3D Print of the month. September 2018

Inclusions

3D printing by layers of plastic is a great technique and has three principal areas of use for the railway modeller. All of these can be enhanced by including other materials within the 3D print. This month we look at how such inclusions are used, what enhancements they bring and how they are achieved. This was originally planned as a possible 'morning session' talk, but it is maybe a bit niche for that.

Models: 3D printing allows complex models to be made with very little expense. Models can be made bespoke to suit the user's need and scaled to almost any size within reasonable limits. Structural changes and improvements ("take the back off that to fit a servo", "Make it fit a peco chassis") can be achieved straightforwardly.

Structure: There are many areas 'behind the scenes' on a layout where 3D printing can be of benefit. Servo mounts, motor mounts, mimic panels, brackets and supports of all kinds can be made to exact specification on the 3D printer. And these can be achieved with little expense and only moderate skills.

Tools: Items can be 3D printed to make the things that the hobbyist is doing easier. Jigs to set offset distances between tracks, or tracks and platforms, ballast distribution tools, blocks to hold buildings 'square' during gluing. And these are just some of the current offerings in the WOSAG catalog, which can be found elsewhere on this site.

All of these can be improved or enhanced by including other things in the 3D print.

Metals: Including a small washer adds weight and will make a mobile figure or fixture stand better (did you know that subbuteo players each had a washer in their hemispherical base?) Adding a vertical bolt or piece of wire can provide a spindly model with stiffness that isn't naturally available in plastic at scale.

Coin makes a 3DP beer opener

Magnetic inclusions in fixing blocks

Magnets: Magnets, particularly the rare earth /neodymium magnets are really useful. They locally apply a considerable force, to hold things together, or push things apart, in addition they can be used to activate reed relay switches, and so can be useful in train detection, animation, control, and a dozen other applications. In some situations they can even be used to provide levitation, literally taking railway modelling to another dimension! They are very inexpensive and readily available, typically from our friends in the Far East.

Spaces/voids: One of the fundamental tenets of design is that the space is often as important as the material. Simple gaps, and the ability to 'see through' a model improves realism, and thus appeal. Most structural elements and nearly all tools have some sort of alignment hole or attachment slot or whatever. Gaps can simply be designed in to the 3D print, though a little care is needed in designing for manufacture, to ensure that it is possible to print the part without excessive overhang.

Glass: Glass can be use to simulate glass, but perversely, it's not very good at it! When used in glazing a model, glass can look out of scale unless it is a very fine, and thus expensive, crystal glass. One trick is to hoard old dead LCD displays, the front of which is a single rectangular sheet of very very fine glass.
Ordinary glass is useful however, for modelling water surfaces. And leaded and coloured glasses, used in the manufacture of 'stained glass' can greatly enhance lighting effects.

Glazing: Given the above, the better ways to glaze buildings and rolling stock is to use clear plastics. Sheet acrylics are available that are entirely transparent, but true transparency is rarely needed. What is more often required is a semi-transparent or translucent material that allows light through, but suggests dirty windows. This can be achieved by lightly sanding/scotchbrite-ing acrylic, or by using 3D printed transparent filaments, which generally are not very transparent!

Plastics: One of the most interesting things to insert into a 3D print is a 3D print. The same 'pausing' commands that allow inclusions in a 3D print is also used by some manufacturers to allow filament changes 'on the fly' during the print. This allows some really nice effects, but there are limits, since everything on the same layer has to be the same colour. If your printer doesn't allow this then it is only a matter of a firmware upgrade, or a firmware hack, to get it to work.

3 colour sign created by switching filaments

Electronics: From simple LEDs, reed relay switches to complete modules, 3D prints can provide robust enclosures and clever camouflage for layout electronics.

How to do it

The simple way to allow inclusion is simply to design an item that will, when complete, accomodate the inclusion. Slots, for example, in the fixing blocks allow little neodymium magnets to be inserted. Holes allow for machine screws to go through blocks. Some of the Wosag track laying 3D prints use metal screws inserted after the parts are manufactured.

Slightly less simple is building the item in two or more parts, so that the inclusion can be added and then the parts glued or screwed together. Cyanoacrylate adhesive (super glue) is a great glue for PLA prints, and some enormous gothic prints are possible by printing parts and then gluing them together.

Lastly it is possible to pause and then restart the printer mid-print. This allows, for example, a hex pocket to be modelled in to the part, then the printer pauses, a metal nut is pushed in to the pocket, and the printer carries on, entombing the nut forever inside the plastic to make an invisible and very strong joint. Entombing an SMT LED within a model, for example, will allow a glow to emanate from it.

Caveats: There are various possible problems and things to be aware of. Most of these are just common sense, but there may be some here that are new to you.

The layered nature of 3D printing means that any inclusion in a pocket has to go down into the pocket. We can't leave anything 'sticking up' or the printhead /nozzle will touch it on the next pass. Whilst this probably won't harm the printer, it will almost certainly dislodge the print from the printbed, failing the print. It is better to design in a little clearance gap above the inclusion.

Magnets have a magic temperature, called the *"Curie Temperature"* at which they cease, temporarily, to be magnetic. Hot melt plastic, like soldering, can affect magnets.

Gaps are holes. Holes can weaken structures. Particularly at scale.
Wide gaps can sag during the manufacturing process. This can be mitigated by having the slicer program add supports, but that brings it's own problems in that these supports need to be pared away after the part has been printed.

Really fine glass is dangerous to handle, and difficult to cut. Be careful.

Non fine glass, ie window glass or picture frame glass, can be heavy.

Electrical items that may need replacment (filament bulbs, batteries) are not good candidates for entombment.

G-Code: The data that is sent to the 3D printer to make it do it's thing is called g-code. It consists of a long series of text instructions:

The same G-code are used for all Computer Numerically Controlled (CNC) machines, Lathes, mills, etc as well as 3D printers. The encoding is fairly simple. Lines that start with a G tell the machine to go to a position. G0 means go fast to a position, G1 means go under control to a position. The lines that start with a M are machine specific instructions. Thus it is a trivial matter to open the g-code file in a text editor

```
G90 ; Absolute positioning
M82 ; Extruder in absolute mode
M190 S50
; Activate all used extruder
M104 T0 S210
G92 E0 ; Reset extruder position
; Wait for all used extruders to reach
temperature
M109 T0 S210
;Layer count: 50
;LAYER:0
M107
G0 F9000 X105.973 Y113.308 Z0.300
;TYPE:SKIRT
G1 F1800 X106.706 Y112.714 E0.04707
G1 X107.499 Y112.199 E0.09424
G1 X108.336 Y111.773 E0.14110
G1 X109.149 Y111.460 E0.18456
G1 X109.522 Y111.346 E0.20402
G1 X109.828 Y111.265 E0.21981
G1 X110.123 Y111.197 E0.23492
```

G-code from the start of a model

and add a line to cause the 3D printer to pause. Once the right spot in the file has been located one only needs the correct command to insert. They are mostly M type, machine specific commands.

```
M0          ; Unconditional Stop
M1          ; Conditional Stop, machine still accepts codes
M226        ; Pause
M600        ; Change filament ( Prusa | Marlin |Reprap)
            printers
G4 3000     ; Pause for 3000 tenthseconds (5 minutes).
```

One issue with pausing is that whilst pausing is easy enough, different printers have different means of 'unpausing'. Not all printers have the same buttons/controls. Some have none!

Conclusions: Including 'foreign bodies' in a 3D print is fairly easy to do and can have many uses for the railway modeller. This article has pointed out some of the opportunities and some of the pitfalls, and given some pointers about how to design and print with inclusions. As usual please feel free to contact my self, the AG convener Davy, or any of the 3D printing group to share ideas, experiences.