AG1LE

(Affordable Gauge 1 Locomotive Engineering)

Adrian Johnstone, May 2019

This is an initial discussion document not a firm proposal

Hardware

Cheap, low quality 3D printers are widely available. The usual technology is filament deposition in which prints are built up using an extruded strand of plastic. The resulting prints are quite tough, but with a noticeable grain which even in our scale requires work with wet and dry paper and a good space filling primer before painting.

Recently, a new generation of high precision machines exemplified by the Cetus 3D has started to appear. My experiments indicate that a very good finish can be obtained using 0.1mm layers and a 0.2 mm nozzle using these machines, at the expense of *extremely* long print times (e.g. several days for a wagon and perhaps a week for an engine). Lower quality prints can be produced in a few hours. These machines cost about £350.

CAD software

The main work of this project is the production of accurate 3D models which can be given away online as public domain hardware. Engineers and draughting professionals like to use parametric 3D drawing packages, of which SolidWorks is probably the market leader, although it has very high initial and ongoing costs. Competition is appearing, including online cloud-based tools such as Onshape and Fusion 360, low cost re-issues of conventional software such as Alibre Atom3D, and development projects for open source parametric modellers such as FreeCAD. There are also a variety of tools targeting animation rather than engineering, such as Blender.

All of these tools have very steep learning curves, and there are other reasons to think carefully about whether to commit to them. SolidWorks and other professional tools are prohibitively expensive. Cloud based services usually hold design data in the cloud, and may start charging at any point. FreeCAD and other community efforts are not mature enough to be relied upon. Alibre Atom at £200 is probably the best of these options at the moment, especially given the recent tutorial series in Model Engineer's Workshop.

There is another alternative, and that is to used programming-language style scripting tools. Many of the visual drafting tools have some sort of limited scripting facility, but it is usually only used for simple automation of repetitive tasks as an adjunct to 'point-and-click' model building. Tools such as OpenSCAD, OpenJSCAD and Cava-3D (which is my own project) have scripting as their only design entry mode: the scripts are then rendered for visual display or as meshes which may be processed directly by 3D printer software.

The advantage of these tools is that the basic set of features (and thus the learning curve) is very simple and the scripts are ordinary text files – there are no complicated proprietary data formats to worry about, so distribution of public-domain hardware designs is straightforward. The disadvantage is that some operations, especially those involving curves such as adding a fillet to a joint, require a lot of thought.

A particularly encouraging aspect of this approach is that it is easy to create design sub-options and include them all within one script: for instance different styles of chimney or the use of wooden or angle-iron stanchions on a wagon. I have a developing model for an accurately drawn 1923 RCH wagon. A scaling factor is built in to allow 1:32 or 10mm versions to be generated (or indeed O-gauge and full sized variants). There is also a 'bloat' factor for elements such as chamfers which can disappear if one sticks to strictly scale drawings.

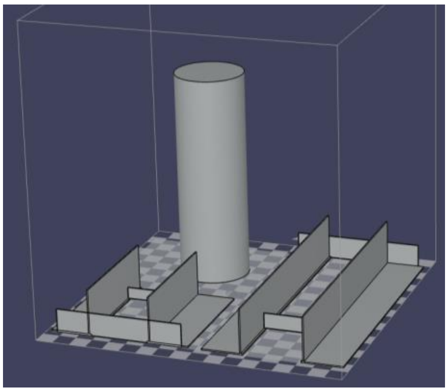
A 3D printed starter engine

I am also presently drawing a rebuilt R24 GER Holden tank, using the Great Eastern Railway Society drawing number L-25 as a guide. Geoff Calver has offered to help gain access to the prototype for more detailed measurements as necessary. Present indications are that there will be less than 0.25Kg of plastic in the printed version; appropriate quality plastic presently retails for between £12-£20 per kilo; hence the materials for the printed engine would cost £3-£5. The printer consumes electricity at the rate of about 2p per hour, which means that a high quality print would use about £3-£4 of electricity. Peter Jackman has identified a source of low cost electric motors which he using in the bogies for his new Deltic design: with batteries and a simple manual speed controller the model could be motorised for around £10-15. Hence we have the prospect of an (unpainted) manually controlled electric loco for less than £20. One of the Deltang spectrum compatible receivers could replace the manual controller for around £25 giving full radio control.

The rest of the train

G1 tends to fixate on locomotives, but unless a new participant has access to a club or G1MRA local group, they are going to need rolling stock. The same 3D printing approach promises RCH wagons in several variants for around £5 each, and a 30' four- or six-wheel GER coach should be the next target, the goal being to offer a complete pickup goods train-in-a-box with a loco, two coaches and a few wagons for less than £80 worth of materials. There is no particular reason why we shouldn't even print some small-radius points and track: such items would not survive prolonged running, but they would enable the new participant to get something running for the kids on Christmas morning.

Printer practicalities



A G1 J69 Holden tank is around 25cm long, and that exceeds the build platform size for many domestic printers. In particular, the Cetus only allows an 18cm x 18cm build. The frames and running boards must therefore be split. It is in any case helpful to print subassemblies such as the boiler barrel and smokebox separately to make finishing and painting easier. Epoxy glues such as Araldite work well on these components. Here is a preliminary sketch of the J69 frames and boiler barrel arranged for printing; the print quality from a CETUS 3D is sufficiently good to need only a coat of primer before painting.

Onwards to traditional G1 live steam

A first useful upgrade for owners of the AG1LE train-in-a-box (TiB) would be to use Association wheel sets on the wagons and coaches so as to add low-down mass and durability. The axle boxes are designed to allow push-in oolite brass bushed sized for association axles. Bushes with smaller holes may be used for, say, Northern Fine Scale wheelsets. We can also consider axle box variants with holes for small ball races.

Now that metalwork has been removed from most school curricula, it is hard to acquire the craft skills necessary to, say, get an even finish on a turned locomotive dome. Although machine tools are available at historically low costs relative to average incomes, a large initial outlay is required - a bold step for those who have never touched a lathe or a mill before taking up the hobby.

For those without machine tools, a variety of services are available to assist the budding locomotive builder: assembly kits from Aster, Barrett and others along with online providers of 3D printing, brass sheet etching and laser cutting. It is very hard to achieve the low costs that I believe are necessary for this project using these routes: for instance, an RCH wagon printed in polished sintered nylon using one of the cheaper services is slightly more expensive than a finished wagon from NFS or Aristocraft.

The key to low cost is home production via either 3D printing or miniature CNC machine tools such as the Sherline mill. The next step along is to use milled (or bought-in laser cut or etched) frames and platework. The CAD model plus the CAM software I have can generate GCode for Sherline and other mills which can be distributed to builders.

Construction of a soft-soldered pot boiler is significantly eased with a Sherline mill, since cutting circular end caps of copper is a tedious filing exercise manually (though not actually difficult). For low pressure oscillator engines silver soldering is not required: in fact the Aster GER tank has a soft soldered boiler. Similarly, a safety valve is unnecessary because the spring-loaded cylinder will be pushed off of its block if the pressure gets too high. A C-type boiler can be constructed for this size model – Peter Jackman has an example of Curly Lawrence's Chingford Express with a C-type boiler. A first improved motor might be suitably updated version of Curly's slip-eccentric steam motor using metric sizes and O-ring's instead of graphite yarn for packing. A twin cylinder version *might* be feasible if adopt JvR's slide-valves-that-look-like-piston-valves approach, as exemplified by Dick Moger's AR1MIG block.

The modularity, with a clear upgrade path, is important to me because I am also interested in principled comparison of things like boiler types, cylinder size and so on. Here are some configurations that would appeal to different constituencies.

Configuration	3D printed electric	Pot boiler oscillator	Pot boiler twin with piston valves	Pot boiler single cylinder slip eccentric	Twin cylinder (meths)	Dick's delight (gas)
Platework	3D printed	Milled brass sheet	Milled brass sheet	Milled brass sheet	Etched brass sheet	Etched brass sheet
Frame	3D printed	Milled steel sheet	Milled steel sheet	Milled steel sheet	Laser cut steel	Laser cut steel
Wheels	3D printed	Milled aluminium	Milled aluminium	Milled aluminium	Walsall or Mark Woods	Walsall or Mark Woods
Motor	N20 6V 400rpm	Oscillator	Twin cylinder	12mmx10mm single cylinder with O-rings	ARM1G twin	ARM1G twin
Valve gear	-	Swapover reverser	Piston valves + swapover reverser	Slip eccentric + D-valve	Slip eccentric with JvR slide valves	Slip eccentric with JvR slide valves
Boiler	-	Pot	Pot	Pot	C-type	Centre flue
Energy	4xAAA NiCAD	Meths: sump + wicks	Meths: sump + wicks	Meths: sump + wicks	Meths: chicken feed + wicks	Gas poker
Water	-	One shot	One shot	ENOTS or equivalent	Side tank hand pump	Side tank hand pump
Fittings	Charging socket and switch	Displacement lubricator	Displacement lubricator, sight glass, pressure gauge, safety valve, regulator	Displacement lubricator, sight glass, pressure gauge, safety valve, regulator	Displacement lubricator, sight glass, pressure gauge, safety valve, blower, regulator	Displacement lubricator, sight glass, pressure gauge, safety valve

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