightening
  - Causing leaks
- Also can happen if parts of filament attach themselves to nozzle and accumulate
  - This is what the silicone sock should prevent

Source: Reddit
Outline

Printer Operation

Problems

Software Operation
• Printer hosts a web server running Mainsail, a web-based UI
• Printer has a touch screen attached to it that runs KlipperScreen
  • Fingers work, but prefer a stylus
Source: https://docs.mainsail.xyz/
Source:
https://klipperscreen.readthedocs.io/en/latest/
Emergency Shutoff

- Shuts down any printer activity
- Switches on the hotend fan
If the “plate” contains multiple objects, you can individually cancel objects.
References

- Niel Rosenberg, Designing 3D Printers: Essential Knowledge
- The Prusa Knowledge Base, even though it’s specific to Prusa printers