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Design for FDM Rapid Prototyping Manufacture (Basic)

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EXECUTIVE SUMMARY

This design manual has been designed for use with the Stratasys Dimension Rapid Prototyping (RP) machine to help you make successful builds.

It introduces general specifications, solutions for cylindrical fits, tappings and springs and support material awareness. Instructions on saving a Solid Edge part file into the appropriate format for RP production are also included. Once the reader is familiar with the concepts, a useful summary of the design data can be found at:

http://reprap.org/bin/view/Main/HintsForUsingTheStratasysDimensionRPMachine

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TERMINOLOGY

Some terms which are commonly used throughout the manual:

ABS	A plastic based on Acrylonitrile-Butadiene-Styrene copolymers; used as the build material in the Stratasys Dimension RP machine.
FDM	Fused Deposition Method: the specific RP technique used by the Stratasys machine.
Infill	The RP process of filling the volume between critical surfaces of components with structural material.
Rapid prototyping (RP)	A technology which can create parts using fused deposition modelling and other techniques. Components are designed using 3D solid modelling software package (e.g. SolidEdge) and then sent to the RP machine which will then automatically manufacture the component using, in this case, ABS. All subsequent references within this document to RP refer to the fused deposition modelling technique. The machine used for this technique was the Stratasys Dimension rapid prototyping machine.

1   INTRODUCTION TO RAPID PROTOTYPING

Rapid Prototyping is a technology which can create parts by building them up in layers. There are several techniques used to do this, however, this manual will only be concerned with the Fused Deposition Modelling (FDM) method employed by the Stratasys Dimension.

Components are designed using a 3D solid modelling software package (e.g. SolidEdge, demonstrated in Figure 1) and then sent to the RP machine, which will then automatically manufacture the component by printing layers of ABS using the FDM method (result shown in Figure 2).
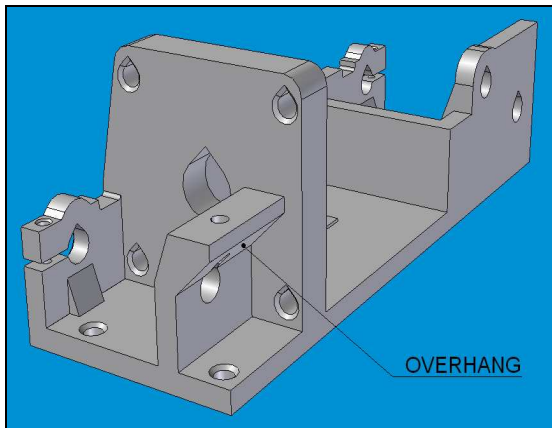

Figure 1: 3D model of a bracket (250 mm long) designed in Solid Edge (a solid modelling program).
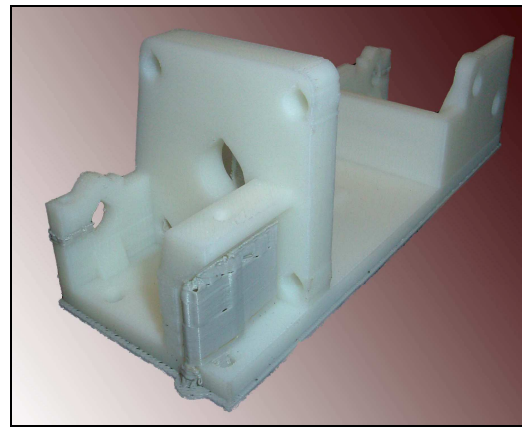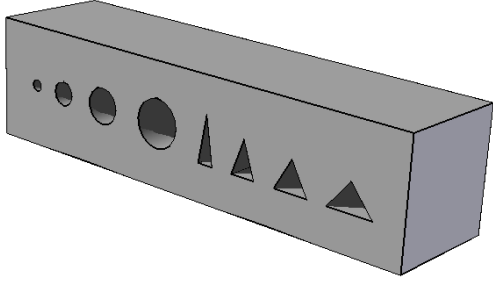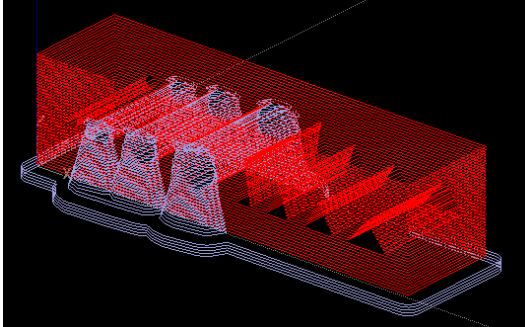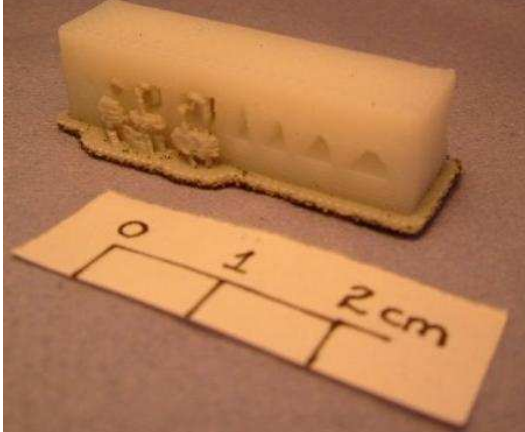
Figure 2: The result from the RP machine. Note the necessary support material for the overhanging feature.

The process starts at the bottom layer where build material is deposited where required. Once that layer is complete the build is incremented to the next layer, depositing material on top of the layer below. Occasionally a component design will include overhanging features (identified in Figure 1). This causes a problem for deposition as the head is required to print onto a void.

The FDM process solves this by automatically building a support platform (or bridge) on which the build material can be printed. This support material is be peeled away when the build is completed.

Table 1 outlines the basic steps taken to manufacture a component using RP technology.

Table 1: Step by step demonstration of rapid prototyping manufacture process

Stage	Visualisation	Details
1		Design is created virtually using a 3D modeller.
2		The 3D model is pre-processed using a program from Stratasys called Catalyst: the design is converted into tool paths for the RP machine to follow. Red lines represent component material. Blue lines represent any support material (required for overhanging features).
3		Tool path information is sent to the RP modeller. The modeller is initiated and then left to manufacture the job.
4		When the RP modeller is finished, the component is unloaded and support material is peeled away to give the finished part. Here the support material can be seen under the part and in the holes at the left.

2   GENERAL DESIGN FOR RAPID PROTOTYPING

2.1   Introduction

The manufacture of a component with a simple geometry (for example: a stand-alone cube) requires no additional knowledge to achieve a successful build in the RP machine.

However, as the geometry and component relationships with other components become more complicated knowledge is required at the design stage to ensure an optimum build. General constraints of the machine need to be considered (e.g. minimum build wall thickness), support material should be avoided if possible to ensure an efficient build and to avoid permanently clogging certain features, holes and shafts with specific fits should be designed to tolerances that will be specified below and spring components should be designed to be built in the correct orientation.

2.2   General design specifications

The FDM machine can build anything within a footprint of 210 mm x 210 mm area, up to a height of 300 mm.

The finished product is made out of ABS.

The product will be accurate to ±0.05 mm.

Minimum wall thickness ~ 0.6 mm.

Typical wall thickness for most designs is 5 mm.

Because the product is made by printing layers, the product has orthotropic strength. It will be strong along the length of the planes (cf a lego brick) but only half as strong across the layers.

2.3   Cylindrical fits

The RP machine cannot reproduce fit features (holes and shafts) to the same accuracy as a traditional workshop machine e.g. lathe or milling machine. Feature dimensions must be tailored using the charts below to achieve the required fit. Fits vary between two different situations:

- True (non-RP) shaft fitting to a RP hole

- RP shaft fitting to a RP hole

The following sub-sections detail the design dimensions to achieve the required fits.

2.3.1   RP hole diameter for true (non-RP) shaft

This section is useful for designing holes in the RP component which house standard cylindrical parts, for example bolts or shafts.

Table 2: Simple metrics for designing RP hole diameters to achieve specific fits to true shaft diameters

Fit type for hole and shaft	Design compensation for hole ø (mm) (add to shaft ø)
Interference fit	+0.1
Tolerance fit	+0.3
Clearance fit	+0.4

E.g. Hole ø required for a running fit to a steel shaft, true ø 8.00 mm. Design hole ø at 8.00 + 0.3 = ø 8.3 mm.

E.g. Hole ø required for a M5 bolt, true ø 5.0 mm. Design hole ø at 5.0 + 0.4 = ø 5.4 mm.

2.3.2   RP hole diameter for RP shaft diameter

For the dimensions of a hole in an RP part to fit to a shaft of another RP component, use the chart in Figure 3.
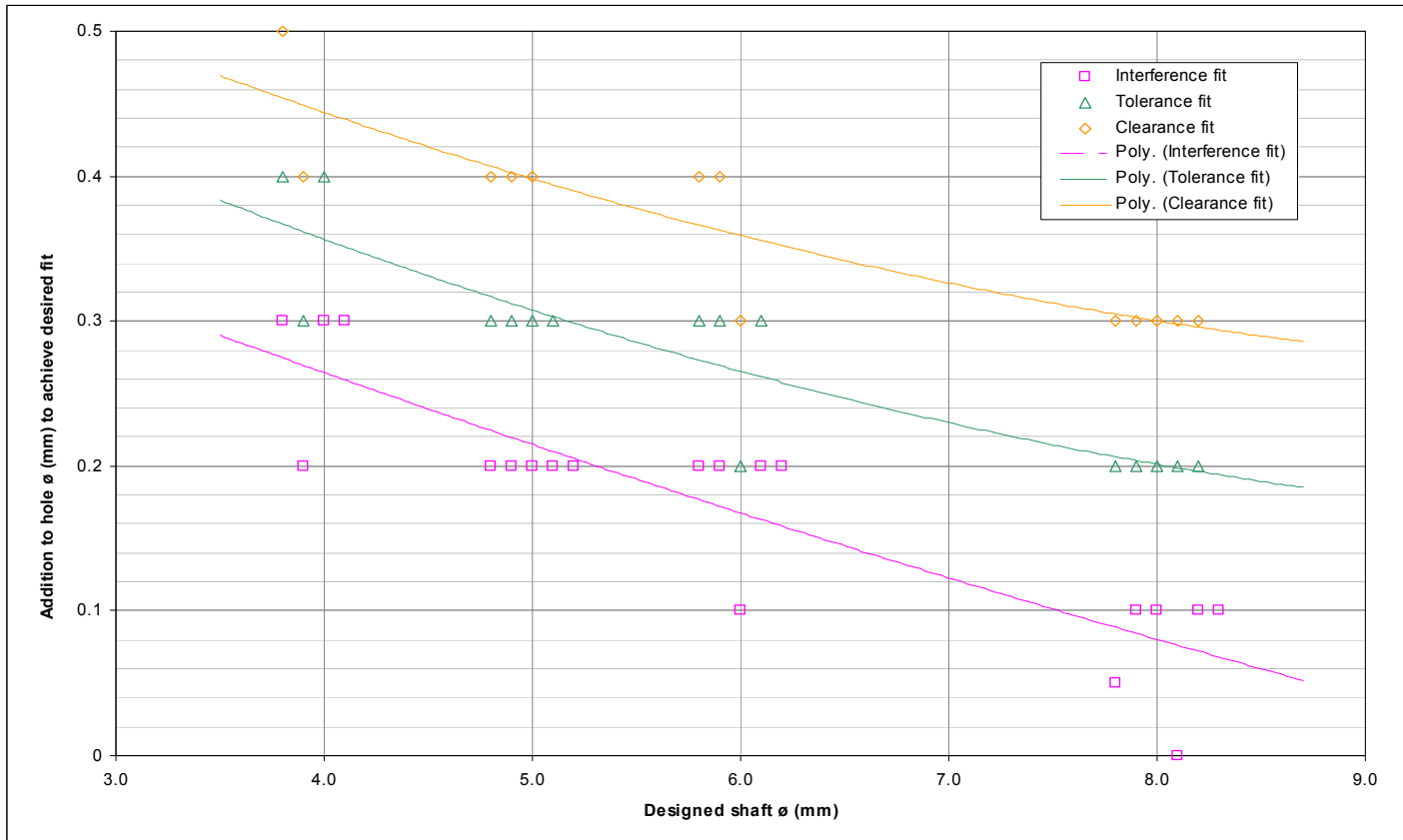

Figure 3: Mapping for fits between RP shafts and RP holes

E.g. For an RP hole to give a tolerance fit on an RP shaft designed at 6.0 mm, the hole must be designed at ø 6.27 mm.

2.4   Tapping

When using fasteners in an assembly it is often useful to have a tapped hole in an RP component. There are three different options:

- RP hole diameter for self tapping screws

- RP hole diameter for metric taps

- RP countersink to house a metric nut (recommended)

The following subsections detail the design dimensions for each of the different options.

2.4.1   RP hole diameter for self tapping screws

Table 3: Hole compensation reference table for screw fits

Screw gauge	Tapping hole ø (mm) design	Clearance hole ø (mm) design
10	4.4	5.2
8	3.8-3.9	4.8
6	3.3-3.4	4.0
4	2.6 (estimate)	3.2

E.g. For a gauge-8 self tapping screw the tapping hole should be designed at ø 3.8 mm and the clearance hole should be designed at ø 4.8 mm.

2.4.2   RP hole diameter for metric taps

Note: If it is expected that the thread is be used frequently or for heavy duty situations (e.g. the component is used for testing) the thread is likely to wear quickly. In these situations therefore it is preferable to use a housed nut (defined in the next section).

Table 4: RP hole diameters for metric taps or nuts

I.S.O Metric coarse thread	Tapping hole ø (mm) on the RP machine	Clearance hole ø (mm)
M3	2.8	3.4
M4	3.6	4.4
M5	4.5	5.4
M6	5.3	6.4
M8	7.1	8.5
M10	8.8	10.5

E.g. For an M6 bolt the tapping hole should be designed at ø 5.3 mm and the clearance hole should be designed at ø 6.4 mm.

2.4.3   RP countersink to house a metric nut

The countersink shown in Figure 4 has a rounded hexagonal profile to constrain the nut axially (the nut will remain in the countersink because of a light push fit) and flats to provide maximum constraint. The critical dimensions for this design are shown in Figure 5.
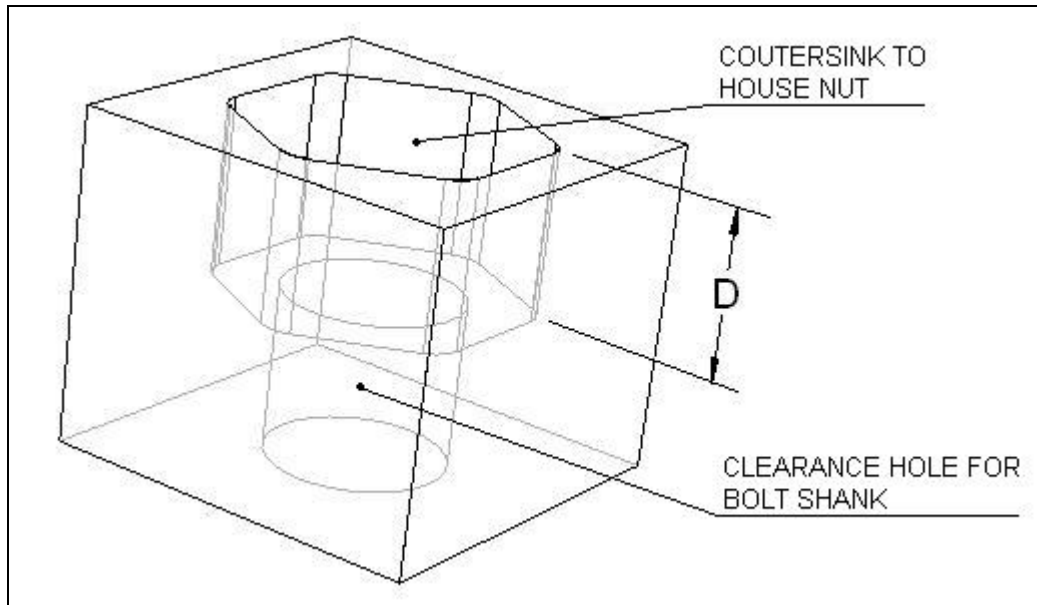
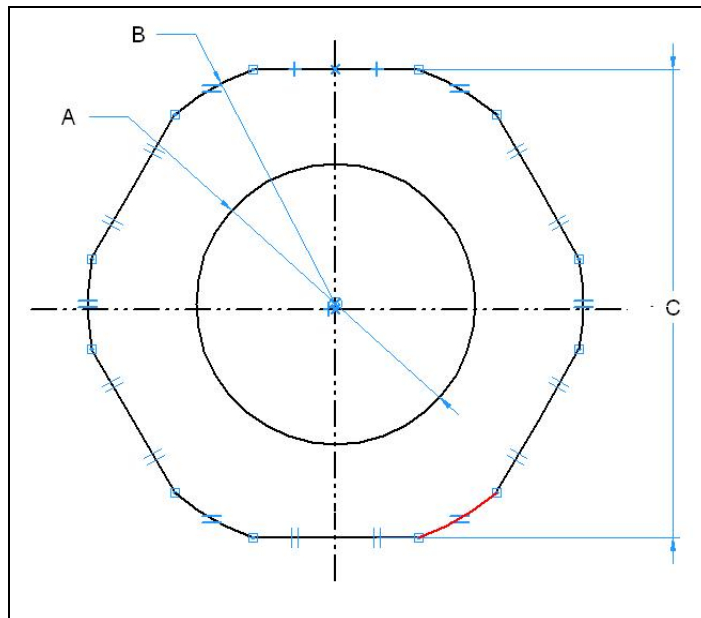Figure 4: Rounded hexagonal countersink to house a nut

Figure 5: Critical dimensions for the rounded hexagonal countersink

Table 5: Design dimensions for the rounded hexagonal countersink

I.S.O Metric nut size	A	B	C	D
	Clearance hole ø (mm)	CS rounding ø (mm)	Hexagonal flat dist (mm)	CS minimum depth for flush nut (mm)
M3	3.4	6.3	6.0	2.4
M4	4.4	7.9	7.45	3.0
M5	5.4	9.3	8.45	3.9
M6	6.4	11.5	10.45	5.0
M8	8.5	14.8	13.35	6.3

Keep in mind that the housing must be positioned so that when it is built, the layers run parallel with the axis of the bolt - otherwise tightening the nut will simply prise the layers apart.

2.5   Springs

The ABS is quite flexible at thicknesses below 3 mm. However, it is important to build the spring in an orientation which ensures that the stress runs along the length of the layers rather than over the weaker interfaces between the individual layers.

Figure 6 illustrates an example of a component which uses a spring section.
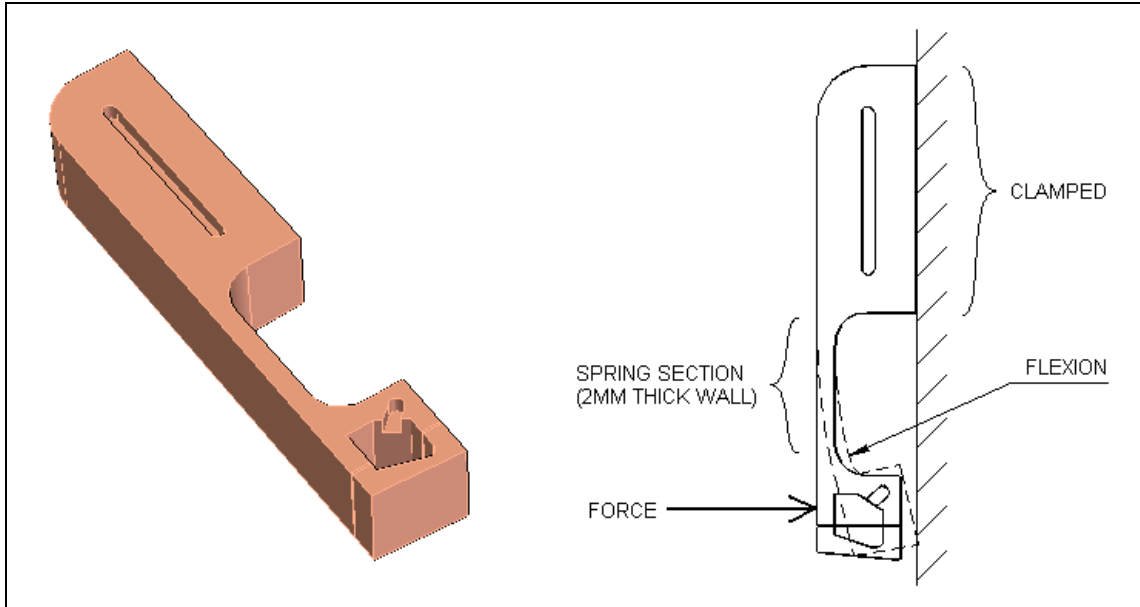
Figure 6: Example of an RP component using a spring section in its design

Figure 7 and Figure 8 illustrate correct and incorrect build orientations with respect to layer orientations for the above example.
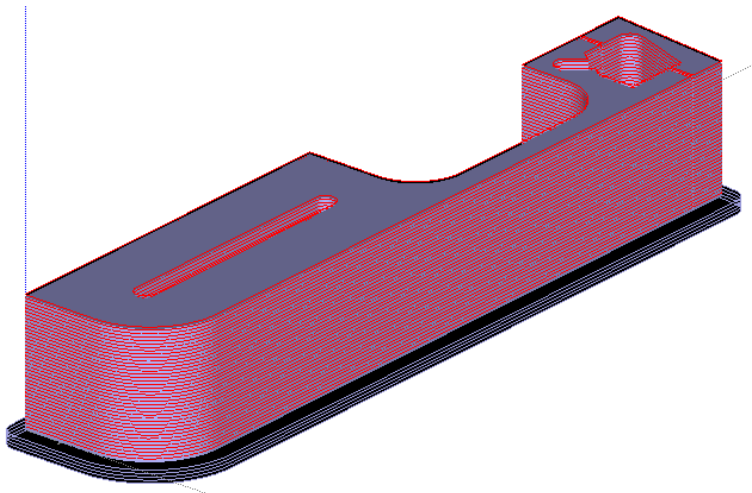
Figure 7: Correct build orientation. Layers run along the length of the sprung section. RP components are weakest in the planes where layers are bound together (the interfaces) – this lay-up ensures that the stress is distributed along the layers and not the interfaces.
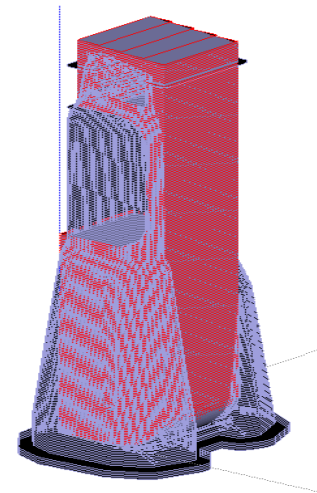
Figure 8: Poor build orientation (ignore support material). Layers cut across the sprung section. Stress concentrated on interfaces.

2.6   Support material awareness

As explained in Section 1, support material will be induced for overhanging features. Support material should be avoided if possible as it will improve the efficiency of the build, improve the finish of the component and save time finishing the component post-manufacture.

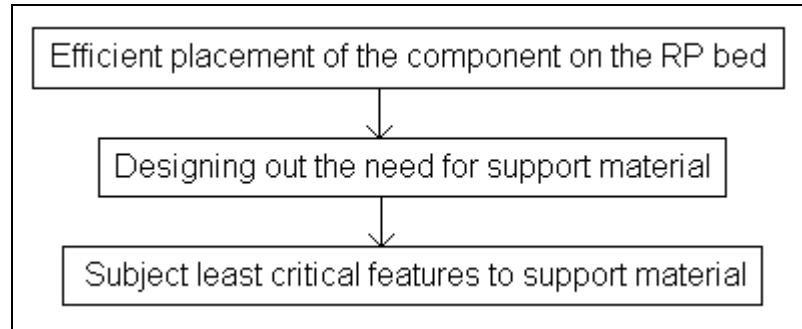A typical approach to avoiding support material is shown in Figure 9.

Figure 9: Approach to avoid the use of support material

Examples of the approach are given below.

2.6.1   Efficient orientation of component during build

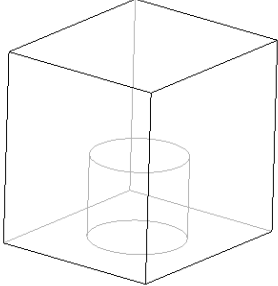Support material can be avoided for simple components by orientating the component appropriately.
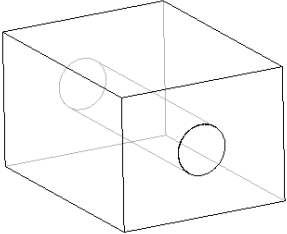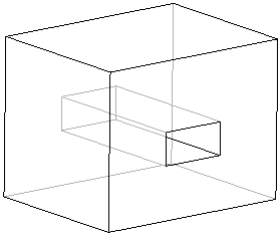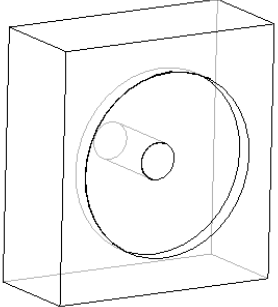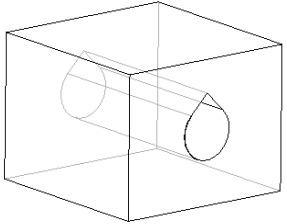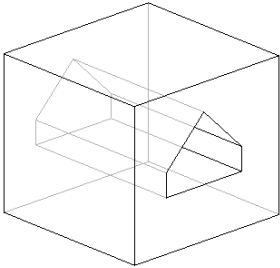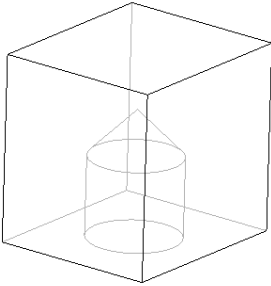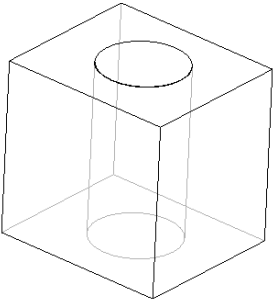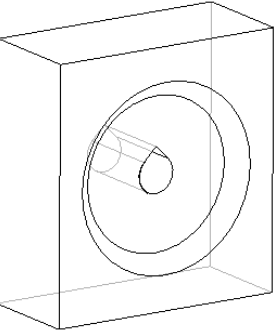
Table 6: Examples of solutions to avoid the use of support material using appropriate orientations

	Example 1	Example 2
Component		
Support material	Support material induced below overhang	Support material induced into the hole. Difficult to remove and reduces the quality of the finish.
Orientation solution		
	Build with largest flat at the bottom	Build with hole axis in the vertical plane

2.6.2 Designing to eliminate the use of support material

Inverse drafts (overhangs) may range from 0 ° to 45 ° without the need for support material. The examples shown in Table 7 assume that the orientation of the features cannot be changed, therefore 45 ° overhangs have been incorporated into the design solutions to eliminate the use of support material.

Table 7: Example of design solutions to avoid the use of support material

	Example 1	Example 2	Example 3	Example 4
Feature	Horizontal hole	Horizontal slot	Blind hole (inverted)	Vertical counterbored
Design solution	Pointed (45 °) hole	Pointed (45 °) slot	Coned (45 °) roof	Through hole	Chamfered (45 °) countersink

2.7 Simple Part Conversion to STL Format in SolidEdge v19

The RP machine reads 3D part descriptions in STL format. A Solid Edge part drawing can easily be converted into an STL format using the following method:

- With the part open, click 'File', 'Save As…'

- Enter a filename (make sure it's in the correct format as stated on the FDM RP web site!)

- Click 'Save as type:' > "STL documents (*.stl)"

- Click 'Options' and ensure parameters match those specified in Figure 10 when saving as an STL file. Failure to do so, whether changes are made or not, might result in the creation of a very small STL file.
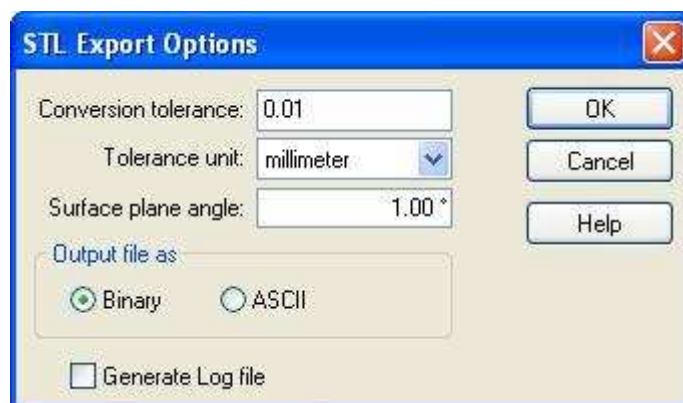

Figure 10: STL export parameters

- You may select ASCII rather than binary if you need a person-readable file. This will be much larger than the equivalent binary file.

- Click 'OK' on all dialogues