Let's get physical: Back to basics

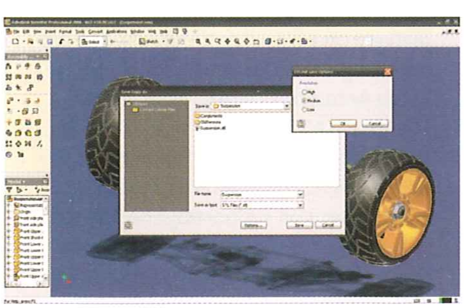
In the first of a series of articles on Rapid Prototyping, we explore the methods, processes and technologies available for those looking to produce physical models of their products for test, evaluation and presentation.

Digital Prototyping is a hugely powerful technology. Taking a product through from concept to production within an entirely digital environment is incredibly compelling. But the fact remains that there are many instances where you still need to be able to interact with a physical product, long before pre-production begins.

Whether you're looking to communicate your designs with non-technical clients or colleagues, or you need a pre-production prototype for marketing, promotion or focus group evaluation, there are many instances where a physical model is invaluable.

Consumer product design is a perfect example. The vast majority of us like to touch, interact with and engage directly with a product – to feel the weight in our hands, how our fingers move across the controls, or how the choice of material and surface texture relates to tactile response. When a product features any form of direct human interaction, there is no substitute for the 'real' thing.

Then there's also the question of validation. While simulation tools are advancing at an incredible rate, many products still require physical testing to see how they perform in the real world, to assess fit, design for assembly, or functional performance.



▲ **Figure 1:** Inventor's STL file output gives you three preset options for resolution control. This is found under

The good news is that Rapid Prototyping can be the answer to all of these problems and the technology is advancing at an incredible rate. These machines allow you to take your digital data and create a physical manifestation of your design concepts or final products – quickly, easily and cost effectively. In the scope of this article we'll look at the basics of RP, and then at how you would go about producing models in direct relation to both Inventor and AliasStudio.

The basics

Rapid Prototyping devices predominantly use layer-based or additive manufacturing techniques. The process starts with a digital 3D CAD model, which is cut up into horizontal slices. The data is then fed into the RP machine and the physical model is built up layer by layer. There are many different types of layer-based RP technologies, each of which vary greatly in terms of the physical properties of the models.

The earliest to gain traction was the Stereolithography (SLA) process from 3D Systems. This uses a targeted laser to cure UV sensitive resin, which is held in a vat. As each model 'slice' is traced out by the laser, the resin is cured and becomes solid. The build platform then moves down incrementally (typically around 0.10mm at a time) and the model is built up layer by layer until you have a finished prototype.

There are a wide range of materials available for SLA machines, and each has different physical properties, but the strength of SLA lies in its ability to build functional models that mimic durable moulded plastic or ABS.

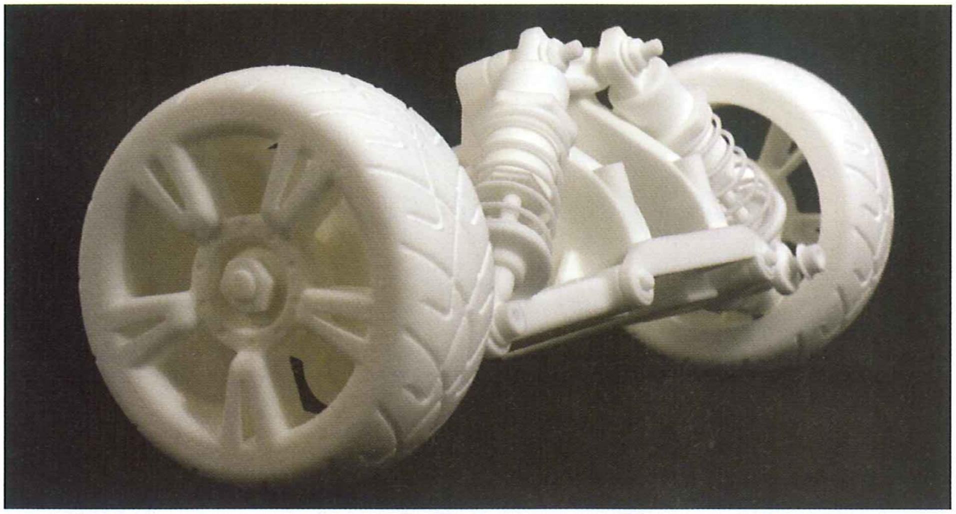
There are many other additive RP technologies. Objet Geometries' PolyJet machines use print heads to form layers and mixes in polymers on the fly for additional hardness. Dimension Printing and Stratasys share the same Fused deposits molten plastic (such as ABS, PC/ABS) through a nozzle to create each layer. Envisiontec uses consumer grade digital projector technology to build UV curable resin-based models. Each have their strong and weak points (strength, accuracy/detail replication, build time, cost etc) and your selection of the process and machine depends on many things, which we'll cover in a forthcoming issue.

Because all of these systems build their parts in fresh air, they also require supports until they are fully formed and these supports must be removed afterwards. Objet and Stratasys use a water soluble support material that's removed with a jet wash, while 3D Systems' SLA machines use the same material to build a support structure. The use of support structures in some systems (particularly with SLA machines) can cause issues with surface quality, but these can be reduced with careful planning in the build set-up software.

Systems from vendors such as EOS and Z Corp differ in that they use powder as the build material, rather than a resin. EOS uses a laser system to sinter the powder particles, whereas Z Corporation 'prints' a binder fluid onto each layer which creates the solid form. One of the key benefits of this approach is that because the entire build chamber is filled with powder, the parts are self-supporting and the process can be optimised by completely filling the chamber with parts, something which can be done manually or automatically in the set-up software supplied with each system.

STL: lingua franca for RP

The majority of RP machines use the STL data format as the conduit between your 3D CAD data and the build process. STL is a tessellated format that sub-divides 3D geometry into triangular facets and the output resolution has



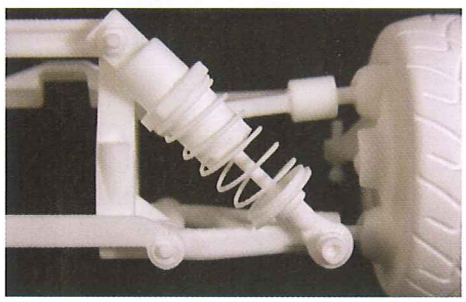
▲ **Figure 2a:** Inventor suspension assembly built using the P100 Formiga laser sintering machine from EOS.

Essentially, smaller triangles means models of higher resolution/accuracy but data size increases proportionally. Another thing worth considering is how you handle assembly models. If you're looking to assemble the parts post build, you can take a single STL file of each of your parts and build them separately. Alternatively, many RP machines allow you to build an assembly in one piece, so all of your mechanisms are fully assembled and, in many cases, working, as soon as they come off the machine.

Unfortunately, Autodesk Inventor only allows you to output a single STL file, whether you're working with a part or an assembly. This is fine if you're looking to manufacture the physical prototype as a whole, but if you need to manufacture separate parts, and then assemble them outside of the build chamber, perhaps using standard fasteners, it's not particularly useful. In terms of resolution control, the system is preset with three options, Low, Medium and High (see Figure 1). Each option varies the tessellation values automatically, but if you want to change the exact parameters, then you have to dive in and edit the registry. The good news is that the pre-sets are workable.

Working with the suspension dataset that comes with Inventor, the low option gives you a pretty coarse model of around 80MB, the medium option steps that up to 200MB and the high resolution option gives you a whopping 500MB file. With experience you will find the most appropriate settings for your model (see page 37 for details on reducing STL file sizes).

With AliasStudio there is a much more transparent, but slightly more complex process. Because AliasStudio works with surfaces rather than solids, you need to do your modelling to a



▲ **Figure 2b:** An example of the level of detail you can achieve on the EOS P100 Formiga. These damping springs built very successfully and are under a millimetre thick.

options. If the tolerances are tighter than 0.1 then you will be fine. It's often worth building the model to tighter tolerances .01 or 0.05. The chances are you will have set these tolerances to match your engineering CAD system.

Once the design is complete, you need to stitch the surfaces together to form a solid. If you want to shell out the model (it can save material for larger objects), you can convert to a mesh (using the NURBS to Mesh command), and add a thickness. Either way, you then use the Export STL command to save out the file. The options for export are changed using an accuracy slider to set the tessellation value – and unlike Inventor you get a preview of the mesh before proceeding. AliasStudio supports both the ASCII based STL format, as well as the more compressed binary format. One point to note is that if you want to read that data back into AliasStudio then you need to save it as binary.

In practice

So with all this technology out there, the question is: what can be done with it? For this article, I've chosen to work with two RP vendors, Electro Optical Systems (EOS) and Z Corporation, so let's

Z Corp colour models

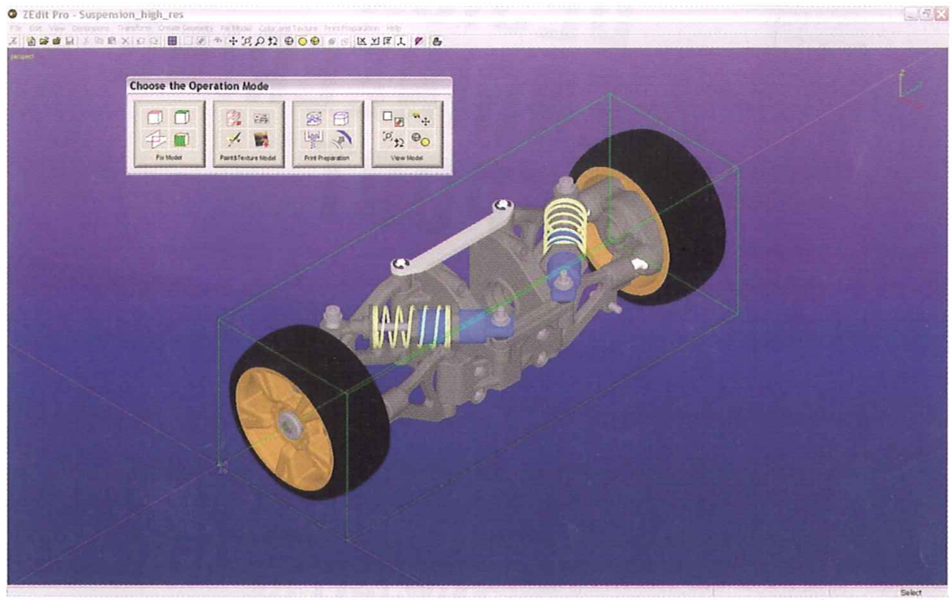
We had intended to bring you pictures of the Inventor suspension colour model produced with Z Corp's 3D printing technology. However, our model got lost en route to our photographer thanks to a certain global courier. If and when the model arrives we shall post images on **www.experiencemanufacturing.com**

In the meantime the image below is of a standard 3D printed colour part from Z Corps's Spectrum 510 machine so you can get an idea of quality of finish and colour.

EOS has a range of machines which use a laser to sinter (heated to point just below melting) powder particles to create each layer. The machines are split into three core groups, which are defined by the material they use: Plastic, Metal or Sand (specifically for casting cores). For this article we are going to concentrate on plastic. The Inventor suspension dataset was built on the entry level P100 Formiga (see Figure 2a). This is EOS' entry level machine, which features a build chamber of dimensions 200 mm x 250 mm x 330 mm, and builds in 0.1mm layers. The material is the standard nylon-based powder and gives you good results, particularly for laser sintering which has advanced incredibly in the last few years. The details such as the damping springs were built very successfully and while fragile, the whole thing is pretty robust (see Figure 2b) .The model took just under four hours to build and cost just over €100.

The fascinating thing about the EOS process is the wide range of materials available. The Polyamide material is available in a variety of options which give you different mechanical or thermal properties. For example, a glass

Figure 3: The VRML file exported from Xanadu and loaded up within Z Corporation's Z Edit Pro application. Colours are retained accurately from the Inventor model and can be replicated within the rapid prototype.



mal loading, or one that provides high impact strength, and flexibility. There are also a couple of task- or process-specific materials, such as lost pattern casting polystyrene with low-ash content. However, two of the most interesting materials are the Alumide and CarbonMide. Alumide is a polyamide-based powder, but contains aluminium powder, which offers higher dimensional accuracy and higher mechanical strength. It's also fully machinable and due to the metallic content has increased thermal conductivity. CarbonMide, on the other hand, is a carbon filled powder which gives you amazingly lightweight parts that have the benefits of extreme stiffness and strength.

While EOS focuses on prototypes with physical properties that mimic production-intent material, Z Corporation's approach focuses more on form and aesthetics. From a pure model building perspective, its products are extremely impressive. Not only are build rates quicker than many of its competitors (around an inch per hour), but it offers one thing that no other RP vendor can, and that's colour.

Z Corp's technology is based on standard HP inkjet technology, but rather than laying down droplets of ink on paper, it deposits resin which is used to build up its 3D models layer by layer. This is called 3D printing.

To achieve full colour models the system adds separate CMYK (Cyan, Magenta, Yellow, black) binder fluids to the resin. But how do you get a colour data model into the machine? The answer is VRML. This presents a bit of a problem when working with Inventor, as it doesn't currently output VRML. Handily another route is available, through a product called Xanadu (www.xanadu.cz) and its Inventor to VRML output add-on. It's a pretty nifty tool and works a treat. I used a trial copy to generate the assembly file. The full version costs a mere $99.

Once you have the VRML file ready, you load it into Z Corp's new ZEdit Pro application and arrange the part in the build chamber (see Figure 3). As you have a finite build volume, you can stack out your build chamber with multiple parts to make the most of your build process. In terms of cost and time, the test dataset we built was scaled up to fit into the whole build chamber and was around 14 inches wide. According to Z Corp, the cost to build this part on its flagship Spectrum 510 machine using the zp131 material was around €65, including all of the consumable costs as well as amortisation of the print-head. The build time was 5 hours 40 minutes. The Spectrum machine has the ability to replicate colours accurately and the models are much more robust than you might expect. What Z Corp's devices excel at is producing models quickly, so that they can become an integral part of your design review and presentation process, and the chances are, their lifetime fact that the parts are cost effective makes that even more attractive.

In conclusion

So, there we have it, a basic guide to rapid prototyping. While we've only concentrated on two vendors, we're going to flesh that out over the coming issues to give you a fuller picture of what can be achieved, and help build a realistic expectation of the costs and the benefits to the product development process.

Rapid Prototyping seems to contradict Autodesk's Digital Prototyping concept, but it's actually a complementary technology. After all, if we can take a product closer to the final design freeze in a digital environment, then the number of physical prototypes can be reduced and, more importantly, made to a much higher quality and one that is closer to the ideal solution. ■

Coming up in the Summer edition of Experience Manufacturing: How to take RP technology further with the skills and capacity of a service bureau.

Reducing data overheads

If you're looking to build complex parts, then STL files can become unwieldy. While this isn't a problem when working with network connected in-house RP systems, for those looking to outsource, data portability can be an issue. Even in today's broadband world, you really don't want to send half a Gigabyte of data using the Web. The good news is that there are a couple of tricks to help. Firstly, Inventor outputs an ASCII version of STL so it can be compressed heavily using standard ZIP tools, giving you a reasonable file size reduction. There's also the .MGX format from Materialise, Europe's largest RP bureau and developer of Magics, the de facto RP pre-processing software. The company recently released MiniMagics, a free viewing tool for STL data. In addition to STL viewing, measuring, checking and sectioning tools, MiniMagics allows .MGX output, which gives you even better compression rates. Taking this month's test dataset at high resolution, the standard STL output file is 570MB. A zipped version gets that down to 78MB, but using MiniMagics .MGX output, this reduces to a mere 5MB. Magics is in use at almost every service bureau, so accepting the data should be

Links to the RP world

- 3D Systems – **www.3dsystems.com**
- Dimension Printing – **www.dimensionprinting.com**
- EOS – **www.eos.info**
- Envisiontec – **www.envisiontec.com**
- Materialise – **www.materialise.com**
- Objet Geometries – **www.2objet.com**
- Stratasys – **www.stratasys.com**
- Z Corporation – **www.zcorp.com**
- Wohler's Associates –