Product management of making large pieces through Rapid Prototyping PolyJet® technology

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Abstract. The rapid prototyping process has already become a classic manufacturing process for parts and assemblies, either polymeric or metal parts. Besides the well-known advantages and disadvantages of the process, the use of 3D printers has a great inconvenience: the overall dimensions of the parts are limited. Obviously, there is a possibility to purchase a larger (and more expensive) 3D printer, but there are always larger pieces to be manufactured. One solution to this problem is the splitting of parts into several components that can be manufactured. The component parts can then be assembled in a single piece by known methods such as welding, gluing, screwing, etc. This paper shows our experience in making large pieces on the Stratasys® Objet24 printer, pieces larger than the tray sizes. The results obtained are valid for any 3D printer using the PolyJet® process.

1. Introduction
Developing projects nowadays involves the use of rapid prototyping technology. Access to this technology involves investing in the acquisition of the 3D printer (s) and software development applications.

All of this comprises major investments compared to classic, traditional technology. That's why most of the pieces are made on 3D printers have very small overall dimensions, rarely medium size (over 500 mm) and extremely rare large sizes (over 1,000 mm). It is difficult for a company to choose the size of the 3D printer correctly. A large printer implies high acquisition costs, high maintenance costs, and high cost of consumables (depositing material and support material). Buying a large 3D printer and using it in most cases for small parts is not economically justifiable. However, how can we make big parts on a smaller size printer than the part? The only way is to divide the piece into components and to join these components into an assembly that ultimately has the appearance and properties of the piece. At this stage some problems arise:

- how do we divide the piece into the components, what criteria?
- what are the mechanical bonding, gluing or welding solutions?
- how will behave the new part?
• what will be the aesthetics of the part?

In fact, all these four problems are correlated with each other. These issues can be answered on a case by case basis: there is no generally valid solution. For example, if a mechanical part only has an aesthetic role in a 3D prototype, then segmenting the part will be based on the visible surfaces. Conversely, if the part has a functional and less aesthetic role, then segmenting the part will be based on the mechanical stress state of the material, without affecting the mechanical structure.

Figure 1. The typical prototyping process on 3D printers.

Figure 2. An example of additive manufacturing and design software module (Netfabb®) [1].

But what happens if a part has to fulfil simultaneously the conditions of functionality, resistance to complex loads and at the same time must have a corresponding aesthetic component? How can this problem be solved? In this case, the current procedure is based on the knowledge and experience of the technologist engineer responsible for 3D prototyping. It is he who has to choose the best solution
for segmenting and then assembling the mechanical part. Let's analyze the case of Rapid Prototyping (RP) on 3D printers using PolyJet® technology. This process is shown in figure 1. Note that the same process explained in figure 1 applies to other RP processes such as Stereolithography (SLA), Selective Laser Sintering (SLS), Fused Deposition Modeling (FDM) or Selective Laser Melting (SLM).

In figure 1, for the "3D Print Optimization" module, we considered the Autodesk® Netfabb® software. The additive manufacturing and design software Netfabb® has tools that help streamline additive workflow and rapidly get from a 3D model to successfully printed parts, as shown in figure 2 [1]. There are other, more or less similar software applications.

2. Presentation of the RP process for parts larger than the printer’s tray
To illustrate more convincingly the issue of considering figure 3. In this case, there are two possibilities:

- to divide the part into a CAD application or,
- to divide the part into a 3D Print Optimization module like Netfabb®.

Segmenting the part in the 3D CAD modeller has the following benefits:

- better control of the split;
- the ability to perform complex cuts on the CAD part, so that future segments joints are hidden from view;
- the mechanical strength of the joint part can be improved by adding bosses, ribs or surfaces for strength and positioning.

The segmentation of the piece in the 3D CAD modeller has the following weaknesses:

- labor-intensive, time consuming activity;
- requires qualified engineer with good CAD knowledge;
- not always the results are what we expected.

The larger part example of figure 3, which was segmented in the 3D CAD modeller, is shown in figure 4.

An example of boss further added to the piece, in order to be easier to position the counterplate and to strengthen the structure to be joined by gluing is shown in figure 5.
Figure 4. A large part divided into six components using 3D CAD modeller.

Figure 5. Components of splitted part to which additional bosses have been added.

The CAD file in STL format has been exported to manufacture this piece. The STL file has been exported from SolidWorks®. The export parameters were:
- deviation tolerance = 0.02 mm
- angle tolerance = 3º.

The resulting STL file looks like in figure 6 and is 107.9 MB in size. This file size is hardly supported by ObjetStudio® (figure 3). A smaller size file could be obtained by reducing the detail level when converting the piece to STL format, but this would affect the quality of the manufactured piece.
The other solution is to divide the CAD part into smaller parts, (which has been done at the end) and then glued to make the final piece. The subcomponents of the part individually 3D printed are shown in figure 7.

The glue types most commonly used are cyanoacrylate. Cyanoacrylate is an acrylic resin that rapidly polymerizes in the presence of water and is usually used with an activator to control the bonding time.

The result of the assembly process is shown in figure 8. The final piece is placed on the tray of the 3D printer just as a marketing presentation, it was not obtained from a single processing.
3. Using the Netfabb® application to simulate the RP process on the Objet24 3D printer

Using Netfabb® was necessary because the RP process is complicated, especially in preparing segmented STL files. The following analyzes were performed:

- standard analysis;
- center of gravity;
- wall thickness;
- shadow area;
- support volume.

For example, wall thickness analysis is shown in figure 8. In the figure, the analysis did not meet the requirements because it was required that the walls of the part be thicker than 2 mm. In fact, the Objet24 printer yields pleasing results to parts with a wall thickness of 1 mm.

Because the parts that had to be subjected to the RP process were of great size, this set of analyzes was aimed at reducing the consumption of materials (construction material plus support material). It is obvious that the building material cannot be reduced to the volume of the piece, but on the contrary it increases when the bosses, ribs or positioning elements are inserted on the piece.

However, by increasing building material by 2% to 5% compared to the volume of the piece, we have reduced the support material by up to 63%.

We must keep in mind that the price of the building material is three times higher than the price of the support material. Aside from lowering the cost price, the segmentation of the piece gives you the biggest advantage: manufacture of larger pieces on small 3D printers.

It remains to be seen how the pieces made of several components bonded to each other behave in time. Another aspect to be studied is the behavior of cutted parts with different planes or surfaces of separation and the shape of these cuts.
Figure 9. The wall thickness analysis of rapid prototyped 3D part.

4. Conclusions and further developments
This work shows the solutions found for prototyping large parts on 3D printers smaller than overall part’s dimensions. The procedure has advantages and disadvantages. The main advantage is precisely the possibility of prototyping the piece.

The second major advantage is that the cost of materials is low, sometimes over 50%. Among the disadvantages are the aesthetic quality of the prototyping part and its mechanical resistance, along with the increase in the duration of the PR process and the need for qualified personnel to carry out these operations.

Regarding the further developments of this topic, we will try to reduce the disadvantages listed above, or even eliminate them. The first thing we study is the mechanical behavior of the part made from several subassemblies. We will try to get closer to the parameters of the base material.

5. References
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