

Liquid-Based

Liquid based RP systems have the initial form of its materials in liquid state. Through a process commonly known as curing, the liquid is converted into the solid state. The following RP systems fall into the following category

- i) 3D systems' Stereolithography apparatus (SLA)
- ii) Cubical's Solid Ground Curing (SGC)
- iii) Sony's Solid reaction Systems (SCS)
- iv) CMET's Solid Object Ultraviolet-Laser Printer (SOUP)
- v) Autostrade's E-Darts
- vi) Teijin Seiki's Soliform Systems
- vii) Meiko's Rapid Prototyping systems for the jewellery Industry
- viii) Denken's SLP
- ix) Mitsui's COLAMN
- x) Fockele & Schwarze's LMS
- xi) Light Sculpting
- xii) Aaroflex
- xiii) Rapid Freeze
- xiv) Two Laser Beams
- xv) Microfabrication

Solid-Based

Except for powder, solid-based RP systems are meant to encompass all forms of material in the solid state. In this context, the solid form can include the shape in the form of a wire, a roll, laminates and pellets. The following RP systems fall into this definition:

- i) Cubic Technologies' Laminated Object Manufacturing (LOM)
- ii) Stratasys's Fused Deposition Modelling (FDM)
- iii) Kira Corporation's Paper Laminated Technology (PLT)
- iv) 3D Systems's Multi-Jet Modelling Systems (MJM)
- v) Solidscape's Modelmaker and PatternMaster
- vi) Beijing Yinhua's Slicing Solid Manufacturing (SSM), Melted Extrusion Modelling (MEM) and Multi-Functional RPM Systems (M-RPM)
- vii) CAM-LEM's CL 100
- viii) Ennex Corporation's Offset Fabbbers

Powder-Based

In a strict sense, powder is by-and-large in the solid state. However, it is intentionally created as a category outside the solid-based RP systems to mean powder in grain-like form. The following RP systems fall into the category

- i) 3D Systems's Selective Laser Sintering (SLS)
- ii) EOS's EOSINT Systems
- iii) Z Corporation's Three-Dimensional Printing (3DP)
- iv) Optomec's Laser Engineered Net Shaping (LENS)
- v) Soligen's Direct Shell Production Casting (DSPC)
- vi) Fraunhofer's Multiphase Jet Solidification (MJS)
- vii) Acram's Electron Beam Melting (EBM)
- viii) Aeromet Corporation's Lasform Technology
- ix) Precision Optical Manufacturing;s Direct Metal Deposition (DMD)
- x) Generi's RP Systems (GS)
- xi) Therics Inc.'s Theriform Technology
- xii) Extrude Hone's Prometal 3D Printing Process

All the above RP Ssystems employ the Joining/Binding method. The method of joining/binding differs for the above systems in that some employ a laser while others use a binder/glue to achieve the joining effect.

RPT Basic Process

Although several rapid prototyping techniques exist, all employ the same basic five-step process. The steps are:

1. Create a CAD model of the design
2. Convert the CAD model to STL format
3. Slice the STL file into thin cross-sectional layers
4. Construct the model one layer atop another
5. Clean and finish the model

1) CAD Model Creation

First, the object to be built is modelled using a Computer-Aided Design (CAD) software package. Solid modelers, such as Pro/ENGINEER, tend to represent 3-D objects more accurately than wire-frame modellers such as AutoCAD, and will therefore yield better results. The designer can use a pre-existing CAD file or may wish to create one expressly for prototyping purposes. This process is identical for all of the RP build techniques. The basic process is similar across the different additive type RP technologies. We will use a ball as an example here. It begins with using a CAD software such as Solidworks to design a 3D computer model. Figure 1.1 is a golf ball designed in Solidworks.



Fig 1.2: CAD model of a ball

2) Conversion to STL Format

The various CAD packages use a number of different algorithms to represent solid objects. To establish consistency, the STL (stereolithography, the first RP technique) format has been adopted as the standard of the rapid prototyping industry. The second step, therefore, is to convert the CAD file into STL format. This format represents a three-dimensional surface as an assembly of planar triangles, "like the facets of a cut jewel." 6 The file contains the coordinates of the vertices and the direction of the outward normal of each triangle. Because STL files use planar elements, they cannot represent curved surfaces exactly. Increasing the number of triangles improves the approximation, but at the cost of bigger file size. Large, complicated files require more time to pre-process and build, so the designer must balance accuracy with manageability to produce a useful STL file. Since the .stl format is universal, this process is identical for all of the RP build techniques.

This 3D CAD model is next converted into a Stereolithography or Standard Tessellation Language (STL) file format. The STL file format only describes the surface geometry of a 3D CAD model. It does not contain any information on the color, texture or material. STL file format can be saved in either ASCII or binary versions, with the latter as the more compact version. The surface geometry is described with triangular facets. Each triangle facets uses a set of Cartesian coordinates to

describe its three vertices and the surface normal vector using a right-hand rule for ordering. An example of how an ASCII STL file format is show in Fig. 1.2.

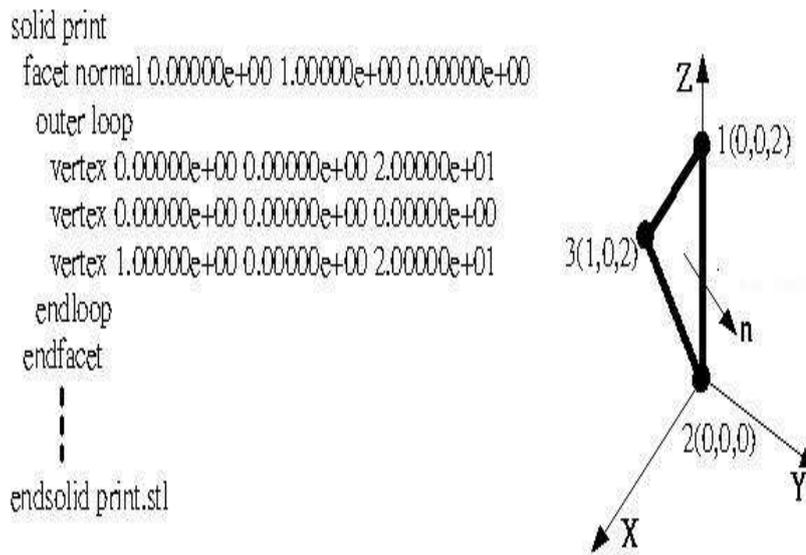


Figure 1.3: ASCII STL file format

To convert a CAD model to STL in Solidworks, File >Save as>Change ‘Save as type’ to .STL Select ‘Options’ for more advance export options. Figure 1.4 shows a print screen of the STL export option. As shown in Fig. 1.4, one can select to export the STL as Binary or ASCII file format in millimetre, centimetre, meter, inches or feet depending on the unit used in the CAD model.

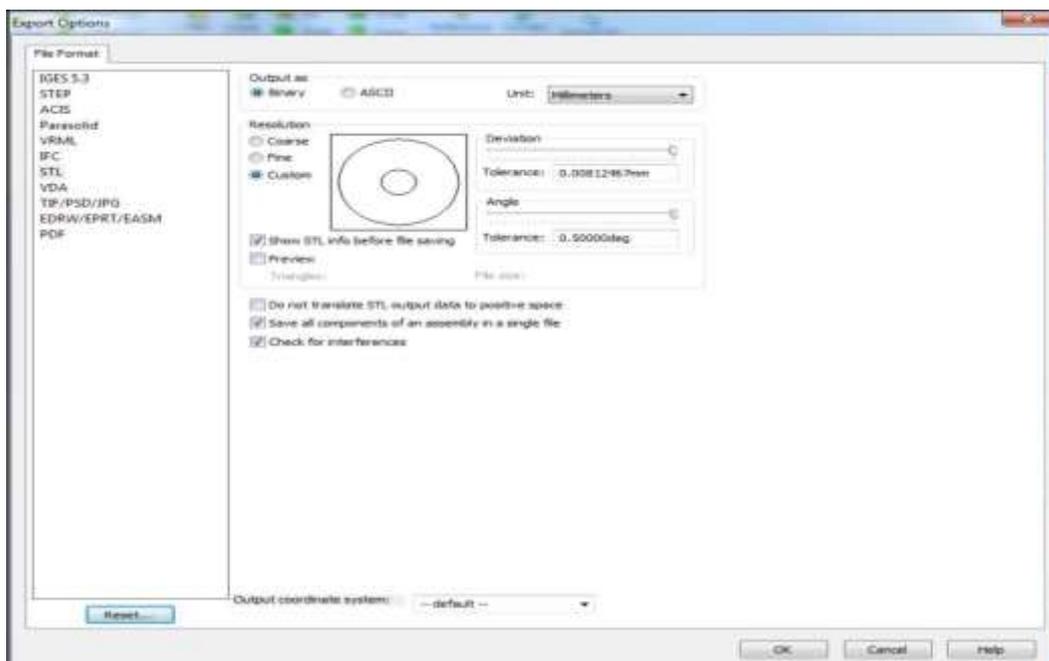


Figure 1.4: Solidworks STL export option

3) Slice the STL File

In the third step, a pre-processing program prepares the STL file to be built. Several programs are available, and most allow the user to adjust the size, location and orientation of the model. Build orientation is important for several reasons. First, properties of rapid prototypes vary from one coordinate direction to another. For example, prototypes are usually weaker and less accurate in the z (vertical) direction than in the x-y plane. In addition, part orientation partially determines the amount of time required to build the model. Placing the shortest dimension in the z direction reduces the number of layers, thereby shortening build time. The pre-processing software slices the STL model into a number of layers from 0.01 mm to 0.7 mm thick, depending on the build technique.

The program may also generate an auxiliary structure to support the model during the build. Supports are useful for delicate features such as overhangs, internal cavities, and thin-walled sections. Each RP machine manufacturer supplies their own proprietary pre-processing software.

The resolution options allow a user to control the tessellation of non-planar surfaces. There are two preset resolutions of ‘Coarse’ and ‘Fine’. The ‘Custom’ setting allows one to adjust the deviation and angle tolerances. Lower deviation tolerance sets tighter accuracy to the tessellation whereas smaller angle deviation sets smaller detail tessellation. The caveat is that tighter tolerances create more triangle facets to describe the 3D CAD model’s surface more finely which causes the file size to be large.

Figure 1.4 shows a CAD model exported to a coarse resolution STL (114KB), fine resolution STL (300 KB), and a very fine resolution STL file (1.51 MB). A more complicated design with complicated features would also result in a large STL file size. Figure 1.5 shows an exaggerated view of how the export STL tolerance option affects how the 3D CAD model’s surface is described. Furthermore, depending on how fine the tolerances are set, computation power to export the CAD model and process the file for fabrication could be an issue. Once the appropriate STL file has been generated, this is then loaded into the individual RP company’s proprietary software to be processed into 2D slices for fabrication.

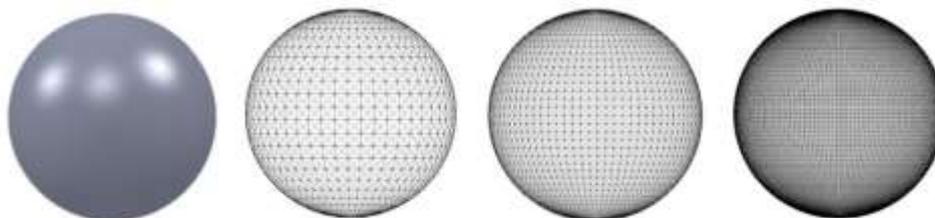


Figure 1.5: CAD model to a coarse STL, fine STL, and a very fine STL file.