

# 3D PRINTING WITH FDM<sup>®</sup>

## HOW IT WORKS

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A 3D printer is a machine that creates objects from plastic or other materials using an additive manufacturing process. Additive manufacturing produces objects in a succession of layers from the bottom, up. This is the opposite of traditional subtractive manufacturing processes, which produce objects by cutting material away from a block to create the shape desired. The term 3D printer was a trademark of Stratasys Inc, which, in 1999, allowed it to enter the public domain and become a generic industry term.

A 3D printer simplifies and accelerates the process of making prototypes and finished goods. The 3D printing process is so easy and yet so powerful that both home-based businesses and Fortune 500 companies count on it. Installations range from a single machine in a hobbyist's basement to manufacturing centers with dozens of systems.

How does a 3D printer work? Beginning with computer-aided design (CAD) data, which defines a tool path, the 3D printer extrudes and deposits molten thermoplastic in layers to build the part from the bottom up. This makes very complex parts easy to produce.

Stratasys manufactures several lines of machines, including 3D printers and their big brothers, 3D production systems (or production 3D printers). This includes the Dimension®, uPrint®, Fortus®, Objet® and Mojo® product lines. At the core of each system is fused deposition modeling, or FDM Technology™. Stratasys FDM machines create functional parts by extruding and depositing thermoplastic materials in layers.

This guide will walk you step by step through the FDM process.

## PROCESS OVERVIEW

FDM builds three-dimensional parts by melting and advancing a fine ribbon of plastic through a computer-controlled extrusion head, producing parts that are ready to use.

### THE AUTOMATED THREE-STEP PROCESS IS QUICK AND SIMPLE:

#### 1. Pre-processing: "slicing" or sectioning CAD design into layers

The FDM process begins in one of two build-preparation programs, Catalyst EX® or Insight®.

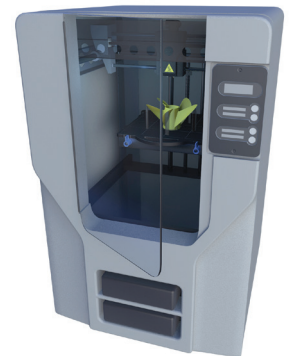


In operation, your first step is to import a design file, pick options, and create slices (layers). The preprocessing software calculates sections and slices the part design into many layers, ranging from 0.005 inches (0.127 mm) to 0.013 inches (0.3302 mm) in height. Using the sectioning data, the software then generates "tool paths" or building instructions, which will drive the extrusion head. This step is automatic when using Catalyst EX. Next, send the job to the 3D printer.

#### 2. Production: the layering process

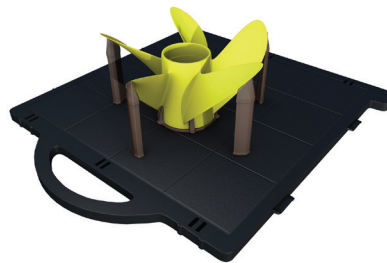
Press "print" to start the building process.

Two materials, one to make the part, and one to support it, enter the extrusion head. Heat is applied to soften the plastics, which are extruded in a ribbon, roughly the size of a human hair. Alternating between part material and support material, the system deposits layers as thin as 0.005 inch (0.13 mm).



#### 3. Post-processing: removing disposable support material

When the part is complete, open the chamber and remove it. Finish up by either washing or stripping away the support material that held the part in place.



The final step is to remove the support material from the part.

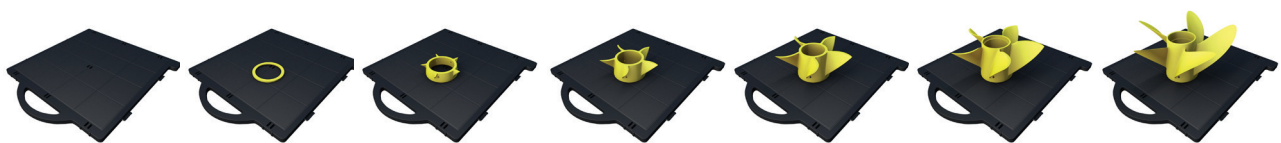
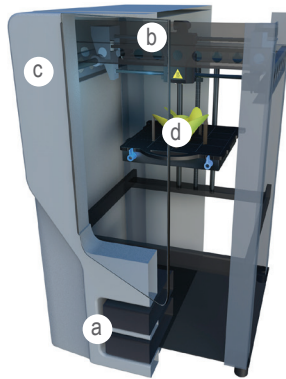


Image shows a part in various stages of the build process.

FDM 3D Printers have build volume capacities ranging roughly from 288 cu. in. to 31K cu. in. (4719 cu. cm to 508K cu. cm). Material cartridges (a) supply plastic filament to the extrusion head (b). In the heated chamber (c), the head moves in the X- and Y-axes while liquefying and depositing material. The Z stage platform (d) moves down to give the part the third dimension.



**Let's take a closer look at the FDM process from start to finish.**

## PROCESS DETAIL

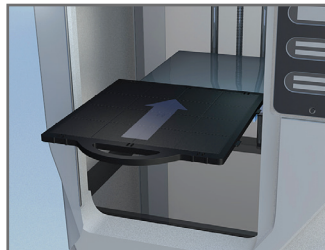
### 1. Create build file

- In Catalyst or Insight, open your CAD file (in STL format), and select a material, color and slice thickness.
- Pick a build and support style to match your application's requirements.
- Select an orientation, or position in which the part will be built, and then let the software do the rest. It sections the design into layers and creates toolpaths for both the part and its disposable support structures. Then it outputs a build file, which defines precise motion control paths.
- Click "print" to send the build file to the 3D printer.



### 2. Prep machine

- Insert the part-material and the support-material cartridges; the system will automatically feed the material filament to the extrusion head.
- Insert a base and close the chamber door. You are ready to build.



- Select your job from the queue, and press the machine's start button.
- The 3D printer heats the build chamber and brings the plastic liquefier up to operating temperature.

### 3. Build part

- The Z stage platform rises to its starting position, just a few thousandths of an inch (or tenths of a millimeter) from the material extrusion tips that protrude from the liquefier.

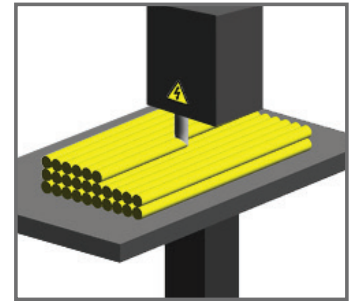


Photo credit: Zureks

- The 3D printer starts with a few layers of disposable support material to provide a foundation. Support material is also used to support features such as overhangs that would otherwise have nothing to rest upon. The extrusion head, which moves about an XY platform, lays down a ribbon of material. After each layer is complete, the Z stage build platform lowers slightly to make way for the next layer.
- The same process used for the support structure is used for the part, except it employs a different material – a thermoplastic, such as ABSplus™ or polycarbonate. When building a part, the extrusion head alternates between part-material and support-material extrusion tips.
- Close-up of process: In the FDM process, each layer of molten plastic is deposited on top of the previous one and flattened slightly by the extrusion head. The layers instantly fuse to one another.

## EXTRUSION DETAIL

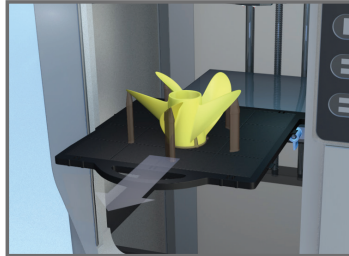
The secret of FDM's accuracy and precision is the coupling of material feed rates and extrusion head motion. Both are constantly changing to produce a flat ribbon of material that measures from 0.008 inch to 0.038 inch wide (0.20 mm to 0.97 mm) and as fine as 0.005 inch high (0.13 mm). On the highest-performance FDM machines, part accuracy or tolerance reaches as high as 0.003 inch (0.08 mm), which rivals injection molding.

Drive wheels push the plastic filament into the hot liquefier section of the tip assembly. The pressure forces the plastic through a tiny orifice in the tip, which presses down to flatten the bead.

Meanwhile, the head accelerates and decelerates as it travels across the platen. As the head speed changes, the drive wheels adjust the material flow rate. The result is a precise ribbon width that adjusts as required to produce the part.

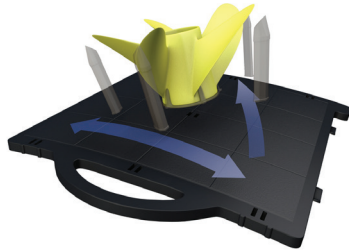
#### D. Remove part

- When the 3D printer display reads “complete,” open the chamber door and remove the build tray.
- Give the tray a twist to release the part. Now, you’re ready for the final step.



#### E. REMOVE SUPPORTS

- The supports have done their job, so it is time to remove them.
- The removal depends on the support material type used:



##### 1. Soluble support material:

This method uses an automated support-removal process in which the material is removed in a tank via an agitated water-based detergent solution.

##### 2. Breakaway support material:

This is a manual removal process, in which you twist, break, and scrape support material from the part. A needle-nose pliers and a pick are usually sufficient.

- The FDM part is now ready for use.



## APPLICATIONS

What can you do with FDM 3D printing? Although the possibilities are endless for product development and manufacturing, most applications fall into four main categories:

### Concept Models

Early in the design process, you can use FDM to make models to review form, fit and ergonomics.



Then update your design based on any flaws you have identified. Again print, review and update your design. Repeat the iteration process until you find the perfect concept. Shifting from the 2D world to physical parts will accelerate the product development process and lower cost. 3D parts that you can touch and feel improve design communication, so you can make better decisions faster.

### Functional Prototypes

To prove your design, you can make a functional precision prototype. Use FDM parts for performance tests and rigorous engineering assessments.



Producing functional prototype components typically takes from a few hours to overnight. It will allow you to catch flaws before they become costly engineering changes. It also reduces time to market and maximizes product performance.

### Manufacturing Tools

In your company's manufacturing process, is there a need for jigs, fixtures, gauges, patterns, molds and dies? You can make them



with production printers instead of spending the time and money to machine, fabricate, mold or cast them. FDM production printers not only reduce time and cost for manufacturing tools, they can improve your assembly process. Layer-based production gives you the freedom to design lightweight, complex, ergonomic shapes that make manufacturing more efficient.

## Finished Goods

Follow the lead of visionary entrepreneurs, aerospace companies, medical device makers and limited-production automakers. For runs of 5,000 or less, instead of using the traditional manufacturing processes of molding, machining or tooling, consider using a production printer to make your parts. Eliminating traditional manufacturing processes cuts time and cost while freeing you to make design revisions whenever necessary. Free from the constraints of traditional manufacturing processes, you can also create new opportunities in custom or extremely low quantity applications.



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