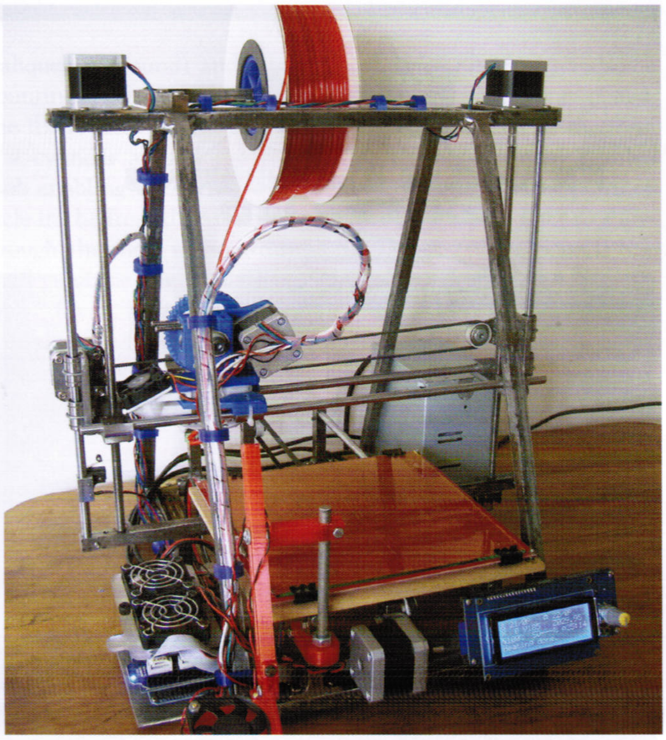
3D printing to make unique castings

Words Neil Glasson and Bob Hayes

3D printers have made the news a lot recently – from being used to make working firearms to fabricating replacement human body parts. Neil Glasson and Bob Hayes open a world of possibilities for technology minded restorers.



Neil's 3D printer

3D printers have become much cheaper and more accessible in recent years. It is now possible for an enthusiastic hobbyist to assemble a very capable Fusion Deposition Modelling (FDM) machine for well under $1000. These machines can be used to "print" in one of several different plastics, turning a spool of filament into elaborate and durable 3D models.

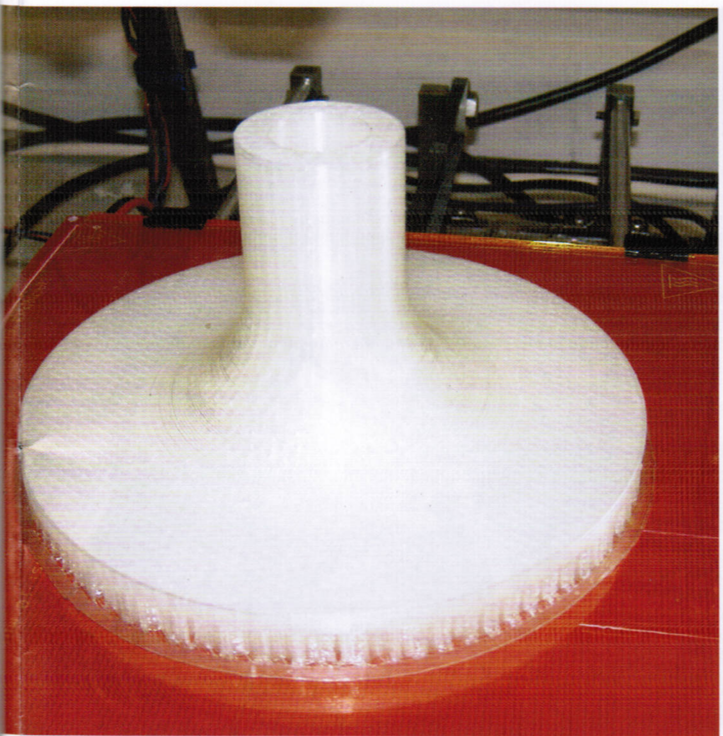
There are vast collections of ready designed models that can be downloaded freely from the internet and printed (www.thingiverse.com, www.youmagine.com, www.cubehero.com). The real power of the technology is realised when you progress to creating your own designs. If you have access to professional CAD (computer aided design) solid modelling software, you can readily produce 3D printer files. Professional CAD software is very capable but also very expensive, putting it well beyond the reach of hobbyists. Thankfully, there are a number of free alternative programs available that allow the user to create complex models with relative ease (sketchup, tinkercad, FreeCAD and OpenSCAD).

I have recently constructed a 3D printer (based on the popular open-source design Prusa Mendel i2). The machine can print components up to 200mm square and 150mm tall. After making an assortment of small plastic knick-knacks and toys to calibrate and test the machine, I was keen to explore how it might be used as a convenient and economical way to manufacture more durable metal components. 3D printers do exist that can build solid metal parts directly, but these are prohibitively expensive for common use. The path I wanted to explore was to use the 3D printer to economically and easily produce patterns that could be used (instead of wax) for investment casting. The user friendly plastic most popular for 3D printing (PLA) is apparently also well suited to investment casting. Investment casting typically relies on making a split female mould, which is used to cast multiple wax models of the parts being produced. Many wax parts are usually joined together onto a wax "tree" which then gets encapsulated in a refractory ceramic plaster compound. Several layers of ceramic are built up to give sufficient strength to the mould. After the ceramic "investment" has cured the assembly is fired. The wax flows out, leaving a cavity which is then re-filled with molten metal. When the metal has solidified and cooled, the investment is removed and the parts are cut from the tree. Investment casting can produce dimensionally accurate components with a very good level of detail. Using a 3D printed prototype instead of a wax part makes it possible to produce investment castings without the expense of making a female mould to cast the wax into. 3D printing therefore makes it viable to economically produce unique investment cast parts in small quantities. 3D printing also allows for greater complexity in cast component design. Parts don't need to be removable from a split mould, therefore complex internal geometries can be readily produced.

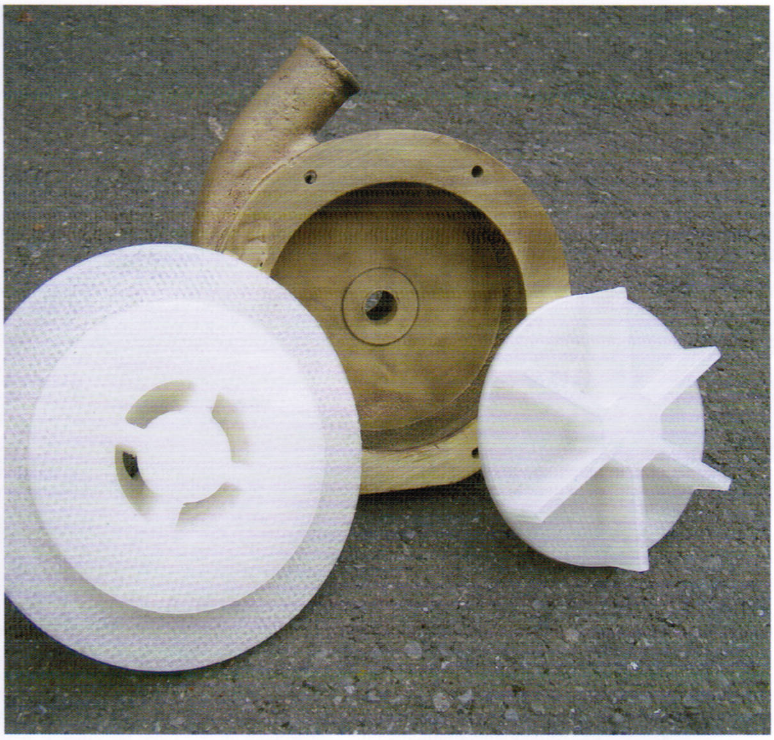
I asked around to find someone who had a good test piece for this process. This is where Bob Hayes enters the story. Having an extensive history in the motor trade and engineering, Bob's first casting experience was using lead in assembling NZR bus batteries back in 1947. He built a die and cast lead bridges to join the plates together. More recently he needed a steering box housing for a 1915 Austin which required extensive pattern making to make a core and outer casting. Having gone to these lengths he could have cast 100 but only needed one. That steering box was very expensive! Most recently he has rebuilt Ross Vesey's Austin 20 water pump by sand casting in aluminium. Now with another water pump needing work, Bob was keen to explore the suitability of this new technology by trialling the 3D printing/investment casting proposal.

He had a brass water pump body, from Ken Roger's 1904 15hp Talbot, which needed replacements for the missing impeller and inlet. Both of these parts could have been machined from solid brass, but this would have involved buying some expensive billets of brass and then proceeding to laboriously machine most of them away. The other obvious alternative was to make wooden patterns and have sand castings made. This may have been the best approach if several of each part were required, but it would have involved either making some complex cores or doing some difficult machining of the inlet casting to produce the internal channels that were needed.

Having identified the test pieces, Bob's sketches were reproduced in 3D using FreeCAD. The model was made 2% larger



The inlet in plastic

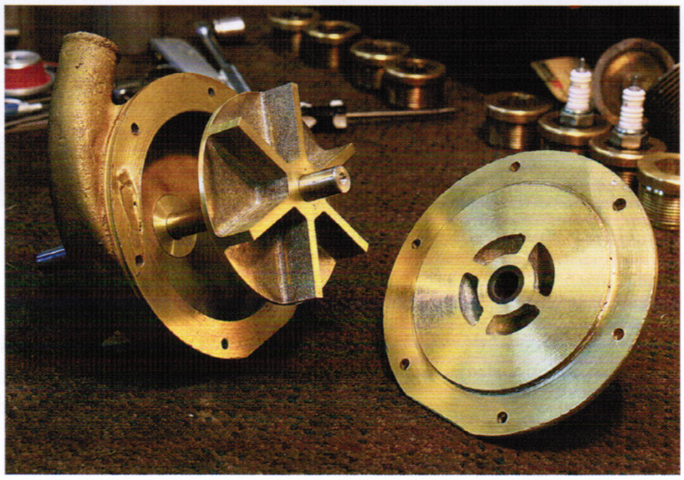


The new inlet and impeller in plastic, alongside the original water pump body

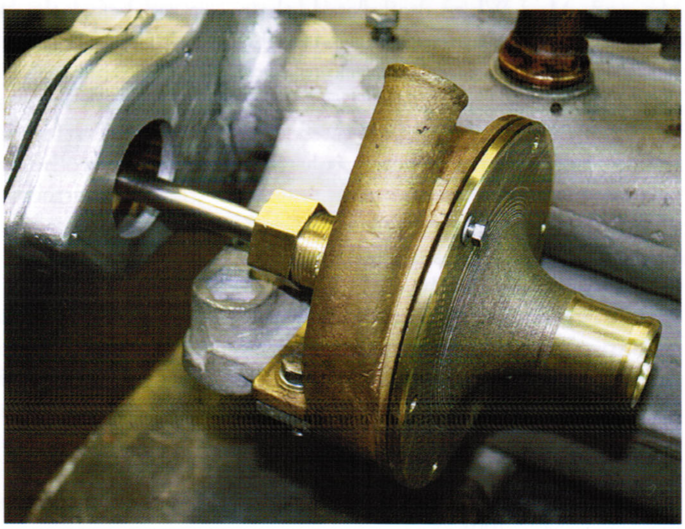
than desired to allow for shrinkage of the casting. The 3D printed parts were the largest I had yet printed - the impeller took about 3 hours on the machine, whilst the inlet took 7 hours. This may seem slow, but the machine runs reliably un-attended and most of the printing happened overnight. About $10 worth of plastic filament was consumed building both plastic parts. To conserve plastic and reduce print time and warping, it is usual to program models to 3D print with the inside volume of the parts mostly hollow. For this particular job, the outside of the models were built with 2 solid layers - the inside having a honeycomb fill pattern of 40% density. This presented a risk for investment casting - if the parts are not completely sealed and there is leakage of the ceramic into any of the inside cavities, these leaks would result in porosity in the final castings. After discussion with Ian Close at Casting Shop Limited in Christchurch, it was decided to brush over the outside of the models with liquid wax to seal them entirely before investment. This gave the added benefit that it smoothed over the fine lines on the surface that result from 3D printing process. For parts where finished appearance is important, more time could be spent manually building up a smooth wax polish finish to the 3D printed parts.

Casting Shop Limited did a faultless job of transforming the plastic parts into brass. The castings showed every detail perfectly. Bob commented that "the pattern and castings were done to perfection". The cast surface is very good indeed. It is possible to achieve a lot more detail than sand casting, which saved a lot of machining and finishing time. Although it cost a little more to cast (compared to sand casting), it cost a lot less for patterns and was perfect for a one-off situation. The pump is now reassembled and working well.

This test has proven that 3D printing certainly has a role to play in the low cost production of unique cast metal parts. This process would be less appropriate if dozens of copies are required, but there is no obvious reason why a 3D printer couldn't be used to conveniently make patterns for sand casting or possibly even to make a female mould to cast wax parts into for investment casting. BW



The machined water pump ready for assembly.
Note that it is the original 1904 housing that has the casting defect on the face, the new parts cast perfectly.



The finished water pump on the engine.