Rapid Fabrication of Disposable Fixtures for Correct Assembly of Split Build Rapid Prototyped Parts

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Abstract

The size of part that can be produced in a single build on any of the commercially available Rapid Prototyping systems is limited by the size of the particular machine's build envelope. Parts which exceed the dimensions of the build envelope are split into sections that fit the machine's envelope and these sections are fabricated separately. Assembly of the sections into an accurate three dimensional object often requires the creation of a fixture. This fixture ensures correct positional and angular orientation of the sections during assembly. This paper discusses the fabrication of such fixtures using Shapemaker II, a Solid Freeform Fabrication process developed at the University of Utah. Using Shapemaker II, large fixtures (4 ft. by 8 ft. or even larger) can be created in just a few hours. While the fixture is reusable, given the low cost of the fixture, it can be considered a throw away item.

Background

Application of rapid prototyping (RP) techniques during the development of a new product is often limited by the size restrictions imposed by the RP technique selected. The build volumes of the various commercial products vary from smaller than one cubic foot up to 32" by 32" by 20". (Thomas, 1996 and Burns, 1993) Even larger sizes are available through at least three different avenues: 1) using NC machining or traditional prototyping 2) large wax and sand prototypes (Berkstresser, 1997) 3) large prototypes from plastic foam (Lee et al., 1997).

It is often not possible to select an RP technique based only on the size of the fixture required. The different techniques produce fixtures with different material properties, with different accuracy, and with different costs. Often one of these factors will override part size as a selection criteria for the RP technique. Thus, it is often necessary to build a relatively large part on a machine with a small build envelope. As mentioned above, this is generally accomplished by splitting the part into multiple pieces that fit within the build envelope of the RP device, building the fixture in pieces, and manually assembling the pieces during post processing. This paper discusses two techniques for cutting an alignment fixture to support the splitbuild parts during assembly.

Fixture Design Specifications

Design specifications for the part fixture are as follows:

a) Construction of the fixture should be rapid and inexpensive.
b) The fixture should provide accurate alignment and positioning of split build parts over large distances.
c) It should orient and locate sections, but leave joints free of supports providing access for joining operations.

Fixture Construction Techniques

For either of the two fixture techniques proposed here, building the basic fixture starts with a solid model of the part. Using CAD software, a solid box surrounding the part is created. The part is then differenced from the box, resulting in a box having a cavity that matches the part geometry. Next, the top portion of the box is cut away to expose the cavity. This cut plane varies according to part height.

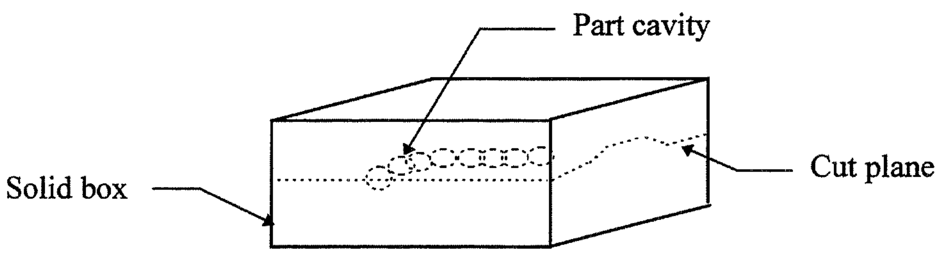

Figure 1. This figure shows how CAD software is used to enclose the part within a solid box. The box is then cut to expose the part geometry.

Once the basic fixture is designed, different techniques of fixture can be explored. These The Rectangular Grid fixture and the Multiple Tower fixture are discussed here.

A. Rectangular Grid fixture: The principle behind this fixture technique is to position the part using a rectangular grid of thin planar supports generated from the basic fixture described above. CAD files for each of the cardboard supports on which the part rests were cut on a plotter. A base was also constructed to allow correct registration of the supports.

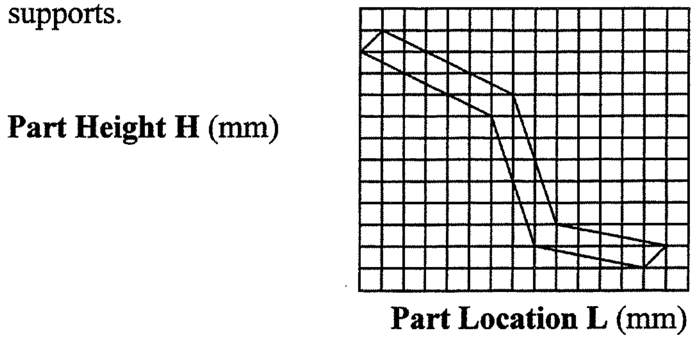

Figure 2. This figure shows the top view of the part enclosed within the rectangular grid.

The Rectangular Grid technique started with the base fixture discussed above. This fixture was divided into a rectangular grid of thin planar cross-sections separated at relatively large distances. Using CAD software, those sections of the grid which support the part were separated from the rest of the grid. Both the location (L) and the height (H) of each support were noted. Each support was then cut using a plotter. Two different kinds of cardboard sections were prepared. These are as follows: first, cardboard sections having a constant (L) and varying (H), and second, cardboard sections having a constant (H) and varying (L).

Each cardboard support was prepared as shown in Figures 3, 4 and 5. Parameters L and H have been marked on each support. Figure 3 shows a cardboard section with vertical slots cut in its lower half. This cardboard section has a constant H and a varying L. This section was mounted on another cardboard section perpendicular to it having slots cut in its upper half at constant L and a varying H parameters (see Figures 3 and 4). The base of the Rectangular Grid fixture consists of a plane board on which a 2 D drawing of the part's top view was printed (see Figure 5). To complete the fixture, the sections and the base were glued together. Figure 6 shows the final assembly of the fixture.

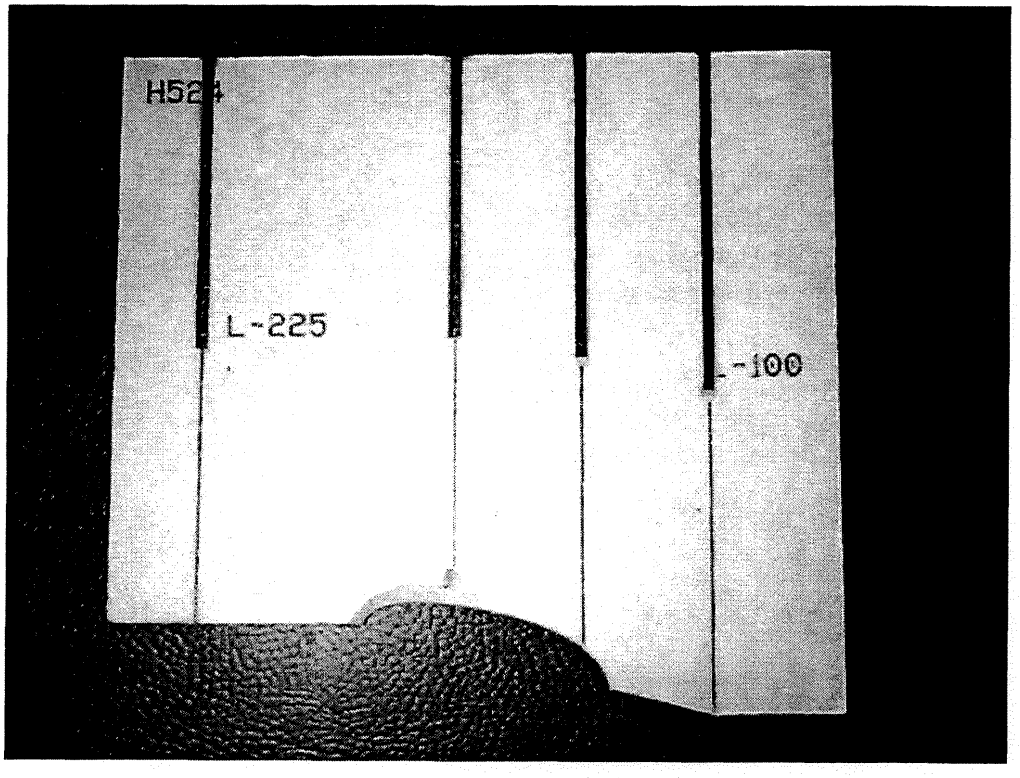

Figure 3. This figure shows the cardboard section at H=524 mm and L varying from 100 mm to 225 mm.

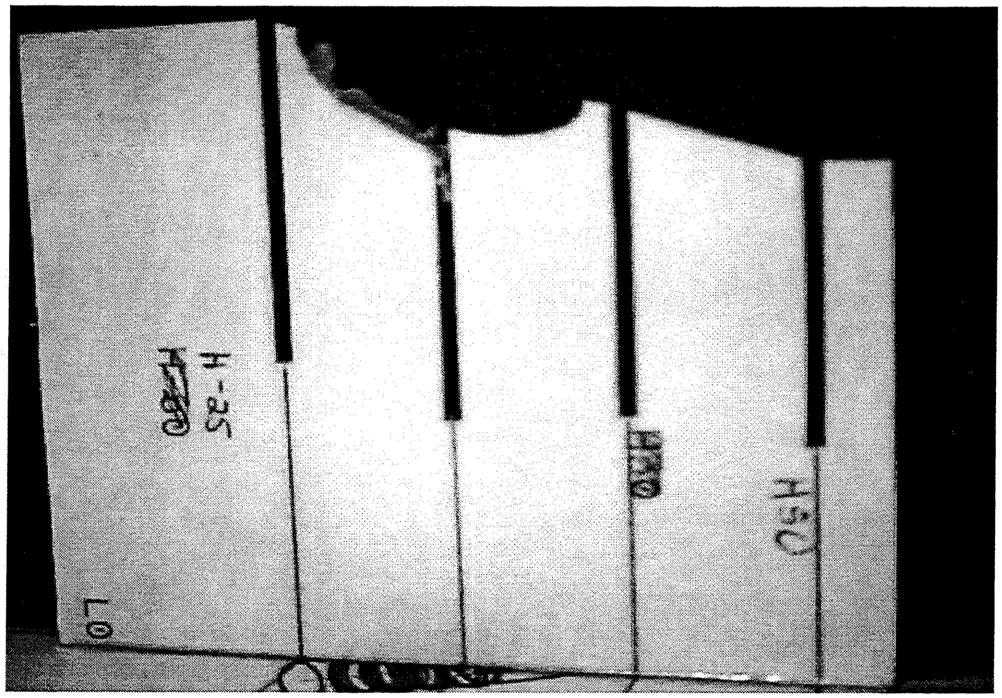

Figure 4. This figure shows the cardboard section at L=0 mm and H varying from 25 mm to 50 mm.

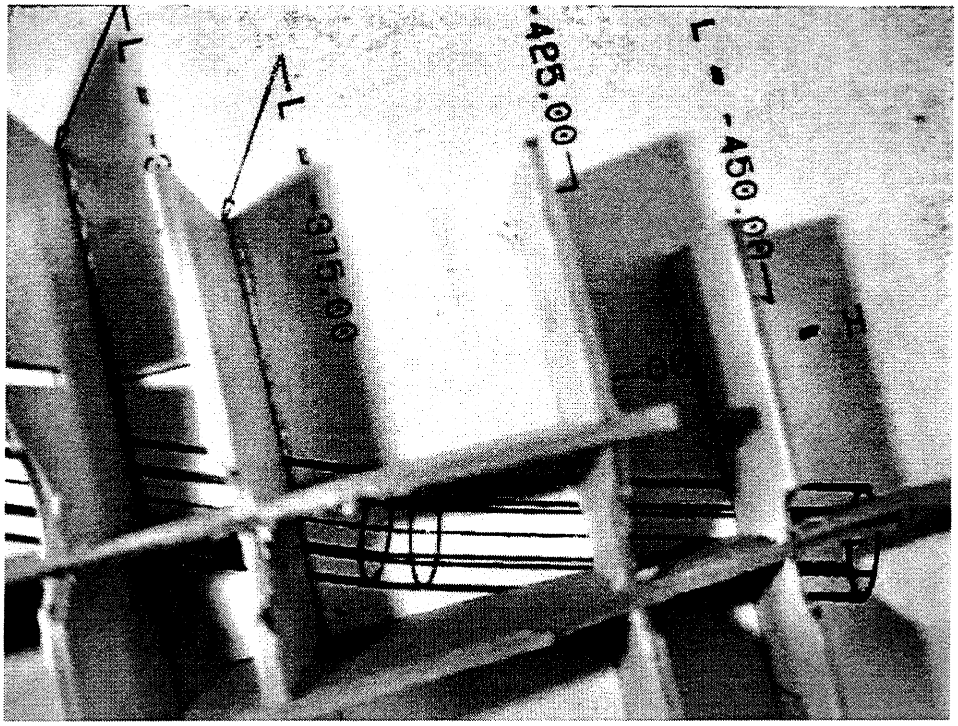

Figure 5. This figure shows the top view of the cardboard sections assembled together to form the grid. The part geometry is printed on the fixture base.

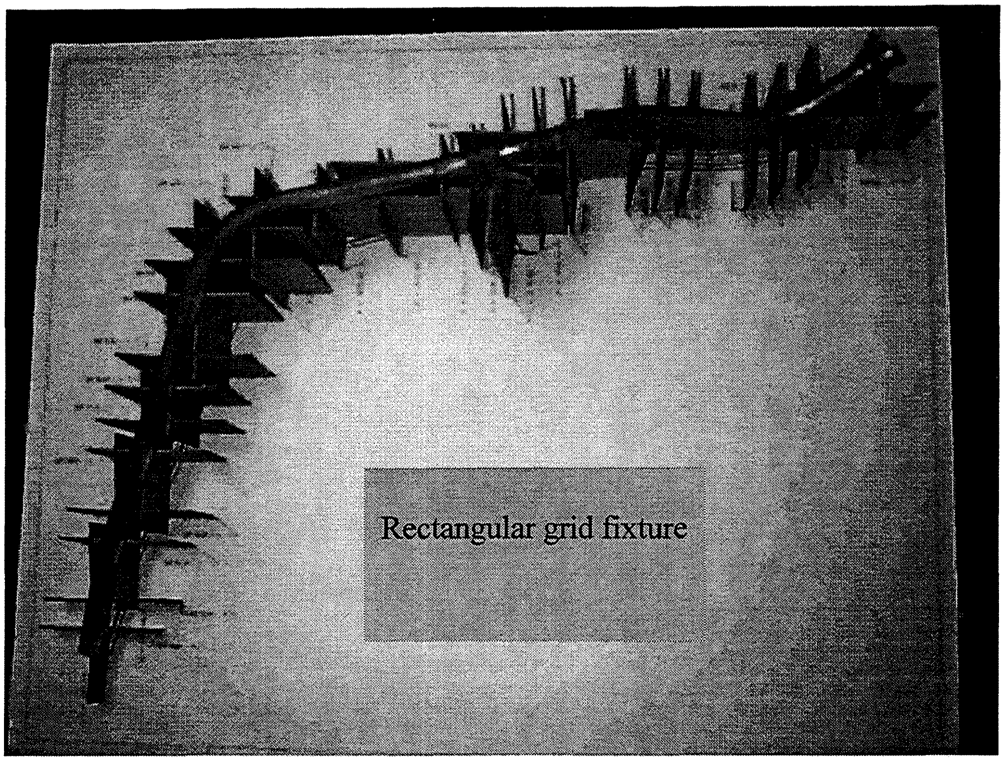

Figure 6. This figure shows the complete assembly of the Rectangular Grid fixture with the part mounted on it.

B. Multiple Towers: The principle behind this fixture technique is to position the part using Styrofoam towers. CAD files for each of the towers on which the part rested were cut using Shapemaker II. A base was also constructed to allow correct registration of the towers.

The Shapemaker II system utilizes *higher order construction algorithms* to cut build parts from thick Styrofoam layers with angled surface edges (Lee et al., 1997). In this manner, Shapemaker II allows rapid construction of large Styrofoam parts. Similar to the Rectangular Grid method, this technique started with the basic fixture discussed earlier. The part is supported at selected locations by means of Styrofoam towers. Using CAD software, decisions regarding tower locations were made based on the part's orientation. It was noted that a more accurate fixture results when the towers are oriented so that the slice direction is perpendicular to the part axis. This orientation also enables a good match between the tower and the part surface. Each tower was differenced from the basic fixture, sliced and built as a separate part using Shapemaker II. Once the layers were cut, they were bonded together. A base for the towers containing positioning holes that locate the towers was also cut on Shapemaker II (see Figure 7). The final assembly, including the towers, base and part is shown in figures 8 and 9.

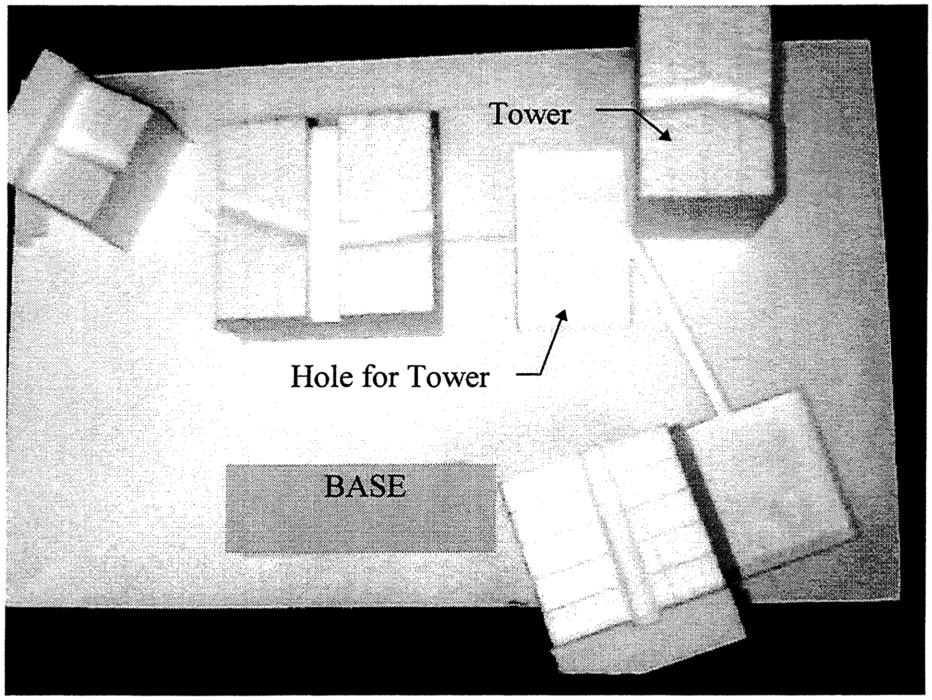

Figure 7. This figure shows the top view of the base of the Multiple Tower fixture. Two of the towers are placed beside the holes.

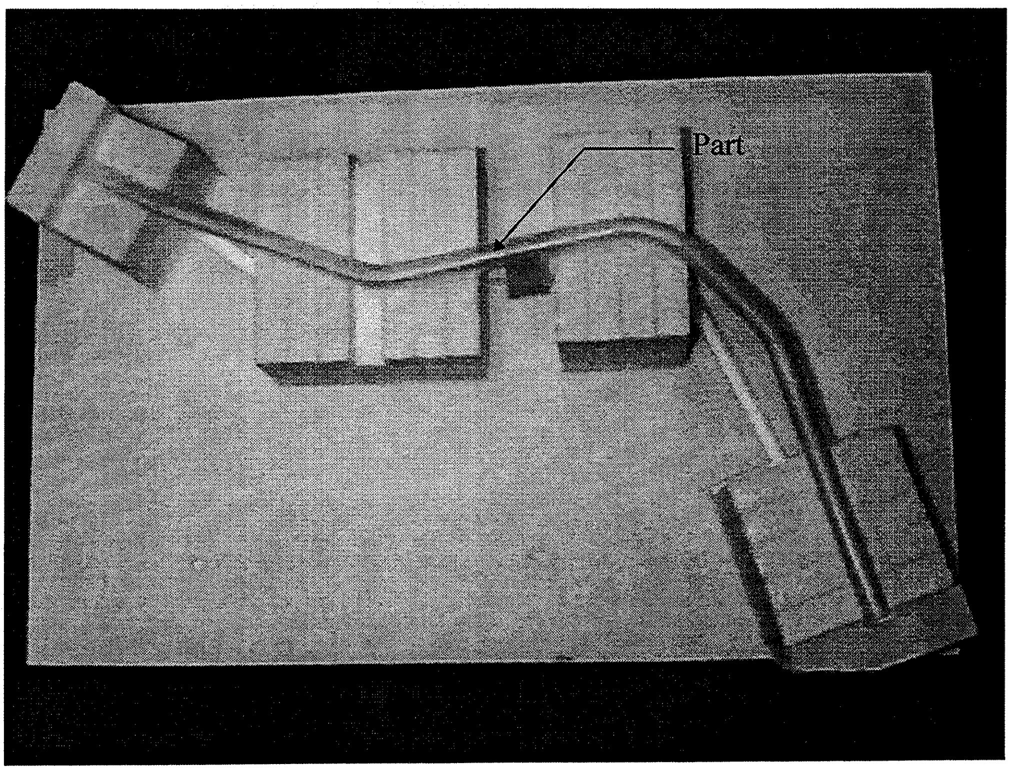

Figure 8. Top view showing the assembled Multiple Tower fixture. The part rests in the tower grooves.

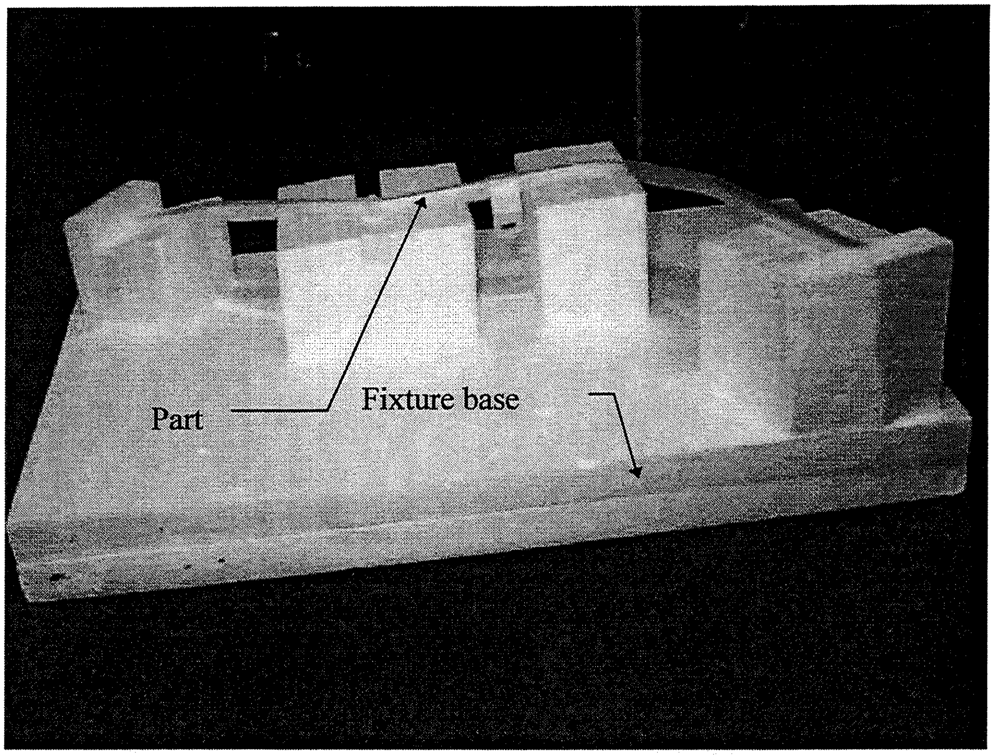

Figure 9. This figure shows the side view of the Multiple Tower fixture.

Results

Rectangular Grid Fixture

The Rectangular Grid fixture did provide accurate alignment and positioning of split build parts over large distances. In addition, it orients and locates sections, leaving joints free of supports providing access for joining operations, as long as the joint lies between the cardboard supports. The construction of the Rectangular Grid fixture however, did not prove to be rapid. The construction of the fixture base and the supports required extensive manual labor. The accuracy of the cardboard assembly is also limited by the operator's skill.

Multiple Tower Fixture

The Multiple Tower fixture did provide accurate alignment and positioning of split build parts over large distances. In addition, it orients and locates sections, leaving joints free of supports providing access for joining operations. The construction of the fixture was also rapid and inexpensive. The fixture was designed in five hours and built in two hours with a material cost of $5.00. The resulting fixture is quite stable for the weight of the part. One problem with the Shapemaker II system however, is its inability to cut angled edges greater than 50 degrees. This will limit the accuracy of the fixture.

Comparing The Fixtures

Because the Rectangular Grid supports are thin, they contact the part in 2D lines. This provides accurate support for any geometry. The Multiple Tower fixture however, supports the part with thick layers having ruled surface edges. If the fixture is designed such that a 3D curve part surface must lie against the ruled edge layers, positional error will result. This difference is shown in figure 10. In both cases, CAD files used for fixture design are limited by the accuracy of their stl file format (Novac 1997).

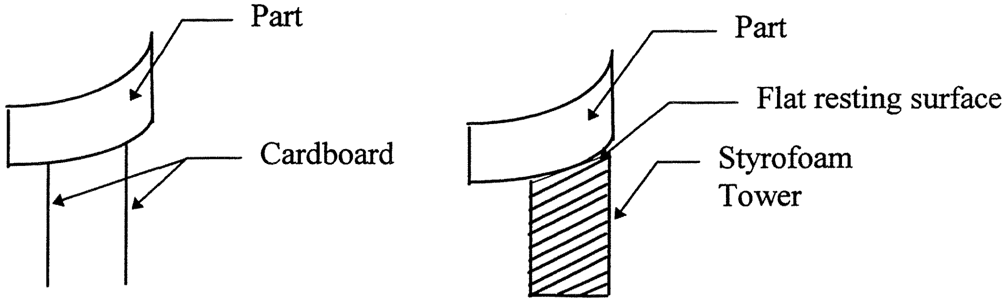

Figure 10. The cardboard supports support the part exactly, while the Styrofoam supports can potentially cause position error.

Conclusion

Parts which exceed the dimensions of the build envelope can be split into sections that fit the machine's envelope and fabricated separately. Assembly of the sections into an accurate three dimensional object often requires the creation of a fixture. This fixture ensures correct positional and angular orientation of the sections during assembly. In this paper, two fixture construction techniques were explored. These are the Rectangular Base fixture and the Multiple Tower technique utilizing the Shapemaker II system. It is concluded that both techniques have desirable features. It is also concluded that research in the rapid fabrication of disposable fixtures is promising and should be continued.

References

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