Z Corporation 3D Printing Technology

Fast, Affordable and Uniquely Versatile

Introduction

Originally developed at the Massachusetts Institute of Technology (MIT) in 1993, Three-Dimensional Printing technology (3DP™) forms the basis of Z Corporation's prototyping process. 3DP technology creates 3D physical prototypes by solidifying layers of deposited powder using a liquid binder. By definition 3DP is an extremely versatile and rapid process accommodating geometry of varying complexity in hundreds of different applications, and supporting many types of materials. Z Corp. pioneered the commercial use of 3DP technology, developing 3D printers that leading manufacturers use to produce early concept models and product prototypes. Utilizing 3DP technology, Z Corp. has developed 3D printers that operate at unprecedented speeds, extremely low costs, and within a broad range of applications. This paper describes the core technology and its related applications.

How does Z Corp.'s technology work?

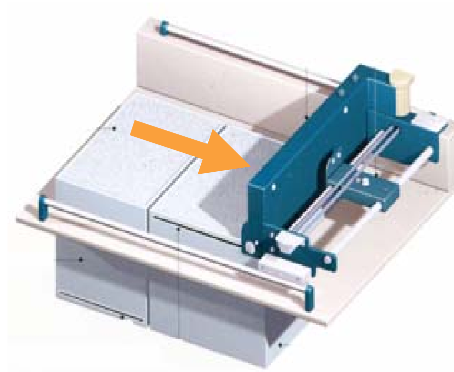
Source Data

Z Corp.'s 3D printing technology leverages 3D source data, which often takes the form of computer-aided design (CAD) models. Mechanical CAD software packages, the first applications to create 3D data, have quickly become the standard for nearly all product development processes. Other industries such as architectural design have also embraced 3D technologies because of the overwhelming advantages they provide, including improved visualization, greater automation, and more cost-effective reuse of 3D data for a variety of critically important applications. Due to the widespread adoption of 3D-based design technologies, most industries today already create 3D design data and are capable of producing physical models with 3D printers from Z Corp. The software that drives Z Corp.'s 3D printers accepts all major 3D file formats, including .stl, .wrl, .ply, and .sfx files, which leading 3D software packages can export. In addition to mainstream applications in mechanical and architectural design, 3D printing has expanded into new markets including medical, molecular, and geospatial modeling. Additional sources of data include CT/MRI diagnostic data, protein molecule modeling database data, and digitized 3D-scan data. As designing and modeling with 3D technologies has become more pervasive, developers have created a large number of software packages tailored for use in specific industries. A small sampling of 3D software packages that are directly compatible with Z Corp.'s 3D printers appear in the table below.

SolidWorks®	Maya®	RapidForm™	3D Studio Viz®
Pro/ENGINEER®	SketchUp®	Alias®	Form Z®
CATIA®	RasMol	Raindrop GeoMagic®	VectorWorks
3D Studio Max®	Rhino®	Inventor®	Mimics

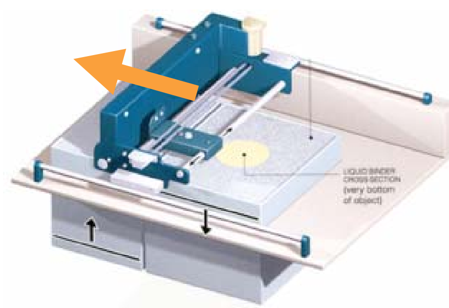
After exporting a solid file from a 3D modeling package, users can open the file in ZPrint™, the desktop interface for Z Corp.'s 3D printers. The primary function of ZPrint is to cut the solid object into digital cross sections, or layers, creating a 2D image for each 0.1016mm (0.004") slice along the z axis. In addition to sectioning the model, users can utilize ZPrint to address other production options, such as viewing, orienting, scaling, coloring, and labeling multiple parts. When a user decides to print the job, ZPrint software sends 2D images of the cross sections to the 3D Printer via a standard network, just as other software sends images or documents to a standard 2D printer. Setup takes approximately 10 minutes.

3D Printing



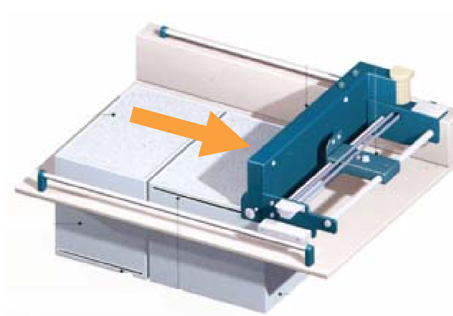
Spread a layer of powder

Z Corp. 3D printers use standard inkjet printing technology to create parts layer-by-layer by depositing a liquid binder onto thin layers of powder. Instead of feeding paper under the print heads like a 2D printer, a 3D printer moves the print heads over a bed of powder upon which it prints the cross-sectional data sent from the ZPrint software. The Z Corp. system requires powder to be distributed accurately and evenly across the build platform. 3D Printers accomplish this task by using a feed piston and platform, which rises incrementally for each layer. A roller mechanism spreads powder fed from the feed piston onto the build platform; intentionally spreading approximately 30 percent of extra powder per layer to ensure a full layer of densely packed powder on the build platform. The excess powder falls down an overflow chute, into a container for reuse in the next build.



Print cross section

Once the layer of powder is spread, the inkjet print heads print the cross-sectional area for the first, or bottom slice of the part onto the smooth layer of powder, binding the powder together. A piston then lowers the build platform 0.1016mm (0.004"), and a new layer of powder is spread on top. The print heads apply the data for the next cross section onto the new layer, which binds itself to the previous layer. ZPrint repeats this process for all of the layers of the part. The 3D printing process creates an exact physical model of the geometry represented by 3D data. Process time depends on the height of the part or parts being built. Typically, Z Corp.'s 3D printers build at a vertical rate of 25mm – 50mm (1" – 2") per hour.



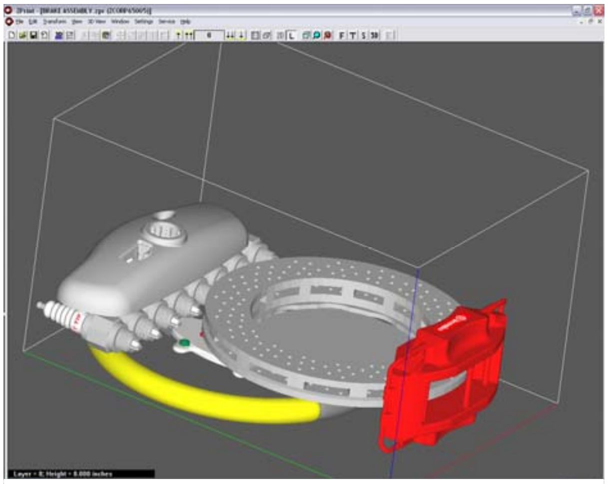
Print a layer of powder

When the 3D printing process completes, loose powder surrounds and supports the part in the build chamber. Users can remove the part from the build chamber after the materials have had time to set, and return unprinted, loose powder back to the feed platform for reuse. Users then use forced air to blow the excess powder off the printed part, a short process which takes less than 10 minutes. Z Corp. technology does not require the use of solid or attached supports during the printing process, and all unused material is reusable.

Z Corp.'s 3D printing is fast

Z Corp. 3D printing is the fastest additive technology commercially available on the market. Other companies often refer to their equipment as 3D printers, however these systems rely on processes using a vector approach or single-jet technology to deposit all build material. Z Corp. uses inkjet print heads with a resolution of 600 dpi (dots per inch), focuses on a drop-on-demand approach, and manufactures the only true 3D inkjet printers available. The technology allows printing of multiple parts simultaneously, while only adding a negligible amount of time to the print time for one part. Many people mistakenly believe that "raster is faster but vector is corrector," but that is not always the case. In printing, especially 3D printing, the accuracy of the models depends on the ability to jet when and where required. This is a function of jet size and motion control. Z Corp.'s precise inkjet implementation results in high-definition, quality parts.

Also contributing to the overall speed of the 3D printing process is the method used to distribute material. Z Corp. uses a spreading method for depositing more then 90 percent of the material, which is extremely efficient and fast. Z Corp.'s 3D printers dispense only a small percentage of the build material, the binder, through the print heads. Other additive prototyping technologies deposit 100 percent of the build material through a nozzle, resulting in very slow print speeds and lengthy prototyping turnaround times.



The ability to stack and nest parts within the build chamber allows for more efficient use of overnight and weekend time

The fundamental inkjet approach is the primary contributor to greater speed, although there are several other reasons why Z Corp. systems are the fastest. ZPrint software processes data in parallel with the printing of the part. While the 3D printer deposits the first layer, the software slices and processes the fifth layer. Some additive technologies process all tool paths before the job begins. Although the processing time may seem to be fast, it is often only a fraction of the total time it takes to build the part. It can actually take up to an hour to prepare a job with multiple parts using some additive technologies.

Z Corp.'s 3D printers enable the stacking of parts vertically because they do not require rigid support structures. Producing parts with other types of additive technologies requires structural supports along the vertical axis, limiting the ability to stack or nest parts. With Z Corp.'s 3D printers, users can utilize the entire build area and produce multiple parts with only one set-up procedure, further reducing the total number of builds and processing time.

Z Corp.'s 3D printers produce color models

Z Corp. applies the proven 2D color inkjet methodology to 3D printing and produces the only 3D printers with 24-bit, full-color capabilities. When printing 2D images from digital files, computers convert the RGB values (Red, Green, and Blue colors displayed on the monitor) to CMYK colors (Cyan, Magenta, Yellow, and Black). Typically, a 2D color desktop printer will have a print head with three of the color channels, CMY, and another for black, K. Using these four inks, the printer combines several dots in each printed pixel though the use of ordered dither patterns to create the appearance of thousands of colors. The same principle applies to 3D printing. Z Corp.'s 3D printers use four colored binders: cyan, magenta, yellow and clear, to print colors onto the shell of the part. ZPrint software communicates color information to the printer within the slice data. Full-color 3D printing produces prototypes with the same coloring as the actual product. Users also use color to represent

Reebok® shoe and color prototype

analysis results directly on the model or to annotate and label design changes to further enhance the communication value of the model.

These examples of color models show meaningful and creative applications for color 3D Printing including product labeling, topographical analysis, and production planning.

While color can be an essential communications tool, many 3D software packages do not provide a simple way to produce 3D files that include color data. To address this challenge, Z Corp. developed ZEdit™ software, a Microsoft® Windows® based program that facilitates the addition of color data to 3D part files. ZEdit is a tool for part coloring, markup, labeling, and texture mapping. Users also utilize it to map .jpeg files onto 3D part geometries. ZEdit software works with files from any of the leading 3D software packages.

Z Corp.'s 3D printers produce high-resolution models

Z Corp. first introduced high-resolution 3D Printing (HD3DP™) in 2005. The HD3DP concept is the result of a combination of print-head technology, materials advancement, firmware, and mechanical design. Z Corp.'s highly engineered inkjet print heads, with 600-dpi, high-resolution capabilities, are the product of years of research. Z Corp. leverages the engineered print heads in combination with proprietary firmware to control the print head during the printing process, accurately and precisely depositing colored binder in the areas indicated by the ZPrint software. Additionally, Z Corp.'s 3D printers control the print head movement while positioned extremely close to the powder, reducing inaccuracies related to fanning of the binder spray.

Z Corp.'s 3D printing is Affordable

Z Corp.'s 3D printers produce very little waste. The unprinted powder surrounds and supports complex parts during printing. Users can reuse all unused support powder. Thus, printed-part volume becomes the basis for all part-creation costs. Other additive processes require the building of solid support structures to support complex geometries during the printing process. Users have to discard these support structures after use, and the wasted material contributes significantly to the cost of additive technologies.

Z Corp.'s 3D printers are dependable and easy-to-use, resulting in low operating costs. Modular design and standard inkjet printing technology combine to produce a reliable system that is straightforward to operate and easy to maintain. The use of an "off-the-shelf" print head allows for inexpensive, quick replacement of the system's primary consumable component. The application of modular design techniques to the printer's electronics, printing, and maintenance components makes the printers efficient to maintain with minimum downtime, further reducing costs.

Z Corp.'s 3D printers are easy to use

The straightforward user interface and simple part-making process make Z Corp.'s 3D printers accessible to everyone involved in product design. The materials used are non-toxic, completely safe, and do not require specialized operating environments such as a lab or a shop. Users can operate Z Corp.'s 3D printers right in an office rather than in a designated space with specialized requirements. Because of the intuitive ZPrint software interface and simple set-up procedures, anyone can efficiently operate one of Z Corp.'s 3D printers, eliminating the need for a dedicated machine operator. Z Corp.'s reliable technology allows its 3D printers to run unattended during the printing process, reducing user interaction to the simple setup and part removal steps, which generally take less than one hour.

Z Corp.'s 3D printing is versatile

Z Corp.'s initial focus and vision was to produce a 3D printer for conceptual and visualization models. As adoption of 3D printing grew, however, so did the number of 3D printing applications. Z Corp.'s 3D printers have become uniquely versatile because of the innate flexibility of their delivery mechanism. The process of bonding loose powder to solidify into parts is compatible with many types of materials. While the 3D printer remains exactly the same, users can change the build material to produce parts with a wide range of material properties to meet various application requirements. Z Corp. offers five materials and continues to develop other materials to provide performance enhancements for additional applications. Users can select the best material to support the needs of a specific application.

Composite material model with engineering label

High-Performance Composite Material makes strong, high-definition parts and is the material of choice for printing color parts. The most widely used Z Corp. material, high-performance composite material enables color HD3DP on the 600-dpi platform 3D printer. Fine resolution on small features and excellent strength make this material suitable for applications ranging from concept modeling to sand-casting patterns. It consists of a heavily engineered plaster material with numerous additives that maximize surface finish, feature resolution, and part strength. This material is ideal for:

- High-strength requirements
- Delicate or thin-walled parts
- Color printing
- Accurate representation of design details

Direct Casting Metal Material creates sand-casting molds for non-ferrous metals. This material is a blend of foundry sand, plaster, and other additives that when combined produce strong molds with good surface finishes. Direct casting metal material can withstand the heat required to cast non-ferrous metals. Users of this "ZCast®" process can create prototype castings without incurring the costs and lead-time delays of tooling.

ZCast 3D Printed mold and cast aluminum part

Investment Casting Material fabricates parts that users dip in wax to produce investment casting patterns without molds or geometric constraints. The material consists of a mix of cellulose, specialty fibers, and other additives that combine to provide an accurate part while maximizing wax absorption and minimizing residue during the burn-out process. Users utilize investment casting material to create high-quality castings with excellent surface finishes in a number of industries.

Snap-Fit Material creates parts with plastic-like, flexural properties, which are ideal for snap-fit applications. Z Corp. has optimized this material for infiltration with the Z-Snap™ epoxy. Users utilize snap-fit material to create plastic-like parts that snap into other components and assemblies.

Example of model produced using elastomeric materal

Elastomeric Material creates parts with rubber-like properties. Optimized for infiltration with an elastomer, this material system consists of a mix of cellulose, specialty fibers, and other additives. Users utilize elastomeric material to produce accurate parts that are capable of absorbing the elastomer, which gives the parts their rubber-like properties.

One of the important advantages of Z Corp.'s 3D printing systems is the array of material properties that are available for a 3D-printed part. Users can wick or infiltrate resins into the part allowing the part to take on the physical properties of a cured resin. This capability provides users with greater versatility without having to change out the primary materials in the 3D printer. The printed structure is a strong but porous matrix, and infiltration fills the pores. For concept and visualization models, users can infiltrate parts with wax or fast-curing, one-part resins. Users can infiltrate parts produced as tooling or fixtures with high-strength epoxy, creating very hard, rigid parts in a fraction of the time that it takes to have them machined. Users can also use 3D printed molds for prototype blow molding and thermoforming, saving valuable time and prototype tooling costs.

Conclusion

The core competencies of the MIT 3DP patent were versatility and speed. Z Corp. has continually developed and built upon those ideas through ongoing machine innovation and materials development. By introducing the first color high-definition 3D printer, the first affordable monochrome 3D printer, and numerous software and materials advancements, Z Corp. has attained a leadership position for technological innovation in the rapid prototyping industry. Z Corp. will continue to advance its core technology, finding new and creative ways to provide tools for visualization of 3D data in real space.

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