

What's RP?

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RP, or to give it its full title of Rapid Prototyping, is a technique which creates a facsimile of an object without needing the tooling associated with making a real version of the object. The process is widely used in engineering where the facsimiles can also be used for initial testing in wind tunnels, etc., and is increasingly used in medical applications. Currently in our industry, the usual reason to create a rapid prototype is to assess the appearance of a moulded sole.

How can it help?

Rapid prototyping is worth considering wherever the specialist equipment and tooling needed to make a real item are prohibitively expensive and/or slow. In the footwear industry, that usually means moulded soles and heels. Uppers are a little different in that specialist tooling or machinery is rarely required. The principal benefits are the opportunity for early decision making and avoidance of unnecessary tooling costs.

The process allows visual assessment of an item often within a day of its design, very much faster than would be possible if conventional techniques were used. This can be done confidently because the same files that created the prototype will be used to create the final moulds. This reduces the chances of changes being requested later.

Even if a company is using a 3D CAD package with photo realistic graphics, the image is still on the screen and is not accessible. Alternatively, the 2D engineering drawings to specify a mould's features are necessarily complex and it is not always easy to visualise the resultant sole from the diagrams. So, until moulds are made and the first soles moulded, there is no certain way of judging the suitability of the appearance. Many of the leading athletic companies use RP as it is particularly helpful for the increasingly complex sole designs required for today's market.

Adidas was so pleased with its experiences that it has allowed its case study to appear on the Objet Geometries website. It shows an impressive time reduction compared with CNC milling from 25 hours down to seven hours for a prototype on the Objet Geometries equipment. Nike approve the Z Corporation equipment and Roi, one of its suppliers, is quoted in Z Corporation press releases as recovering its investment within a year when using the Z Corporation Z406 colour 3D printer with ZP15e elastomer. Reebok uses RP not only for visualisation of new designs, but also for the initial production of units. It prepares 'bridge' tooling (temporary moulds with limited life) by coating the rapid prototype with metallic material. This mould is then used to produce a few pairs of soles in the actual material to be used.

How does it work?

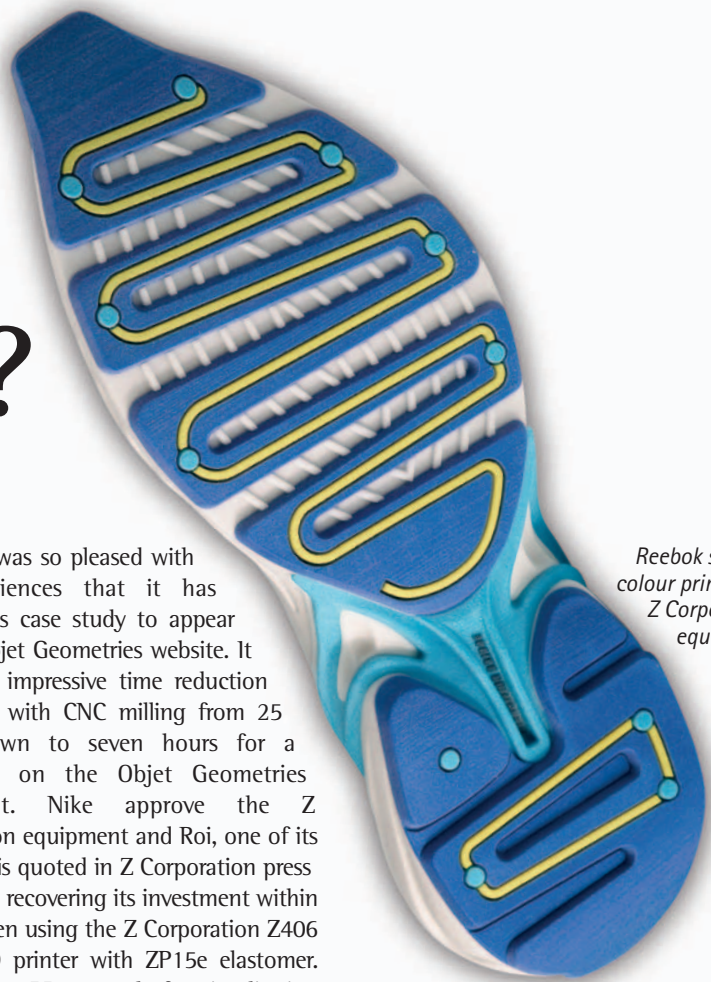
Initially the item must be described in a computer file format suitable for use by the rapid prototyping process. There are two formats in wide use (STL and IGES) and translation software is available so file formatting is not usually a problem. Files can be created in two ways:

- Manual — making a 3D model like a sculptor then using a laser scanner to input it into a computer
- Virtual — on-screen usually by drawing (or modelling on Sensable Technologies system)

The resultant file can then be sent to the rapid prototyping machine to produce the item.

There are several methods of producing the item which work with differing materials. In simple terms there are three techniques to gradually build up the item:

- Layers of a paper-like material
 - Layers of liquid polymer
 - Layers of powdered compound
- The first two are the main technologies



Reebok sole 3D colour printed on Z Corporation equipment

used in the industry—Laminated Object Manufacture (LOM) and Stereolithography.

Laminated object manufacture

The LOM concept was first shown to the shoe industry by Torielli which featured the Helysis equipment on its stand at Pirmasens in the late 1980s/early 90s. This used the 'laminated object manufacture' technique where vertical cross sections of the object are laser cut from a roll of fibrous material, then stacked and bonded together to form the prototype. The bonding agent resulted in a hard object which was fairly brittle.

These early machines used layers of 0.5–1.0mm and created prototypes with somewhat 'stepped' surfaces. If a very smooth effect was required, the prototypes were rubbed down but fine textured surfaces could not be rendered. Fortunately the technology progressed and layer thickness is now typically much less at 0.025–0.25mm, giving a far more precise shape and finish. In addition, increased computing power and software allows the edge of each layer to be sloped on some systems.

Stereolithography

The LOM technique is still used but is increasingly being replaced by stereolithography. This process was

patented in 1986 by Charles Hull and is based on printing technology rather than cutting. Stereolithography (SLA) prototypes are constructed from a liquid photopolymer that uses light as the catalyst to initiate crosslinking and setting of the polymer (curing). In the original technique (*Figure 1*), a tank of polymer is used with a build platform positioned just below the surface of the photopolymer.

An ultraviolet laser scanning system is used to draw the first cross section on the surface of the photopolymer, which adheres to the platform. When the layer is complete, the elevator assembly lowers the platform into the vat and the next layer is drawn, with each new layer adhering to the previous one. The process repeats until the object is completed. Actual build times can range from under an hour to more than a day, depending on the photopolymer, laser power, and the object geometry.

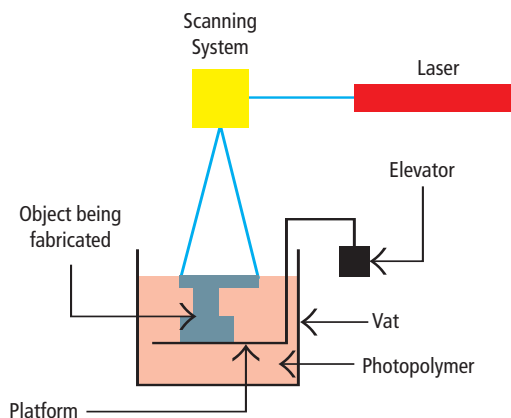
The fused deposition modelling system from Stratasys Inc., uses an extrusion technique to supply the layers of thermoplastic material instead of a tank.

Recent advances in inkjet printing have facilitated the development of an even more efficient technique and Objet Geometries was the first to introduce this to the footwear industry. In its 'Fullcure' system the photopolymer is inkjet printed through eight heads at a thickness of only 16 microns in the exact shape of each layer. A sacrificial gel material supports overhanging areas during production of the item and is easily removed on completion of the prototype by a high pressure water jet.

More recently, Z Corporation has brought its 3D printers to the footwear industry and is proud of its integral inclusion of colour in the build of the prototype. Before this, colour had to be added by manually painting the surfaces.

Metallic items can be produced by Stereolithographic sintering (SLS). This builds up layers of metal particles, using a doctor blade to ensure an even layer before applying the bonding agent. The resultant block is then treated in a furnace to burn away

Figure 1: Layout of the original stereolithography process



Sole in black Tango material

the bonding agent which is replaced by molten metal. The resultant prototype is then fully functional for all uses including testing (*Figure 2*).

Which system to choose?

Whichever technique is used, as the layers become thinner, so more of them

have to be produced for each object and the production time is naturally extended. It is therefore important to select a suitable machine without over specification. The shape of each cross section can now be reproduced with an accuracy of around $\pm 0.03\%$. This level of sophistication provides very accurate results which allow multiple part items to be created with fine tolerances between the separate parts. Also, intricate textures and very smooth surfaces can be created without the need to bench finish.

What does it cost?

It is possible to install a 3D printer system of a level typically suitable for footwear from around \$38,000. Depending on usage, this can be good value for money but the cost of consumables, etc., also has to be considered.

Latest developments and future prospects

The newest developments are increasingly life-like flexible materials, and the inclusion of colour. Objet Geometries Fullcure Tango materials are rubber-like compounds with various degrees of elasticity and a Shore hardness of 75 or 61. Their advantage is that they flex and can stretch around seams, etc., to give a normal fit and appearance on an upper.

Future developments are concentrating on rapid manufacturing, namely end use items produced by rapid prototyping techniques. Depending on the materials used and the quantities required, this can be surprisingly cost-effective for some applications. For example, cassette tapes are already produced this way. More complex metal items can also be made, even including a battery. There are various research projects looking at this 'fabrication' topic and over the next few years there should be several commercial applications. It may not have repercussions for moulded soles but we could find it entering the footwear industry for fashion items such as buckles, where only limited quantities are needed. 

Figure 2: How the Z Corporation system works

