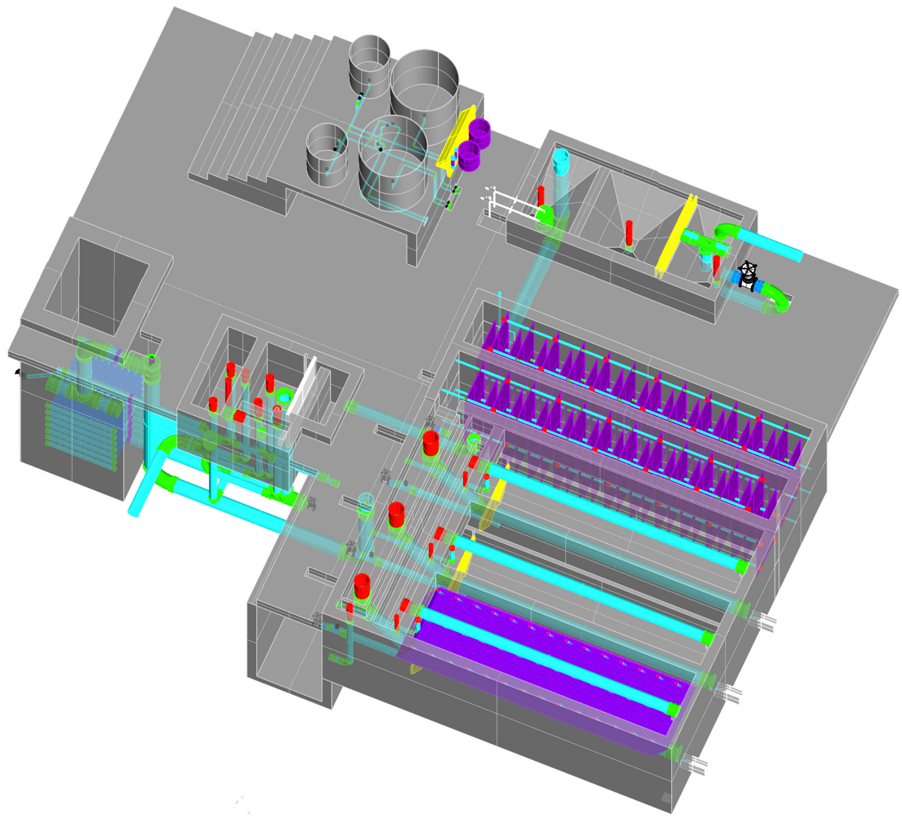


SMALL SCALE PLANT MODEL

Final Research Report – Fall 2013

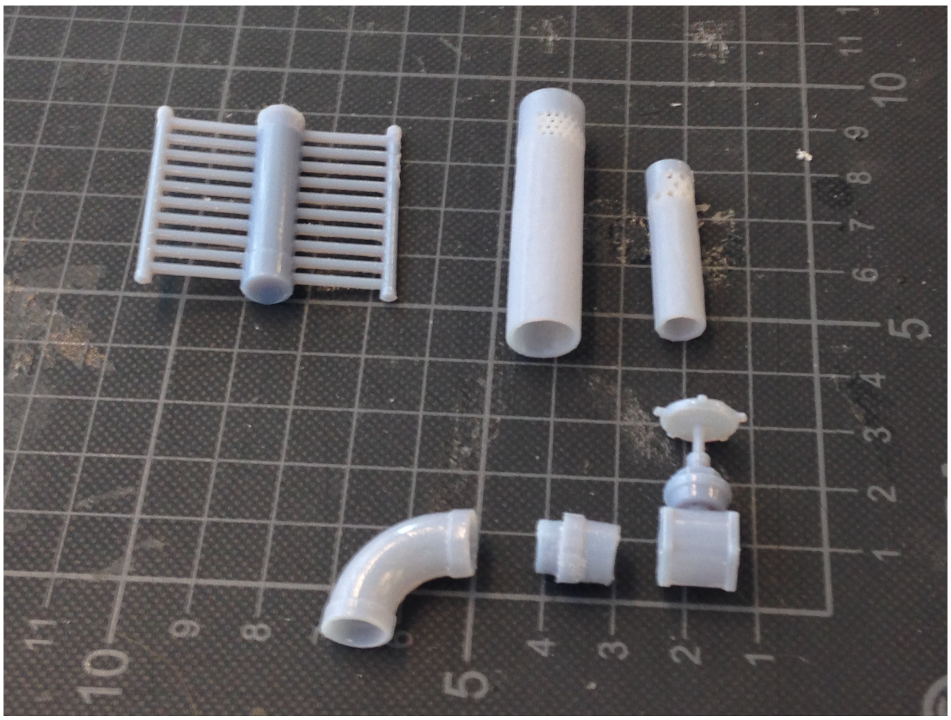
12 December 2013

Abstract

The Small Scale Plant Model team seeks to construct scale models of AguaClara plants that will, through their tangibility, facilitate AguaClara's educational outreach efforts and encourage the support and sponsorship of donors. The models will be small and durable enough to travel to Honduras, and they will clarify potentially confusing features of the plants they depict. Over the past semester, the Small Scale Plant Model team has taken the goals and analyses of the previous semesters and has constructed a model in an attempt to meet these goals. The model components were modeled in 3d to be 3d printed or were formatted to be laser cut. The team has 3d printed and laser cut almost all necessary parts and has assembled an almost entirely complete final model. Next steps now only include adding detailed components to complete the model, though the ultimate goal will be to optimize the process of model-making/printing to reduce complexity and ambiguity in assembly.

Introduction

After abandoning the method of building a model completely in plexiglass/acrylic, team member and architecture student Jordan Berta entered into collaboration with AguaClara in order to more actively participate in model-making. On the basis of the goals of previous teams, Professor Monroe Weber-Shirk expressed his desire to entirely 3d print the small scale model plant and, at the suggestion of team member Jordan Berta, a method was proposed which combined 3d printed parts within plexiglass containers.



Methods

3D Printing

The first step in determining how the pieces would be 3D printed, the team spoke with shop managers at the department of Architecture Art and Planning in the Rand Hall shop. Frank Parish, who had provided information to AguaClara in the past, and Ben Hagenhofer-Daniell expressed that in order for a part to be 3D printed, it must adhere to the following rules:

1. The object must be a closed polysurface in the 3D environment with no naked or non-manifold (self-intersecting) edges.

2. It must be of a thickness no smaller than the tolerance specified by the machine; this tolerance must also consider the shape of the object being printed and then be optimized to meet the needs of scale and complexity. For printing in a plastic material, this is a minimum of 0.04 inches in wall thickness. This thickness also is the limit on size for what can be printed.

3. 3D printing also prints a support material around the object (and underneath in whatever casts a shadow directly downward) and, in the case of plastic, the support material is lightly water soluble and must be manually cleaned from the part when finished. Thus, very small pipes or entirely enclosed volumes should be printed with this in mind.

4. Printing in the Z direction is costly and organization of parts within the bed to minimize support material reduces cost. Minimum distance between parts should be approximately equal to minimum thickness, but can often be as little as 1/128”. Very small tolerances are possible depending on the object and moving parts can be printed together provided the tolerance is correct.

Professor Hod Lipson also advised the team to explore the 3D-print-on-demand website Shapeways.com which can print a wide variety of materials. The cost in the Z direction with Shapeways is also lower than with the ZCorp Objet printer at AAP. Therefore a decision was made to 3D print the inner complex tank geometry with Shapeways, while the piping and parts would be printed at AAP. This was both an aesthetic and practical choice as AAP prints using a blue plastic which would contrast nicely with the white plexiglass and white 3D prints from Shapeways. The plexiglass containers would also be lasercut at AAP.

Evaluation of 3D Model

AguaClara’s scripted 3D model was re-evaluated in terms of 3D printable componentry versus containers. The 3D model was excellently detailed, but unsuited to 3D printing. There were also discrepancies and intersections within the model which require surface-to-surface connections in order to be printable and buildable physically. Each tank was considered to be built separately and then assembled together on the base.

Like previous teams, Rhinoceros was the 3D modeling software used for the evaluation of the 3D model. Each tank and pipe was extracted and examined. The steps went as follows:

1. The objects were sorted into pipes and fittings and tanks and deconstructed into constituent parts. Pieces were largely separated as they would be in reality, though any particularly delicate or exposed objects would require additional structuring. This was all done in groups associated with each individual tank to simplify logistics.

2. The object was simplified to a collection of single surfaces which were then offset to the minimum distance needed for printing. This process required heavy restructuring to account for tolerances between pipes, tanks, walls, seatings, etc. In Rhinoceros, the commands utilized were the “offsetsrf” command, the “extrude”, “loft” and “sweep” commands were also used.

3. The tanks were simplified to their internal structure, offset outward, and fitted with ribs for both structure and as separator for the plexiglass container.

4. The last step requires a checking for naked edges and non-manifold (self-intersecting) edges using Rhinoceros’s “showedges” command and “selectclosedpolysurface” command.

For support in learning Rhinoceros, please see https://www.rhino3d.com/resources/. (Rhino 5 for OS X is in free beta mode. Fully functional Rhino costs $99 for Windows.) Shapeways.com’s forum and how-to tutorials also provide instructions on other methods of modeling for 3D printing.

Laser Cutting

Laser cutting, then, was minimal when compared to the rest of the production. At this point, all parts were fully articulated in 3D. Therefore, the containers could be constructed in 3D space using material thickness to assure proper joints. For those unfamiliar with the logistics of laser-cutting, this is an essential step.

The two containers which were not 3D printed were the Stacked Rapid Sand Filter and the Flocculator. These were simple rectilinear geometries with few perforations and were, therefore, impractical to print in 3D at this juncture.

Once the containers were modeled around the 3D print container geometry, the pieces were laid out, rotated to the XY Plane, and made into linework using the "make2d" command for cutting. Additional plexiglass was obtained from Ithaca Plastics which has a large stock as well as inexpensive scrap material. The cost differential compared to 3D printing was significant as, for example, a single Sed Tank costs roughly $200 to print, while a sheet of scrap plexiglass for both the Flocculator and SRSF cost $65.

Please note that the laser melts the edges of the plexiglass during the cutting process. Thus the edges are somewhat bevelled. This can be engaged by 1) offsetting the line needed for cutting 2) scoring the lines of its actual size, and then 3) sanding down the pieces to their proper size. This is time consuming, though more accurate. In most cases, this is unnecessary. The tolerance is also important to note as the melting removes material on both sizes of the line of cutting, similar to any saw. It is also incredibly important to remove the top layer of paper (if it is not a plastic material) on the plexiglass before cutting as this will prevent flaming and melting of the plexiglass. This is also a consideration when dealing with very thin pieces as the paper on the underside of the plexiglass can also catch fire. However, do not remove the paper on the underside as it will otherwise scorch the acrylic.

For the platform base, it was also decided to create a thin frame between two pieces of plexiglass in order to strengthen the base. In past prototypes, the size and fragility of the base had caused it to break. Structure is another major consideration in the framing within the interior of any large 3D printed or acrylic model.

Assembly

Assembly is a relatively straightforward process, if logistically challenging. It is important to either label pieces or to keep a record of their origin in order to build a model of this type. This was done, in this case, by simply keeping the parts of constituent tanks separate and referencing the 3D model.

Adhesives for plexiglass and 3D printed plastic come in two forms: Weld-On acrylic adhesive, a chemical bonder which melts and strongly bonds the plexiglass together, and cyanoacrylate superglue, which is most effective on the 3D printed plastic but also bonds the plastic to the plexiglass. It is convenient to use the thicker formula cyanoacrylate as it is easier to manipulate. Accelerant can also be used to help facilitate bonding, though this will often discolor the material at the bond.

It is also important to determine, throughout the process, how and when parts should be assembled. Consider if the parts will fit in the model at each point in the assembly. One must be careful not to build a container only to determine the piping must be built within the tank first.

Please also note that even after parts have been printed, they are still malleable. Model saws, blades, and sand paper can easily shorten or alter a part which may not fit correctly.

Conclusions

The physical model, to this point, has been completed save for the baffels of the Sed Tank and Flocculator, the chemical supply tanks, and the chemical doser (which requires further strategic planning at a 1:20 scale as it is very, very small).

AguaClara retains the original 3D print files which have been formatted and are ready for additional 3D printing, should the need arise. With Shapeways, AguaClara could print individual pieces on demand, though the turn-around time may take anywhere from 1 to 3 weeks. The model built during this term is also largely manipulatable as the parts within it are discreet objects. As a prototype, the goal for this semester was to simply build a model; this process can continue to be refined.

Suggested considerations in moving forward are as follows:
- how to script a model which is 3D printable
- how to print more of the model with pieces intact while still being able to remove support material
- how to minimize cost by optimizing the model's structure
- in what ways can the model be simplified to still communicate major ideas; this can also be key to addressing issues listed above
- could an effective 3D animation communicate concepts as well; Autodesk Maya, for example, can animate particles in a water-like 3D environment